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EXAMINING THE ASSOCIATION OF TEMPERATURE AND RAINFALL VARIABLES WITH HOUSEHOLD FOOD SECURITY AND UNDER-FIVE CHILDREN'S NUTRITIONAL STATUS IN MALAWI

by

ANDREW ALFRED JAMES JAMALI

THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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Abstract

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EXAMINING THE ASSOCIATION OF TEMPERATURE AND RAINFALL VARIABLES WITH HOUSEHOLD FOOD SECURITY AND UNDER-FIVE CHILDREN'S NUTRITIONAL STATUS IN MALAWI

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Addressing the effects of climatic variability on human population is one of the major development challenges facing the world today. This is more critical in the sub-Saharan African region where many people rely on climatic conditions for livelihood strategies such as farming. Among other factors, climatic variables such as rainfall, light intensity and temperature facilitate crop growth and yield which provide food for the population in the region.

Studies report that climate variation influence occurrence of floods and droughts that wash out and dries up crops respectively. Such events lower crop yield, resulting in food insufficiency and in extreme cases food scarcity among populations. Despite the foregoing, not much is known in the country, and scarcely in the sub-Saharan African region as regards how variation in cropping season temperature and rainfall variables associate with crop yield, households' food security and nutritional status of the members, especially under-five children. This knowledge gap exists amid high burden of disease and poor socio-economic conditions among people in sub-Saharan African countries. For Malawi, climatic variation presents a human survival and development concern, as it is located in a region experiencing frequent and severe climatic conditions with wider socio-economic impacts.

Using station-based cropping season temperature and rainfall data from Malawi's meteorological office, and demographic, socioeconomic data from the 2010 Malawi Integrated Household Survey, multi-level logistic regression models were fit to assess climatic and household level factors associated with food security and under-five children's nutritional status. Results showed that controlling for household level demographic and socioeconomic variables, a shorter cropping season rainfall duration and below the season's average rainfall were associated with higher odds of households' food insecurity, stunting, wasting and underweight among under-five children. A higher amount of variation in household food security status and under-five children's nutritional conditions was explained by household level factors. These results highlight climatic and socioeconomic factors which ought to be considered in design and implementation of programs addressing food insecurity and child malnutrition in Malawi, in the context of variable climatic conditions.

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Research Thesis: Declaration of Authorship

Print name: ANDREW ALFRED JAMES JAMALI

Title of thesis:	Examining association of temperature and rainfall variables with household food security and under-five children's nutritional status in Malawi

I declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

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2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
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Definitions and Abbreviations

ACF	Autocorrelation Function
ADD	Agriculture Development Division
AEDO	Agriculture Extension Development Officer
AIC	Akaike's Information Criterion
BIC	Bayesian Information Criterion
CFSVA	Comprehensive Food Security Vulnerability Assessment
DCCMS	Department of Climate Change and Meteorological Services
EA	Enumeration Area
EPA	Extension Planning Area
FAO	Food and Agriculture Organization
FEWSNET	Famine Early Systems Warning Network
GHA	Great Horn of Africa
GHI	Global Hunger Index
GFSI	Global Food Security Index
HCES	Household Consumption and Expenditure Surveys
HDI	Human Development Index
HIS	Integrated Household Survey
IPCC	Intergovernmental Panel on Climate Change
ICC	Inter Class Correlation Coefficient
IFPRI	International Food Policy Research Institute
IOD	Indian Ocean Dipole
ITCZ	Inter Tropical Convergence Zone
LSMS	Living Standards Measurement Survey
LPM	Linear Probability Model
MGDS	Malawi Growth and Development Strategy
MNA	Mean Nutritional Assessment
MUAC	Middle Upper Arm Circumference
MUST	Malnutrition University Screening Tool
NAPEC	National Agriculture Production Committee
NSO	National Statistical Office
OR	Odds Ratio
PDO	Pacific Decadal Oscillation
SDG	Sustainable Development Goals
SEA	South East Africa
SGAM	Subjective Global Assessment of Malnutrition
SNHT	Standard Normal Homogeneity Test
SSA	Sub Saharan Africa
UNICEF	United Nations Children's Emergency Fund
VCI	Vegetation Condition Index
USA	United States of America
USEPA	United States Environmental Protection Agency
WHO	World Health Organization

Chapter 1. Background and Introduction

1.1 Overview

This chapter presents the introduction and background to the study. It sets the stage for the study by discussing climate variability and its relationship with food security and human nutritional conditions, the context within which the study was undertaken, objectives and research questions, significance and justification of the study, policy implications of the findings and further research following from the study.

1.2 Background and Introduction

Ending hunger, achieving food security and improving nutritional conditions of people around the world is one of the major development pursuits in this century (FAO, IFAD et al. 2017). Studies report that since industrial revolution, levels of carbon dioxide and other heat absorbing gases in the atmosphere have soared, causing approximately up to 1.0°C of global warming (uWang 2005, IPCC 2007, Ho 2013, Team, Pachauri et al. 2014, Ebi and Loladze 2019, Fernandez, Townsend-Small et al. 2019). Although warming of both sea and land surfaces during medieval and pre-medieval times has been reported Duan, Yao et al. (2006), Nicholson, Nash et al. (2013) the rate at which it occurred is argued to be far much lower than today (Team, Pachauri et al. 2014). Scientific research concludes that industrial activities in the modern age have intensified current global warming patterns, argued the main cause of global climate variation and change (Boko 2007, IPCC 2007, Abraham, Cook et al. 2014).

In the sub-Saharan Africa region, climatic variations and changes often are evident in erratic rainfall patterns and inordinate temperatures during the growing season, argued to influence low crop production and resultantly food shortages (Rosenzweig, Iglesias et al. (2001). There are also reports about increase in vectors and spread of vector borne diseases and pests which thrive under extreme climatic conditions such as intense rainfall, leading to floods influenced by variable climatic patterns (Campbell-Lendrum, Manga et al. 2015, Watts, Adger et al. 2015, Watts, Amann et al. 2018). These conditions lead to agricultural productivity and poor quality of human life. Research show variations in occurrence, severity and effects of adverse climatic conditions across temporal and spatial scales, (Team, Pachauri et al. 2014, Estrada, Tol et al. 2017).

Sub-Saharan Africa however is reportedly among major climatic variability hot spots in the world, increasingly experiencing adverse climatic conditions which are threatening survival of populations (IPCC 2007, Kula, Haines et al. 2013). Among other factors, weak governance systems, poverty and low technology among countries in the region are reportedly some of the factors limiting effective counter response to the effects of climatic variation and change in the region (Stephenson, Newman et al. 2010, Kula, Haines et al. 2013, Ward and Mahowald 2014).

Most analyses about effects of climatic change and variability in the sub Saharan African region i.e. Kundzewicz, Kanae et al. (2014) and Gizaw and Gan (2017) have focused on extreme climatic events such as intense rainfall and dry conditions often associated with floods, landslides and droughts, and their effects on human lives. Other studies i.e. De Souza, Kituyi et al. (2015) and Thornton, Ericksen et al. (2014) have explained how droughts reduce crop yield, affecting food availability among populations in the region. However, Connolly-Boutin and Smit (2016) and (Serdeczny, Adams et al. 2017) contend that apart from occurrence of extreme climatic events i.e. intense rainfall, temporal variations in long-term conditions of rainfall and temperatures also influence poor crop yield and household food shortages, which provide requisite conditions for malnutrition and diseases among the population in the region. As noted by Ogden (2018) and Tjaden, Caminade et al. (2018), these temporal variations in climatic variables are associated with low farm productivity and poor quality of human lives.

Despite the fore-going, few studies in the SAA region have analysed these claims in order to provide scientific and policy-focused input on how variations in temperature and rainfall conditions at varied spatial-temporal scales influence household food shortages and poor health, manifested in human nutritional conditions, let alone in the context of increasingly global climatic variability and change (Githeko, Ototo et al. 2012, Mabaso and Ndlovu 2012, Myers, Smith et al. 2017). Few studies have discussed pathways involved in these relationships (McCarthy, Canziani et al. 2001, Ziervogel, New et al. 2014). This knowledge gap exists despite food insecurity and malnutrition being major health and development concerns in the region (FAO and UNICEF 2018).

Overly worrisome in this situation is that research on how variations in climatic conditions are affecting different facets of people's lives i.e. food security and nutritional conditions remains scanty in the region (De Souza, Kituyi et al. 2015, Weber, Haensler et al. 2018), despite climatic conditions playing a significant role in the livelihoods and health of people in the region. This research and knowledge gap also exists against the background that the SSA region is a climate change hotspot (Müller, Waha et al. 2014, De Souza, Kituyi et al. 2015), further characterised by development related problems such as poverty, rapid population growth, environmental degradation, low technical ability and political will to address effects of climate change and variation (Tucker, Daoud et al. 2015, Barbier and Hochard 2016).

Malawi is located in South-East Africa, a region characterised by erratic rainfall and temperatures (Boko 2007, Ray, Gerber et al. 2015, Kandoole, Record et al. 2017). Projections indicate increasing climatic adversity leading to floods and droughts (Arndt, Schlosser et al. 2014, Murphy and Tembo 2014, Pachauri, Allen et al. 2014). The country's economic and social development is dependent on climate sensitive agriculture (Mzembe and Meaton 2014, Kandoole, Record et al. 2017). The productivity of this sector is increasingly threatened by adverse climatic variability likely to affect survival of the population and impacting on socioeconomic development (Lipper, Thornton et al. 2014, Haug and KG Wold 2017). High population growth and density further strains availability and provision of resources for education and health services to the growing population (Ricker-Gilbert, Jumbe et al. 2014).Higher unemployment, child malnutrition, environmental degradation and declining viability of ecosystems to support the growing population further complicates the country's growth and social development prospects (Poppy, Jepson et al. 2014, Kamndaya, Kazembe et al. 2015).

Despite Malawi's climate sensitive food production system, amid poor socio-economic indicators, few studies have examined how variations in climatic conditions affect households' food security and children's nutritional status (Msowoya, Madani et al. 2016, Stevens and Madani 2016). This gap occurs against the dependency of the country's main livelihood strategy (farming) and indeed its economic growth on climatic conditions. Considering the importance of food security and good nutritional conditions to the country's human capital development, examining how variations in climatic conditions associate with food security and nutritional outcomes is an imperative development research and policy undertaking.

This is so because information from such research would provide relevant input for addressing the adverse effects of climate change on the country's agriculture sector, which is key to economic growth and health of the population. Such research would also provide a picture on how climate variation adds additional pressure to existing socioeconomic problems, providing input for climate sensitive development strategies for the country. The current study addressed this knowledge gap by assessing trends in selected cropping season temperature and rainfall variables, examining how they relate with households' food security situation and malnutrition status of under-five children in Malawi. The study envisaged to provide relevant policy and programmatic input for mitigating and adapting to the effects of climate variability on household food security and child nutritional status programs to enhance human development capital.

1.3. Study context

1.3.1. Geography and Climate

Malawi is located in the south east African region, lying between latitudes 9° 22' and 17° 7' south of Equator and between longitudes 32° 40' and 35° 55' east of Greenwich (Nicholson, Klotter et al. 2014, Organization 2017, WMO 2017). It is bordered by Tanzania to the north and north-east, Zambia to the north-west and Mozambique to the south-east and south-west (figure1).

Figure 1. Map of Malawi and Neighbouring countries

Source:https://www.nationsonline.org/oneworld/map/malawi_map.htm:09.4.19.

The country is 900km long (north to south) and 200 km wide (east to west) and its territory is 118,483km^2, of which 24,208km^2 is covered by water, mainly Lake Malawi, the third largest in Africa (WMO 2017). The mean surface elevation of Lake Malawi is 474 m.a.m.s.l. and its deepest point is 706m below sea level. The Lake has over 500 species of fish, the largest fish species content for a fresh water lake in the world (Jury and Mwafulirwa 2002, Weyl, Ribbink et al. 2010), and it is the main tourist attraction for the country. The land elevation rises from 37 metres above mean sea level (m.a.m.s.l) in the Lowe Shire Valley to 3050 m.a.m.s.l. on the peak of Mount Mulanje (FAO 2015). As of 2010, the largest share of land; 40.5 percent was used for agriculture, followed by forestry; 26.8 percent. The share of land to various uses has not changed substantively over time (figure 2), as observed from three epochs spanning 30 years (1990-2010). This is despite increases in population size and the need for more land for cultivation and settlement to carter for the increasing population (Munthali, Davis et al. 2019, Ngwira and Watanabe 2019).

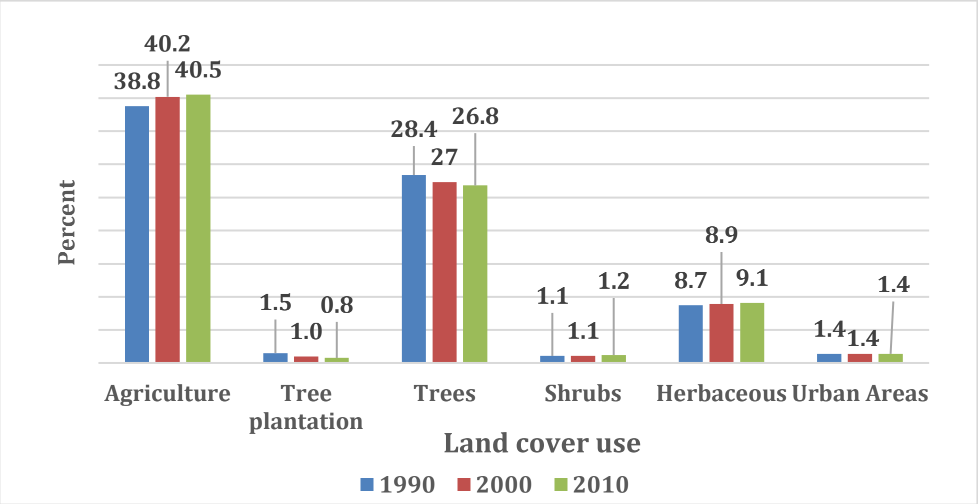

Figure 2.Land use change in Malawi, 2010
(Source: Atlas for Malawi land cover and land cover change, 2010)

Malawi's topography is divided into four major physiographic zones. The highlands are located in the southern part of the country, covering Mulanje, Zomba, and prats of Phalombe district (Haack, Mahabir et al. 2015). The central region is generally a plane, covering Lilongwe, Kasungu and parts of Mchinji districts, and the northern region has plateaus stretching from Mzimba, parts of Rumphi and Chitipa districts. The rift valley escarpment and rift valley plains lie along the shores of Lake Malawi, the Upper Shire i.e. Mangochi district and the Lower Shire valley; Chikwawa and Nsanje districts (Venema 1990, Dijkshoorn, Leenaars et al. 2016).

The country has a dry and seasonal sub-tropical climate with average annual rainfall varying between 725 and 2500mm, and a mean of 1800mm. Rainfall is influenced by the Inter-Tropical Convergence Zone (ITCZ) (Malawi Government, 2006). This is a broad zone in the equatorial low pressure belt towards the north-easterly and south-easterly trade winds (Kumbuyo, Yasuda et al. 2014, Mkandawire 2014). This is the main rainfall bearing system for the country, others being the tropical cyclones which are essentially intense low pressure cells that originate from the Indian Ocean, moving from east to west. These bring widespread heavy rainfall mostly in southern Malawi, which sometimes cause floods (Nicholson, Klotter et al. 2014).

The Convergence Ahead of Pressure Surges (CAPS) system develops as high pressure cells continue to move over the southern tip of the sub-continent, causing isolated but locally heavy rains that normally precede the onset of the rainy season in the country (Frenken 2005). The easterly waves system from near Madagascar which penetrate the Zambezi valet during the summer are mostly active towards the end of the rainy season (March/April). These also cause isolated but locally heavy rains in some parts of the country (Kumbuyo, Yasuda et al. 2014). Humidity ranges between 50 to 87 percent for the drier months of September-October and January-February respectively (Malawi Government, 2006). A warm wet season commences in November through April, with December, January and February being high rainfall months (figure 3).

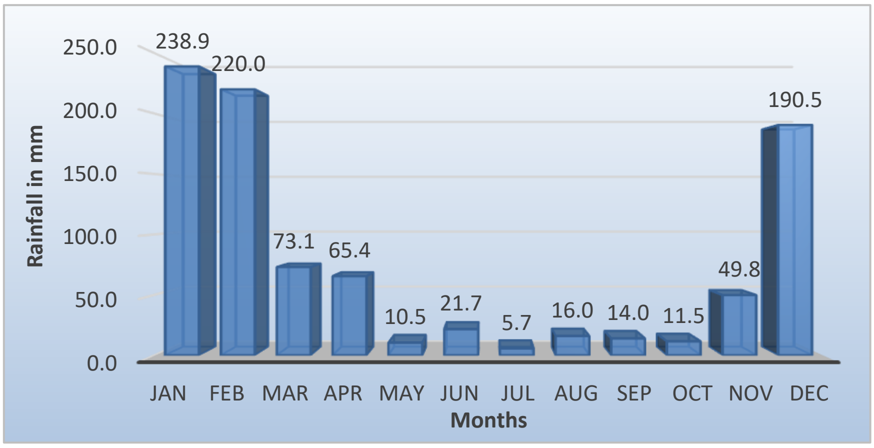

Figure 3. Malawi's average annual rainfall distribution in months (1970-2015) (Source: Own calculations from daily rainfall data obtained from DCCMS Malawi, 2017)

Malawi's mean temperatures vary between 17 °c in winter season to 27°c in summer. The mean maximum and minimum temperatures are 28°C and 10°C respectively in the plateau areas, 32°C and 14°C respectively in the rift valley and plains (Malawi Government, 2006). The highest temperatures occur in October and November, and the lowest in June and July (Figure 4).

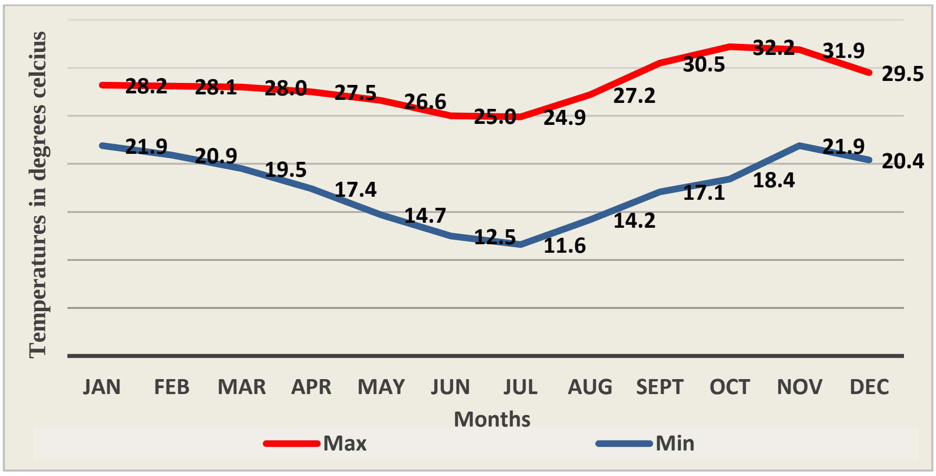

Figure 4.Monthly maximum and maximum temperature distribution for Malawi, 1970
(Source: Own calculatons using DCCMS Malawi data)

A hot dry season stretches from September to October, where temperatures range between 25-37 °c. Frost may occur in isolated areas in June and July, peak of winter season (Malawi Government, 2006).

1.3.2. Temperature and rainfall variation in Malawi

Over the last four decades, Malawi's climate has shown increasing variability evident in inordinate patterns of rainfall and increasing temperatures. Figures 5 and 6 show distribution of annual average rainfall and temperatures with unstable patterns over time.

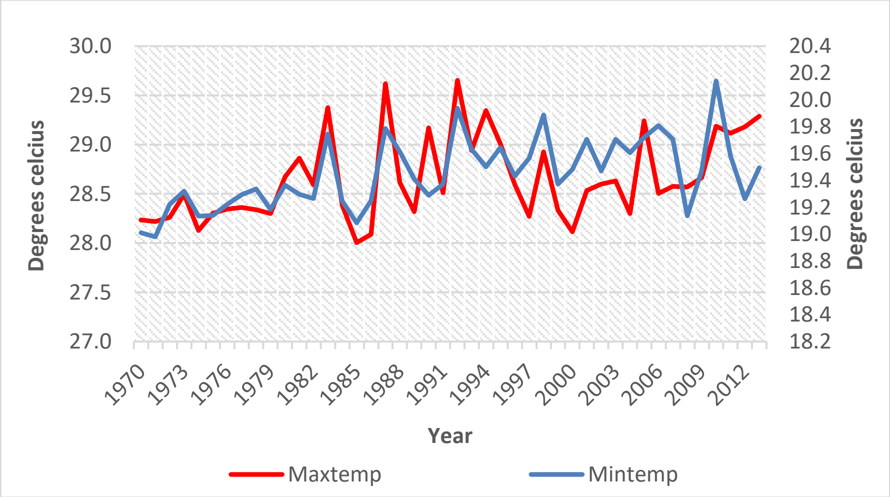

Figure 5. Average annual temperatures variation, 1970-2013
(Source; Own calculations using data from DCCMS, Malawi)

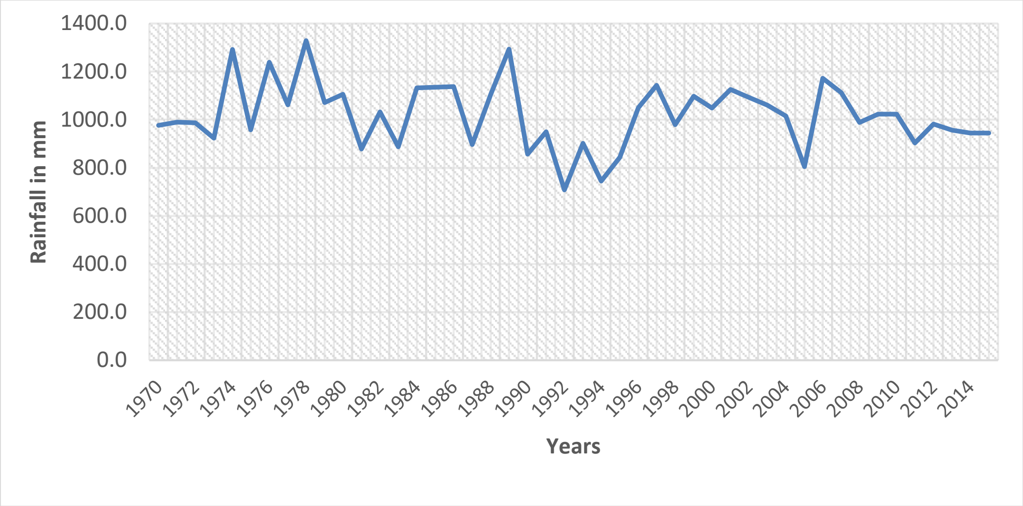

Figure 6. Average annual rainfall variation, 1970-2015
(Source; Own calculations using data from DCCMS, Malawi)

Apart from natural climatic variability, unstable temperature and rainfall patterns are reportedly influenced by warming trends over the 1961 to 2005 period with mean temperatures increasing from an average of 22°c in 1961-1970 to 22.6°c in 1991-2000 (Warnatzsch and Reay 2019). Malawi is frequently affected by droughts and floods, with shorter average return period of 1 to 5 years in different areas in the country (Jayanthi, Husak et al. 2013). Records of national disasters (Appendix 4) show frequency of the floods and droughts and their effects such as disruption of livelihoods, destruction of infrastructure and facilitating spread of infectious diseases i.e. diarrhoea and malaria among the population, due to use of contaminated water and growth in vectors like mosquitoes respectively (Jørstad and Webersik 2016, Kruger 2016). Climate change and variation is reported to influence spread of infectious diseases in southern Africa. High temperatures, longer rainy seasons and inadequate ran water drainage are enhancing incubation conditions for mosquito borne diseases especially malaria, and regions that were not prone to such infections will increasingly become affected (Bickton 2016).

Estimates show that 2.7 percent of Malawi's GDP is lost to combined effects of floods and droughts on the agriculture sector (MalawiGovernment 2017), hence lowering the country's economic growth prospects owing to its climate dependent agriculture. On a macro-level, such natural disasters often scale up government budget in order to support affected services, derail pro-economic growth investment and enhance foreign and national debt, to carter for relief and reconstruction projects following damages and losses (MalawiGovernment 2015).

1.3.3. Economy

Malawi's economy is largely dependent on the Agriculture sector, accounting for 85 percent of employment (MalawiGovernment 2015), contributing close to a third (27 percent) of the Gross Domestic Product (GDP) through farm exports (FAO 2015).
Major exports include: tobacco, tea, coffee and cotton, contributing 90.1 percent of all exports on aggregate (Malawi Government 2017). Tobacco only accounts for 75 percent of the exports, the main source of foreign exchange for the country. Major export markets are the European Union, Southern African Development Community (SADC), Common Market for Eastern and Southern Africa (COMESA) and the United States of America (USA) (Malawi Government 2017). According to the 2018 Annual Economic Report, the country experienced a growth in the economy of 5.1 percent in 2018, attributed to better agriculture production and reduction in inflation. Other productive sectors are tourism, manufacturing, wholesale and retail trade. Malawi's major imports are petrol, paraffin, diesel and synthetic fertilisers. Analysis shows that imports have historically outpaced exports, making Malawi a net importing country, a situation that has retarded the country's economic growth (Malawi Government 2016).

Malawi's Human Development Index (HDI) is estimated below global average for countries with low HDI and also below the SSA regional index. As of 2017, the country's HDI was estimated at 0.447, representing 40.2 percent since 1990 (World Bank 2017). The 2017 Gross Domestic Product per capita (GDP per capita) was US$486.45 lower than the sub-Sahara African regional average; US$1,638. The country's poverty prevalence has not changed over the past 8 years; with 50.5 percent of the population living below the World Bank classified poverty line; less than US$1.90 a day (World Bank 2017). The majority of the poor reside in the rural, depending on farming for food and income (MalawiGovernment 2017), yet this sector is challenged by a variable climate (Warnatzsch and Reay 2019), amid poor socioeconomic conditions (MalawiGovernment 2017).

The main development challenges Malawi faces include vulnerability to climatic shocks, high inflation, low productivity influenced by lack of complementary investments in agriculture, inefficient patterns and composition of public expenditure in the agriculture sector (International Monetory Fund 2017).

The country has a narrow raw material export base which is heavily reliant on tobacco, despite its declining market on a global stage due to anti-smoking lobby. This export base has not diversified over time to spur growth (Malawi Government 2016), raising concerns on the country's economic future. Rapid rates of land degradation currently estimated at an annual cost of U$320 million dollars also compound Malawi's development prospects (Kirui 2016). Many people rely on forests for firewood and charcoal for domestic use and income in order to obtain income (Palamuleni, Ndomba et al. 2011). There are also challenges on the country's energy sector especially the hydroelectric power, currently affected by adverse climatic conditions such as floods and droughts. Only 11 percent of the population access electricity (International Bank for Reconstruction and Development 2017). Low technological and infrastructure development has also crippled the country's manufacturing base, essential for value addition of agriculture commodities and other products meant for exports.

1.3.4. Livelihoods

In Malawi the main source of livelihood is agriculture production, practiced by 64.1 percent of the population (MalawiGovernment 2017). This sector provides food and income for basic necessities of life i.e. health, education and housing to the population, Apart from cultivating crops and raring animals on farms, fishing and forestry are other sources of livelihood especially for people living along the lake shores and forest reserves (MalawiGovernment 2017). Major food crops in the country include maize, which is the staple food crop, rice, potatoes, cassava and groundnuts which are cultivated both for cash and food for farming households (Malawi Government 2017). Tobacco, coffee, tea and cotton are cultivated for export, especially for large scale estate farmers (Kandoole, Record et al. 2017). Other predominant livelihood strategies include wage employment, small scale wholesale and retail businesses, which account for 16 percent of the population and mostly common among urban than rural residents (Malawi Government 2013). Due to increasing climatic variability evident in adverse events such as floods and droughts (Jørstad and Webersik 2016), major livelihood strategies such as agriculture production are under threat, as crops and animal are washed away during floods or die of water and heat stress during droughts and higher temperatures (Adhikari, Nejadhashemi et al. 2015).

This is reportedly common in arid and semi-arid areas of the country i.e. lower shire valley (Joshua, Ngongondo et al. 2016). Damages and losses incurred by farming households during these events cause significant loss of livelihoods, plunging them into poverty (Harrigan 2008). This affects economic growth prospects, considering agriculture is the main source of exports for foreign exchange. Food insecurity and malnutrition have also emerged as significant concerns (Stevens and Madani 2016), which are argued to influence poor frame of health among the people, and consequently poor human capital for the country's economic growth (IFPRI 2018).

1.3.5 Demographics and Health

Malawi is one of the highly populous countries in the sub-Sahara African region, with a population of 17,563,749 people (Malawi Government 2018), representing a 35 percent inter-censual increase from 13,029,498 recorded in 2008 (Malawi Government 2018). The proportion of females in the population is greater than males; 51 percent against 49 percent respectively and more people reside in the rural than urban areas; 84 percent against 16 percent respectively (Malawi Government 2018). Over the past 10 years, Malawi's population has been growing at a rate of 2.9 percent per annum (Malawi Government 2018), above the SSA and SEA sub-region population growth rates; 2.6 and 2.7 percent per annum (United Nations 2015). The country's total fertility rate is estimated at 4.4 children per woman, declining from 5.7 children per woman in 2010. The median birth interval as of 2015 was 41months, increasing from 32.7 months in 1992 (Malawi Government 2015), indicating that women are taking longer to conceive following a recent birth. This could lead to slowing population growth.

The country has a higher proportion of younger people, with 43.9 percent aged under 15 years (Malawi Government 2018) as figure 7 shows. The high proportion of young people contributes to a higher dependency ratio in the population, which could have significant financial costs on provision of infants' and under-fives' child growth services. Among such are the need for sufficient nutritious food, provision of curative, preventive, growth monitoring and basic education services important for a healthy and productive human capital. Such investment is crucial for the country's economic growth and development (WHO 2001).

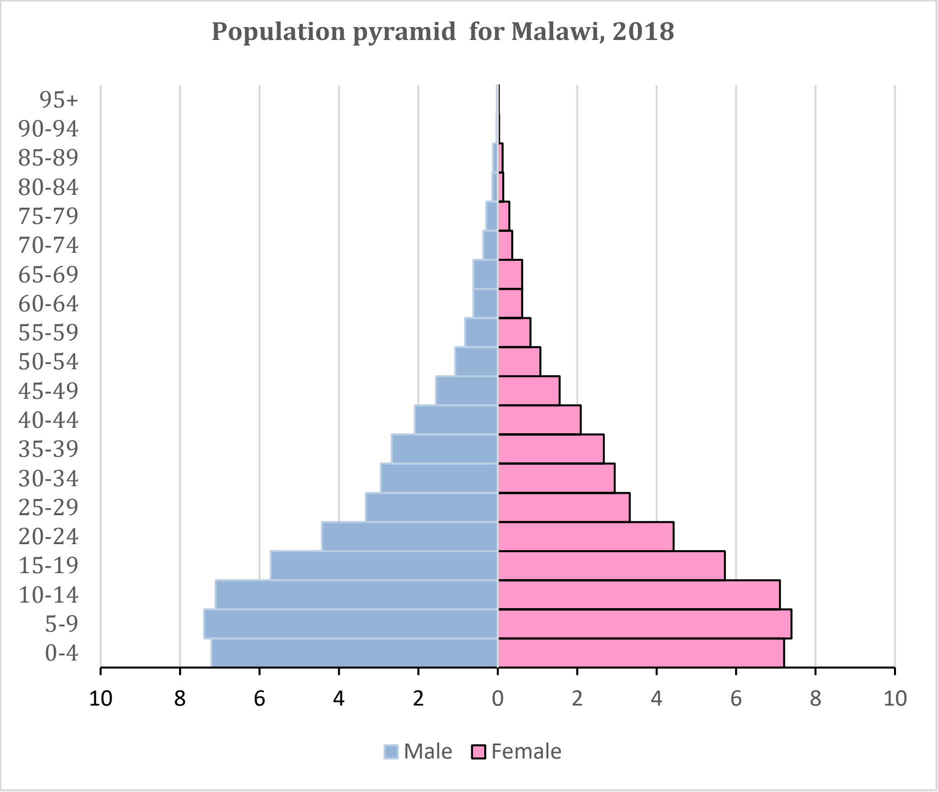

Figure 7. Population pyramid showing age and sex structure for Malawi, 2018
Source: Own calculations from the 2018 round of Population and Housing Census (PHC)

However, for Malawi, increased demand for such services does not match the country's economic resource base, a situation that compromises quality of young lives as it impairs the country's socio-economic productivity and development. Malawi's health indicators are not by world's standards impressive, with life expectancy at birth estimated at 53 years for females and 51 years for males, one of the lowest in the world (WHO 2016). The infant mortality rate is also high, estimated at 43.4 deaths per 1000 live births and is largely influenced by a higher burden of disease attributed to HIV/AIDS and malnutrition, alongside infectious diseases and poor nutritional indicators (Bowie 2006, de Onis, Onyango et al. 2006, CHH 2013). Major causes of death in Malawi include HIV/AIDS, Tuberculosis, Diarrheal diseases, Malaria, Neoplasms, Nutritional deficiencies and non-communicable diseases (CDC 2019).

Due to increasing climatic variability, which is noted in periodic and increasing frequency of floods, there are arguments about increase in malaria infections due to increased vector growth, biting frequency and infections rates (Pachauri, Allen et al. 2014, Campbell-Lendrum, Manga et al. 2015) influenced by persistent floods during the rainy season.

Increasing incidence of droughts at varied spatial scales in the country have also been argued to influence incidence of diarrheal diseases due to reliance on unsafe water sources such as dams, wells and rivers for domestic use. These open water sources are directly exposed to adverse environmental conditions during floods and droughts which make water unsafe for use by humans (Manda and Wanda 2017), However, considering that for the majority of the population, such open sources of water are the only available water resource points, yet they are directly affected by adverse climatic conditions, concerns about increasing waterborne infections in the population are high (Bennett, Lowther et al. 2018). Essentially due to climatic variability in the country, there are concerns about increase of infectious diseases such as malaria and waterborne infections and diseases such as diarrhoea and dysentery, which are feared to be exacerbated by adverse climatic conditions in the country.

There are also concerns of increased perennial household food insecurity caused by floods and droughts washing away crops during the cropping season, which are associated with increasing climatic variability (Poppy, Jepson et al. 2014, MalawiGovernment 2017, FAO and UNICEF 2018). These situations diminish households' food resources, alter consumption patterns and predispose the members to food insecurity and malnutrition (FAO and UNICEF 2018). Nutritional estimates show that 42 percent of children under–five are stunted, 17 percent are underweight and 4 percent wasted (Malawi Government 2015). In the event of declining favourable climatic conditions these figures might worsen, since climatic conditions are argued to be key to household food production in the country.

1.3.6 Intersection of climate variability, human food security and nutrition

Studies have shown that the link between climatic variability, human food security and nutrition is both direct and indirect. In areas where food production systems are dependent on climatic conditions such as temperature and rainfall i.e. sub-Saharan Africa (Tirado, Hunnes, et al, 2015; FAO,2018), above and sometimes below normal climatic conditions in a cropping season negatively affect crop production and food availability (Felix and Romuald 2012, Kraemer, Cordaro et al. 2016). Further, intense rainfall cause floods which wash away crops and animals on farms, directly causing loss of crop and livestock productivity, leading to food shortage and scarcity in the affected areas (Rosenzweig, Iglesias et al. 2001, Fischer, Shah et al. 2002, Clark and

Tilman 2017). This directly affect households' 'food availability', a key component of 'food security'. In some instances, floods and storms destroy infrastructure i.e. market buildings, roads and bridges, cutting out physical access to food resources to affected populations (Twerefou, Adjei-Mantey et al. 2014, Spalding-Fecher, Joyce et al. 2017, le Roux, Khuluse-Makhanya et al. 2019). This situation indirectly affects 'Access to Food'. Contaminated water resources due to floods or droughts (FAO and UNICEF 2018) have also been argued to affect proper household 'food utilization' i.e. preparation, treatment and quality, influencing infections associated with poor hygiene (Wheeler and Von Braun 2013, Chakrabarti, Dinesh et al. 2017).

Intense rainfall has also been associated with erosion of cultivable sketches of fertile lands due to floods, while droughts hardens soil particles on farmlands, resulting in poor crop yield (Lipiec, Doussan et al. 2013, Siebert, Suennemann et al. 2019), affecting 'stability of food' among affected people. Studies i.e. Menhus, Umer, et al 2017; WHO,2018, have also noted an indirect intersection between climatic variability and human nutritional condition. For instance, intense floods and droughts have been associated with higher vector growth and transmission to human bodies, leading to infections and illnesses among human populations (WHO, 2018). Frequent illnesses influence poor nutritional conditions as the body fails to recover enough to make effective utilization of consumed food due to decreased intestinal absorption, direct loss of nutrients in the gut and internal diversion of metabolic responses to infection (Jensen, Berens et al. 2017). Among under-five children, these conditions result in increased susceptibility to more childhood infections and diseases due to weakened immune systems (FAO, IFAD et al. 2017, Hawkes and Fanzo 2017). In this regard, adverse climatic variability has indirect negative intersection with human nutritional conditions and in extreme cases, ultimately health.

In some instances, climatic variability has been associated with positive effects. For instance, melting ice in the Arctic is argued to facilitate increased mobility of ships enabling trade and access to various resources, energy production and fishing among countries in the region (Crépin, Karcher et al. 2017). In a framework that explains positive and negative impacts of global warming and climatic variability on the agriculture sector, Kim (2008) and Grimm, Chapin III et al. (2013) argues that increase in crop productivity due to carbon dioxide concentration, low level temperatures, extended crop growth period due to longer seasons, new varieties of crops arising from changing climatic patterns are some of the positive feedbacks of global warming on the agriculture sector. However, temperature rises, increasing weeds, blights, pests associated with warming, increasing moisture stress and drought in the tropical regions i.e. SSA and the Horn of Africa, are mentioned as negative effects associated with climatic variability, having direct implications. However as Thornton, Ericksen et al. (2014) and also Zulu (2017) argues, depending on geo-spatial and environmental characteristics, areas might experience decreasing food crops production as reported in sub-Sahara Africa while others might have improved food production and trade such as in western Europe.

With reference to SSA, Tirado, Crahay et al. (2013) contends that household poverty, socio-economic and social-cultural factors coupled with poor early warning systems and emergency preparedness, social and political unrest, exacerbate food insecurity. Considering the purported intersection of variation and changes in climatic patterns with human livelihoods, food security and nutritional outcomes as evidenced from different analyses, it is important to understand the implications of changes in climatic patterns both short and long term on various facets of human lives. Such understanding is crucial for policies and programs aimed at addressing adverse effects of analysed climatic variations or changes on human survival and development, which is important to achieving the Sustainable Development Goals (SGDs) 2016-2030.

1.4. Problem Statement

In the sub-Saharan African region, studies on how climatic variability and change affect peoples' lives i.e. Müller, Waha et al. (2014), Serdeczny, Adams et al. (2017) have focused so much on assessing effects of extreme climatic events such as floods and droughts. However, Pendergrass, Knutti et al. (2017), (Hamlet, Jean et al. 2018) contend that apart from extreme climatic events, periodic variations in average conditions of climatic variables i.e. surface temperatures and precipitation also have significant negative effects on people's lives at different spatial and temporal scales.
However, information to support this claim in the SSA region is scanty (Edame, Ekpenyong et al. 2011, Zewdie 2014). This research gap exists against climate dependent livelihood and economic systems predominant in the region.

The implication is ineffective design and implementation of programs addressing adverse effects of climatic variability on various aspects of human lives i.e. health and sustenance, key to human and socioeconomic development. In Malawi, although Joshua, Ngongondo et al. (2016) have researched on effects of varying temperature and rainfall on crop production and food availability, no research attempts have analysed how seasonal variations in these climatic variables relate with household food security and child malnutrition status across Malawi's districts, the pathways involved and modulating conditions (Stevens and Madani 2016). This research gap exists despite food insecurity and malnutrition being some of the major development challenges in the country (Malawi Government 2016). The implication of this knowledge gap is that Malawi would partially address the adverse effects of climatic variation in its social and economic development programming, as focus is emphasized on addressing climatic hazards only, leaving equally important effects emanating from slow but salient variations in seasonal climatic conditions.

Such a situation renders the country continually vulnerable to perennial food insecurity and malnutrition among household members, especially under-five children, whose physical form is already burdened with diseases and poor health. These effects would result in poor human capital development, negatively affecting the country's socioeconomic development. The current study attempted to address the observed research gap by examining association of seasonal climatic variation with household food security and nutritional status of funder-five children. It also examined pathways and factors modulating this association, to provide information on how the problems could be addressed in the country.

1.5. Study Objectives and research questions

The objectives of the study were to:

1. Assess trends in selected temperature and rainfall variables in order to detect a climate variation signal in the country.
2. Examine relationship between selected cropping season temperature and rainfall variables with crop yield, in order to assess how climatic variation associate with food availability in Malawi.

3. Analyse how selected cropping season temperature and rainfall variables associate with household food security and under-five children's nutritional status, and the pathways involved in the relationship.

To achieve these objectives, the following questions were addressed:

1. What have been trends in the selected cropping season temperature and rainfall variables in Malawi over time?
2. How have the trends in selected cropping season temperature and rainfall variables related with food crop yield as a source of food in the country?
3. How do variations in cropping season temperature and rainfall variables relate with household food security condition and under-five children's nutritional status, controlling for demographic and socio-economic factors modulating the relationship?

1.6. Significance of the study

In examining trends for selected cropping season temperature and rainfall variables, this study provides information important for planning water resources management, especially in areas where detected trends suggest significant declining water availability amid rising temperatures. Appropriate measures would therefore have to be considered to ensure sustained crop production and livestock productivity.

Malawi's cropping season rainfall is the main recharge system for rivers and lakes which provide water for both domestic and economic activities. Understanding trends and variability of rainfall is significant in strategizing generation and provision of the country's hydroelectric power which depends on river water i.e. Shire river. Poor river water recharge following unfavourable rainfall entail erratic energy supply due to reduced water volume, siltation due to soil erosion and drought which reduces water levels in reservoirs. This hampers industrial productivity, slow down economic growth and social development investment, a situation that leads to poverty and underdevelopment in the country. As such, the current study is significant as it will provide input for designing strategies to address effects of climatic variability on the water and energy sector, crucial for the country's development.

Climatic variation and its associated results i.e. occurrence of extreme events such as floods and droughts, are reported to affect living conditions of people i.e. livelihoods, and health, especially in areas where climatic conditions play a significant role in sustaining people's lives. For a country like Malawi, understanding how variations in climatic conditions associate with food security and human nutritional status especially among under-five children, is a research imperative. This is so because malnutrition and food insecurity are some of the major development challenges confronting the country. Information from studies of this nature is critical in the design of strategies to reduce household food insecurity and malnutrition in the context of variable climatic conditions currently being experienced in the country. Further, the current study concerns climatic issues, livelihoods and food security as well as nutrition, which concerns health. The cross-disciplinary approach engaged in addressing the study's objectives demonstrates linkages that exists in different areas which in concert affects human quality of life. Such evidence is crucial for design of multi-pronged approaches to addressing development challenges confronting human societies in this century.

1.7. Justification of the study

Various studies have analysed Malawi's temperature and rainfall patterns at different spatial and temporal scales based on models rather than data from observations i.e. Gama, Mapemba et al. (2015), Warnatzsch and Reay (2019). Despite relevance of these analyses on efforts to address climate variability effects, few studies have used observed station-based data to analyse long term trends in cropping season temperature and rainfall variables and their effects in the country. This research gap limits understanding on observed other than model based periodic changes in characteristics of Malawi's cropping season climatic conditions. Using long term station based data, the current study addresses this research gap to provide input for addressing adverse seasonal climatic effects on crop production in the country. Furthermore, records about occurrence of climatic hazards such as floods and droughts at different spatial scales serve as evidence that Malawi' s climate is adversely becoming variable over time. Analysis of average variations in seasonal temperature and rainfall patterns at various spatial scales provide understanding on how other than climatic hazards, seasonal climatic shifts influence household food production, information that is scanty in Malawi.

Such information is crucial for planning programs for addressing the effects of variable seasonal climatic conditions on food crop production in the country. Malawi's development indicators are not impressive. A high population and faster rate of growth, higher dependency ratio, (Malawi Government, 2018), higher burden of disease and malnutrition (UNICEF, 2017; WHO,2017), shortage of cultivable arable land and poor agricultural productivity (Bain, Awah et al. 2013), (Chirwa and Ngalawa 2008), low economic growth and high poverty rates (MalawiGovernment 2017, World Bank 2017). Climate variability presents an additional challenge to the country's already poor micro and macro-economic and social development conditions, yet few studies have examined how climatic, demographic and socioeconomic variables relate to affect development challenges such as food insecurity and malnutrition in the country.

The current study contributes to a body of knowledge demonstrating the intersection of climatic, demographic and socio-economic factors in explaining household's food security and malnutrition as some of the major development challenges facing Malawi. Such information is important for formulation of multi-pronged strategies with which to address the country's food insecurity and sustained malnutrition in the population, which lowers the country's human capital development and economic growth. As such, this study is significant.

Chapter 2 Literature review

2.1. Overview

This chapter reviewed studies about climate change and its variability, with a focus on arguments about its causes, occurrence and impacts across various temporal and spatial scales in different parts of the world. It also investigated pathways through which human populations are affected by climatic conditions with a focus on the associated effects of climatic variability and change on households' food security status and nutritional conditions of household members. A systematic literature review approach was adopted involving identification of relationships, contradictions and inconsistencies in research findings and arguments from studies pertaining to the subject matter. Qualitative, quantitative and mixed methods studies were reviewed concurrently to understand how complex research questions in the studies' focus were resolved. Studies reviewed pertained to climatic trends and their associated effects on human lives, especially on livelihood strategies such as agriculture production, from where many people in the regional context of the study i.e. SEA rely for food and income, as well as nutritional outcomes. However, few of such studies let alone cross-disciplinary in design were identified.

Various materials were consulted i.e. journal articles, policy documents, local and international development program reports, among others. The materials related to the period between 1990 to 2019, purposefully selected because it is within this period that discussions on global climatic change and variation and their intersection with human food security and nutritional conditions have attained pivotal attention in global, regional and local (country) development strategies and programs. The search terms included; 'climate', 'climate change' climate variability', 'crop production', 'food security', 'malnutrition' and 'human nutritional conditions' among others. The results were refined with key words such as *'Africa', 'Southeast Africa', 'Asia', 'Australia', 'America, 'South Pacific' and 'America',* and also key words representing major countries such as *'USA', 'UK', 'China'* to provide research studies related to the current but conducted in different regions and countries around the world.

The purpose of the review was to identify gaps in research on climatic variations and their association with human food security and nutritional conditions, compare their focus, design, methodologies, findings and implications of the findings to global, regional and local policy programs related to the focus of the current research.

Reviewed studies were selected if they were:

1. English language publications
2. Published in peer reviewed scientific journals
3. Government development strategy documents, policy and programs documents
4. From globally accredited research organisations i.e. IPCC, UNICEF and WHO
5. From regionally and nationally accredited research and policy institutions.

The search engines were web of science, PubMed, google scholar and Elsevier, via google chrome and internet explorer. Emphasis was on articles and reports related to the current study's focus, those with recent information about climatic variation and change, food security and human nutritional conditions, especially for sub-Saharan African region. The review focused on understanding how the selected studies relate or differ with the current research study, their design and methods used during the analyses, results and interpretation of their findings with reference to policy and programs on climate variation and change, and more so association of climatic variation with human food security and child nutritional status in Malawi and Africa. This review provided input to the design of the current study especially conceptual and analytical frameworks, methods of analysis and how findings could be interpreted to highlight important policy, programs and further research implications with reference to the focus of the current study.

The major limitation in the review of literature for the current study was that there were few studies conducted in the south-east African region and Malawi in particular that have been cross-disciplinary in approach, linking climate analysis with agriculture and human health, especially on the subject of nutrition. This limitation entails that there were few reference points for the current study's design and methods of analysis in addressing the research questions. However, this limitation adds to the novelty of the current study in setting the stage for cross disciplinary studies on climate issues and their relationship with people's livelihoods and health outcomes, especially nutritional conditions.

The following sections discuss conceptual issues, measurement and situation of the discussions about climatic change and variability, food security and human nutrition conditions at global, regional and national scales. It also reviews studies that have discussed the intersection of climatic issues with human food security and nutritional status, providing basis for the current study's conceptual framework.

2.2. Conceptual issues, measurement and situation of global and regional climate, food security and human nutrition

2.2.1. Climate, Climate Change and its Variability: Conceptual issues

Since the establishment of the Inter-Governmental Panel on Climate Change (IPCC) in 1988, and release of its first Assessment Report in 1990 which detailed the state of scientific knowledge about climate change and its socio-economic effects, discussions about climate change have assumed pivotal position in global development agenda i.e. the Millennium Development Goals (1990-2015) and Sustainable Development Goals (2016-2030). Debates however continue on conceptual issues about climate and its delimitations, degree and agents of global climatic change, robustness and credibility of methods for analysing changes in climatic properties, emerging risks associated with climate change and variability (Ornes 2018, Porter, Kuhn et al. 2018).

The Inter-Governmental Panel on Climate Change (IPCC,2014), conceptualizes climate as an interactive complex system consisting of the atmosphere, land surface, snow and ice, ocean and other bodies of water and living things. This is described in terms of the mean and variability of climatic properties such as temperature, precipitation and wind over a period of time, ranging from months to millions of years, with 30 years being the standard (Pachauri, Allen et al. 2014). According to the American Environment Protection Agency (EPA, 2016), when energy from the sun reaches the earth, the planet absorbs some of this energy and radiates the rest back to space as heat. The earth's surface temperature depends on this balance between incoming and outgoing energy. Average conditions remain stable unless there is a shift in the energy balance, which could cause average temperatures to become warmer or cooler, leading to a variety of other changes in the lower atmosphere, on land and in the oceans (Environmental Protection Agency 2016). The global energy balance is affected by physical and chemical changes in the earth's climate, which can either be natural or influenced by human actions.

The changes are measured by the amount of warming or cooling they can produce, which is called ‘radiative forcing’ (Environmental Protection Agency 2016). Changes that have a warming effect are called ‘positive; forcing, while changes that have a cooling effect are called ‘negative’ forcing. When positive and negative forces are out of balance, the result is a change in the earth’s average surface temperature. In essence, the climate system evolves in time under the influence of its own internal dynamics, due to changes in external factors i.e. natural phenomena such as volcanic eruptions, solar variations, and human-induced changes i.e. industrialization, which piles gases in the atmosphere (Stocker, Qin et al. 2013).

Climate is sometimes loosely described as weather, however there is a temporal difference between the two. For instance, weather is defined as a short term atmospheric condition at a place, often limited to hours and days, while climate refers to these conditions over longer periods i.e. 30 or more years (Team, Pachauri et al. 2014). The atmospheric conditions concern temperature, precipitation, humidity, evapotranspiration, light intensity and visibility, wind strength and direction among others. These processes result from uneven heating of the earth’s surface by the sun, leading to temperature differences. Such differences cause air currents (wind) to develop, moving heat from a region of higher concentration to one of low heat concentration (Lutgens, Tarbuck et al. 1995, Stocker, Qin et al. 2013).

Climate variability refers to fluctuations in states of climatic properties at various time intervals over certain periods of time i.e. short term, longer term, periodic, seasonal, without causing changes in average conditions on a longer-term basis (IPCC 2007, Xu, Tang et al. 2017). The term denotes deviations of climate statistics over a given period when compared to long term statistics of the same calendar period. These deviations are termed anomalies, caused by natural internal processes within the climate system (internal variability) or variations in the natural or anthropogenic external factors (external variability) (IPCC 2007). Global climate variability is influenced by El Nino Southern Oscillations (ENSO) and to a smaller scale the Pacific Decadal Oscillations (PDO) (Goddard and Dilley 2005), which are oscillations in the temperatures of the atmosphere and the ocean in the eastern equatorial pacific region roughly between the international dateline 120° west (Turner 2004).

Climate variability is sometimes confused with climate change, which refers to statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period, typically decades i.e. 30 years or longer (United Nations Framework Convention on Climate Change (UNFCCC) 1992).The changes in climatic properties are naturally caused by volcanic eruptions, solar variability, plate tectonics or shifts in the earth's orbit. However, climate science research has concluded that apart from natural forces, modern industrial activities have augmented changes in climatic properties globally (Stocker 2014), leading to various devastating impacts on human populations around the world. A key difference between climatic variability and change is in persistence of 'anomalous' conditions, when events that used to be rare occur more frequently over a longer time period or vice-versa (Gutro 2005). In statistical terms, the curve of frequency distribution representing the probability of specific meteorological events changes, modified in amplitude, shifted about a new mean or both (UNFCCC,1992).

Considering the close connections between climate variability and climate change, the (WMO 2017) warns that care must be taken not to confuse the two, observing that many regions of the world experience greater variability often confused for climate change in climatological terms. Variability can be weak in some regions and periods of the year i.e. not much difference in conditions within that periods. In other places, the time periods and the conditions can swing across a large range, from freezing to very warm, or from very wet to very dry, exhibit strong variability. Occasionally, an event occurs or sequence of events could occur that has never been observed or recorded before, which all could be part of variability, resulting from natural variability. However, increased frequency of such events within a space of time could signal human influenced climatic variability (WMO 2017).

2.2.2. Measurement of changes in climate and its variability

Assessing variations in climatic conditions provides understanding on climatic changes and their associated impacts on human populations at different temporal and spatial scales. Such understanding provides important input for formulating interventions to address adverse effects associated with changing climatic conditions. Considering the complexity of the climate system, robust, multi-pronged approaches, instruments and methods are required to detect and measure changes in climatic properties.

Large-scale volume of accurate time-series data on climatic variables and accurate skills among climate researchers are required to produce reliable climate assessments, with which to inform climate change policy programs at varied spatial scales. This entails that assessing climate change or its variations is such a mammoth task, calling for suitable approaches, methods, skills and long-term reliable data, which could be challenging. There are different approaches through which changes in climatic properties are detected and measured. For instance, Dendochronology is a study of growth in tree rings or coral reefs layers from which scientists generate knowledge about past environmental and climatic conditions in a particular place (Khaleghi 2018).

Tree rings, coral reefs, limestone, deposits (speleotherms) such as stalactites and stalagmites in caves have been used to understand ancient climate (Riebeek 2005). Pioneered by the American scientist A.E. Douglous (1867-1962) the approach involves recording number of layers or rings grown over periods of time and seasons to deduce information about temperature, rainfall and other environmental conditions at the time they were created (Eakin, Kleypas et al. 2008).The growth rings incorporate materials from the surroundings and thus create a record of the environment's history.

Although dendochronology has been useful in the analysis of climate and changes in its properties, there are concerns on its reliability. For instance, trees vary in species (Fritts, Vaganov et al. 1991) and some do not have consistent seasonal and annual records of ring growth (Dünisch and Latorraca 2016). Oak for instance is argued to have reliable records of ring with no known case of missing annual growth ring (Anning and McCarthy 2013). However, birch and willow have erratic growth cycle (Janecka and Kaczka 2015)while Alder and pine though with decay-resistant wood occasionally miss a year (van der Maaten-Theunissen, van der Maaten et al. 2015) and sometimes 'double up' by having two rings in the same growth season. This makes it difficult to have consistent records for measuring climatic features in areas these trees exist. There are also challenges with perfect site selection where trees can be studied, i.e. location where there are older trees, non-climatic disturbances i.e. fire, wind, wildlife, earthquakes, volcanic eruptions or humans (Sheppard 2010), all of which could affect quality of tree rings data.

Copenheaver, Pokorski et al. (2006), Hart and Classen (2003) have also argued that changes in industrial revolution have affected recent dendrochronology records, where they have become erratic and in higher elevations, tree ring data has declined, making it difficult to reliably measure environmental and climatic changes.

Climate scientists (Paleoclimatologists) also study earth's climatic history by examining samples of drilled glaciers and ice sheets, called ice cores. These features provide records of what the planet was hundreds of thousands of years ago. Ice sheets and glaciers near earth's north and south poles form from years of accumulating snowfall. The weight of each year's snowfall compresses down the previous layers of snow and after so many years all of this pressure helps to form glacial ice (Stoller-Conrad 2017). Researchers drill ice cores from deep inside ice sheets in Greenland and Antarctica, as well as some high-latitude ice caps and mountain glaciers to test how much oxygen, carbon dioxide and nitrogen levels it contains, whether levels have gone up or down over time.

They also collect ice cores in many regions around the earth to study regional climate variability, compare and differentiate that variability from global climate signals (Alley 2010), hence providing knowledge about global climatic change. Among limitations associated with measuring climate variability and change using glaciers and ice sheets data is that there is need for huge scientific investments over longer periods of time in order to collect reliable data (IPCC,2013), which in resource constrict situations is not possible. In other situations, ice flow may disrupt layers quite close to the bed and ice flow progressively thins layers with increasing burial so that diffusion or sampling limitations eventually obscure annual layers (Alley 2000). In essence, annual layers are not observed because of depositional or postpositional effects, limiting the climatic analysis. Although in such situations correlation is done with well dated records, and radiometric techniques are applied or ice flow modelling performed (Alley 2000), most ice lack sufficient dating to allow precise radiometric dating (Sigl, Jenk et al. 2009), another shortfall that affects precise analysis of ice cores to provide insights about past climatic conditions.

Since climate is usually described in terms of mean and variability of temperature, precipitation, and wind at various temporal and spatial scales, climate scientists examine states of these variables from time to time to ascertain global and regional changes.

For instance, earth and sea surface temperatures are sometimes reconstructed and measured to provide a picture of past or future climatic conditions(Stocker, Qin et al. 2013). Climate scientists also use rainfall, snow fall and relative humidity to understand climatic variation and long term changes (O'Gorman 2014, Harpold and Brooks 2018). However, there are limited areas especially in Africa that have stations that cover wider spatial and temporal scales, let alone with reliable time series (UNFCCC 2006). Such situations limits understanding of prevailing and past climatic conditions in the continent.

Parmesan and Hanley (2015) argues that anthropogenic climate change will influence all aspects of plant biology over coming decades. The two contend that many changes in wild species have already been well documented as a result of increased atmospheric carbon dioxide concentration, warming climate and changing precipitation regimes. However, there are variations in plant response to such climatic changes, majorly influenced by functional traits, classification, life history and provenance. Essentially, biomass and vegetation patterns may be analysed in a variety of ways to provide evidence of how ecosystems change and adaptation to climatic changes.

Lucht, Schaphoff et al. (2006) used dynamic global vegetation models (DGVMs) to compute the terrestrial carbon balance and the transient spatial distribution of vegetation based on two scenarios of moderate and strong climate change i.e. 2.9k and 5.3 temperature increases. In this study, spatial redistribution of major vegetation types and their carbon balance were analysed up to 2100. Results showed that the world's land vegetation will be more deciduous than at present, and will contain about 125 billion tons of additional carbon. Further, the ability of the terrestrial biosphere to sequester carbon from the atmosphere was noted to decline strongly in the second half of the 21 century, indicating some influences in climatic patterns over time.

de Sassi and Tylianakis (2012) explains that living organisms are linked through trophic relationships with resources and consumers, the balance of which determines overall ecosystem stability and functioning, and this helps to compare overall effects of changes at multiple tropic levels. The team studied a combination of experiments in a grassland system to test how biomass at the plant, herbivore and natural enemy (parasitoid) levels respond to the interactive effects of two key global change drivers i.e. warming and nitrogen deposition.

Results showed that higher temperature and elevated nitrogen generated multi-tropic community that was increasingly dominated by herbivores. Synergistic effects of the drivers on biomass were detected, with variations across trophic levels. Further, reduced parasitism rates mirrored the profound biomass changes in the system, findings that carry important implications for the response of biota to environmental changes (de Sassi and Tylianakis 2012).

Despite the importance of biomass and vegetation characteristics in understanding patterns of climatic variations and change in different areas, there are some limitations. Körner and Basler (2010) observes that phenological events such as bud burst, flowering and senescence have received so much attention in the light of global warming, prompting questions as to how increasing global warming will affect arrival of spring and length of growing season in temperate regions, where spring events have advanced by 2.5 days per decade. Considering that there is wide variability in plant's phenology and response to climatic conditions at different spatial and temporal scales (Hatfield and Prueger 2015, Rezaei, Siebert et al. 2018), it is difficult to rely on vegetation only to tell more about prevailing and past climatic conditions, let alone make future projections. As such, multiple analyses over extended periods would be required in order to detect accurate and informative details about climatic conditions, other than single approaches like biomass and vegetation analysis. Such complex undertakings many not be feasible in resource and expertise constrained settings like the SAA region, a situation that limits understanding of regional climatic patterns.

Changes in intensity of solar radiation also enable assessment of climatic variations in some situations. Haigh (2011) argues that evidence of variations in solar activity on millennial timescales can be found in records of cosmogenic radionuclides. Further, statistical analysis at decadal and centennial periods has also detected signals of solar variability in climatic data. Chemical composition of air or water have been measured by tracking levels of greenhouse gases such as carbon dioxide and methane, and measuring the ratios of oxygen isotopes (IPCC 2007). However, although analysis of these climatic variables has provided insights about variations in climatic conditions, there have been some limitations with respect to assessing extremes in variables such as temperature and precipitation.

A number of studies have shown differences between different datasets including their representation. Critical gaps exist in the amount, quality, consistency and availability of data in particular with precipitation (Alexander 2016). There are also large uncertainties with gridding methods and how assumptions are applied when assessing spatial and temporal changes in precipitation. Avila, Dong et al. (2015) and Gervais, Tremblay et al. (2014) further noted major problems with climatic extremes where they are noted to be sensitive to scaling issues, in which there are fundamental mismatches between spatial representativeness of point-based and gridded values. Such inconsistencies affect robustness of climate analysis, which in turn could affect design and interventions to avert and address the effects and impacts of climatic variation and changes in different areas.

Another method for assessing climatic conditions and their changes is by modelling climatic variables. Climate models are mathematical representations of the climate system, expressed as computer codes (Stocker, Qin et al. 2013).They are the primary tools available for investigating the response of the climate system to various forcings, for making predictions on seasonal to decadal time scales and for making predictions in centuries to come and beyond (Team, Pachauri et al. 2014). The choice of the model depends directly on the scientific question being addressed by the researchers. Models are routinely and extensively assessed by comparing their simulations with observations of the atmosphere, ocean, cryosphere and land surface (Randall, Wood et al. 2007). In essence, the models' ability to simulate important aspects of the current climate increase confidence and reliability of its results.

Among models which the IPCC rely on when assessing global climatic conditions are the General Circulation Models (GCMs), which simulate circulation of the atmosphere by calculating properties of the earth's atmosphere, oceans, cryosphere and land surface (Mechoso and Arakawa 2015). These are most advanced tools for simulating response of the global climate system to increasing green gas houses concentrations. They depict the climate using a three dimensional grid over the globe, typically having a horizontal resolution of between 250 and 600km, 10 to 20 vertical layers in the oceans (Pachauri, Allen et al. 2014). The Ocean General Circulation Models (AOGCMs) were specifically standard climate assessment models used in the 4th Assessment Report (AR4).

They model the dynamics of the physical components of the climate system (atmosphere, ocean, land and sea ice) and aerosol forcing, to make projections based on future greenhouse gas emissions (Stocker, Qin et al. 2013). The Earth System Models (ESMs) considered the current state-of-the-art models and they expand on AOGCMs to include representation of various biogeochemical cycles such as those involved in carbon cycle, the sulphur cycle, or ozone (Heavens, Ward et al. 2013). These models are argued to be the most comprehensive tools for simulating past and future response of the climate system to external forcing in which biochemical feedbacks play an important role (Heaven, Ward et al, 2013).

The Earth System Models of Intermediate Complexity (EMICs) are another type of climate models which attempt to include relevant components of the earth system but often in an idealised manner or at lower resolution than the AOGCMs (Stocker, Qin et al. 2013). These models are applied on scientific questions that attempt to understand climatic feedbacks on millennial time scales or exploring sensitivities in which long model integrations or land ensembles are required (Claussen, Mysak et al. 2002). Regional Climate Models (RCMs) are limited area-models with representations of climate processes comparable to those in the atmospheric and land surface components of AOGCMs, though typically run without interactive ocean and sea ice (Wang, Leung et al. 2004). These models are used to dynamically downscale global model simulations for some particular geographical region to provide more detailed information (Wang, Leung, et al 2004).

Despite the importance of these climatic models in explaining and predicting global and regional climatic conditions, there have been scepticism on their results by other climate analysts. Lupo and Kininmonth (2013) argues that properties inherent in models make dynamic predictability impossible. On this account, other techniques must be used to simulate climate. However, in many scientific investigations, each technique does introduce its own bias with varying magnitude into model projections. It is such biases that affects the validity of the model, leading to erroneous findings and conclusions. Further, GCMs have also been observed to suffer from missing important chemical and biological processes, apart from the physical processes, a situation which Lupo and Kininmonth (2013) argues is missing or inadequately represented in current ‘state-of-the-art’ climate models.

Idso, Legates et al. (2019) also explains that global climatic models sometimes present an incomplete understanding of the climate system, having an imperfect ability to translate knowledge into accurate mathematical equations. Lupo and Kininmonth (2013) further argues that sometimes the computers used in modelling earth's climatic conditions suffer from limited ability to process huge amount of complex data, leading to inaccurate results for climate assessment. Further, sometimes there exists large differences between model predictions and observations when comparing elements of climatic systems such as pressure, wind, clouds, temperature, sea ice, and precipitation, among others (Idso, Legates et al. 2019).

In essence global climatic models do sometimes fail to reproduce important atmospheric phenomena, inaccurately presenting the complex natural interconnections. Bader, Covey et al. (2008) specifically bemoans climate model simulation of precipitation where comparing simulated and observed latitude-longitude precipitation maps reveals most striking disagreements in the tropics. According to the team, in most models the appearance of the Inter-Tropical Convergence Zone (ITCZ) of cloudiness and rainfall in the Pacific is distorted and the rainfall in the Amazon Basin is substantially underestimated. The team warns that such errors may prove consequential for a number of model predictions such as forest uptake of atmospheric carbon dioxide, which may lead to erroneous conclusion about regional warming and climatic conditions. Such poor simulation undermine reliability of climate change prognostications (Lupo and Kininmonth 2013), leading to poor understanding of global and regional climatic patterns. This could cripple design of effective strategies and programs to avert, mitigate or adapt to effects of changes and variations in climatic conditions on human populations at varied spatial and temporal scales.

There also concerns that in many instances it is difficult to access climate data to be used for modelling climatic elements because it is expensive to mine, let alone according to formats of retrieval, which also vary, increasing complexity with regard to quality of assessments made from it (Beniston and Verstraete 2001). Some observational data may not be available for certain times and areas, and there is often incompatibility between socioeconomic and physical data for climate modelling efforts since these data are sometimes collected by different agencies for different purposes.

This review so far shows that much as climate models provide understanding about global climatic phenomena, there are some important concerns about their limitations that ought to be understood, in order to avoid erroneous interpretation about climate phenomena. However, climate modelling is still the most significant source of information for understanding and predicting global and regional climatic patterns in many situations. As such efforts to improve quality of performance in climate models is crucial in order to enhance accurate prediction of future climatic conditions, key to strategies for addressing effects of climatic variation and change at varied temporal and spatial scales.

2.2.3. Trends and effects of Global and regional climatic patterns

Mounting evidence indicate that since the 1960s, significant warming of the sea and earth's surface is largely due to human activity (Thompson 2010). In Europe, analysis by Peña-Ortiz, Barriopedro et al. (2015) revealed increased summer length, average of 2.4 days, a trend confined to the post 1979 period when lengthening rates ranged between 5 and 12 days in a decade over Western Europe and the Mediterranean region. Stainforth, Chapman et al. (2013) also assessed temperature distribution across Europe since 1950 and found a band from Northern France to Denmark experienced hottest days of at least 2 degrees Celsius, four times the global mean over the same period. Further observations showed that in winter season, the coldest nights were warming fast particularly in the Scandinavia.

Projections indicate that changes in climatic properties in the region will continue for the foreseeable future. Analysis of severe convective storms based on an ensemble of 14 regional climate models in Europe and the Mediterranean region by Púčik, Groenemeijer et al. (2017) found that by the end of the current century, the simultaneous occurrence of latent instability, strong deep layer shear and model precipitation across central and Eastern Europe showed higher variability, indicating that Europe is experiencing increasing climatic variability over time. The effects of these climatic changes have varied in magnitude, severity and locations. There are direct and indirect effects of climatic change and variability (McMichael 2013). Direct effects are those which cause immediate damage and discomfort among human populations, without operating through other mechanisms (Adler, Leiker et al. 2009).

Among such are heat waves which reportedly cause heart failure, wild fires which destroy the environment and disturb ecological systems, rises in sea levels which threaten low lying communities, extremes in global hydrologic cycles which result in destruction of infrastructure (Hofmeister, Rogall et al. 2010). Indirect effects operate through other mechanisms to bring about adverse conditions among human populations that result in injuries, diseases and deprivation of means for survival (Adler, Leiker et al. 2009). Among such are water and air pollution, causing vector and water borne diseases, exposure to environmental toxins leading to diarrhoea, cardiovascular and respiratory diseases, shortage of food resources as a result of climatic hazards such as droughts and floods among others (Haines, Kovats et al. 2006, Woodward, Smith et al. 2014).

In Europe, Gray, Dautel et al. (2009) argues that climate variation was affecting vector biology and disease transmission. A study based on vector tick Ioxodes ricinus showed that increased warmer winters and hotter summers were associated with change dynamics and pattern of seasonal activity, resulting in a bulk of the tick population becoming active in the later part of the year. Models performed by the team further showed that eight important tick species were likely to establish more northern permanent populations in the climate-warming scenario, exposing human population at various health risks.

Using an ensemble-based on European flood hazard assessment models, Rojas, Feyen et al. (2013) quantified the economic effects of river floods in European countries. Results showed that with no adaptation mechanisms, expected annual damages attributed to variation in the region's climatic patterns amounted to 55billion Euros a year, projected to rise to 98 billion Euros by 2080. However, this study did not establish whether the effects were influenced by natural or anthropogenic influences. Estrada, Tol et al. (2017) attempted to address this gap in a study examining the global economic impacts of observed climate change during the 20th century, using five impact functions of different integrated assessment models (IAMs). The study found that during the first half of the century, the amplitude of the impacts associated with natural variability was considerably larger than that produced by anthropogenic factors, and the effects of natural variability fluctuated between being positive and negative. The non-monotonic impacts were mostly determined by the low-frequency variability and persistence of the climate system.

This analysis seemingly contradicts the popular argument that anthropogenic forcing has higher magnitude effects on global climatic variability (IPCC, 2014). However, although the IAMs did not agree on the sign (nor on the magnitude) of the impacts of anthropogenic forcing, they indicated that the influence of these type of forcing grew over the first part of the century, rapidly accelerated since the mid-1970s (following growth in industrialization). The deceleration of the effects observed during the first decade of the 21st century, is argued to be influenced by accentuated interaction of effects between natural and anthropogenic forcing. Results further showed that the economic impact of the anthropogenic forcing was approximately ten percent of the world's GDP by the end of the 20th century, and that of natural forcing about one order of magnitude lower than those associated with anthropogenic forcing by solar forcing. This suggests that increasing anthropogenic influence due to industrialization was associated with higher negative impact than natural forcing.

In the Asia-Pacific region. Choi, Collins et al. (2009) analysed spatial and temporal changes in extreme events of temperature and precipitation using data spanning 1955-2007 from 143 weather stations in 10 Asian–Pacific Network (APN) countries. Results showed that the annual frequency of cool nights (days) had decreased by 6.4 days a decade (3.3 days a decade) and frequency of warm nights had increased by 5.4 days per decade (3.9days/decade). The study further found that the change rates in the annual frequency of warm nights (days) over the last 20 years (1988-2007) had exceeded those over the full 1955-2007 period by a factor of 1.8(3.4). The frequency of summer warm nights and days were also noted to change rapidly per unit change in mean temperatures than the corresponding frequencies for cool nights and days, indicating variable temperatures in the region.

Another study by Abram, Gagan et al. (2008) used a suite of coral oxygen-isotope records to reconstruct a basin-wide index of Indian Ocean Dipole (IOD) which was associated with climatic extremes in and around the Indian Ocean. Results showed increase in frequency and strength of IOD events during the 12 century associated with enhanced seasonal upwelling in the Eastern Indian Ocean. The team argues that although the El Nino Southern Oscillation was historically associated with variability of the IOD and the Asian monsoon, the recent intensification of variability of the IOD coincided with the development of direct, positive, IOD-monsoon feedbacks, attributed to greenhouse warming.

These climatic conditions have had varied effects across the Asia-Pacific region. For instance, a study by Loo, Billa et al. (2015) investigated the impact of climate change on the seasonality of monsoon Asia and its effects on the variability of monsoon rainfall in Southeast Asia. Results showed that there were general increasing decadal variations in precipitation and temperature anomalies before the 1970s, but beyond the 1970s, global precipitation anomalous showed increases that almost corresponded with increases in global temperature anomalies for the same period. The shifting phenomenon of other monsoon season in the region were noted to impact the variability of rainfall and the onset of monsoons in Southeast Asia, predicted to delay for 15 days the onset of the monsoon in the future.

These were associated with damage to lives and property, destruction of the environment and farmlands, leading to food insecurity and financial losses in the region. In Indonesia, Thailand and Viet Nam, high frequency and intensity weather events such as heat-waves, droughts, floods and tropical cyclones have often resulted in water shortages affecting agriculture production and human food security (Choi, Collins et al. 2009, Zhuang, Suphachalasai et al. 2010). Wild fires, degradation of coastal regions and health risks associated with these events have been reported among the populations in the region. Climatic projections in the region by Schewe and Levermann (2012) and Gasparrini, Guo et al. (2017) show increased warming and drying coupled with sea level rise, increased incidence of disease outbreaks, declining crop yields, loss of rich forests, damaged coastal resources all of which will adversely affect the economies, resulting in human suffering. These findings attest to the negative impact of climatic variation at different temporal and spatial scales in the ASIA Pacific region, which appears not different from developing countries.

In Africa, Thompson (2010) observes that over the last 35 years, ice-core records of climatic and environmental variations from low latitude high elevation polar regions show that glaciers have served as early indicators of climate change. Observations of the 20th and 21st century glacier shrinkage on Mount Kilimanjaro confirm continuous existence for periods ranging from hundreds of years to multiple millennia. The argument is that climatological conditions that dominate those regions currently are different from those under which the ice fields originally accumulated and had been sustained, indicating changes in climatic patterns over time.

In another study, James and Washington (2013) scaled down global climate models to continental level in order to examine temperature and rainfall anomalies over Africa. This analysis found a wet signal (higher rainfall) in the east African region, a dry signal (drought) in southern Africa, the Guinea coast and the west of the Sahel regions. These variable climatic patterns had wider socioeconomic impacts that affected the health and livelihoods of people in the regions. For instance, droughts and floods were associated with low crop production, lower household incomes and consequently food insecurity. Increasing incidences of infectious diseases i.e. malaria, diarrhoea, thriving under increasingly warming and humid conditions were also recorded, suggesting that prevailing climatic conditions negatively impacted people's survival.

However, this study does not explain that these climatic effects did not work independent of various factors that might have provided requisite conditions for these effects to surface. For instance, socioeconomic (Vozoris and Tarasuk 2003) and even demographic conditions that might have influenced these effects, considering that Africa is generally a poor, highly populous and geographically prone to adverse climatic effects (Busby, Smith et al. 2014). Anyah and Qiu (2012) also analysed the 20th and 21st century precipitation and temperature patterns and changes over the greater Horn of Africa based on a sample of Coupled Model Inter-comparison Project version 3 models output. Results showed that the equatorial eastern Africa region (including the entire greater horn of Africa) had been experiencing a significant increase in temperature from the early 1980s. The models found higher likelihood of increasing minimum and maximum temperatures in the future.

Another study conducted in Ghana by, Adu-Prah, Appiah-Opoku et al. (2017) based on time-series analysis of temperature and rainfall showed climatic anomalies in selected agro-ecological zones between 1981-2009. Increasing temperatures from 0.5 to 1 degree with varying inter-annual distribution were detected, providing evidence of local climatic variations even at local ecological zone levels. Weber, Haensler et al. (2018) used an ensemble of 10 different general circulation model-regional climate model simulations to assess global warming in Africa. Results of the analysis showed that regions between 15° S and 15°N had expectations of hot nights and longer and more frequent heatwaves even if the global temperature will be kept at 2°C. Further, daily rainfall was expected to increase toward higher global warming scenarios affecting the African sub-Saharan coastal regions.

A study by Serdeczny, Adams et al. (2017) assessed the physical and social repercussions of climatic change impacts in sub-Saharan Africa by combining original data on heat extremes, precipitation and aridity, with probabilistic projections (regional sea level rises) and review of literature. Extreme heat events, increasing aridity, changes in rainfall patterns with more pronounced declines in different parts of the SSA region, especially eastern and southern Africa, with predictions of sea-level rises under 4 degrees warming by the end of the current century were detected. Unlike the European region, these climatic patterns were argued to affect rain-fed agriculture systems, resulting in food insecurity, spread of infectious diseases and food price increases, highlighting spatial variations in climatic effects around the globe. Informative about climatic variation effects, the assumptions used in the model were not discussed, considering that climatic effects do not operate in isolation, suggesting the results ought to be considered within the limits of the study.

Reviewed literature on drought analysis in Africa based on lake sediments, tree ring chronologies written oral histories and projections from global climatic models by Masih, Maskey et al. (2014) also suggest a gloomy climatic picture in the continent. Results showed frequent droughts in the years 1972/73, 1983/84, 1991/92, 1999-2002 in northwest Africa, 1970s and 1980s in Western Africa especially the Sahel region, between 2001–2003 in the southern and south-eastern Africa, 2010-2011 in the Horn of Africa. Predictions show persistent and increased drought intensity and aridity at continental scales with large differences at various spatial scales. These wide scale droughts are associated with higher demand for water among population, environmental and land degradation which affects people's survival.

A mapping of climate vulnerability in Africa by Busby, Smith et al. (2014) also noted severe consequences of what was termed 'accidents of geography', amongst which were exposure to cyclones, storm surge, drought, intense rains, wild fires among other physical phenomena. These varied across spatial scales in the region, with coastal and densely populated regions having a larger share of these climatic misfortunes. The effects include poor health and limited access to survival resources i.e. arable land for farming, and infrastructure.

In Malawi, Kaonga, Kosamu et al. (2015) assessed climatic variation in the city of Lilongwe by analysing solar radiation and temperature data from Chitedze station, spanning 29 years (1985-2013).

Results showed an increasing pattern of minimum temperatures in the city, but solar radiation and maximum temperatures showed increased variation over the period of analysis. Although the study attributed the increasing solar radiation in the city to rising atmospheric carbon dioxide concentration, the country's carbon food print is by global standard negligible, standing at 10.85mtCO_2e*, translating to 0.02 percent of world total as of 2011 (USAID 2016). Land use change, forestry and agriculture could however be the most significant contributors to the country's rising carbon footprint, influenced by increased population in need of land for agriculture and infrastructure.

However, these results do suggest the need for large spatial scale analysis on changes in surface solar radiation as a result of increased carbon concentration in the atmosphere, driven by industrial gases. Results of such analyses could guide efforts to address climatic variations and changes influenced by the two key drivers; land use, forestry and agriculture. Further, considering that climate is such a complex system involving other variables i.e. precipitation, wind patterns and sea level temperatures, it is hardly possible to establish that Malawi is undergoing significant climatic changes based on patterns of two climatic variables analysed in the study.

In what could seem an attempt to address limitations of the above study, Ngongondo, Xu et al. (2015) examined spatial and temporal characteristics of key water balance components using a 30 year (1971-2000) rainfall, temperature and evapotranspiration data, and soil moisture capacity extracted from global gridded surfaces of selected soil characteristics database. Results showed that in Malawi, areas of high rainfall and runoff were detected in the south-east and north east highlands of the country, decreasing westwards. Statistically significant trends in mean temperature and declines in annual rainfall and runoff were detected, though the later were not statistically significant.

The team contend that these results signify decreasing water availability during the studied period, suggesting that the country's climatic conditions could negatively affect livelihoods such as farming. However, though spatially comprehensive i.e. using 27 weather stations, the use of point-based (station) data limits understanding of climatic patterns of the country, since only areas with weather stations might have been the only ones covered in the study. Such scenarios compromise the overall analysis of climatic patterns for the country, leading to gaps in understanding climatic variation and changes, as well as mapping their impacts.

Apart from scientific and statistical analysis of climatic elements such as temperature and rainfall providing insights about climatic conditions of the country, evidence from qualitative studies also provide an empirical picture about Malawi's climatic conditions over time. A study by Sutcliffe, Dougill et al. (2016) on seasonal changes in climatic properties found that farmers preferred early maturing and drought resistant cultivars on account of perceived variation in rainfall characteristics during the growing season. Among the perceived changes were delays in onset of cropping season rainfall, shortening duration and increases in dry spells during the season. Another study by Joshua, Ngongondo et al. (2016) cross validated people's perceptions on rainfall patterns during the growing season and station-based rainfall data spanning 50 years. Results showed that seasonal rainfall had higher variability linked to the general pattern of change observed in southern Africa. In essence, Malawi's climatic patterns reflects the regional situation, where people's livelihoods are likely to suffer.

Most studies assessing effects of climatic variability on human populations highlight negative ones (Rojas, Feyen et al. 2013, Gizaw and Gan 2017)i.e. injuries due to catastrophes like floods, landslides, and rise in infectious diseases due to high vector growth and distribution, especially in poor, hotter and low lying areas. Tol (2009) argues that climate change impacts may well be positive, although in the long run, negative impacts might outrun the positive. However, other analysists have isolated some few positive effects associated with the changing climatic patterns in other areas. For instance, In Europe, Branscombe (2018) argues that while warming climatic conditions slow tourists flow in warmer European countries like Spain, Portugal and Greece, there would be an upsurge in European countries that have colder climates, because warming conditions would provide favourable weather for migration of people in seasons conventionally unfavourable, such as winter. Such changes would boost national income from tourism, local revenues and economies in the countries.

Jacob, Kotova et al. (2018) also argues that there could be rise in household savings among countries in the Scandinavian and Mediterranean regions as families spend less on heating costs as winter months get milder. In other instances increasing warming in some regions would result in increasing precipitation, which would provide water for domestic and agricultural use (Jacob, Kotova et al. 2018), leading to longer seasons and higher production of agriculture, enhancing food availability and income.

However, these positive climatic spin-offs do not override the serious negative and sometimes deleterious effects such as heat waves, fierce storms, floods and droughts causing food insecurity and poor health across the globe (Stocker, Qin et al. 2013). As such, efforts to adapt to and mitigate effects of global and regional climatic changes are an urgent imperative.

This section presented a conceptual overview of climate change and variability in order to provide basic understanding on concepts used in studying climate and its changes. The section further discussed methods for analysing climatic variation and change, highlighting strengths and weaknesses, suggesting improvements wherever possible. A discussion on global climatic trends and their effects, with a focus on European, Asia-Pacific and African sub-continents was also made to provide insights about regional climatic patterns.

Evidence indicate that global climatic patterns have undergone change aided by the influence of increased proportions of greenhouse gases in the atmosphere, leading to global warming and erratic climatic patterns. There are more negative than positive effects associated with such changes in climatic conditions, ranging from direct threats to human and animal life to diseases affecting and socio-economic impacts. These effects vary in type, magnitude and severity, presenting varied consequences on human lives. The effects have been rife in poor resource and geographically prone regions of the world i.e. SSA and south- east Asia. More studies are required at lower spatial scales to highlight climatic impacts in such areas other than on extended geographical scales like regions, in order to inform local policies and programs for mitigation and adaptation.

Models play significant role in projecting impacts but are limited to developed regions, with better skills, equipment for examining climatic effects. Few of the models have been used in developing regions, largely due to inconsistent observational data with which to model climatic parameters. Such situation leads to gaps in understanding variability of climatic conditions at varied spatial scales in developing regions of the world, slowing down design of strategies to address adverse effects of climate change. There are still difficulties in isolating causes from associative factors of climatic impacts across varied spatial scales, largely because climatic effects are sometimes influenced by some non-climatic factors i.e. socioeconomic and demographic characteristics of affected regions.

Further, focus of the studies has been examining associative than causative factors of noted climatic effects on human populations. Few studies have isolated the effects as climatic and non-climatic factors, affecting design of interventions with which to address the negative climatic effects at different spatial and temporal scales. Further, emphasis of most studies has been on examining effects of adverse climatic extremes rather than effects on changes in average conditions over varied temporal scales. This leads to continued limited understanding on how average changes in climatic conditions at varied spatial and temporal scales affect people, limiting effective design of strategies to avert and mitigate the effects.

There is therefore an urgent need to extend analysis of climatic change effects to lower than regional spatial scales, using longer time series observation other than model data, highlighting the negative effects associated with average weather and climatic conditions other than only focusing on climatic extremes. Such bold steps will provide information for specialised policy programs addressing local and lower spatial scales climatic change or variation of effects in order to deal with climate change and variation induced human suffering.

2.3. Conceptual overview, measurement and trends in global and regional food security conditions

2.3.1. Conceptual overview of food security

Historically, the emergence of food security as a concept dates back to an exposition by Thomas Malthus in 1798, who predicted that population growth would unavoidably supersede food production in future. Although there have been efforts to avert growing imbalances between population growth and food availability globally, there still remain challenges to feed growing world population (Barrett 2010). In 1996 the World Food Summit defined food security as a condition which exists when all people at all times have physical and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and health life (FAO 2008). Food security as a concept has four dimensions namely; food availability, food access, food utilization and food stability. Food availability addresses the 'supply side' of food security and is determined by level of food production, food stocks, food aid, and net trade (import vs export) (Rose 2010).

There are various factors which influence food availability and these vary from place to place, time to time, exerting their influence on food security individually and sometimes concertedly with other factors. Caswell, Yaktine et al. (2013) classified factors influencing food availability as individual, household and environmental in nature. Environmental factors concern geography and climate. Since the most basic source of food is production on farm lands, location of farm land and its quality determines suitability of crops that could be cultivated for food. Rainfall and temperature are key climatic factors to food production as they provide water and warmth required for various plant phenological processes essential for good yield and food availability (Kumar, Ahmad et al. 2017).

Different crops respond differently to different soils, influenced by environmental characteristics which have significant bearing on soil texture and nutrient composition, all of which affect crop growth and yield (Whitmore and Whalley 2009). In essence climate as an environmental factor affects all components of crop production i.e. area, cropping patterns and intensity and as well as yield, which is an essential element of food production and availability (Iizumi and Ramankutty 2015). Caswell, Yaktine et al. (2013) explains that consumers choose foods for consumption within the context of their own, their household’s preferences and available resources.

Households purchase foods and other market goods to maximize utility or well-being, based on their preferences and subject to the constraint that the cost of those goods is less than or equal to the sum of all sources of income. According to the household production theory, households combine time and market goods to produce commodities for consumption. Essentially, households’ preferences and resources do influence food availability. At an individual level, labour force participation, earnings and education characteristics are some of the factors which influence availability of food on the household, since they determine an individual’s capability to produce food. Individual level factors are majorly influenced by personal attributes and characteristics, which enables people engage in activities that would help them get food for themselves and their households.

Food access refers to the physical, economic and social means through which food is made available to people (FAO, IFAD et al. 2017). This dimension was first presented by Amartya Sen in a treatise on Poverty and Famines (Sen 1976). The concept has three elements; physical access, economic access and socio-cultural access.

Physical access refers to logistical ability to access food, i.e. presence of roads linking markets, market themselves, and transport to where food is found by those in need (Burchi, Fanzo et al. 2011). Economic access to food security refers to availability of income to the people that need food at a given place and time. For instance, if food is available and physical infrastructure such as roads and markets are available but households do not have income with which to purchase the food, such people would hardly be food secure. Social access to food security refers to situations where there are no socio-cultural or traditional barriers to access of food by individuals or households in a given context (Gibson 2012, Tshediso 2013).

This dimension emerged as a result of situations where food is available and there is physical and economic (financial) access to it, but some people are barred from accessing it due to traditional sanctions which could determine who accesses food, of what type, when, how and how much of it (Zhou, Shah et al. 2017). For instance, women, children, and elderly people are barred from accessing and consuming certain foods on account of tradition or cultural dictates. In other places, social cohesion and deprivation influences food access to some people (Carter, Dubois et al. 2012). Certain groups of people are barred from accessing some foods in certain conditions due to religious reasons, despite food being physically available and economically accessible (Musaiger 1993, Hajdu, Hadju et al. 2009, Zhou, Shah et al. 2017).

Food utilization, refers to the way human bodies make the most of various nutrients from the eaten food. This concept also relates to safe and nutritious food which meets dietary needs of people (Jones, Ngure et al. 2013). This dimension is facilitated by feeding practices, food preparation, food and diet diversity, intra-household food distribution and allocation, and biological utilization of food, all of which determine individual nutritional status (Bimerew and Beyene 2014). Food utilization is increasingly becoming a key focus in food security analysis owing to changing nature of food availability and access, as a result of improved technology (FAO 2008). For instance, in modern days, foods are produced with higher technology i.e. hybrid seeds and fertilisers, processed and preserved using various modern technologies, all of which affects food quality (Gómez, Barrett et al. 2013). Changes in global climatic conditions have also posed negative effects on food preservation technologies, compromising optimum utility of food value (Vermeulen, Campbell et al. 2012), which is an essential component of food security.

The fourth dimension of food security is food stability. Food security does not have to be for a moment, a day or a season only, but permanent, with assurance of sustainability (Clover 2003). To be food secure, all other dimensions of food security; availability, accessibility and utilization must be ensured at all times (Burchi, Fanzo et al. 2011). Individuals and households must not risk losing access, availability and utilization of food due to economic shocks such as unemployment, or rising food prices, political instability i.e. conflicts, climatic or cyclical events i.e. seasonality, man-made disasters i.e. accumulation of food stocks, diversification, constant access to healthcare, clean drinking water and sanitation among others (FAO 2008).

The flip-side of food security is food insecurity, which is by default the opposite of the four concepts of food security; availability, accessibility, utilization and stability (Bartfeld and Dunifon 2005). Food insecurity exists whenever the availability of nutritionally adequate and safe foods or the ability to acquire acceptable foods in socially acceptable ways is limited or uncertain(National Research Council 2006). Essentially, food insecurity is a social and economic problem of lack of food due to resource or other constraints, not voluntary fasting or dieting, or because of illness, among other reasons. This condition is experienced when there is uncertainty about the future of food availability and access, insufficiency in the amount and kind of food required for a healthy life style or the need to use socially acceptable ways to acquire food (Farzana, Rahman et al. 2017).

There are two types of food insecurity; chronic and transitory food insecurity, both concerned with the time dimension of the concept. Chronic food insecurity is long term or persistent. It occurs when people are unable to meet their minimum food requirements over sustained or longer periods of time (Hart 2009). The causes of chronic food insecurity include poverty and lack of assets with which to produce food and financial resources for acquiring food (Tolossa 2002). Chronic food insecurity can be addressed with long term development measures such as education or access to productive resources such as credit. However, chronically food insecure people need direct access to food to enable them raise their productive capacities (Timmer 2014). Transitory food insecurity is a short term or temporary food deficit caused by a sudden drop in the ability to produce or access enough food to maintain a good nutritional status.

This situation results from short-term shocks and fluctuations in food availability and food access, including year to year variations in domestic food production, food prices and household incomes. Transitory food insecurity is relatively unpredictable and can emerge suddenly. This could make planning and programming more difficult as it requires different capacities and types of interventions, critical of which are early warning systems and safety net programs (FAO 2008).

The concept of seasonal food insecurity falls between chronic and transitory food insecurity, but it is of limited duration and can be recurrent, transitory food insecurity. In essence, it occurs when there is a cyclical pattern of inadequate availability and access to food, associated with seasonal fluctuations in the climate, cropping patterns, work opportunities and disease. Cyclical food insecurity is usually more easily predicted than temporary food insecurity because it generally follows a sequence of known events. An important factor to note is that the four dimensions of food security are more intertwined than independent of each other in their potency to affect human populations. For instance, food must be available first before it is accessible, whether physically or economically. Food must also be accessible before it is utilized.

These three dimensions i.e. availability, accessibility and utilization must be stable at all times if one or a group of people are to be deemed food secure in a given geographic, economic and socio-cultural context. These inter-relationships indicate that efforts to analyse and address food insecurity must consider the linkages existing among these dimensions if they are to be effective. A major problem however in understanding food security as a concept is that it is very complex in nature because it touches on so many areas of life i.e. social, economic, cultural, environmental and sometimes psychological conditions, which vary across contexts.

Food security is basically an international concept. Much as it can be locally adapted depending on how the four elements i.e. availability, accessibility, utilization and stability are conceptualised within a given context, It is generally a global concept and this enables comparability of the conditions across varied socio-economic dimensions at varied spatial and temporal scales. In Malawi, there is no locally adapted definition, however, considering that Malawi’s source of food is own production from the farm, and that maize is the main staple food in the country, its shortage among households spells significant concerns on food security (all elements).

As such maize availability is synonymously conceived as a key component of food security in the country (Stevens and Madani 2016). As Gibson (2012) noted, food security as a concept is wrapped up inside an ever growing bundle of societal aspirations including inter-alia under-nutrition, poverty, sustainability, free trade, national self-sufficiency, reducing female subjugation among other issues. This entails that understanding the meaning of the concept requires lots of triangulated data about how food secure or insecure an individual or group of people could be and levels of food security or insecurity. This realization is key to efforts designed to address food insecurity, with a focus on fully understanding just what it indeed is included, implied, understood or excluded within the food security catchall (Gibson 2012).

Addressing food insecurity therefore might require long term measures that directly or indirectly act on the causative factors (Chilton and Rose 2009). Such efforts include addressing poverty by providing people with credit schemes, enhancing education to raise people's skills, employment prospects, earnings and improving access to food through aid, and enhancing productive capacity to produce food and a human rights approach to food security (FAO 2008, Holben and Marshall 2017).

2.3.2. Measurement of food security

Measuring food security is challenging due to interconnectedness of its multiple dimensions. Coates (2013) argues that though food security has been successfully deconstructed by various analysts, its measurement still remains inconclusive.Various challenges have however been mentioned with regards to measures of food security, i.e. measuring dietary adequacy, as it vary from one context to another, distinguishing the constructs for which diet represents, differentiating various components of food dimensions i.e. food access, applying cut-off points for defining food insecurity, mitigating potential response bias from experience-based measures i.e. food availability, acknowledging trade-offs and validating measures amid great diversity in approaches, (Jones, Ngure et al. 2013). Despite the foregoing, there are globally recognized measures and indicators that are applied to assess various dimensions and elements of and associated with food security.

The global hunger index (GHI) was developed by International Food Policy Research Institute (IFPRI) to measure hunger using equally weighed indicators such as undernourishment, child wasting, stunting, underweight and child mortality on a 100–point scale(Myers, Smith et al. 2017). This scale is categorized from low to extremely alarming hunger as a sign of severe food insecurity (Coates 2013). This indicator takes into account factors of insufficient food availability, undernourishment and mortality, as such comprehensive enough to measure food security and malnutrition (Wiesmann 2006). Some analysts have reported challenges associated with using this measurement. For instance, assessing malnutrition requires analysing diet and frequency of food uptake, deciding how many and which food groups to include in the measure, how to account for quantity of each food groups consumed, what recall period to use and how to assign cut-off points in defining levels of dietary diversity (Wiesmann 2006, Jones, Ngure et al. 2013).

These factors have led to variation in measurement outcomes and lack of harmony in the measurement of food security using this indicator (Jones, Ngure et al. 2013). Further, hunger has many facets, and as such it is not sufficient for the index to only capture food availability. The direct consequences of hunger such as shortfalls in nutritional status and reduced changes of survival also need to be taken into account in the GHI. Vitamin and mineral deficiencies also ought to be considered. These data are not sufficient on an international scale, making it difficult to assess the global hunger and food security situation (Von Grebmer, Fritschel et al. 2008).

Another popular food security measurement is global food security index (GFSI). This is a multi-dimensional tool that assesses country level trends in food security using 30 indicators focusing on affordability, availability, access, quality and safety of food. It provides a standard against which country level food security is measured (The Economist 2018). This measurement looks at the dynamics of food systems around the world and the central question it seeks to answer is; how food secure is a country? Although food security is complex and multifaceted, influenced by culture, environment, geographic location, the index does not capture intra-country nuances, by distilling major food security themes down to their core elements. Further, Künnemann and Epal-Ratjen (2004) explains that the ‘affordability indicators’ used in the index assume that all people are consumers, whilst in reality, most of the food insecure people are mainly producers and partially consumers buying food on the market. As such, a careful methodology has to be applied to determine 'food consumption' as a share of the household expenditure. The team further observes that the world poverty lines misses out at least on the whole range of countries what people harvest and collect to feed themselves, such that simplistic monetization may lead to wrong data on poverty and to wrong policies for addressing people's needs (Künnemann and Epal-Ratjen 2004). However, despite these reported shortfalls, this measurement tool enables a country-level food-security assessment and has become a policy benchmark for government and a country diagnostic tool for investments to address global food insecurity (The Economist 2018).

Another measure of food security is dietary diversity score (DDS) and it addresses the dimension of food utilization by analysing consumption of food at household and individual level i.e. women, children and men (Thapa G 2017). This indicator was developed by the Food and Agriculture Organisation (FAO) of the United Nations as a qualitative 24-hour recall measure of all food and drinks consumed by a respondent or household. The 24-hour recall period is less prone to recall errors, less cumbersome for respondents than a seven or thirty-day period (Ochieng, Kirimi et al. 2016). Calculating the scores is a straightforward process and training others to collect data does not require a lot of time.

The measurement provides a fuller picture about foods consumed at household and individual levels. It is also a proxy measure for individual and household economic access to food and its availability, considering that before food is utilized it has to be accessed (Coates 2013). In rural agricultural based communities, dietary diversity is used when food supplies are still adequate i.e. up to 4-5 months after the main harvest. Considering that there are seasonal differences in dietary diversity patterns in many areas around the world there is need for measuring dietary diversity in different seasons in order to come up with a complete usual diet for individuals and their households (Kennedy, Ballard et al. 2011). In non- agriculture-based communities however, dietary diversity scores can be measured anytime, especially if seasonality is not an important issue. Among the weaknesses of the measurement is that dietary assessment modules vary from one context to another, as such require tailoring the assessment to contextual situations. Further, the scores applied on each of the questions used in the assessment do not provide a quantitative dietary intake and are not a direct measure of nutrient adequacy (Bell, Saltzman et al. 2016).

In addition, the cut-off points do not predict nutrient adequacy in the contexts for all population groups, and when applied on households, the dietary diversity scores do not provide information on individual household members and cannot be used to draw conclusions about individuals (Thapa G 2017). Despite these weaknesses, dietary diversity is still a relevant and reliable indicator for assessment of not only food security but also nutritional status at household and individual level. Its information is key to design of nutrition interventions, especially among under-five children in developing countries, where complex nutrition measures are limited due to data, skills and resources (Burchi, Fanzo et al. 2011).

Household consumption and expenditure surveys (HCES) have also increasingly become a useful tool for measuring national level estimates for prevalence of undernutrition based on consumption and expenditure of certain foods (FAO 2018). HCES facilitate measurement of access to food security through analysis of poverty, consumer prices and household socio-economic status. However, recall information from household expenditure is sometimes unreliable since it is based on memory than records as in most developed regions of the world where food inventories or receipts are kept with strictness to assess expenditure.

The other limitation of these surveys is that they are expensive and might take time to produce results of analysis, which in situations of urgent policy and program guidance i.e. disasters, social conflicts might not be feasible, as such not universally applicable across contexts. There are also possibilities of over-estimation of the measurements because waste foods are included as part of consumption, and are qualitatively thought to be inferior (Lividini, Fiedler et al. 2013). Some purchased foods within the recall period are not consumed and some foods consumed during the recall may not be purchased within the recall period (Fiedler, Lividini et al. 2012). All these have effects on the accuracy of the measurement. However, these surveys are a useful policy tool on food insecurity assessment as they are based on information from a large section of societies, thus providing a broader picture of the food security situation in a given context, important for broad-based policies to avert hunger and food insecurity.

The household food consumption score (HFCS) is a measure of household food security which addresses the access and utilization dimensions of food security. The measure was developed in 1996 by the World Food Program (WFP) and it aggregates household level data on diversity and frequency of food groups consumed using a seven-day recall data from a comprehensive food security and vulnerability assessment survey (CFSVA)(Kennedy, Berardo et al. 2010). Frequently assessed foods are staples i.e. cereals, meats, fats and oils. The frequency of consumption is multiplied by weights to provide scores which show food insecurity. Based on the scores, a household's food consumption can be further classified into one of the three categories: poor, borderline or acceptable. It also serves as a proxy indicator of household calorific availability. The HFCS captures information about the usual household diet, incorporating consumption frequency over a seven-day recall period unlike the Household Dietary Diversity Score (HDDS) which only gathers information about the previous day consumption (Kennedy, Ballard et al. 2011).

Although both indicators were designed to capture the quantity (energy) and quality (nutrient adequacy) of food, no gold standard measure has ever validated their results. As such these indicators should only be used as proxy for energy sufficiency (quantity dimension). Although the standard nutritional value weights were applied to the food group index in order to reflect the calorie content of the diet pattern than an index where all food groups are equally weighed Wiesmann, Bassett et al. (2009) suggests that the weights do not usefully increase association of the HFSC index with caloric intake over an unweighted version of the index, and the weights themselves are not based on a clearly defined nutritional metric. Further, like all recall-based dietary measurement methods, this indicator suffers from errors associated with respondent recollection of foods consumed over longer periods, like seven days (Kennedy, Ballard et al. 2011).

2.3.3. Modelling food security

Considering that in many developing countries, access to adequate and sufficient food is generally unstable due to various factors i.e. perennial low crop production and low income, poverty, adverse climatic conditions and poor survival strategies (Kennedy, Nantel et al. 2004), household and individual food security is therefore thought of in a dynamic sense (Capaldo, Karfakis et al. 2010). Such understanding entails that more widely food security is considered and measured in terms of current access to food other than forward projection whose input is crucial for programs addressing food insecurity. In such situations modelling food security status plays an important role in policy formulation and programs design (Capaldo, Karfakis et al. 2010).

Among the models that have been applied in household and individual food security assessment are the Rasch Measurement Models. These belong to a group of Item Response Theory Models (IRTs) used in social science research to analyse performance of attitudinal data in psychology, education, medicine, marketing and other fields, where testing is a relevant component. (Moffitt and Ribar 2016). The Rasch measurement models relate responses from multiple binary (yes/no) questions about an underlying condition to that condition. They separate two kinds of parameters, one that describe qualities of the subject under investigation, and the other relates to qualities of the situation under which response of a subject is observed. Using conditional maximum likelihood estimation (CML) both parameters may be estimated independent of each other. The models are well suited to cope with dichotomous and polytomous responses, where response categories may be ordered or unordered, and incorporating linear structures that allow modelling effects of covariates and analysis of repeated categorical measurements (Moffitt and Ribar 2016). Rasch models have been used to develop food security scales and compare measures from subsets of the food security questions and from alternative sets of questions, to identify thresholds of very low food security among households and individuals (Moffitt and Ribar 2016).

Christiaensen and Boisvert (2000) argues that to reduce future food insecurity and undernutrition, policy design should address the uncertainty that households face alongside their risk management options. As such, vulnerability analysis (VA) is argued to offer a solution to this problem by providing a quantitative estimate of the probability that a given household will lose access to sufficient food in the near future. Although a standard model has not arisen yet in the field of food security analysis, different analytical methods coexist which adapt to analytical advances made in the field of poverty analysis to food security analysis, enabling poverty and food security analysis together (Christiaensen and Boisvert 2000).

The team proposed an estimation procedure that could be replicated using data from a single household survey, arguing that compared to static food security analysis that categorise households into 'food secure' and 'food insecure', 'vulnerability analysis' allows households to be classified into four categories. Relying on calorie consumption and its probability distribution, households are disaggregated into chronically food insecure, transitory food insecure, permanently food secure and transitory food secure. This categorisation improves the targeting of resources since it enables policy makers to distinguish between currently food insecure households that are able to improve their situation without external assistance (i.e. transitory food insecure) from currently food insecure households that are not able to improve their food security situation with external assistance (Christiaensen and Boisvert 2000).

Food security vulnerability assessment models draw from poverty vulnerability models, which define vulnerability as a probability that the household's expected dietary energy consumption measured in kilocalories will fall below the standard threshold. The index is used to evaluate the future nutritional adequacy of the two period consumption plan stemming from inter-temporal optimization in the presence of imperfect capital markets (Christiaensen and Boisvert 2000). The advantage of these vulnerability assessment models is that they are dynamic and 'forward looking' i.e. assessment of risk of shortfall regarding future ability to attain a certain threshold of well-being, other than the current 'access' to food security. The models assess food security ex ante rather than examining it as ex post outcome hence important for policies addressing food insecurity. The analysis is cast in a stochastic framework and can therefore fully consider the uncertainties associated with future food insecurity such as the role of external shocks and the strategies that households, communities or public institutions can adopt in order to reduce the likelihood of negative outcomes (Scaramozzino 2006).

Further, the categorization of vulnerable population into different groups spells the unique policy intervention that would be required to address the food insecurity needs of each group, ensuring proper targeting of resources. The major disadvantage of most of the food security vulnerability models is that responses to a set of the questions could be affected by respondents' bias based on perceptions, where people may exaggerate their vulnerability in expectation of assistance, especially in developing countries, where such surveys are associated with relief and safety nets as interventions. The 'exaggeratory effect' which leads to the bias may pose a threat to quality of data input for the models. Efforts to address this form of bias are therefore essential prior to the collection of data i.e. 'response drift' as suggested by Pérez-Escamilla and Segall-Corrêa (2008) where respondents may have adjusted their internal standards of food security based on changing environmental conditions.

Further, individual's perceptions of food security may not necessarily represent the experience of all household members, yet the experience – based measures such as the Household Food Insecurity Scales and require the respondent to answer on behalf of all household members (Jones, Ngure et al. 2013). Recall biases associated with vulnerability analysis methods also pose a significant challenge, leading to inaccurate measurements on the scale as the responses become varied and sometimes not fitting with the tools and models to be used in the analysis. There are also challenges with setting 'cut off' points in the scales that are generated to classify people into different categories (Pérez-Escamilla and Segall-Corrêa 2008), and also deciding basis for the cut-off points to ensure people are in one category only.

There are also concerns about clarity of the concepts being measured and the levels of their application i.e. individual or household, since in most cases there is interrelationship among food security elements (National Research Council 2005). Further, most questions in food security analysis concern food uncertainty, food insufficiency, hunger, whether these concern food security or insecurity, and what is actually being modelled. All these challenges entail that modelling food security situation is a complex undertaking, requiring multiple approaches that might cut across disciplines and methodologies in order to establish a true reflection of the situation on the household or the individual's food security situation.

2.3.4. Global, regional and local food security situation

In 2016, FAO, IFAD et al. (2017) estimated that globally, 815 million people experienced hunger and food insecurity as of 2016, most of which were in the sub-Saharan Africa region, South-Eastern and Western Asia. These regions experience adverse climatic conditions, social and political conflict which influence poverty and economic slowdown, plunging households into severe food insecurity and abject poverty (Auvinen 1997, Ikejiaku 2009, FAO, IFAD et al. 2017). According to 2017 FAO estimates, the European and Central Asian region had 14.3 million people who experienced severe food insecurity between 2014 and 2016. The situation was greater in the Caucasus (5.4. percent) followed by South-eastern Europe (5.2 percent), with varied levels of severity across countries (FAO, IFAD et al. 2017). Among the central Asian countries, the prevalence of food insecure people was 2.1 percent (approximately 1 million people) and the European Union having the lowest share.

In Africa, Sasson (2012) observes that an estimated 1 billion people were suffering from various forms of food insecurity in 2012, raising concerns of missing the 2015 targets set in the Millennium Development Goals (MGDs) of halving extreme poverty and hunger. Sub-Saharan-African alone constituted 239 million food insecure people, with projections of an increase in future (Chakona and Shackleton 2017). Latest statistics indicate that in 2017, 124 million people across 51 countries and territories of the globe faced crisis levels of acute food insecurity or worse, with urgent humanitarian action (FAO, IFAD et al. 2017) required. Estimates indicate an increase of 11 million people (11 percent) in this category from 2016, influenced by intensified conflict in countries like Mynamar in south-eastern Asia, north-eastern Nigeria, Democratic Republic of Congo (DRC), and South Sudan in Central Africa (FAO, IFAD et al. 2017).

Malawi's food security is dependent on agriculture, influenced by rainfall and various socio-economic factors such as poverty, labour, land, availability of inputs among others (Chilowa 1998, Dorward and Chirwa 2011). Crop production has always been the main source of food, especially the 85 percent of the population residing in the rural (Goletti and Babu 1994, Malawi Government 2016), such that crop yield and precisely maize, is associated with household and indeed national food security (Chirwa and Ngalawa 2008, Dorward and Chirwa 2011, Aragie, Pauw et al. 2018).

The country's food security situation is precarious in the sense that apart from poor socioeconomic conditions influencing household food insecurity, its unstable climatic patterns evident in variable rainfall, has negatively affected crop production and consequently food security among households (Sahley, Groelsema et al. 2005, Sutcliffe, Dougill et al. 2016). Frequent droughts and floods regulate crop production and indeed household and national food security, amongst which have been the 1949/50 drought (Babu and Chapasuka 1997), the 1971/72 (Savage 1973), and the 1991/92 one which caused more severe food insecurity in the country (Devereux 2002, Dorward and Chirwa 2011). Other spatially sparse but with severe crop failure and food insecurity consequences droughts occurred in 2001/02, 2003/04 (Devereux 2002, Hajdu, Hadju et al. 2009). Localised flash floods with severe food insecurity effect in affected areas occurred in the 1983/84 and 2014/15 cropping season (Kimaro and Sibande , Suckall, Fraser et al. 2017).

A 2016/15 cropping season FEWSNET report indicated that the country experienced high food insecurity in the 2015/16 cropping season, where by October 2015, up to 6.7 million people were classified as food insecure.

Although government and international humanitarian agencies have implemented interventions to reduce number of food insecure people in the country, not much has improved as the number of people experiencing different forms of food insecurity appears to increase, both in the urban and rural settings (Makombe, Lewin et al. 2010, Fisher and Lewin 2013). Among other factors, adverse changes in spatial and temporal characteristics of cropping season temperature and rainfall in many parts of the country, amid population growth pressure on land resources, shortage of cultivable lands, poverty and ever-rising costs of farm inputs amid ailing macro-economic conditions (Makombe, Lewin et al. 2010, Dorward and Chirwa 2011) influence food insecurity in the country. The overall effect of poor food security status is poor human health and human capital development, leading to low productivity, poverty and underdevelopment, at individual, household and national (FAO 2015).

Efforts to address hunger and food insecurity are pivotal to government development plans, as highlighted in the over-arching development strategy, the Malawi Growth and Development Strategy (2016-2022). However, more information is required to understand how variable climatic conditions add to the pressure mounted by poor socioeconomic conditions in augmenting food insecurity in the country. The current study sought to address this knowledge gap by examining how variable temperature and rainfall conditions, in concert with various socioeconomic factors influence household food insecurity in the country, in order to inform policies on food security.

2.4. Conceptual overview measurement and situation of child nutrition Status

2.4.1. Conceptual overview of child nutritional status

Unicef (1994) describes nutrition as the interaction of food intake, infectious diseases and the environment, influenced by socio and macro-economic conditions at individual, household, community and national levels. The Vienna 17th International Congress on Nutrition extends UNICEF's perspective to a totality of functional (metabolic and behavioural) characteristics of an organism, its dietary intake and the environment.

A well balanced diet combined with regular physical activity is considered fundamental to good nutrition and health (Kraemer, Cordaro et al. 2016). Poor nutrition on the other hand results in reduced body immunity, increased susceptibility to disease, impaired physical and mental development and reduced productivity (Skerrett and Willett 2010). The complex interaction of biological, environmental and socio-economic factors in determining human nutritional status makes nutrition measurement a complex undertaking (FAO, IFAD et al. 2017).

2.4.2. Measurement of human nutritional status

Measurement of human Nutritional status involves interpretation of anthropometric, biochemical, clinical and dietary data to determine nutritional status of individuals or population groups as influenced by the intake and utilization of nutrients (Knox, Zafonte-Sanders et al. 2003, Gurinović, Zeković et al. 2017). Information about nutritional status i.e. nutritional assessments, is essential for identification of potential critical nutrients for population groups at risk of deficiency; formulation of recommendations for nutrient intake; development of effective public health nutrition program for nutrition-related diseases, and prevention and monitoring the efficiency of such interventions (Elmadfa and Meyer 2014).

Nutritional assessments in any application has three general purposes: detection of deficiency states, evaluation of nutritional qualities of diets, food habits and supplies, and prediction of health effects (Combs Jr and McClung 2016). There are three types of nutritional assessment systems which have been employed in population-based studies and in the care of hospitalised patients namely; nutritional surveys, nutritional surveillance, and nutritional screening. Nutritional surveys are cross sectional evaluations of selected population groups conducted to generate baseline nutritional data from which to learn their overall nutritional status and identify sub-population groups at nutritional risk (Combs Jr and McClung 2016). On the other hand, nutritional surveillance is continuous monitoring of nutritional status of selected population groups i.e. risk groups, for an extended period of time (Derso, Tariku et al. 2017). These are conducted to identify possible causes of malnutrition to inform interventions. Nutritional screening is comparison of individuals’ parameters of nutritional status with pre-determined standards, and it is conducted to identify malnourished individuals requiring nutritional assistance (Rasheed and Woods 2013).

Different methods and techniques are used to measure human nutritional status, and they vary by objective of measurement, population characteristics i.e. age and health condition among other factors. The choice of method is guided by the objective of measurement, advantages and disadvantages of the methods, accuracy and reliability (Corsi, Subramanyam et al. 2011). Methods of nutritional assessment fall into five categories namely; Dietary assessment, anthropometric assessment, clinical assessment, biochemical assessment and sociological assessment (Combs Jr and McClung 2016). Dietary assessments involve estimation of nutrient intakes from evaluations of diets, food availability and food habits, using instruments such as food frequency questionnaires, food recall procedures, diet histories and food records (Kennedy, Ballard et al. 2011).

Anthropometric assessments involve estimation of nutritional status based on the physical dimensions and gross composition of an individual's body (Trapp and Menken 2005). Clinical assessments involve estimation of nutritional status by analysing medical history and conducting physical examination to detect signs and symptoms (Fontes, de Vasconcelos Generoso et al. 2014). Biochemical assessment involve estimation of nutritional status based on nutrient stores, functional forms, and metabolic functions (Sauberlich 2018).

Sociological assessment involve analysing non-nutrient factors affecting nutritional status i.e. socioeconomic status, food habits and beliefs, food prices and availability, food storage and cooking practices, drinking water quality, breastfeeding and weaning practices, age and cause specific mortality rates, birth order and family structure (McIntosh 1996). Most methods for measuring nutritional status fall in broader categories such as the Subjective Global Assessment of malnutrition (SGA)s, the Malnutrition Universal Screening Tool (MUST), the Mini Nutritional Assessment (MNA) and Nutritional Risk Screening (NRS). The methods rely on information about medical history, dietary intake, amount of weight loss, biochemical variables and anthropometric measurements (Filipović, Gajić et al. 2010). Nutritional assessment is also done using plasma protein as marker of protein energy malnutrition, and prognostic nutritional indices especially for hospitalised patients (Pham, Cox-Reijven et al. 2006).

The Subjective Global Assessment Score (SGA) is a clinical technique for measuring nutritional status of patients based on features of history and physical examination (Detsky, Baker et al. 1987). The method was developed as a tool for nutritional assessment among critically ill patients i.e. those with renal failure, cancer and surgical patients on dialysis treatment among other critical illnesses (Fontes, de Vasconcelos Generoso et al. 2014). The premise for use of this method is that protein calorie malnutrition increases patient morbidity and mortality risk. As such assessment of nutritional status is an important component of good medical care as it helps to identify those who would benefit from nutritional support (Araújo dos Santos, de Oliveira Barbosa Rosa et al. 2015).

The SGA predicts nutrition associated complications by identifying malnutrition, distinguishing it from a disease state, predicting outcome and identifying patients in whom nutritional therapy could alter outcomes of their conditions (Araújo dos Santos, de Oliveira Barbosa Rosa et al. 2015). This method improves nutritional understanding based on body-mass index, height, weight and dietary intake, all of which require re-call of numbers. This might be problematic for people with memory or estimation problems (Carniel, Santetti et al. 2015), compromising input data for the index. Various studies have been conducted to validate the SGA results, for instance in Brazil, Carniel, Santetti et al. (2015) validated the SGA using a cross-sectional study with 242 patients aged 30 days to 13 years treated in paediatric units of a tertiary hospital with acute illness and minimum hospitalization of 24 hours. Age, sex, weight and length at birth, prematurity, body mass index, upper arm circumference, triceps skinfold and subscapular skinfold were some of the physical variables used to validate the SGA. Statistical tests involved use of ANOV, Kruskal Wallis and Mann-Whitney, Chi-square technic and Kappa coefficient.

Concurrent validity results showed a weak correlation between SGA and anthropometric measurements ($p<0.001$), but the inter-observer reliability showed good agreement among examiners, with a Kappa 0.74), suggesting that the SGA was a reliable nutritional measurement. The advantage of the SGA is that it does not rely on patient memory or physical parameter which could be affected by non-nutritional factors to predict future or progression of nutritional status (Araújo dos Santos, de Oliveira Barbosa Rosa et al. 2015).

In instances where this method is used alongside the physical and anthropometric ones, correlation of the SGA score with results from any of these anthropometrics indicate reliability of the SGA (Janardhan, Soundararajan et al. 2011). However, the technique is criticised for subjectivity on the part of the analyst, in that it is harder for researchers to describe the prognostic manoeuvre and demonstrate reproducibility of the results (Detsky, Baker et al. 1987). Even so, the technique has been considered reliable in assessment of nutritional conditions for patients in clinical settings (Fontes, de Vasconcelos Generoso et al. 2014).

Malnutrition Universal Screening Tool (MUST) is another nutritional measurement technique used in clinical practice, mainly to predict clinical outcome in elderly people with illnesses (Ahmed, Arnold-Jellis et al. 2015). In some instances the technique has been used to screen malnutrition in both hospitals and the community (Parsons 2011). It takes into account domains not directly linked to food intake, but clinical when dealing with frail individuals such as those with functionality (mobility) depression and cognitive impairment (Ahmed, Arnold-Jellis et al. 2015). MUST is reportedly effective in predicting mortality and length of stay in older people. However, it has not been established whether a high malnutrition risk score was indeed an independent predictor of the observed clinical outcomes (Rasheed and Woods 2013). Lower Mini Nutritional Assessment scores (Lower version of the MUST) are associated with increasing mortality, prolonged length of stay and greater likelihood of discharge to nursing homes (Rasheed and Woods 2013) attesting to its reliability as a nutritional measurement tool especially among elderly people (Rasheed and Woods 2013).

One of the challenges associated with this method is the need to perform anthropometric measurement alongside it, while clinicians tend to prioritise other clinical tasks. For instance, in a study exploring factors influencing the use of the MUST by nurses in two Australian hospitals, Porter, Raja et al. (2009) used medical records, focus groups discussions and audio-recorded group narratives to generate data used for analysis. Results indicated that screening completion was limited by workloads, uncertainty about screening policy and also individual's skill in use of the tool, highlighting common shortfalls of this nutrition measurement technique. Despite this limitation, this method has been a reliable screening tool for predicting mortality in hospitalised elderly patients, compared to other methods i.e. the Birmingham Nutrition Risk (BNR) and Body Mass Index (BMI) (Henderson, Moore et al. 2008).

Nutritional Risk Screening Tools (NRS) are another set of methods for assessing present nutritional status and risk of impairment due to increased metabolism stress of a clinical condition (Rasmussen, Holst et al. 2010). As other nutritional assessment techniques, the method addresses questions about weight loss, recent food intake, current body mass index (BMI) and disease severity in order to predict risk of malnutrition. It is reportedly an essential first step in the structured process of nutrition care for identifying patients that will likely benefit from nutrition therapy and has been used in many studies assessing association between nutritional risk and clinical outcome (Rasmussen, Holst et al. 2010).

The commonly used methods for measuring child nutritional status are those that rely on anthropometric data such as age, weight and height, from which indices such as weight for age, height for age and weight for height are computed (de Onis, Onyango et al. 2006). Z-scores are then computed for each of the indices based on the reference population. According to WHO standards, a child is considered stunted i.e. low height for age if their z-score is below -2 standard deviations, and severely stunted if their weight for age is below -3 standard deviation units. A child whose weight for age is less than -2 standard deviations units is considered underweight, and a severely underweight child would be less than -3 standard deviation units. A child whose weight for height z-scores is less than -2 standard deviation units is considered wasted, and one whose z-scores are less than -3 standard deviation units is considered severely wasted (De Onis, Brown et al. 2012).

There are challenges however associated with use of anthropometric data. For instance, in settings where recording of data is a challenge i.e. conflict ridden societies, or where there are illiterate and poorly trained data collectors, incorrectly recorded data results in incorrect computations of nutritional indices (Blössner, De Onis et al. 2006). Analysts have also questioned use of United States children as the standard of comparison, arguing that it misclassifies a large number of children across the globe because socioeconomic conditions of the US as a developed country are different from that of the developing world (Gorstein, Sullivan et al. 1994, Trapp and Menken 2005). There are also challenges with deciding which of the anthropometric indicators i.e. height for age, weight for age or height for weight to use in a given nutrition assessment context since these indices examine different forms of malnutrition (de Onis, Onyango et al. 2006).

Such situations limit comparisons of nutritional conditions across contexts (Gorstein, Sullivan et al. 1994). Other anthropometric indicators used in measuring nutritional status include Mid-upper arm circumference (MUAC). This indicator is used to screen under nutrition in under-five children. The method is simple to apply as it does not require measurement of height and weight of a child, which is often difficult for inexperienced and less technical personnel (Blössner, De Onis et al. 2006). It can also be used in emergency situations i.e. conflict-ridden areas, where it is not possible to collect data about child age, weight and height. The MUAC of less than 12.5 is suggested as a proxy indicator for low weight for height in children. However, other analysts i.e. Corsi, Subramanyam et al. (2011) have argued that MUAC overestimates under nutrition in younger children and underestimates it in older ones, as such may need standardization of the scores in order to reflect accurate results.

Another anthropometric indicator is leg length as calculated difference between ASD standing height and trunk length. It provides the ratio of leg length to total height or leg length to trunk length, and it can be calculated as leg length for age z-scores (Grace, Davenport et al. 2012). This indicator assesses lower body growth and it is a proxy for overall length or stature. The indicator is often used in adults potentially as a marker of nutritional status (Grace, Davenport et al. 2012). Advantages of this anthropometric measure are that data is easily collected through less costly population based surveys especially in the SSA region.

Further, the indices computed from the data do not require highly trained technical personnel since they are easy to calculate and this cuts down costs (Goossens, Bekele et al. 2012). Despite these advantages, anthropometric measures are prone to bias. According to Norton and Olds (2001) measurement errors of anthropometry concern reliability in the degree to which within-subject variability is, due to factors other than measurement error variance or physiological variation. There is also within-subject variability and imprecision in the variability of repeated measures due to intra and inter observer measurement differences. The greater the variability between repeated measurements of the same subject by one (intra-observer differences) or two or more (inter-observer differences) observers, the lower the precision of the estimate (Norton and Olds 2001). Mueller and Martorell (1988) further argues that it is systematic bias which could be a result of instrument error, or measurement technique, all of which result in systematic bias to all measurements relative to well calibrated equipment used by expert anthropometrist. Further, although weight for age is useful for assessing growth faltering, acute infectious diseases and poor nutritional intake, it does not distinguish between acute and chronic forms of under nutrition, composite of height and weight of child, hence difficult to interpret (Corsi, Subramanyam et al. 2011).

Height for age identifies longitudinal growth and cumulative under nutrition. It measures past and long-term nutritional status in an adverse environment. However, the index is less sensitive to marginally inadequate or short-term nutritional insufficiency, and cannot differentiate between past and continuing chronic nutritional deficiencies (Corsi, Subramanyam et al. 2011). Weight for height assesses present nutritional status and can be used when age is unknown or unreliable. It can also quantify under nutrition along with overweight and obesity in children. However, it is not substitute for weight for age or height for age and is unsuitable for use in adolescents. It also does not indicate if low weight for height is a result of chronic under nutrition. Essentially, different nutritional indicators are applied in different context and their uses vary from one context to another, advantages and disadvantages. There is therefore need for a proper rationale when selecting methods for analysing nutritional conditions for individuals and population in different contexts.

2.4.3. Models used in nutrition assessment

Most models used to assess malnutrition are not specific to malnutrition assessment per se, owing to multifaceted factors affecting nutritional conditions and the complexity associated with its measurement (Haddad, Kennedy et al. 1994). As such, models used in nutrition assessment are adaptations from other analyses not specific to nutrition itself (Poon, Labonté et al. 2018).

Among such is the socio-ecological model of human behaviour, which is commonly used in public health, especially programs addressing obesity (Solar and Irwin 2010, Lele, Masters et al. 2016). The conceptual framework for this model classifies data into four nested categories based on the social scale analysis i.e. country, markets and communities, households and individuals. Each level has its own data requirement depending on focus of analysis. For food security and nutrition analysis, required country level data could be about food balance sheets, market conditions and transactions which may it involve (Lele, Masters et al. 2016).

In situations where users require data about households, indicators of food consumption are applied, and where individual anthropometric data is required, measurement of body size i.e. child's height, weight, mid-upper arm circumference, biomarkers and clinical data are included in the model (Lele, Masters et al. 2016). Data required at each of the levels of the model are used to classify observations from extreme undernutrition to obesity and diet related diseases.

Kusumayati and Gross (1998) applied the socio-ecological model in a study where remote sensing was applied to poverty mapping and assessment of relationship between ecological characteristics of the community and their nutritional status. Regression analysis results showed that geographic variables i.e. distance to nearest market, main soil type, rice field area and perennial cultivation, were significant predictors used in ranking communities with poor nutritional status. Non ecological factors such as food consumption, health service status and living conditions were also significant predictors of the communities' nutritional conditions. Hersey, Anliker et al. (2001) also applied the socioecological model to examine association of food shopping practices and diet quality, using the 1996 National Food Stamp Program Survey data in the US. Analysis of 24-hour dietary recall data showed that shopping practices were significantly associated with availability and increased consumption of nutrients among households.

The result attested to significant cross-level relationship between household level characteristics i.e. food shopping patterns and individual nutritional status, characteristic of socio-ecological models. Socio-ecological models have the advantage of incorporating multiple analytical levels which enables tracing what factors contribute to a situation or behaviour in a given context (Fleury and Lee 2006, Lee, Bendixsen et al. 2017), which is key to design of targeted strategies and interventions for addressing identified problems. However, the models do not test explanations of health and illness, suggesting that the complexity of the socio-ecological perspectives may limit comprehensive testing and interventions development (Stokols 1996). Further, there is lack of sufficient specificity to guide conceptualization of a specific problem owing to the multiple levels of analysis. This makes it difficult to determine when and where to intervene to address the problematic situation (McElroy 2002).

Socioecological models are also generally costly to implement due to multiple layers of data requirement, which limit their use in resource poor nutritional assessment programs (Fleury and Lee 2006). Despite these limitations however, the model still has been useful in programs on human behaviour, food security and nutritional analysis.

Apart from socio-ecological models, statistical models have also been employed to identify, quantify, and analyse relationships, patterns and trends in human nutrition conditions (Sweeney 2012). Some of them include correlation or effect analysis, multiple linear regression, random or mixed effect regression, quantile regression, ignorable likelihood and multiple imputation methods, longitudinal models, estimation equations and dimension reduction models (Yu, Liu et al. 2018). Among the mean based methods are Pearson's correlation coefficient, mean-based regression models i.e. linear regression models, linear mixed models and linear time series models.

Probability models often used in nutritional assessment include logistic regression, which predict outcomes of a categorical dependent variable based on a set of predictor variables i.e. examining association of risk of diabetes based on a set of other variables i.e. dietary intake amounts, exercises among others. There are also probabilistic index models which are applied on data variables that follow non-normal shapes and are skewed. These models summarise the covariate effects on the shape of the response distribution, while providing sufficient information on the covariate effect sizes (Sweeney 2012).

Among studies in which statistical methods were applied to assess nutritional conditions include Aquino and Philippi (2011) who applied logistic regression models on bio-socio-economic data about 300 hospitalised adult individuals aged 18-64 to assess risk of malnutrition among hospitalised patients. Logistic regression results showed that recent involuntary weight loss, apparent bony structure, decreased appetite, diarrhoea, inadequate energy intake and being male were associated with malnutrition among the patients. A study by Sarkar (2016) examined the socio-economic and demographic determinants of child undernutrition in India using data from National Family Health Survey. Results of the ordered probit analysis found that the probability of severe undernutrition was significantly influenced by a child's age, its birth order, mother's education, mother being underweight, household wealth and size among other variables. As can be noted, statistical models are also applied in the assessment of malnutrition and factors associated with it in different contexts.

Despite the significant contribution of statistical models in assessment of human nutritional outcomes, there are some limitations associated with their use. For instance, regression analyses are based on assumptions which analysts put on variables used in the models. Some of these are assumptions about linearity of the phenomenon being measured, constant variance of the error terms, independence of error terms and normality of the error term distribution (Jeon 2015).In some cases, these assumptions are not tested by researchers, either by performing partial regression plot, comparing null plot to residual plot among other options. Such oversight affects the robustness of the fitted model in terms of predicting outcomes, leading to erroneous results and their interpretation. Issues of multi-collinearity, where independent variables might have strong correlation that leads to reducing the model power are also glossed over in some statistical model analyses examining social phenomena.

Further, smaller sample size influenced by logistical constraints result in model results that cannot be generalised, hence less applied in other contexts, making models less useful. However, despite these limitations, statistical models still play a significant role in explaining relationships and predicting outcomes of relationship of variables of interest within a given research context, providing relevant policy input for addressing various socio-economic problems in varied contexts.

2.4.4. Global, regional and local situation of under-five children nutritional status

Ensuring good nutritional condition for under-five children is an important pursuit for countries affected by wide spread hunger and food insecurity. Nearly half of all deaths in under-five children are attributable to under nutrition, (De Onis, Brown et al. 2012, FAO and UNICEF 2018). Persistence hunger, perpetrated by poverty, conflicts, low economic growth and poor social security systems in some countries influence poor nutritional conditions (Kandala, Madungu et al. 2011, Bain, Awah et al. 2013). Adequate nutrition is essential in early childhood as it plays a crucial role in organ formation and function, building immune system, neurological and cognitive development (De Onis, Brown et al. 2012, Cunha, Leite et al. 2015, Nurliyana, Shariff et al. 2016). For some countries, economic growth is not only dependent on technological advancement but also human development, which is crucially dependent on proper and sufficient nutrition before birth of the child, throughout childhood and adult life

(De Onis, Brown et al. 2012). As such, nutrition is recognised as a basic pillar for economic and social development, and little surprise it has been one of the development goals in the Millennium Development Goals (MDGs) and currently, Sustainable Development Goals (SGDs) (Hawkes and Fanzo 2017). A UNICEF/WHO/World Bank Group Joint child malnutrition estimate report for 2017 shows that across the globe, 151 million under-five children were stunted, representing 22 percent of all under-five children, 51 Million under-fives were wasted, representing 7.5 percent of all under-five children globally, and 38 million under-five children were overweight, representing 5.6 percent of all under-five children. In Africa, 58.7 million under-five children are stunted, 35 million wasted and overweight 17.5 million classified as underweight. Within the sub-continent itself, the highest number of stunted under-five children is in the east African region, with over a fifth (23.9 million) of under-five children classified as stunted and 13.8 million wasted (FAO, IFAD et al. 2017).

Malawi is among countries with more malnourished children under the age of five in Africa. Current estimates from the demographic and health survey conducted in 2016 show that 37 percent of children under-five are stunted, 3 percent are wasted, 12 percent underweight and 5 percent are overweight (MalawiGovernment 2017). Although these statistics show declines from 1992 (stunting, 55 percent, underweight 24 percent), the proportions are relatively high in comparison to other countries within the east African region (MalawiGovernment 2017). Of utmost concern however is that different from other countries in the region i.e. Burundi, Ethiopia, Mozambique (Atinmo, Mirmiran et al. 2009, Rowhani, Degomme et al. 2012) where conflict is one of the main factors driving these statistics, Malawi's situation is influenced by poverty and increasingly adverse climatic conditions affecting productivity.

Further, its location in the south-east African region calls for urgent action against food insecurity and nutrition as the region is projected to experience long term and persistent climatic variation, which could have negative effects on its agriculture based food production and economy, leading to deepening poverty, food insecurity and under-nutrition (Frich, Alexander et al. 2002, Nicholson, Klotter et al. 2014). Understanding what changes in climatic variables are crucial to food production and how this happens within the context of other pressing demographic and socio-economic factors crucial to nutrition is therefore an important research pursuit.

Such an undertaking would provide relevant information for developing strategies to address malnutrition in the context of changing and adverse climatic events, yet such information still remains scarce in the country. The current study addressed this gap by examining association of selected climatic variables i.e. temperature and rainfall, with household food security and under-five nutritional status in the country.

2.5. The intersection and effect of climate variables on food security and nutritional status

Climate change and variation presents one of the greatest survival threats human populations are confronted with in this century. Although its inclusion in United Nations sustainable development goals (SDGs) towards 2030 shows global commitment to address it, a solid understanding on patterns, severity, spatial and temporal-variation of climatic variables, and how human populations are affected by such variations is yet to unfold in many regions of the world. Despite the foregoing, few research attempts have addressed this knowledge gap, let alone in developing regions i.e. sub-Saharan Africa, where climate change has been observed and is projected to be severe.

Of utmost concern in this quagmire is understanding how variations in patterns of climatic variables intersect with human food security and nutritional outcomes especially for under-five children, which are key components of human capital development for economic growth and social development. This calls for efforts to examine the nexus of patterns of climatic variables, environmental conditions and human livelihoods, considering the pivotal role each of these plays in sustaining human populations. Unpacking pathways to this complex intersection is an important prerequisite to design and implementation of interventions to avert and adapt to the negative effects of variable climatic patterns on food security and nutritional outcomes.

Studies i.e. ovats et al. (2006)Weber, Haensler et al. (2018) Vermeulen, Campbell et al. (2012) Haines, Kovats et al. (2006) have attempted to explain how climatic variables intersect with all dimensions of food security (availability, accessibility, utilization and stability), environmental conditions i.e. forest cover, land, socio-economic factors i.e. (means of food acquisition, policies governing food security) and health i.e. disease transmission and morbidity within a context where food is produced. These studies also observe that at a human level, climate change or its variation will affect key conditions for good health i.e. clean air, water, food, shelter and control of diseases.

Lake, Hooper et al. (2012) noted that variation in climatic variables have varied effects on human populations. For instance, in developed countries (with technological advances) increasing temperatures and decreasing precipitation might result in changes in food production processes i.e. farming arrangements, where due to such adverse climatic conditions, technologically oriented farming i.e. use of less water demanding food crop seeds, might be employed to counter effects of adverse climate change on crop yield and production. This would be enabled only if there is sufficient economic investment in the agriculture sector and crop science to generate climate change resilient and adapting seeds and fertilisers, which currently remains a challenge.

The situation is rather different in the context of developing countries i.e. in sub-Saharan Africa, where adverse climatic conditions i.e. insufficient rainfall and warming conditions directly affect crop production and food availability, with no or ineffective mitigation and adaptive strategies due to lack of or low investment in mechanized agriculture and crop science (Kang, Khan et al. 2009, Gemeda and Sima 2015). In essence, while climate variation might influence changes in farming systems in developed countries, it can result in crop failure and food shortages in less developed ones. The dependence of most food production systems on climatic conditions also suggests that variations in climatic conditions could result in changes in food production systems and food crops in a given context as a way of adapting to changing climatic conditions, (Clapp, Newell et al. 2018). This could entail migrating from traditional food types normally consumed as staples to others that may not have been preferred if it were not for the fact that they withstand prevailing adverse climatic conditions, yielding better than traditionally preferred ones.

Such arrangements could have significant implications on nutritional outcomes in the population. However, despite recognising these issues, few research attempts on this matter have been engaged in developing countries, let alone in the sub-Saharan Africa region, which could provide input for addressing climate variation influenced food insecurity and poor nutritional outcomes. Despite such a status quo, few studies have attempted to address this information gap i.e. Kraemer, Cordaro et al. (2016) who observed that the connection between climatic variation and nutrition is multifaceted.

The team argues that in regions whose food production systems rely on climatic conditions i.e. farming, climatic variables such as rainfall and temperature, their temporal variability and seasonality, shocks i.e. floods, droughts and heat-waves, affects crop and livestock production, leading to shortage of food.

Adverse climatic conditions also directly or indirectly affect human health i.e. spread vectors and diseases, which attack both human and livestock, resulting in low productivity, low income and deepening poverty. These conditions exacerbate food insecurity and poor nutritional conditions (Campbell-Lendrum, Manga et al. 2015). Hagos, Lunde et al. (2014) also attempted to demonstrate the intersection of climatic variables with household food security and nutrition, in a study where fixed effects regression models were used to examine effect of climatic variation on child under nutrition in some agro ecological zones in Ethiopia. Results showed that controlling for household level socio-economic variables, increasing temperature was associated with increases in wasting among under-five children, and increasing rainfall was associated with increasing stunting.

Despite these linkages, the use of fixed effects regression models limited understanding on effects of spatial variations in patterns of climatic variables such as temperature and rainfall on the outcome variables. Essentially, how variation of climatic conditions in ecological zones influenced nutritional outcomes. Such analytical oversight affects design of target specific interventions to address food insecurity and undernutrition. Further, most studies assessing effect of climatic variables on food security status focus on examining how varying climatic conditions affect crop yield, on the assumption that in developing countries, food security is synonymous to crop yield. However, this assumption could apply in areas where food security is reliant on crop production, whose low returns have direct negative implications on food availability for the people, which is key to nutritional health.

However, human nutrition is not only influenced by food uptake, but also incidence of diseases and infections affecting them (Wu, Lu et al. 2016), whose frequency and severity aided by adverse climatic conditions lowers the body's utilization of nutrients (Rice, Sacco et al. 2000, Scrimshaw 2003). As such, understanding the effect of climatic variation on nutritional outcomes requires analysis of all possible pathways through which these effects occur.

However, such wider focus studies are still scarce in the SSA region, as such limiting understanding about how climatic variation affect human nutritional conditions. Among variables often used in assessing climatic influences on crop yield and food security are temperature and rainfall. Each crop is affected differently by different patterns of climatic variables throughout its life course i.e. germination, growth and yielding, influenced by its phenology (Guan, Sultan et al. 2015). For instance, in a study conducted in Kenya, Ochieng, Kirimi et al. (2016) noted that rising temperatures during the cropping season were associated with reduced maize yield per hectare while tea production increased.

Excess rainfall during the season negatively associated with tea yield per hectare while maize yield per hectare improved. In another study, Kukal and Irmak (2018) examined climatic effects on maize, sorghum and soybean yield in the Great Plains of the United States of America, using climate and crop data sets spanning 55 years. Results showed that a quarter variability in the regional average yields were explained by variability of temperature and rainfall. Temperature increases had significant detrimental effects on sorghum and soybean but incremental effects on maize yield, while precipitation increases were associated with increased yield in all the three crops.

However, although in the two studies statistically significant associations between climate patterns and crop yield were the observed, none of them explained pathways that led to this kind of association, let alone intermediary variables that might have influenced such relationships. Such gaps provide an incomplete picture about factors that influence association between climatic patterns and crop responses in a given context, weakening design of interventions to address negative effects of climatic conditions on crop production and consequently on households' food security and nutritional conditions.

In Malawi, increasing climatic variability has had harder effects on the agriculture sector, especially crop production (FAO 2016). However, analyses have often focused on examining effects of extreme climatic events such as floods and droughts, dominating the country's cropping season in recent years (Coulibaly, Gbetibouo et al. 2015). Gaps on how changes in seasonal patterns of climatic variables affect agriculture production, let alone how household food availability and nutritional outcomes are affected still exist (Zewdie 2014).

Few attempts to seal this knowledge gap have been reported, i.e. Devereux (2007) and Stevens and Madani (2016) who used five global circulation models to examine impacts of climate variation on maize production and food security in Lilongwe district, one of Malawi's major staple food producer. Results showed that temperatures were expected to increase alongside erratic rainfall patterns. However, there were no attempts to expand the spatial coverage of the study and explain how such climatic patterns would affect food security, let alone associated nutritional effects in the population.

Another study by Msowoya, Madani et al. (2016) also used an ensemble of fifteen GCMs under two emission scenarios to project long term changes in climate variables for Lilongwe district in multiple decades i.e. 2046-2065 and 2080-2099. This study also found declines in maize yield of up to 14 percent midway through the century due to climate variation. Like Devereux and Madani's studies reviewed earlier, this study's findings had limited spatial applications and no attempts were employed to examine implications of such climatic trends on the country's food security and human nutrition conditions, despite these being key social development pursuits for the country.

Although simulation models have been useful in data scarce contexts i.e. in the SSA in providing a picture about climatic influences on various aspects of human lives, discrepancies between model simulations and reality often weaken model reliability and usefulness, resulting in further knowledge deficit on the subject of research. Using real time climate data obtained from weather station records has then been encouraged, as this reflects empirical observations, essential for analysing climatic effects on various aspects of human lives i.e. crop production for food and income. A study by Matsui (2016) attempted to provide a picture about how varying temperature and rainfall patterns affect maize, potatoes and groundnuts production based on i1 years station-based data using regression models.

Results showed that maize was highly sensitive to climatic variations unlike groundnuts and sweet potatoes, stressing variations in crop response to climatic patterns. However, like all other reviewed studies, pathways influencing varying responses to prevailing climatic conditions and how such responses were influenced by other intervening variables were not examined, neither were implications on food availability and nutritional outcomes in the study context.

Eminent in all reviewed studies are gaps on understanding how climatic variation associate and affect food production, pathways involved in the processes and effects on food availability and nutritional outcomes. Further, studies have limited their focus to assessing impacts of extreme climatic conditions i.e. floods and droughts, leaving out increasing seasonal variability of temperature and precipitation, which is also key to crop production and food availability.

In addition, analysis of climatic effects on crop production has also relied less on station-based observation data and much on model simulation, a situation that has in some cases obscured reality. This has led to less use of model results for planning interventions to address climatic variation on crop production in Malawi. Spatial and temporal coverage of most climate variation-crop response analyses has also been weaker, owing to data limitations and expertise in modelling crop-climate relationships. This situation also leads to less information for planning climate change response in the agriculture sector. These knowledge and information gaps necessitate further research attempts to address increasing demand for studies to provide input for policy and programmatic responses to climatic change and variation, its effects on food security and mitigation of its impacts on various facets of human life.

2.6. Conceptual frameworks for analysing relationship of climate change, food security and child nutritional status

Different researchers attempting to understand the intersection and relationship of climatic change and variability with household food security and human nutritional status have suggested various conceptual frameworks. A few of these were reviewed to identify elements what could be adapted to the current study's analysis framework. To begin with, Grace, Davenport et al. (2012) analysed the interaction between climatic conditions and child malnutrition in sub-Saharan Africa, with Kenya as a case study as shown in figure 8. below.

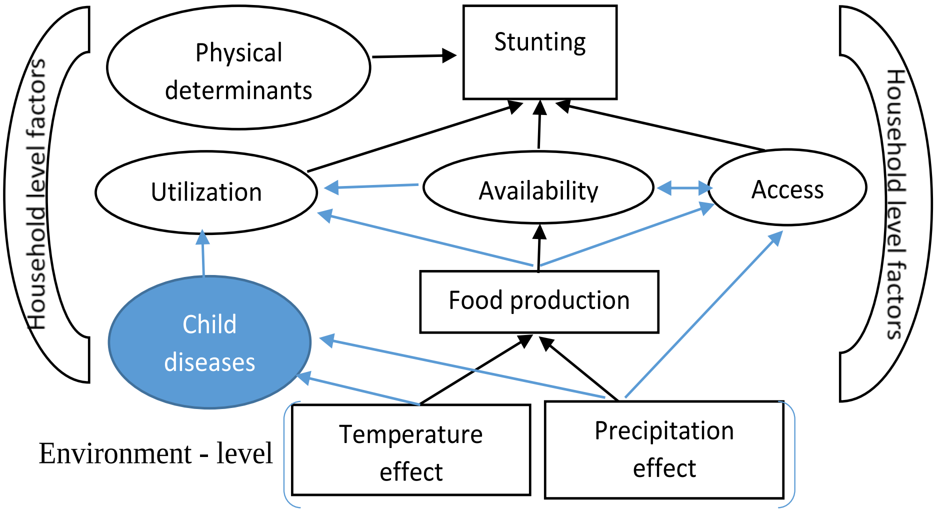

Figure 8.Conceptual links of temperature, rainfall, food production and stunting
Grace, Davenport et al. (2012)
NB: The blue lines indicate connections that are missing in the framework and the blue shaded oval indicates a missing variable in the framework

The framework begins at environmental level, where changes in climatic variables i.e. temperature and rainfall directly relate with food production, which directly relate with food availability and consequently stunting in children. Food utilization and access also independently relate with stunting as a form of malnutrition. There are also physical determinants of child stunting, operating at a child's level i.e. its age and sex, which determine its nutritional conditions. All these relationships operate within the context of household level factors which modulate nutritional outcomes. Amongst such are socio-economic conditions which determine availability, access and utilization of food resources at the household level.

Although the framework provides a picture of how changes in climatic variables relate with malnutrition in children, it is simplistic, considering that relationship of climatic variables and malnutrition is multifaceted and complex. For instance, temperature and rainfall patterns do not only influence food production which is a key factors to food availability, but also transmission of vectors and diseases (Campbell-Lendrum, Manga et al. 2015). Frequent infections and illnesses disrupt uptake and use of nutrients from food, essential for building body immunity from diseases (Bain, Awah et al. 2013), all of which affects a child's nutritional status (Katona and Katona-Apte 2008). Further, adverse temperature and rainfall conditions also directly relate with food access and utilization, which in the framework, have direct implications on child nutritional conditions. Intense rainfall causes floods, destroy infrastructure i.e. market structures, roads, thus limiting access to areas where food could be sourced.

This situation causes unavailability of food among households, facilitating malnutrition. This relationship has not been explained in the framework. In addition, the framework has also not considered interactions among food security concepts in influencing nutritional outcomes. For instance, food availability on its own does not directly relate to child stunting. It rather operates through utilization, where consumption is located. This concept has other dynamics affecting it, i.e. households' cultural beliefs and practices governing preparation and consumption of food. In a context where the interaction between food availability and utilization is not analysed, it is easier to suggest that children would be expected to have better nutritional status on account of availability of food, without considering its utilization. This would be a gross miscalculation.

In addition, the framework does not explain demographic and socioeconomic factors which in concert with other factors affect child nutritional status. Among such are household size, age and weight of the mother, age of the child, birth order and birth weight, which other studies (Frongillo, de Onis et al. 1997), Blössner, De Onis et al. (2006) have argued are important factors on variations in child nutritional status. A younger woman is likely to deliver a low birth weight baby due to not fully mature physiological built up. Low birth weight babies have difficulties surviving in early life as they may not stand early childhood infections and diseases (Adair and Guilkey 1997), which predispose them to malnutrition, among other ills. Further, they may not have fully and strongly developed immune systems against infections, and may be prone to illnesses that compromise their health, also leading to malnutrition.

Further, a household with many people has a higher food quantity requirement, which in the event of insufficient food might impact on young members because they have little resilience, let alone abilities to seek alternative foods. A poor household does not have the economic muscle to augment their food sources in times of food limitations compared to one that is better-off (El-kholy, Hassanen et al. 2012). These conditions could have important negative effects on their health, leading to malnutrition among household members, yet these elements have not been explained in the framework. There are also macro-level factors operating above the household, which affect child nutritional conditions, amongst which are policies and programs relating to food production, marketing, the economy and health system functioning, all of which have important implications on food availability, its access and utilization, key to nutritional outcomes among households. However, these cross-cutting elements have not been discussed by the framework, limiting its power to explain relationship of climatic variability, food security and nutritional outcomes among under-five children.

In another framework analysing association of climatic factors with under-five children's nutritional status. Bowles, Butler et al. (2014) categorised effects of climatic change and its variability as primary, secondary and tertiary. According to the team, primary effects originate from climatic conditions whose effects are direct in nature, for instance, higher temperatures or heat waves causing deaths, intense rainfall causing injuries, deaths and destruction of infrastructure (Kjellstrom 2009). On the other hand, secondary effects wield their influence on human nutritional status through environmental conditions i.e. stagnant water after floods facilitating growth of vectors and spread of water borne diseases to people (Wu, Lu et al. 2016).

Further, in most rural settings, people rely on untreated water from open sources such as rivers, wells and dams for their day to day use, (Haines, Kovats et al. 2006). Floods during rainy seasons cause runoff which carry dirt into such open water sources, polluting water. Use of such water expose communities to infections such as diarrhoea, cholera and other water borne diseases, which compromises their health. Young household members i.e. children gets more susceptible to ill-health and malnutrition as frequent exposure to such conditions erodes their body immunity (Moore, Azman et al. 2017). Precipitation declines and droughts also cause insufficient soil water for crops, leading to poor crop yield, consequently food insufficiency at household level (Whitmore and Whalley 2009). All these factors are argued to work in concert to negatively affect human nutritional conditions.

Although the framework has discussed primary and secondary effects of climatic variation on child nutritional conditions, which generally operate at individual level, like Grace, et al 2014 framework, it misses macro-level socio-economic factors which could be termed 'tertiary effects', through which primary and secondary effects operate to influence poor child nutritional conditions. Among such are access to health services and economic conditions in given context i.e. prices of food, availability and functional markets, and road networks which enhance access to food resources. High priced food impact poor households, limit their access to food, alter their consumption patterns (Hersey, Anliker et al. 2001, Sulaiman, Sulaiman et al. 2009) and influence poor nutritional condition among its members, especially children.

Further, under-five children are prone to infections due to their fragile immune systems (Simon, Hollander et al. 2015), and so in need of unlimited access to health service provision i.e. growth monitoring and curative services (Lavy, Strauss et al. 1995). However, dysfunctional health systems and service provision directly impact on child health outcomes i.e. malnutrition. As such, the framework misses macro-level factors influencing child nutritional conditions.

In another framework, Myers, Young et al. (2011) explains how climate change and variability affects human health. Figure 9 below is a diagrammatic illustration of the framework.

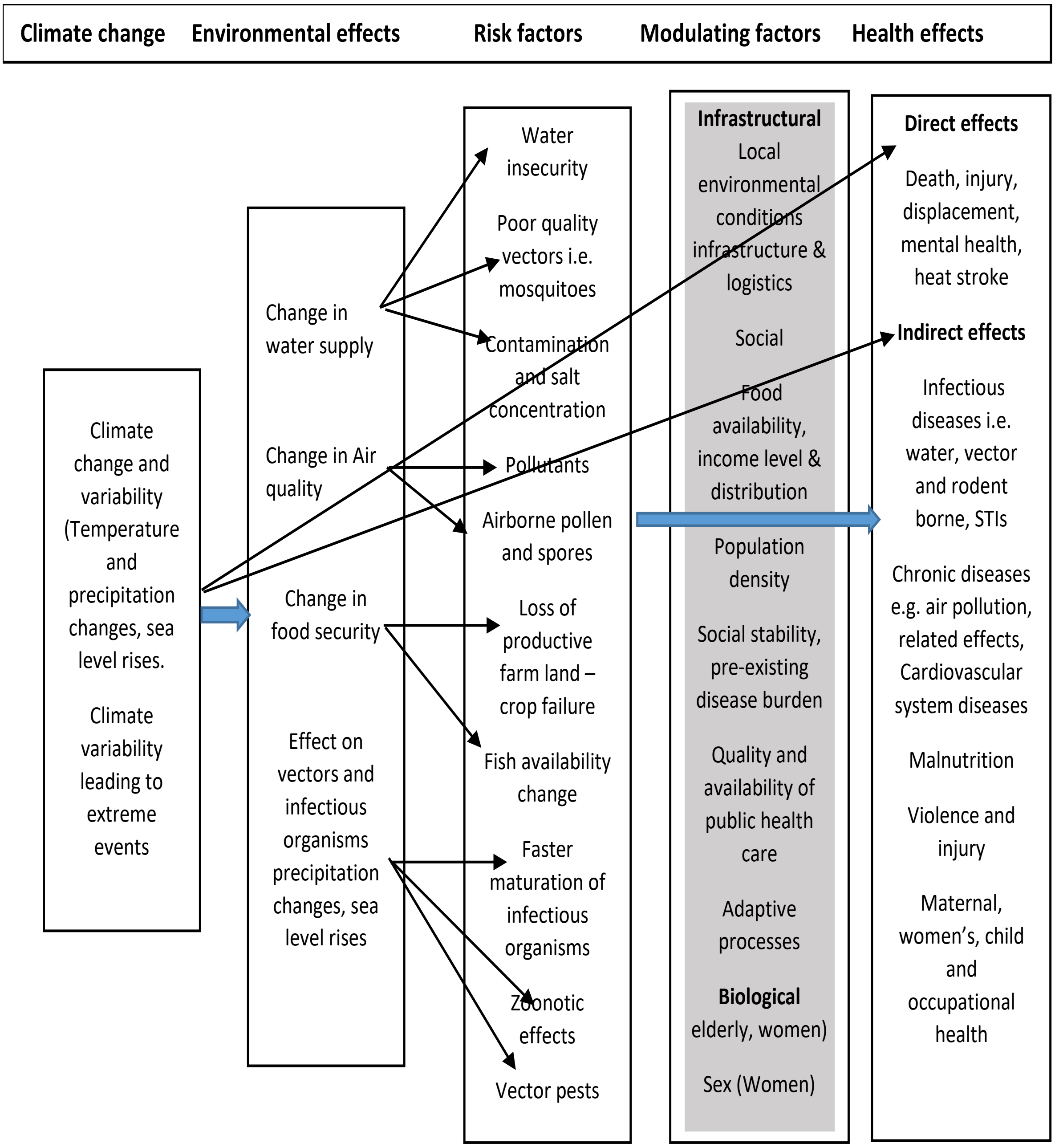

Figure 9. Impact of climate change on human health, Myers et al (2011)

The framework views climate change through increased temperature and rainfall variation, causing environmental effects such as changes in water supply and its quality, changes in food security and effects of vectors and infectious organisms. These provide a requisite setting for risk factors to human health. For instance, changes in water supply facilitate risks of water insecurity, poor water quality, contamination and salt concentration, which directly impacts human health. Changes in temperature and precipitation patterns also have direct effects on human health, such as deaths, injuries, displacements, heat stroke and mental health effects. Changes in environmental air quality facilitate air pollution, airborne pollen and spores, which are risk factors influencing indirect health effects such as chronic and cardiovascular diseases.

Further, temperature and rainfall variation also influence food insecurity, which is a risk factor to health through loss of productive farmland and crops, leading to malnutrition. Zoonotic diseases and pests are also considered risk factors to human health, influenced by environmental effects associated with vector growth and infections. The risk factors to human health are perceived to be modulated by infrastructural factors i.e. logistics, environmental conditions; social factors i.e. food availability, income level and distribution, social stability and pre-existing disease burden; quality and availability of public health care, adaptive processes, and biological factors i.e. age, sex of the person, all of which determine response and adaptation to adverse effects of climatic conditions.

Myers' framework ably shows multiple factors working in concert to affect human conditions including nutritional status. However, some of the pathways through which climatic changes and variability affects human health are not explained, let alone the feedback loops that also exists in the complex inter-relationships between different blocks of the frameworks. First, the framework does not explain how rising sea levels, variability of temperature and rainfall would influence food security and under what contexts. Food security as a concept involves availability, accessibility, utilization and stability of food, and if at all climatic variability and change affects food security, there have to be explanations about how each of the concepts is affected. For instance, changes in onset, cessation of rainfall and increases in temperatures affects phenological processes of plants, leading to low yield, directly lowering availability of food within a given crop production setting (Körner and Basler 2010).

As pointed out in the reviewed frameworks, inordinate climatic and weather conditions i.e. intense rainfall leading to floods cause contamination of water. Frequent adverse climatic conditions entail persistent food shortages in a given setting, resulting in 'instability' in availability, accessibility and possibly utilization of food, all of which have direct links with malnutrition. These pathways have not been explained in the framework, yet they are essential in locating intervention points to address climatic influences on populations' food security in a given context. Further, despite recognizing modulating climatic effects on human health (including malnutrition) the framework does not explain how each of the modulating factors facilitate occurrence of each of the adverse health effects.

The oversight in linking each of the modulating effects to a particular health effect limits design of target specific interventions with which to avert or adapt to the effects of changing or variable climatic patterns on human health. Literature i.e. Bensassi, Stroeve et al. (2016) argues that in some regions of the world, there are potential benefits associated with changing climatic patterns. For instance, melting ice in the polar regions has facilitated mobility of ships which has eased transportation and trade, increasing access to food and other survival resources. Such positive feedbacks also ought to be acknowledged in our understanding of how climatic change or variability affects human populations, in order to design context specific interventions in dealing with climate change.

In addition, recognizing the contribution of human activity to climatic variation and change is another significant factor. For instance, extensive use of fertilizers on farmlands (Maraseni and Maroulis 2008), industrial growth and bio-technology have all been argued to influence climatic variability and changes (Mgbemene, Nnaji et al. 2016), despite the noble goal to enhance agricultural productivity in order to address food insecurity in affected regions. Frameworks for analysing relationship and effects of climatic change and variation on human health ought to highlight such feedback loops in order to locate fault-lines in design of interventions to address climate change health effects. However, such elements are not explained in the above framework. The current study adapted a few elements from the reviewed frameworks to explain how climate variability relate with and affect household food security and child nutrition status in Malawi. Figure 10. presents a diagrammatic illustration of the framework, detailing pathways of the relationships.

At climate level, variation in temperature and rainfall patterns at different temporal and spatial scales i.e. inordinate temperatures and rainfall during a crop growing season affects crop yield, from which households derive their food. Onset, cessation, dry-days, duration of rainfall and temperature ranges within a cropping season have implications on various phenological processes of crops. For maize, inordinate conditions of these climatic variables affects seed germination, plant development, pollination, kernel formation and ultimately quantity and quality of crop yield. The amount and quality of crop yield directly determines households' food security status, especially its availability.

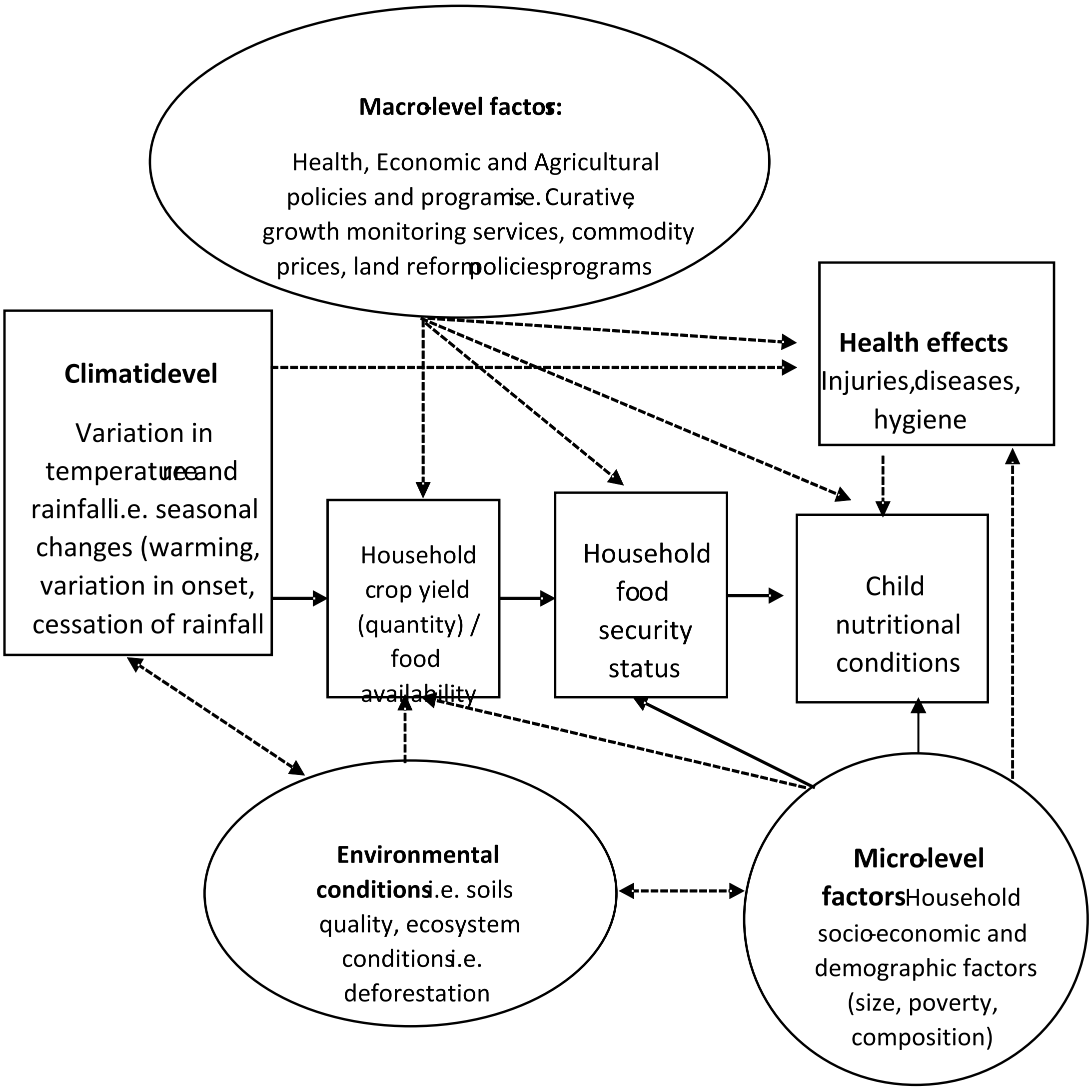

Figure 10. Conceptual framework for the study (Adapted from Myers et al, 2011)

NB: *Solid arrows in the framework indicate pathways of relationships which have been analysed in the current study. Broken or dashed arrows indicate pathways of relationships of climatic variables, household food security and nutritional conditions which have not been analysed in the study, due to data limitations.*

Sale of farm produce especially for rural households provide income with which to access other food resources that may not have been derived on the farm, hence augmenting household diet, essential for good nutrition and health. These relationships are modulated by macro and micro level factors. For instance, at a macro-level, economic conditions i.e. prices of food, land policies, sale of agriculture inputs, produce, availability of functional and accessible food markets also affect households' ability to produce and access food and consequently nutritional status of members. Health policy programs and systems i.e. availability of functioning and accessible diseases prevention, curative, immunizations and growth monitoring services for under-fives also has direct implications on their nutritional conditions.

At a micro-level, households' demographic and socio-economic characteristics i.e. size and composition (age and sex of members i.e. head, mother, child), income levels and poverty also do influence nutritional conditions of under-five children (El-kholy, Hassanen et al. 2012, Ghani, Zubair et al. 2017). Quantity of food allocated to household members is influenced by household size i.e. the more the members, the more the demand for food, influenced by household age and sex composition, since food consumption varies by age and sex, and level of physical activity engaged by household members (Ajao, Ojofeitimi et al. 2010, Humphries, Dearden et al. 2017). Income and poverty levels, mother's demographic and socioeconomic characteristics i.e. age and education have also been associated with a child's nutritional condition (Eshete, Abebe et al. 2017, Fadare, Amare et al. 2019).

Adverse climatic conditions i.e. floods, droughts have indirect influences on child health outcomes, where floods cause water contamination, microbial growth, all of which result in poor hygiene hence infections which lower body immunity and efficient utilization of nutrients, leading to malnourishment (Okaka and Odhiambo 2018). There are also feedback loops in the relationship of climatic variables, household food security and nutritional conditions of under-five children, where micro-level factors i.e. socioeconomic conditions and demographics affect production of food on the farm, influencing food security and consequently nutritional conditions. For instance, poor households may not be able to produce enough food to meet their demand. Higher dependency ratio on the household lowers its ability to produce and purchase food, as there are less producers than consumers in the household.

Ultimately this affects food availability, alters consumption patterns, all of which influence poor nutritional conditions among the members (Fentaw, Bogale et al. 2013). Further, environmental conditions i.e. deforestation contributes to climatic variability (Bamwesigye, Hlavackova et al. 2019) i.e. changes in rainfall patterns and temperatures, facilitating growth of pests attacking crops and harvests, leading to low yield, household food shortage and unavailability , and ultimately poor child nutritional conditions (Islam and Wong 2017).

Population pressure on the environment limits availability of cultivable land, leading to low food crop production and availability, and consequently poor nutritional conditions among households (Dorélien 2015). This conceptual framework shows that the relationship of climatic variables, household food security and under-five nutritional conditions is complex, operating through various factors and feedback loops, whose analysis could also be complex. However, for the purpose of the current study, only the solid arrow pathways were analysed as data for the other variables represented in the pathways was not available. Recognizing the complexity and multifaceted nature of the variables involved in the framework, a careful selection of variables was made in order to include in the analysis number and type of variables likely to produce plausible results, which could inform policy and incite further research on the subject.

Chapter 3. Study design, sources and quality of data used in the study

3.1. Overview

This chapter discusses the study's design, sources and quality of data used in the analysis. Section 3.1 is an outline of the chapter, section 3.2 describes the research design of the study, preceded by a review of major research designs. This provided basis for choice of the study's design and methods of analysis. Section 3.3 describes the sources and quality of data used in the analysis.

3.2. Research design for the study

Creswell (2013) explains that there are three main types of research designs namely; quantitative, qualitative and mixed methods. In the quantitative design, the investigator uses a post-positivist claim to develop knowledge on a subject matter. The approach emphasizes cause and effect thinking, reduction of variables, hypothesis testing, measurement and testing theories about the issue being investigated. Data is gathered through experiments and surveys using pre-determined instruments such as questionnaires and observations. Results are presented in numerical summaries, i.e. averages, ratios and proportions, using tables, graphs and other visual aids.

In the qualitative research design, the researcher makes knowledge claims based on a constructivist perspective, drawing knowledge from multiple meanings of individual experiences i.e. historical and social constructions, to develop a theory (Creswell 2013). The researcher establishes meaning of a phenomenon from participants' view. Data is collected by observing participants' behaviours, participating in their day to day living and conducting interviews using open-ended techniques and tools to examine an issue in a given context. In the mixed methods approach, the researcher makes pragmatic knowledge claims using quantitative and qualitative data on information which is collected sequentially or simultaneously. The approach collects both numeric and text data, representing both quantitative and qualitative views used to answer research questions (Johnson, Onwuegbuzie et al. 2007).

Morris (1991), Carr (1994) and Choy (2014) observe that quantitative research designs are objective, analytically critical and verifiable. These characteristics minimize bias, enhance validity and reliability of results. However, it does not delve deeper to explain cause and effect on issues being investigated (Morris 1991). Carr (1994) argues that unlike the quantitative research design, qualitative research design ensures broader and deeper understanding of a research subject. Through its open-ended approaches, it generates information that captures behaviours, values, beliefs and assumptions that clarify and explain underlying causes and factors for issues being investigated. However, the design lacks objectivity and it fails to provide replicable and verifiable results (Choy 2014).

According to Johnson, Onwuegbuzie et al. (2007) the mixed methods research design blends qualitative and quantitative characteristics to provide a comprehensive picture of an investigation. It allows both measurement and exploration of a subject matter in depth, gathering quantifiable, replicable, deeper and broader information on the research area. However, the approach requires expertise to ensure that results from the two research approaches (quantitative and qualitative) are coherent and credible. The design is also logistically challenging to implement because it requires more resources and time. On account of the shortfalls in both quantitative and qualitative research designs, Creswell (2013) recommends researchers to carefully consider a research design that ensures appropriate data and methods of analysis are chosen and applied for credible results.

The current study adopted a quantitative research design. The choice of the design was guided by the nature of the study, which focused on assessing trends in climatic variables and their association with household food security and under-five children's nutritional status. Analysing trends require quantification, so too assessment of its association with crop yield, food security and child nutritional status, which falls in the quantitative research domain, hence the choice of this research design.

3.3. Type and sources of data used to assess trends in temperature and rainfall variables

To address the first question of the study, temperature and rainfall data were assessed for trends in order to provide a part background picture of the country's climatic conditions, which was essential in understanding relationship between climate and crop yield, households' food security and child nutritional status in Malawi.

Temperature and rainfall data were obtained from the Department of Climate Change and Meteorological Services (DCCMS) in Malawi. Rainfall data spanned 45 years (1970/71 to 2015/16) while temperature data spanned 43 years (1970/71-2013/14) both for the cropping season. The reference period for these data i.e. greater than 30 years follows the standard recommendation for detecting plausible changes and trends in climatic data i.e. 25 – 30 years (Wang, Hamann et al. 2016). The data was collected from 27 stations, one in each of the country's 27 districts out of 28. Data for one district i.e. Likoma had a lot of gaps over the chosen time interval for analysis, as such it was left out of the study. In Malawi, temperature and rainfall data are collected on a daily basis by met station officers, who compile the statistics at monthly, seasonal and annual periods of time, by summing daily records in case of rainfall, and calculating means for temperature. The yearly overlap in the reference period of the data follows the country's main cropping season which runs from November–April of every year, a period when Malawi receives 95 percent of its rainfall, synonymously referred to as the annual rainfall season (Ngongondo, Xu et al. 2011, Vincent, Dougill et al. 2014).

3.3.1. Quality checks on selected temperature and rainfall data variables

Data quality checks were performed to provide basis for choosing appropriate methods for analysing trends in the climate variables, as different methods and techniques are robust on different climatic data (Javari 2016). In the current study, data quality checks included normality tests, detecting outliers, checking for temporal homogeneity and persistency in the data series.

3.3.1.1. Normality tests

Most statistical analysis techniques assume that the data is normally distributed; having an equal mean, median and mode, where 68 percent of the data are located within one standard deviation (Osborne 2005, Ghasemi and Zahediasl 2012). This assumption fits with parametric data analysis techniques i.e. correlation, regression, t-tests and analysis of variance. Although it is hardly possible that climatic data i.e. rainfall and temperature could be normally distributed due to natural variations inherent in the variables over time, normality tests provide guidance on choice of methods for analysing some climatic data, if plausible results are to be obtained (De Lima, Carvalho et al. 2010). For instance, tests for homogeneity and detection of trend requires prior assessment of the data distribution in terms normality.

There are a number of methods used to test normality in time series data. Among such are graphical methods, which show shape and distribution of the data. These include frequency plots or histograms, normal probability plots, quintile plots, ranked data plots, box and whisker plots, stem and leaf plots (Melek, Lu et al. 2005). These methods do not show statistical significance in the tests, and decision about normality of the data series is based on visual judgement (Machiwal and Jha 2012). However, statistical methods provide a measure of statistical significance of normality tests based on comparison with a standard normal distribution. Among such are chi-square goodness of fit test, Kolmogorov-Smirnov (K-S test), Anderson-Darling test, Cramer-von Mises test and Shapiro-Wilk test (Ghasemi and Zahediasl 2012).

In the current study, histograms were plotted for time series temperature and rainfall data to enable visual analysis on normality of data distribution, while Shapiro-Wilk tests were performed to show how statistically significant were the temperature and rainfall data series used in the study. The technique was opted for because it is robust enough to detect normality in data series compared to other statistical methods i.e. Kolmogorov-smirnov. Shapiro-Wilk test was also recommended by the United States Environmental Protection Agency (USEPA, 2006) as a reliable statistical technique for testing normality in climatic and environmental data. The test examines whether a random data sample $x_{1,}x_{2,\ldots}x_n$ of a time series climate variable is normally distributed. The null hypothesis assumes the data are normally distributed and the alternative hypothesis otherwise. The test statistic is given as:

$$W = \frac{\left(\sum_{i=1}^{n} a_i\, x_{(i)}\right)}{\sum_{i=1}^{n} (x_i - \bar{x})^2} \qquad (1)$$

where $x_{(i)}$ is ordered (increasing ordered) sample values of the data i.e. total annual rainfall, a_i are constants generated from the means, variances and co-variances of the order statistics of a sample of n size from a normal distribution. Small values of the test statistic W indicate departure of the data series from normality, when the null hypothesis is rejected. Bigger values indicate otherwise. In this study, this test was performed using statistical package for social sciences (SPSS) software v.24.

3.3.1.2. Detecting outliers

Detecting outliers is one of the preliminary processes in time series climate data analysis. Singh and Upadhyaya (2012) defines outliers as data or patterns of data that do not conform to a well-defined notion of normal behaviour in a sample distribution. Outliers are extreme values that are abnormally high or low in a distribution. Naveau, Nogaj et al. (2005) asserts that detecting outliers has become important in climate research because they represent a key manifestation of non-linear patterns in climate systems, which could have impacts on economic and social activities among human populations.

Although analysis of mean climatic conditions for different climatic variables has served to alert the world on detrimental effects of climatic variation and changes, understanding patterns of climatic extremes which are mostly detected as outliers is important as it serves to provide cues on spatial- temporal changes in climatic patterns that could be linked to global warming and climatic change and variability, as well as serve as basis for analysing climatic change itself. According to Esterling, Meehl et al, (2000) societal infrastructure is becoming more sensitive to weather and climate extremes, exacerbated by global climatic change. In wild plants and animals, climate change influenced extinctions, distributional and phenological changes, and species range shifts are increasingly being reported, most of which are understood as responses to extreme weather and climatic conditions.

Climatic extremes are placed into two broad groups; those based on climate statistics i.e. those that indicate statistical measurement of a climatic variable such as ‘low’, ‘medium or average’ or ‘high’ rainfall or temperatures at set times i.e. days, months, year. The other broad group represents more complex event-driven extremes i.e. droughts and floods (Esterling, Meehl, et al, 2000). Understanding climatic extremes and their patterns provide important information for designing mitigation and adaptation strategies against associated effects of the extremes on human beings at different spatial and temporal scales. It also serves to provide information for projecting future climatic and weather outlook which serve as input for early warning systems against adverse climatic events. A major limitation however is that climatic extremes (outliers) are hard to predict since they rarely obey statistical patterns and laws (Naveau, Nogaj et al. 2005), suggesting there still remains gaps in our understanding of patterns of some climatic variables at varied spatial and temporal scales in the world today.

Although analysing climatic extremes may not seem important and common in regions where extremes in climatic variables do not occur so frequently, it could be an urgent undertaking in spatial scales they are frequently intense i.e. floods and droughts in the south-east African region. Climatic extremes indicate presence of abnormal patterns in a specific climatic variable, generally comprising outlier values when in the series. Since outliers distort statistical properties of a data distribution i.e. mean and variance, their presence might affect patterns of data, precision and accuracy of models based on the data for a given climatic variable, misrepresenting a climatic reality.

Detecting outliers in time series climatic data therefore helps in ensuring that an accurate view about the climate variable in focus is detected. Statistical analysis of climatic data requires prior knowledge of characteristics of the data for the variable being analysed as some statistical techniques are robust for certain characteristics of data while others may not produce reliable estimates. For instance, trend analysis requires prior knowledge of data distribution, whether it is normal or non-normal in order to decide robust techniques for analysing the data i.e. parametric or non-parametric techniques for trend detection. Since data normality is an important statistical property of time series data analysis, it is important to checks for outliers in the data series (indicated by non-normality in the distribution) to decide on methods of analysis in order to get reliable results.

There are different types of outliers; point outliers, contextual outliers and collective outliers. A point outlier is one in which an individual data value is considered anomalous with respect to the rest of the data. A contextual outlier data is one which is anomalous based on the structure of the data set. A collective data outlier is one in which a collection of data observations is anomalous with respect to the entire data set, where the individual data themselves are not outliers but their occurrence together as a collection (Singh and Upadhyaya 2012). Apart from these three, there are also outliers data described as ‘spatial-temporal outlier’, and these are data whose thematic attributes are significantly different from those of other spatially and temporally referenced data (Wu, Liu et al. 2010).

In this study, focus was on detecting point outliers on the premise that the study intended to among other issues establish periods of shifts in the patterns of the temperature and rainfall data series among other issues i.e. points where there has been significant turns in the pattern of the distribution of values in the series. For instance, which year did Malawi's rainfall begin to decline? What significant event was recorded associated with the turn in the series i.e. rainfall decreasing following a drought, what were the values then and what pattern has been assumed since this the turn.

Another reason for detecting point outliers in the data series analysed in this study was that point outliers distort statistical properties of the data series i.e. mean and variance, which are critical statistical properties for examining data prior to modelling a given climatic condition. If outlier data values are maintained in a given data distribution, they affect precision and accuracy of the model results, which in turn presents erroneous picture of a climatic reality, hence the need to analyse point outliers in the data series. If detected, such outliers ought to be removed, unless there is scientifically valid reason for maintaining them in the sample i.e. if they truly reflect a climatic reality (a naturally influenced climatic extreme in the variable), other than a mistake on recording the value by the met personnel. In the current study, an outlier data value was dropped from the data series when it was apparent that it was affecting results of analysis i.e. trend detection in time series temperature and rainfall data variables.

There are different methods used to detect outliers; univariate and multi-variate methods. The later fall in another broader category of parametric and non-parametric methods (Ben-Gal 2005). Within non-parametric methods are 'distance-based methods' which are based on local distance measures of data values. The advantage of these methods is that they are capable of handling large data sets. Parametric methods assume a known distribution of the observations in which their tests are based, flagging out as outlier observations that deviate from the model assumptions (Papadimitriou, Kitagawa et al. 2003). However, these methods are unsuitable for high-dimensional and arbitrary data sets without prior knowledge of the underlying distribution (Papadimitriou, Kitagawa et al. 2003). Among common methods for detecting outlier data in meteorological studies are multivariate regression and artificial network, genetic algorithm and Mahalanobis Distance (Mirzaei 2014).

Univariate methods include 3xSD (Standard deviation) ±M (median), Box Whisker plot or Tuckey's Hinges, and Grubb's test. Each of these methods has its own assumptions about the data distribution and location of outliers in the data series. Non-parametric univariate methods i.e. the 3xSD ±M and Tuckey's Hinges assume that all data values cluster around a central point i.e. the median. As such, the method locates the median of the data distribution (in ascending order) by dividing the data distribution in quartiles. Once the first and third quartile data points are located, an interquartile range is calculated, providing a statistical way to identify where the bulk of the statistical data points (50 percent) sit in the range. Using this range, outlier data points are then located at the lower and upper end of the distribution.

Although the methods are easy to perform, the assumption that the bulk of the data are located around the centre of the distribution might not be correct for all data types since the distribution might depend on the nature of the data(Manoj and Senthamarai Kannan 2013). For instance, it is unlikely that values for longer time series average annual rainfall in a given place could cluster around its mean (Dawson 2011). This would suggest less variation over time, or that the pattern could be nearer stationary distribution. In addition, 3xSD ±M and Tuckey's Hinges do not show how statistical significance of the difference between detected outliers and a normal sample distribution. As such it would be difficult to make a correct judgement on the suspected outliers values (Solak 2009, Manoj and Senthamarai Kannan 2013).

Grubb's test assumes that the data on which outliers are to be detected is normal or near normal distribution. Although this assumption is not correct with most climatic data, some researchers have used the method to ion climatic data i.e. Clarke (2010) and (Mirzaei 2014) arguing that it has higher statistical rigour to detect outlier values than others. Grubb's method assumes that there is at least a single outlier in a given data distribution and it is the maximum or minimum value, but this entails that values falling short of this criterion are overlooked, as such not effective enough a technique for outlier data detection. As can be observed from this brief overview of outlier detection techniques, each has limitations i.e. assumptions that do not stand in all circumstances, and weaker outliers detection ability. To overcome this problem, Huang, Wang et al. (2016) recommends use of a combination of methods so that their technical deficiencies are compensated by each-other. In the current study, outlier values detection was performed using Tuckey's fence and Grubb's test.

In Tuckey's fence, the inner fence is decided as follows: $\mathrm{Q1} - (1.5 \text{ x IQR})$ which is the difference between the first quartile and the product of the inter-quartile range with a multiplier. The outer fence is decided by adding the third quartile to the product of the inter-quartile range and the adjustment factor i.e. $\mathrm{Q3} + (1.5 \text{ x IQR})$. The method tests the hypothesis of no outliers in the data series. Outlier values are shown in a box plot above or beneath the whiskers of the plot depending on the position of the values. This method was performed in a computer software; Statistical Package for Social Sciences (SPSS).

Grubb's test was used in detection of outliers on climate data used in the analysis because it was able to show statistical significance of detected outliers which Tuckey's fence could not show. The method was developed by Grubbs in 1969 and improved in 1972 by Stefansky. It detects outliers in a univariate data set that follows an approximately normal distribution. According to Solak (2009) most outlier detecting methods are designed to trace one outlier at a time, and as soon as the outlier is detected, it is removed from the data and the process is repeated until no more outliers are detected. However, Solak (2009) noted that Grubb's test can handle more than one outlier at a time. In this study, the method tested the null hypothesis of no outliers in temperature and rainfall data. The tests statistic is presented as follows:

$$\mathrm{G} = \frac{|\mathrm{x_i} - \bar{\mathrm{x}}|}{\mathrm{s}} \qquad (2)$$

where G is the test statistic, $\mathrm{x_i}$ is a data value in the time series data distribution, $\bar{\mathrm{x}}$ is the mean of the time series data distribution, s is the standard deviation of the data series calculated with the suspected minimum or maximum outlier value included. The critical value for a two sided Grubb's test is calculated as:

$$\mathrm{C} > \frac{\mathrm{N}-1}{\sqrt{\mathrm{N}}} \sqrt{\frac{\mathrm{t}^2_{\alpha/(2\mathrm{N})\mathrm{N}-2}}{\mathrm{N}-2+\mathrm{t}^2_{\alpha/(2\mathrm{N}),\mathrm{N}-2}}} \qquad (3)$$

where $t_{(\alpha/2n,n-2)}$ denotes the critical value of the t-distribution with $(n-2)$ degrees of freedom significant at $\alpha/2n$. If $G \geq C$ then the suspected value is an outlier. In testing whether the upper or maximum value of the data distribution is an outlier, the test statistic is given as;

$$\mathrm{G} = \frac{\mathrm{x_{max}} - \bar{\mathrm{x}}}{\mathrm{s}} \qquad (4)$$

Where $\mathrm{x_{max}}$ denotes the maximum data value in the series, s is the standard deviation of the series and $\bar{\mathrm{x}}$ the mean, and G the test statistic. In testing whether the lower or minimum value of the distribution is an outlier, G is given by:

$$\mathrm{G} = \frac{\mathrm{x_{min}} - \bar{\mathrm{x}}}{\mathrm{s}} \qquad (5)$$

Where G, is the test statistic, $\mathrm{x_{min}}$ denotes the minimum value in the distribution, $\bar{\mathrm{x}}$ the mean of the data series and s denotes the standard deviation of the data series. The detected outlier values were re-examined to find out whether they were as a result of human error or a natural occurrence. In cases where the outlier value originated from human error, the value was corrected taking the mean of its two adjacent values as the correct data value (Ngongondo, Xu et al. 2011). Naturally occurred data values were not tempered with to avoid distorting a real climatic reality in the tested variable.

3.3.3.3. Testing for temporal homogeneity

Homogeneity tests check whether the data series are free from artificial changes influenced by non-climatic effects. This is the case because inferences drawn from time series climatic data depend on 'continuity' of the measurement processes or lack of change points (Reeves, Chen et al. 2007). Change points are discontinuities in the data influenced by human error, location change of stations, environment, equipment shifts and change in techniques for capturing the data (Alexandersson and Moberg 1997, Khaliq and Ouarda 2007, Reeves, Chen et al. 2007, Kang and Yusof 2012). A data series is described as homogenous if there are no breaks in the distribution over time (Javari 2016).

In the current study, homogeneity tests provided basis for selecting methods for detecting trends or assessing persistency in climate data series used in the current study. Any in-homogeneity identified was examined carefully to check if it reflected and artificial anomaly in the data series or a naturally occurring climatic occurrence. In the event of the former, the data could be analysed as separate components, guided by the breaks or points of inhomogeneity to ensure that only 'true' natural effects are examined (Ahmad and Deni 2013). Among methods for detecting inhomogeneity are Kohler's double mass analysis, cumulative deviation tests, Worsely's likelihood ratio test, standard normal homogenisation test (SNHT), the bivariate test, the residual test, the penalized maximal t-test, regression based Eastering and Pateerson test, Pettitt's test, Buishand's test (Ngongondo, Xu et al. 2011, Kang and Yusof 2012). Each of these methods has its own assumptions which ought to be considered before being applied. In the current study, three methods were used; the Pettitt's test, standard normal homogeneity test (SNHT), and the Buishand range test. The choice of using three methods to test for homogeneity in the climate data series was on the account that the study intended to look into multiple aspects of the data set i.e. point of homogeneity (beginning, middle or end of the series; year of shift, and statistical significance of shift in the patterns of the variables. The methods tested the null hypothesis that the data series are homogenous, while the alternative hypothesis stated that a step-wise shift in the mean of the data values occurred over time. The methods detect temporal homogeneity at different time points in the data series. The SNHT detects breaks at the beginning and the end of the time series data distribution (Toreti, Kuglitsch et al. 2011), while Buishand and Pettitt's tests are more sensitive to breaks located in the middle of the series (Hänsel, Medeiros et al. 2016).

Pettitt method is based on the ranks of the elements of the data series and the SNHT and the Buishand range test suppose that the values are normally distributed. Considering these differences, it is advisable to use more than one method when testing inhomogeneity in climatic data series to accurately detect breaks. In the current analysis, a data series were declared inhomogeneous if two of the methods detected as such i.e. detection of same kind of shift direction (upward or downward) and same year of shift. Mallakpour and Villarini (2016) argues that Pettit's test is based on Mann-Whitney two sample rank based test and it detects shift in the data at an unknown time, t. The null hypothesis states that there is no change in the distribution of a sequence of random values while the alternative hypothesis states that the distribution function $F_1(x)$ of random variables from x_1 to x_t is different from the distribution function of F_2 (x) of random variables from x_{t+1} to x_T, suggesting a break in the mean of the time series data over time. The test statistic of the method is dependent on D_{ij}, derived as follows:

$$D_{ij} = \operatorname{sgn}\left(x_i - x_j\right) = \begin{cases} -1 & \text{if } \left(x_i - x_j\right) \; =< 0 \\ 0 & \text{if } \left(x_i - x_j\right) \; = 0 \\ +1 & \text{if } \left(x_i - x_j\right) \; => 0 \end{cases} \quad (6)$$

where x_i and x_j are random variables i.e. total rainfall at time i and j, with x_i following x_j in time (total rainfall for 1975 and 1976). The test statistic $U_{t,T}$ depends on D_{ij} as follows:

$$U_{t,T} = \sum_{i=j}^{t} \sum_{j=t+1}^{T} D_{ij} \qquad (7)$$

The test statistic $U_{t,T}$ is assessed for all random variables from 1 to T; then the most significant change point K_T is selected where the value of $|U_{t,T}|$ is the largest.

$$K_T = \max_{1\leq t<T} |U_{t,T}| \qquad (8)$$

A change point occurs at time t when the statistic K_T is significantly different from zero at a given level; 0.05. The approximate significant level is given by:

$$\rho \cong 2 \exp\left(\frac{-6\,K_T^2}{T^3 - T^3}\right) \qquad (9)$$

when the $p -$ value is less than the pre-assigned significance level α the null hypothesis is rejected, indicating that the data is divided into two sub-series (before and after the location of the change point), with two different distribution functions.

The standard normal homogeneity test (SNHT) was developed by Alexanderson in 1986, and to inhomogeneity in time series data by examining undocumented discontinuities which are observed in form of abrupt shifts in the mean values of observations (Khaliq and Ouarda 2007). The basic assumption of SNHT is that the ratio r between a given data value x_i where $i = 0$ and its next $x + 1$ in the series remain fairly constant in time. Inhomogeneity in the values is revealed as a systematic change in this ratio r.

The normalized series of the ratio: Z_i are defined as:

$$Z_i = r_i - \bar{r} / s_q \qquad (10)$$

where $\bar{r}$ is the sample mean value of the ratio and s_q the sample standard deviation of the ratio r_i at time step i, where $i = 1$ year. Following the assumption that Z_i was normally distributed the null hypothesis for all variants of the SNHT is given as:

$$H_O: Z_i \in n(0,1)\ i \in \{1, \ldots, n\} \qquad (11)$$

Indicating that the whole data series is homogenous. The alternative hypothesis is that there is inhomogeneity in the data series, i.e.

$$H_a \left\{ \begin{matrix} Z_i \in N(\bar{r}_1, s)\ i \in \{1, \dots, a\} \\ Z_i \in N(\bar{r}_2, s)\ i \in \{a+1, \dots n\} \end{matrix} \right\} \quad (12)$$

where $\bar{r}_1$ is the mean ratios for the first a years, $\bar{r}_2$ is the mean ratio during the last $(n-a)$ years, and s is the standard deviation of the ratios.

According to Alexandersson and Moberg (1997) the test statistic; T is interpreted as a high value at year $'a'$ suggesting that $\bar{r}_1$and $\bar{r}_2$ depart significantly from zero, making H_O unlikely. This maximum value of T is denoted as T^s_{max} and is derived as follows:

$$T^s_{max} = \underset{\substack{1 \le a \\ \le n-1}}{\mathrm{Max}} \{T^s_a\} = \underset{\substack{1 \le a \\ \le n-1}}{\mathrm{Max}} \{a\bar{x}_1^{-2} + (n-a)\, a\bar{x}_2^{-2}\} \ (13)$$

Where $\bar{x}_1$and $\bar{x}_2$ are the mean values of the series before and after the shift. The corresponding value of $'a'$ is the most probable break point i.e. the last year at the old level. The null hypothesis is rejected when T^s_{max} was above the selected significance level, which depends on the length of the time series being analysed. Alexandersson and Moberg (1997) gave critical T values for 10 percent, 5 percent and 2.5 percent levels i.e. $T_{90,} T_{95} T_{97.5}$ respectively when determining the statistical significance of the maximum point in the data series where the null hypothesis is rejected. The null hypothesis for the series is rejected for T_x greater than T_{90} or T_x greater than T_{95} depending on the chosen confidence levels in the SNHT tables.

According to Kundzewicz and Robson (2004) Buishand test is based on rescaled cumulative sum of deviations from the mean and it detects change points around the middle of the data series. The Buishand U statistic is derived as follows:

$$U = \frac{\sum_{K=1}^{n-1} \left(\frac{s_k}{\sigma_x}\right)^2}{n(n+1)} \quad (14)$$

where s_k and σ_x are the adjusted partial sum and the standard deviation of a given series x_i that tests for homogeneity is given by;

$$s_{*k} = \sum_1^n (x_i - \bar{x}) \quad (15)$$

where:

$$\sigma_x^2 = \sum_1^N (x_i - \bar{x})^2 / n \quad (16)$$

where $\bar{x}$ is the average which is given by:

$$\bar{x} = \frac{1}{n} \sum_1^n x_i \quad (17)$$

where n is the number of observations and x_i values of the observation in the data series. The null hypothesis of the test is that there is no shift in the mean of the data series, and the alternative hypothesis suggests a shift in the mean over time.

Under the null hypothesis, the S_k variable defined earlier follows a normal distribution with a zero mean and a variance that is equal to the following;

$$\sigma^2 = \frac{1}{n} k (n - k) \qquad (18)$$

where σ^2 is the square of the standard deviation, n is the number of observations in the series and $k = 0$ to n. The significance of the shift can be tested using the re-scaled adjusted range or partial sum which is the difference between the maximum and minimum values of s_{*k}:

$$R = \max_{0<k<n} s_{*k} - \min_{0<k<n} s_{*k} \qquad (19)$$

Where $'R'$ is the re-scaled adjusted range statistic and s_{*k} the adjusted partial sum, which is compared to the critical values of the range at different time series lengths, at 1 percent significance level. If $'R'$ is greater than the critical value, then the null hypothesis is rejected, suggesting that the time series data distribution has a break. Hence there would be a need for further examination of the year of break in order to make a decision to treat the series as two different distributions or one.

3.3.1.4. Testing for randomness or non-persistence in data series

Persistence is a tendency of successive values of time series data to ‘remember’ their antecedent values and to be influenced by them (Machiwal and Jha 2012). Mathematically, it is the correlational dependency of order k between each i^{th} element and its lag; the $(i - k)^{th}$ element of the series. In time series analysis, data ought to be random and independent from each other in order to avoid detecting a false trend that arises from auto-correlated values. In the current study, temperature and rainfall data were tested for persistence. This was done using the ‘autocorrelation function’, which measures the correlation between two terms or values of the data series. According to Machiwal and Jha (2012) the technique is a process of self-comparison, expressing the linear correlation between an equally-spaced series data values and the same series at a specified time lag. The auto-correlation function is given as:

$$r_k = \frac{\sum_{i=1}^{n-k} (x_i - \bar{x})}{\sum_{i=1}^{n} (x_i - \bar{x})^2} \qquad (20)$$

Where ′r ‘is the correlation coefficient and k is the lag of the data series being tested for persistence, and lag-k is autocorrelation coefficient taking the value of 1 for a perfect positive autocorrelation and -1 for a perfect negative autocorrelation. $\bar{x}$ is the mean value of the time series x_i and n is the number of values or data points in the series. In this method, non-persistent series have autocorrelations near zero for all time lag separations except the zero lag coefficient which is always 1. The Anderson’s test assesses the upper and lower values of the autocorrelation function. This is obtained as follows:

$$(r_k)\text{upper} = \{1/(|n-k)\}\ (-1 + z_{1-a/2}\sqrt{n-k-1}$$
$$(r_k)\text{lower} = \{1/(|n-k)\}\ (-1 - z_{1-a/2}\sqrt{n-k-1} \qquad (21)$$

where $z_{1-a/2}$ is the standard normal variate at α i.e. 0.05, ′n′ is the number of observations and ′k′ is the lag of observations. If the value of $'r_k'$ is less than the critical values in Anderson’s test above, the null hypothesis of non-persistence in the data series is rejected, indicating that the data series are auto-correlated. If the $'r_k'$ fall above the critical values in the Anderson’s test, the null hypothesis is not rejected. In this case, it would be advisable to continue with trend testing on the data series using methods that call for independence of data series values such as the Mann-Kendall trend test.

In the current study, the test for randomness of the data series was performed using Ljung-Box technique, which is described as function of accumulated sample autocorrelations $'rj,'$ up to any specified time lag $'m'$. The autocorrelation function of m is determined as:

$$Q(m) = n(n+2) \ + \sum_{j=1}^{m} \frac{r_j^2}{n-j'} \qquad (22)$$

Where $'n' =$ number of usable data points after any differencing operations. The statistic examines residuals from a time series model in order to see if the underlying population autocorrelations for the errors may be ‘0’ (up to a specified point). Residuals are assumed to be ‘white noise’ meaning they are identically, independently distributed (from each other). The ideal autocorrelation function (ACF) for residuals is that all autocorrelations are ‘0’, meaning that $Q(m)$ should be ‘0’ for any lag $'m'$.

When the $'rj'$ are the sample autocorrelations for residuals from a time series model, the null hypothesis distribution of Q$(m)$is approximately a x^2 distribution with df = $m - p$, where $p =$ number of coefficients in the model.

When no model has been used so that the ACF is for raw data, $p = 0$ and the null distribution $Q(m)$ is approximately a x^2 distribution with df = m. In both cases, a p-value is calculated as the probability past $Q(m)$ in the relevant distribution. A small p-value (<0.05) indicates the possibility of non-zero autocorrelation within the first $'m'$ lag. The tests for persistence were performed using the computer software XL-Stat V.2016.

3.4. Detecting onset, cessation, duration and number of dry-days in a rainfall year

In Malawi, annual rainfall build-up commences in August-September when the country begins the warm dry season. Highest temperatures are recorded in October and early November, and they facilitate higher rates of evapo-transpiration which in concert with the Inter-Tropical Convergence Zone (ITCZ) result in onset of rainfall mid to end November (Clay, Bohn et al. 2003), terminating in April in a normal rainfall year. There are variations in commencement of annual rainfall across the country, influenced by topography and air pressure systems. For instance, in the southern region, annual rainfall commences around mid-November, followed by central region early December, then the northern region early or late December to early January (Palamuleni, Ndomba et al. 2011).

In the current study, onset of annual rainfall was confirmed when an area received 25mm of accumulated rainfall in 10 days without 10 consecutive dry days where rainfall was below 2mm, occurring in the next 20days. For the purpose of this analysis, a rainfall year was considered to run from August to July following build-up of the rain bearing system i.e. ITCZ (Nicholson, Klotter et al. 2014). This convention was also used by Kimaro and Sibande (2018) in the assessment of cropping season rainfall trends in Malawi. The end of cropping season rainfall season was determined when rainfall not exceeding 25mm in 15 days of a given rainfall year was recorded.

According to the rainfall pattern of the country, annual rainfall cessation occurs mid to end April in the southern region, end April in the central region, early to mid-May in the northern region.

This convention was also used by Kimaro and Sibande (2007) in a study to examine the effects of changes in growing season rainfall on maize yield in Malawi. The length or duration of cropping season rainfall is determined by number of onset and cessation days. Variations in onset and cessation of rainfall determine its intensity, a crucial factor for planning and managing water resources, predicting and mapping floods, droughts and their impacts on human populations (Hadadin 2005). Rainfall duration is found by subtracting rainfall onset days from its cessation days in a given rainfall period. Tadross, Suarez et al. (2009) and Fiwa, Vanuytrecht et al. (2014) have applied this approach in their analyses on changing patterns of rainfall and its effects in southern Africa and Malawi respectively. This approach was also employed in the current study.

Understanding trends in dry-days during a rainfall season gives insight on its implications on hydrological resources on which human and animal populations survive. It also provides input for precipitation models to assess water availability at various temporal and spatial scales (Polade, Pierce et al. 2014). There are different conventions used to estimate dry days i.e. a day with less than 1mm rainfall (Méndez-Lázaro, Nieves-Santiango et al. 2014) or one with less than 2mm (Fiwa, Vanuytrecht et al. 2014). The current study adopted a method used by Kimaro and Sibande (2007) which defines a dry day as one with less than 4mm of rainfall in a rainfall season, considering the country's rainfall characteristics and patterns.

3.5. Type of crop data used in the study

In Malawi, crop production data is important for monitoring food security policies and programs. As such, ensuring quality of crop production data is one of the key goals in collection and compilation of agricultural data. In the current study, maize yield data was used to assess association between climatic data i.e. temperature and rainfall variables, and crop yield. The following section describes how maize data is collected and how quality is ensured in Malawi.

3.5.1. Methods and processes for collecting maize yield data in Malawi

In Malawi crop production data is collected through a survey. The crops are divided into major and minor crops. Major crops are those which cover more than five percent of cultivated area, amongst which is maize.

Minor crops cover less than five percent of cultivated area i.e. groundnuts. Implementation of the survey follows the sectors' administrative units as presented in Figure 11.

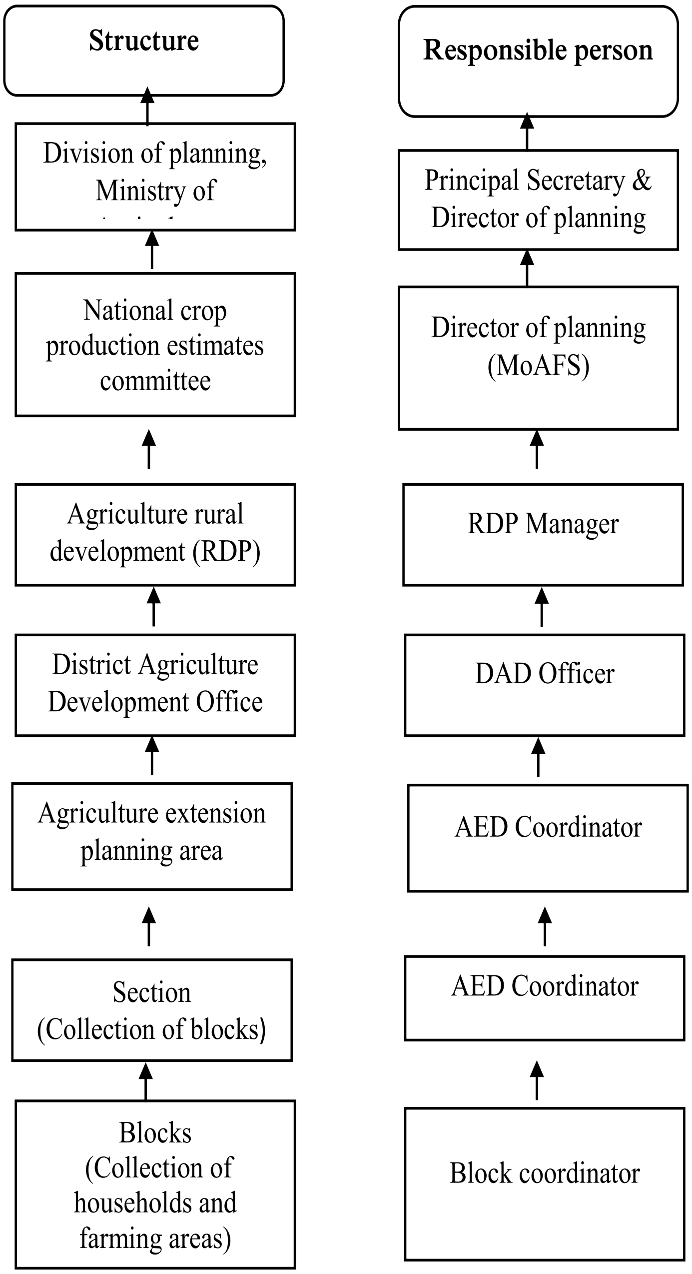

Figure 11. Data flow during crop production estimates surveys

Crop production estimates surveys are conducted in the smallholder agriculture sector, separate from the estates or commercial sector. The surveys are conducted annually in four different rounds. Table 1 shows an outline of activities conducted in each of the four rounds of the survey and the type of data collected.

The first round of the survey involves listing and selecting agricultural blocks, listing of households in each of the selected blocks, selecting agricultural households and measuring area for major crops grown by the sampled households.

Table 1. Activities in crop production estimates survey in Malawi

Round	Activity	Type of data collected
1	Listing and selecting agricultural blocks.	Number of blocks and those selected for the survey.
	Listing households in each of the selected blocks	Number of households in selected blocks
	Selecting agricultural households in the blocks for the farming season	Number of households selected for the survey
	Measuring area for major crops in the farming season	Size of areas covered by major crops grown in the season
	Recording crops grown by sampled households in the blocks.	Number and types of crops grown by selected households
2	Verifying and adjusting area measurements for major crops in sampled agriculture households.	Area covered by major crops by sampled households
3	Measuring area for minor crops in selected blocks	Area and types of minor crops grown by selected households
4	Weighing of yield for selected households	Crop yield and production estimates

Results obtained from this round are used to determine area for crops grown in the extension planning area (EPA), district and agricultural development divisions (ADD). In this round, initial crop yield estimates for both summer (main farming season) and winter are made relative to the previous farming season. The relative yield figures are used to forecast crop production for the current year. These results are presented to the national agricultural production estimates committee (NAPEC) for validation. The committee meets towards the end of January or early February in the respective farming year. The second round of the survey involves verifying and adjusting measured area for major crops grown by the sampled agricultural households. Results obtained are used to determine EPA, district and ADD area covered by different crops in that farming season.

Area for minor crops is measured on an agricultural block and not on agricultural household as it is with major crops. New survey estimates of yield and production are prepared for both summer and winter crops. The updated survey results are presented at the second NAPEC meeting which is held end of March or early April of the reference season. The third round of the survey is conducted during crop harvesting, between May and June of the farming season. The main activity in this round is weighing harvest to obtain actual yield of major crops based on sampled households and their fields. In this round, there are no alterations of any data collected in the previous round. Results for this round are used to estimate production of crops at EPA, District and ADD levels, which are presented in the NAPEC meeting held mid-June of every farming season.

The fourth and final round of the survey is conducted in August and its main activity is weighing late maturing and winter crops in the season. This round presents production estimates for late maturing and winter crops, which are tabled for validation at the NAPEC meeting taking place mid-September. The sampling plan for crop production estimates surveys involves selection of individual agriculture households to estimate yield of major crops and selection of individual agriculture blocks to estimate yield for minor crops. For major crops, a two-stage stratified sampling method is applied. In this method, stratum is a collection of EPAs. Each EPA consists of sections and individual sections consists of eight agricultural blocks which form the primary sampling unit.

When estimating yield and production of major crops, the first step is selection of 25 percent of the blocks in each EPA using systematic random sampling. The second stage is identification of secondary sampling units. These are agricultural households which are drawn from selected blocks. This selection follows a serial listing of all households in the selected blocks. A sample of 20 percent of the listed households in each of the blocks is thereafter drawn using systematic random sampling technique, selecting 15 households from each block. Estimating yield and production of minor crops involves application of a one stage stratified sampling technique. As is the case with major crops, each stratum is made up of a number of EPAs. However unlike when estimating yield for major crops, the agricultural block becomes the primary and only sampling unit when estimating yield for minor crops.

Estimating area, yield and production of minor crops is based on twenty-five percent of blocks in the EPAs already identified during estimation of yield and production of major crops. However, for minor crops individual households are not selected and data relating to crop area, yield and production is estimated from all farmers growing minor crops in the selected blocks. The sample proportion for estimating yield and production for minor crops is 25 percent. Extrapolations for crop yield and production estimates start at the EPA level. All listing of households and blocks in a section and EPA is done by the agriculture extension development officer (AEDO). Once blocks are selected and agriculture households identified, the next activity is to measure areas or garden to be used for cropping in the respective season. This is considered a critical exercise in the survey both in terms of precision and timeliness of results to ensure reliable crop production forecasts. This activity commences in November for each farming season. All gardens and plots within the garden cultivated by selected agricultural households are measured, whether planted or not. In Malawi, most gardens and plots have irregular shapes.

To reduce the complexity of measuring such areas the officer responsible i.e. AEDO assumes that each households' garden or plot takes the shape of a rectangle or square. Crop area measurement is done using the 'give and take' method. This method involves superimposing an assumed rectangle or square on a piece of land and shading the parts that fit the rectangle or square, as illustrated in figure 12.

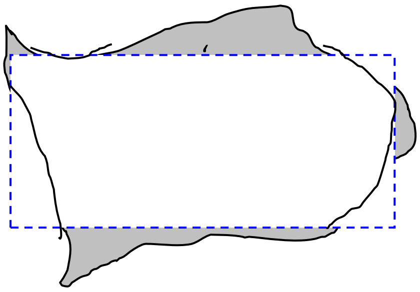

Figure 12. An illustration of the 'give and take' method for crop production Survey

By treating the area of the rectangle as equivalent to the area of the garden, the shaded areas outside the rectangle or square are excluded or 'given' away while the unshaded areas inside (which are part of the garden) are included or 'taken' as part of the garden. In estimating area for the garden or plot, the shaded and unshaded areas cancel each other out such that the area of the rectangle is close to the actual area of the irregularly shaped garden as a whole. Once the AEDO has approximated the length and width of the plot, individual rectangles and squares are measured in paces. To do this, the AEDO draws sketches of the gardens and plots for individual sample households in a notebook and uses pegs and sticks to identify the four corners of all rectangles and squares to be measured. When the number of paces along the length and width of a rectangle or square is known, they are converted to meters using a specified conversion table. To convert the paces to meters, the AEDO has to establish a personal pace length or 'pacing coefficient' which is an average of a three times repeated pacing. These lengths or coefficients are updated annually. To calculate the area of the rectangle the length is multiplied by its width. The AEDO also compiles garden and plot crop areas for selected households in sampled blocks within a section and EPA. Details about the ADD, district, section and block in which crops yield and production are estimated are also collected. Area for each selected and measured garden or plot is presented in hectares, rounded up to two decimal places. In cases where one part of the garden is planted with one crop and in another there is a mixture of crops, the plots are treated as separate. In this case, the same crop area is entered on the same appropriate crop headings.

After checking all entries and calculations on area for plots and gardens selected for the study, records are presented to the AEDC who checks and validates the data. Forecasts of all crop yield considered in the survey is done by the AEDO soon after planting is completed. These assessments are subjective and are made in relation to crop situation at the same time in the previous growing season, taking into account the prevailing weather situation, supply of inputs such as fertilisers and crop germination, based on the AEDO's own judgment. Yield assessments relative to the previous farming season are recorded in terms of scores i.e. +1, +2, +3 or -1, -2, using specified guidelines.

The assessments are made for the whole block not only for any individual selected farmers in the survey, such that it reflects the situation for all farmers growing that particular crop in the selected block. Following this assessment, the AEDO tabulates individual crop area and yield for the sampled households in order to estimate yield for the sampled blocks, mainly in the first and second crop forecasts. The forecasts are then verified upon harvest, where actual yield and production are calculated from the lowest administrative unit i.e. block to the highest i.e. national level, and the results are presented for approval by the NAPEC.

3.6. Socio-economic data used for analysis in the study

Demographic and socio-economic data was used to examine relationship between temperature and rainfall variables with household food security and under-five children's nutritional status in the study. The data was obtained from the fourth integrated household survey (IHS) conducted by the National Statistical Office (NSO) between March 2010 and March 2011 in Malawi. This is a locally adapted version of the World Bank Living Standards Measurement survey (LMS) program which is conducted every 4-5 years among developing countries. The purpose of the survey is to monitor socio-economic conditions of people in the countries at set time intervals in line with global development strategies such as the 2016-2030 sustainable development goals (SDGs).

In Malawi, the integrated household surveys are implemented at 4-5year interval, with the purpose of providing a picture about peoples' socio-economic conditions. The information from the survey helps to formulate, monitor and evaluate socio-economic development programs, along the implementation of the Malawi Growth and Development Strategy (2017-2022). The IHS2010/11 was a nationally representative sample survey which collected information from 12,271 households statistically representative at national, district, urban and rural levels. The sample design and coverage was based on the 2008 Malawi Population and Housing Census listing and cartographic information. The survey targeted individuals and households living in the country's 27 of the 28 districts except Likoma Island which could not be reached for logistical reasons.

A stratified two-stage sample design was applied during the survey, where the primary sampling unit was census enumeration areas (EAs) as defined in 2008 Population and Housing Census frame. This is a smallest geographical area established for the census, with defined boundaries. An average EA has 235 households. A total of 768 EAs were selected across the country, with an average of 24 EAs in each district. A total of 16 households were interviewed in each EA. The IHS produces benchmark poverty and vulnerability indicators, information about population demographics, education, health, household enterprises, consumption (food and non-food), housing conditions, agriculture, anthropometrics and social welfare information. Four types of questionnaires were used in the survey (Appendix a).

The first was a household questionnaire which collected information about demographic and socio-economic conditions of households i.e. age, sex and distribution of the population, education, health, employment, poverty, expenditure and credit facilities among others. The second questionnaire collected information about agriculture, i.e. farming activities (crop and animal husbandry) during the survey year. The third questionnaire collected information about fisheries and the fourth questionnaire collected information about the community i.e. presence and access to social services and infrastructure by the people across the country. According to the NSO, a community was defined as a village or urban location surrounding a selected enumeration area commonly recognised by the residents as a community. The head of the household provided all information pertaining to household members, its characteristics and activities done on the household. Other respondents to the questionnaires were agricultural extension workers, health workers, local merchants and religious leaders.

Prior to conduct of the survey, training was done for field workers i.e. enumerators, team leaders and field coordinators. The purpose was to ensure that all survey participants were conversant with the tools (questionnaires) and its administration to ensure quality data. A total of 113 people involved in the survey were trained in various areas i.e. data collection, consistency checks, processing, analysis and report writing. There were 16 team leaders, 75 enumerators, and 22 data capturing clerks. Each district had 16 mobile teams of survey personnel comprising of enumerators, data entry clerk, driver and supervisor. The data entry clerk captured data right in the field using a laptop, printed it and did consistency checks at EAs level with the supervisor and team leader. Errors detected during consistency checks were corrected by the survey team right in the field before leaving the concerned EA and households.

The data and completed questionnaires were then sent to NSO headquarters in Zomba, Malawi, where a second entry was made by a team of clerks to verify data keyed in the field. Upon being satisfied of its quality, it was entered in a data processing software and further edited before tabulation. Analysis was performed in computer software called STATA, where summary statistics, tables and graphs were used in presenting results of the survey.

3.7. Conclusion

This chapter described types, sources and quality of data used during analysis in the current study. This involved explaining the nature of the data, the purpose of collecting and compiling the data, the institutions involved in collecting the data, strategies, instruments and personnel involved in the processes of collecting and processing the data, regularity (periodicity) of collection, quality assurance and levels of aggregation of the data. The methods and techniques used during analysis of the data have been discussed separately in the analysis chapters of the thesis, based on the objectives of the study. This approach was taken because the study’s objectives are mutually exclusive such that different methods were used in answering the research questions to address the study objectives.

Chapter 4. Results for climate data quality assessment

4.1. Overview

Station based climate data is prone to errors from different sources i.e. human mistakes when recording the data, environmental and physical features i.e. trees and topography, and change of instruments capturing the data, among others (Ngongondo, Xu et al. 2011, Gubler, Hunziker et al. 2017). As such, it is important to assess quality of this type of data prior to analysis as it provides basis for deciding methods and techniques to use when analysing the data (Chakraborty, Pandey et al. 2013). Among quality assessment tasks performed in the current study were normality tests, detecting outliers, testing for homogeneity of the mean or variance, and testing randomness or persistence of data series. These tasks were also used by Ngongondo, Xu et al. (2011) and Isioma, Rudolph et al. (2018) during analysis of spatial and temporal characteristics of rainfall and temperature in Malawi and Nigeria respectively. The current chapter presents results of the assessments.

4.2. Results for normality tests on time-series cropping season rainfall and temperature data

Normality tests on selected temperature and rainfall data series were performed using two methods, the Shakiro-Wilk test and plots of histograms. The Shapiro-Wilk technique tested the hypothesis that the time-series data are normally distributed, while histograms allowed visual inspection of patterns in the data distribution to check if they fit a normal distribution. Table 2 presents results of normality tests on the seven climatic variables used in the study.

Table 2.Shapiro-Wilk normality test results for temperature and rainfall data

Variables	Kurtosis	Skewness	S-W Test Statistic	Sig. level
Total rainfall	0.685	-1.038	0.884	0.001
Rainfall onset	-1.250	-0.062	0.750	0.048
Rainfall cessation	6.458	-1.347	0.862	0.000
Rainfall Duration	-1.192	0.107	0.748	0.037
Dry-days	-1.222	-0.133	0.846	0.044
Maximum Temp	34.104	-5.453	0.439	0.000
Minimum Temp	20.878	-3.399	0.636	0.000

Sig. level: 0.05

Table2 shows that all the seven climatic data are not normally distributed, confirmed by the Shapiro-Wilk test statistics which are all values are below zero, with the tests being statistically significant. In this regard, the null hypothesis of normality in these data distribution is rejected. These results were also visually confirmed by the shape of the distribution of the data series for the variables, which showed departure from normality (Appendix B). Out of the analysed 27 stations, only 3 were detected to have normally distributed average annual rainfall data series for the 45-year analysis period; Kasungu and Nkhotakota stations in the central region of the country, and Chisombezi station in Chiradzulu district, southern region.

Results further show that 24 of the 27 stations had non-normally distributed annual rainfall onset data series over the period of analysis, while three out of 27 stations were detected to have a normal distribution for annual rainfall cessation data series; Karonga and Rumphi district in the northern region and Dowa station in the central region of the country. Results also show that 25 of the 27 stations had non-normally distributed average annual rainfall duration data series, and three out of 27 stations; Mangochi, Dowa and Nkhata-bay had normally distributed average annual maximum temperatures over a 43-year period, while only two out of 27; Mzimba and Zomba stations had normally distributed average annual minimum temperature data series over the 43-year period. As can be noted, more than 85 percent of the analysed stations had non-normally distributed data series across all tested climatic variables. These results indicate that detecting homogeneity, persistence and trends in these data variables will require non-parametric techniques, which are robust in handling non-normally distributed data.

4.3. Results for outlier data detection on selected rainfall and temperature variables

In this study, detecting outlier data values in time-series temperature and rainfall data variables was done using Grubb’s test and Tuckey’s fence, discussed in chapter three of the thesis. At national level, Grubb’s test detected no outlier in the country’s average annual rainfall data series over the period of analysis. However, outlier data values were detected in 8 of the 27 analysed weather stations (Table 3), with six stations reporting outlier rainfall values in 1992.

Table 3. Grubb's test results for stations with outlier rainfall data

Station	Detected outlier rainfall value in Millimetres	Reference year	Observed value	Critical value	P-value
Rumphi	595	1992	4.028	3.159	0.0001
Dedza	692	1992	3.170	3.166	0.0490
Dowa	1466.9	1994	3.545	3.263	0.0150
Balaka	586	1992	3.391	3.076	0.0120
Mwanza	553.2	2005	4.517	3.128	0.0001
Nsanje	497.6	1992	4.808	3.278	0.0001

As table 3 shows, observed values of rainfall for the districts were greater than Grubb's critical values, indicating that the rainfall figures were indeed outliers. The test results were statistically significant, with p-values less than 0.05.

In a normal rainfall year, Malawi's annual rainfall commences mid to end November for stations located in the southern region, which is 90 days after the commencement of annual rainfall build-up period, August-October. In the central region, rainfall commences in December to early January, which is 120 days after the commencement of the build-up period. In the northern region, annual rainfall commences January to early February, which is almost 150 days from the commencement of annual rainfall build-up in August.

At national level, Grubb's test and Tuckey's fence detected no outliers in Malawi's average annual rainfall onset data distribution over the 45-year reference period. However, 5 of the analysed 27stations had outlier data values in the series. Results show that in 1986/1987 rainfall commenced 66 days from August at Mchinji station in the central region. This suggests early onset of rainfall for this central region district as rainfall might have commenced in November, contrary to normal pattern where it commences in December in this region. A similar situation was noted for Ntcheu station, where annual rainfall started 63 days from August in the 1996/1997 rainfall year. Nkhatabay station in the northern region shows the earliest onset days for annual rainfall, commencing 12 days from August, contrary to the region's normal rainfall onset pattern, January to early February (Nicholson, Klotter et al. 2014).

Malawi's normal annual rainfall terminates between late March to early April in the southern region, which is almost 242 days from August. In the central region, annual rainfall terminates between end April to early May, which is almost 272 days from August, and in the Northern region, annual rainfall terminates mid to end May, almost 300 days from August. No outlier rainfall cessation values were detected by both Grubb's test and Tuckey's fence at national level over the 45-year period of analysis. However, outlier rainfall cessation days were detected in some few stations (table 4).

Table 4. Grubbs test results for stations with outlier rainfall cessation data

Station	Detected Outlier value	Reference year	Observed value	Critical value	P-value
Rumphi	264	2009	3.165	3.151	0.047
Balaka	265	1976	3.244	3.025	0.019
Neno	297	1976	3.523	3.297	0.019
Mwanza	297	1976	3.376	3.126	0.017
Chikwawa	252	1992	3.592	3.326	0.001

p-value: 0.05

Results in table 4. show that for three of the five stations, outlier annual rainfall cessation days occurred in the 1976/1977 rainfall year. The detected outlier rainfall onset days in the southern region stations i.e. Balaka, Neno, Mwanza and Chikwawa indicate that annual rainfall terminated later than normal i.e. greater than 242 days. The outlier rainfall cessation days for Rumphi station (264 days) in the northern region was less than the normal (300 days) suggesting early termination.

Average annual rainfall duration in Malawi ranges from 150 to 180 days, running from November to April of a rainfall year (Vincent, Dougill et al. 2014). Results show that no outlier annual rainfall duration days at national level were detected by Grubb's test or Tuckey's fence. However, out of the 27 stations two were detected with outlier rainfall duration values; Mchinji station; 63 days in 1996/97, with Grubb's test observed value of 4.324 bigger than the critical value of 3.363 (p-value: 0.000). Another statistically significant outlier rainfall duration value was detected at Dowa station; 61 days in 1994, with Grubb's test observed value of 4.024 bigger than the critical value of 3.263 (p-value: 0.001). This entails that for the two stations, annual rainfall season lasted only 2 months in the reference years, not reflecting the normal rainfall patterns of the area for the years.

In this study, a dry day referred to number of days when total rainfall was less than 2 mm, from August to July of a normal rainfall year. This convention was also applied in a study on Malawi's climatology by Nicholson, Klotter et al. (2014). In the current study, the average number of dry-days in a rainfall year was 64 days. Results show no outlier dry-days at national level were detected by Grubb's test or Tuckey's fence. However, outlier dry days were detected at Nkhata-bay station; 192 days, during the 1999/2000 rainfall year, with Grubb's observed value of 4.035, greater than the critical value of 3.218 (p-value:0.001). Significant outlier dry days over the series were detected at Mchinji station in the central region; 121 days during the 1976/77 rainfall year, with a Grubb's test observed value of 4.014 against a critical value of 3.363 (p-value 0.003). Results in table 5 shows stations with detected outlier average annual maximum temperatures by Tuckey's fence.

Table 5.Tuckey's fence results for stations with outlier maximum temperatures

Station	Outlier value	Month	Year
Nkhotakota	0°C	September	1998
Mchinji	17.9°C	January	2001
Machinga	38.6°C	October	1995
Machinga	37.2°C	October	1996
Phalombe	35.4°C	February	1992
Chiradzulu	34.4°C,	December	2011
Mwanza	37.5°C,	February	1992
Makoka	15.5°C	March	1985
Makoka	12.2°C	April	1982
Makoka	17.3 °C	December	1986
Makhanga	43.5°C	February	1977

As the table shows, most of the stations detected with outlier maximum temperature values for the 43-year period were in the southern region i.e. Makoka in Zomba, Machinga, Phalombe, Chiradzulu, Mwanza and Nsanje. Except for Makoka station in Zomba, most of the detected outliers were above normal temperatures for the detected months. For instance, although October is a hot season month, Machinga's maximum temperatures for 1995 and 1996; 38.8°C and 37.2°C respectively were above the normal range even for hottest stations such as Makhanga in Nsanje, which is a low-lying area. Nkhotakota's 0°C in September 1998 is very unusual since this is warm and dry season month where temperatures are expected to be higher. December, March and April are months in the warm wet season in Malawi, where temperatures are high. As such, Makoka's 15.5°C in March 1985, 12.2°C in April 1982 and 17.3°C in December 1986 were unusually too low for this season, possibly why they were detected as outliers.

4.4. Homogeneity test results for annual rainfall and temperature data

In this study, three methods were used to assess homogeneity in temperature and rainfall data series; Pettitt's test, Standard Normal Homogeneity Test (SNHT) and Buishand's test. These techniques assess homogeneity at different points of data series i.e. beginning, middle and end as described in chapter 3 of the thesis. As such, there was need to use all three methods to ensure accurate detection of homogeneity in the data. Inhomogeneity was confirmed when two or three methods produced a similar result i.e. statistically significant detection of year or point of inhomogeneity in the data series. Results show that three rainfall variables showed statistically significant shifts in the series over time, annual rainfall onset, its duration and mean number of dry days. A significant upward shift in onset of annual rainfall was detected in 1990 and a significant downward shift in rainfall duration was detected also in 1990. A significant shift in average number of dry-days in annual rainfall was detected in 1992 (Figures 13 to 15).

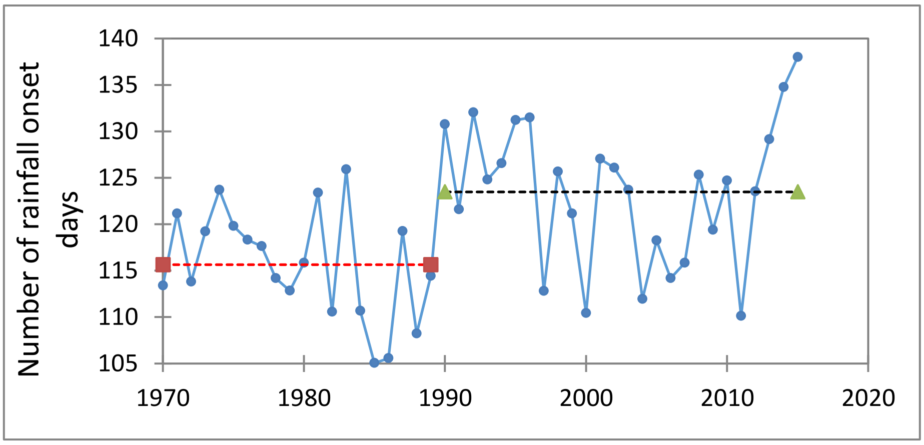

Figure 13. Results for temporal homogeneity tests for rainfall, 1970-2015

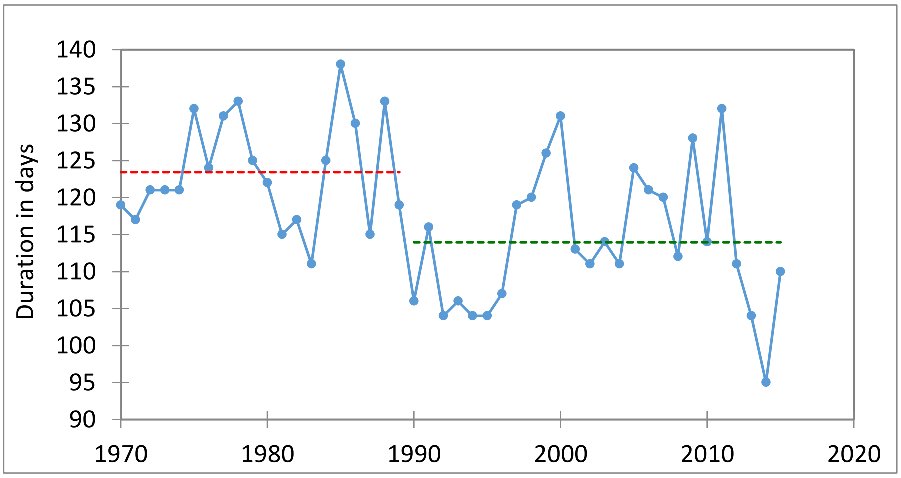

Figure 14.Results for temporal homogeneity tests for rainfall duration, 1970-2015

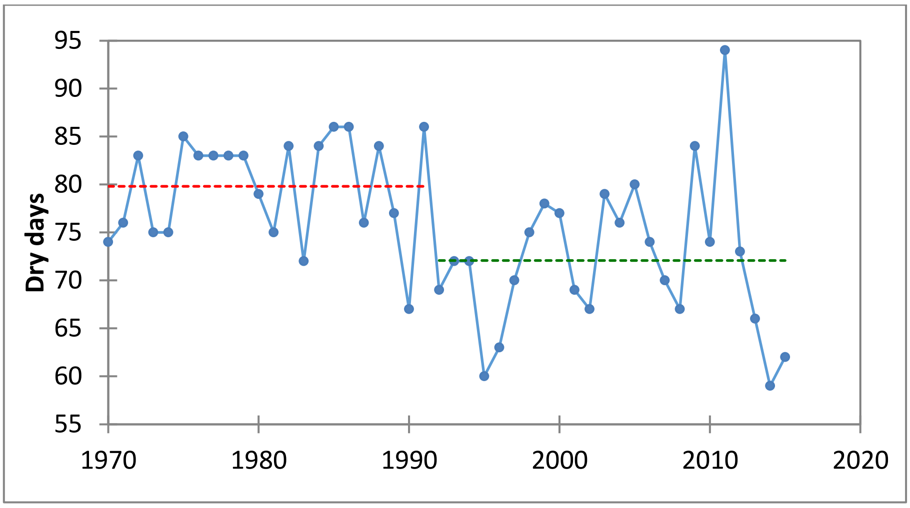

Figure 15. Results for temporal homogeneity tests on dry days, 1970-2015

At station level, results show that of the 27 analysed stations, six experienced shifts in average annual rainfall over the 45-year period (1970-2015) two in each of the country's three regions (Table 6).

Table 6. Stations with significant rainfall shift and year of shift by method

Station	Pettit's test			SHNT			Buishand's Test		
	Test statistic	Shift year	P-value	Test statistic	Shift year	P-Value	Test statistic	Shift year	P-value
Chitipa	390	1986	0.030	9.20	1986	0.030	11.8	1986	0.010
Karonga	452	1979	0.000	17.4	1979	0.000	14.9	1979	0.000
Nkhotakota	644	1980	0.040	10.3	1982	0.020	14.4	1982	0.010
Ntchisi	636	1989	0.000	22.6	1989	0.000	18.1	1989	0.000
Chiradzulu	596	1995	0.000	20.1	1995	0.000	16.7	1995	0.000
Phalombe	295	1995	0.020	8.90	1995	0.040	10.4	1995	0.010

Karonga station had an upward shift in annual rainfall amount detected in 1979, and a similar shift pattern was detected at Chitipa station in 1986, Chisombezi in Chiradzulu district and Phalombe stations in 1995. Nkhotakota and Ntchisi stations experienced a downward shift pattern in the rainfall, detected in 1982 and 1989 respectively (Table 6). These results indicate that despite claims about wide spread spatial changes in Malawi's rainfall patterns i.e. (Sutcliffe, Dougill et al. 2016), there has not been a spatially wide shift in the annual average distribution, considering that only six of the 27 analysed stations experienced significant shift over the 45 year period.

Results further show that few stations have experienced statistically significant shifts in the schedule of annual rainfall onset; 3 out of 27, one in the central region; Kasungu, and two in the southern region; Zomba and Mwanza. Kasungu and Zomba station experienced downward shift since 1981 and 1990 respectively, suggesting that annual rainfall was commencing later than normal over the analysed period. Mwanza station experienced an upward shift in the onset of rainfall, suggesting that rainfall was commencing later than normal based on the 45-year period (1970-2015).

Few stations in the country experienced shifts in average annual rainfall cessation schedule over the period of analysis. Table 7 shows that out of 27, only 4 stations had significant shifts, two in the northern region; Karonga, and Mzuzu, (1979), one in the central region; Ntchisi (1977) one in the southern region Chiradzulu (1992).

Table 7. Stations with significant rainfall cessation shift, year of shift and method

Station	Pettit's test			SHNT			Buishand's Test		
	Test statistic	Shift year	P-value	Test statistic	Shift year	P-Value	Test statistic	Shift year	P-value
Karonga	321	1979	0.050	9.001	1979	0.040	10.627	1979	0.010
Mzuzu	331	1979	0.040	8.078	1979	0.050	10.068	1979	0.030
Ntchisi	396	1977	0.010	13.1	1977	0.000	12.937	1978	0.000
Chiradzulu	643	1992	0.000	15.918	1992	0.000	15.218	1992	0.000

Results further show that over the 45-year period annual rainfall duration has shifted downwards for Karonga (1992), Nsanje (1989), and Chiradzulu (1974) while an upward shift was detected in Mchinji and Ntchisi stations in the central region; 1987 and 1988 respectively (Table 8).

Table 8.Stations with significant rainfall duration shift by method md year of shift

		Pettit's test			SHNT			Buishand's Test		
District	Years	Test statistic	Shift year	P-value	Test statistic	Shift year	P-Value	Test statistic	Shift year	P-value
Karonga	64	360	1992	0.01	9.6	1979	0.03	11.0	1992	0.01
Ntchisi	55	431	1988	0.00	12.0	1988	0.00	13.0	1988	0.00
Mchinji	93	816	1987	0.02	11.4	1987	0.01	15.0	1987	0.01
Chiradzulu	61	465	1974	0.01	11.0	1974	0.02	12.5	1974	0.01
Nsanje	74	535	1989	0.04	8.9	1989	0.05	12.4	1989	0.02

Only three stations had significant shifts in mean number of dry-days during the season over the studied period; Balaka, Mwanza and Chikwawa, all in the southern region of the country. Results further show that at national level, there has been a significant shift in the temperatures over the 43 years analysed.

As can be noted in figure16, there have been significant upward shift in mean maximum cropping season temperatures over the 43-year period in the country since 1989.

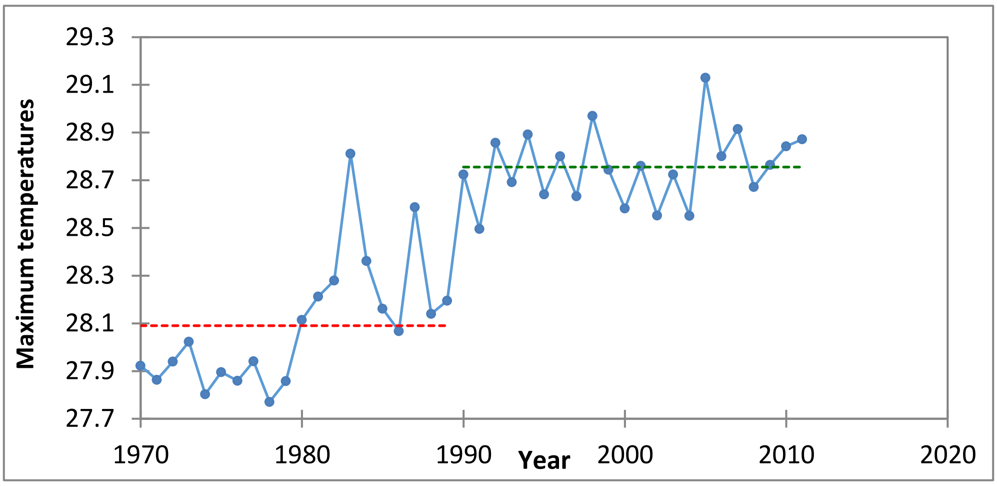

Figure 16.Results for temporal homogeneity tests on maximum temperatures, 1970-2013

Results also show that almost all districts have had upward shifts in annual average minimum temperatures over the 43-year period (1970-2013). Only a few have not experienced changes; Dowa in the central region, Machinga, Balaka and Chikwawa, Chiradzulu. Significant upward shifts in average maximum temperatures have been detected in almost all districts except Karonga, Dedza, Lilongwe, Neno, Chiradzulu, Blantyre and Chikwawa. These results indicate that malawi's temperatures have been increasing over time, like the trends in the SSA region.

4.5. Results for tests of randomness in time-series average annual temperature and rainfall data

In this study, tests for randomness in time-series temperature and rainfall data distribution were performed to check if the data values were correlated overtime. The tests were carried out using two methods; Durbin-Watson test and Ljung-Box. The former technique was done using SPSS v.24 and the latter technique was performed using Excel Stat v.2016. Durbin Watson method tested first order linear autocorrelation in the time series data, which occurs when sequential residual terms are correlated. The cut-off point for determining non-auto-correlated data series is D (test statistic) <1.5 to < 2.5. Any values above this range indicated first order auto-correlation in the data series. For the Ljung-Box technique, the autocorrelation function $Q(m)$ is zero for any time lag m meaning that all data series are uncorrelated.

In both techniques, residuals from a time series model of selected temperature and rainfall variables were observed if the underlying population autocorrelations for the errors added up to 0 up to a specified point. The residuals were assumed to be 'white noise' meaning they are identically, independently distributed (from each other).

Results for Durbin-Watson test showed that there was no autocorrelation of time-series annual rainfall and temperature variables data across all stations in the country. The test statistic (D) for all stations fell within the range of D = <1.5 - <2.5, which indicates that the data series were uncorrelated, suggesting absence of persistence in the data series as shown in table 9.

Table 9.Results of randomness test on residuals for annual rainfall data in Malawi

Climate Variable	Durbin-Watson Test Statistic	P-value
Total rainfall	1.447	0.297
Rainfall onset	1.773	0.796
Rainfall cessation	0.595	0.017
Rainfall duration	2.604	0.456
Dry-days in rainfall	3.020	0.421
Minimum temperatures	2.400	0.247
Maximum temperatures	0.815	0.278

Results show that residuals for rainfall duration and dry-days in a rainfall year data series were correlated, but not statistically significant; D-W: 2.604 (p-value 0.456) and D-W:3.020 (p-value 0.421) respectively. Results for LJung-Box method shows that residuals for all climatic variables analysed were not correlated for all lags except lag 1, which is correlation of the first order residual against itself, as it does not have an antecedent. Figures 17-20 presents auto-correlograms showing graphical illustration of Ljung-Box autcorrelation test result for analysed rainfall and temperature variables at different lags.

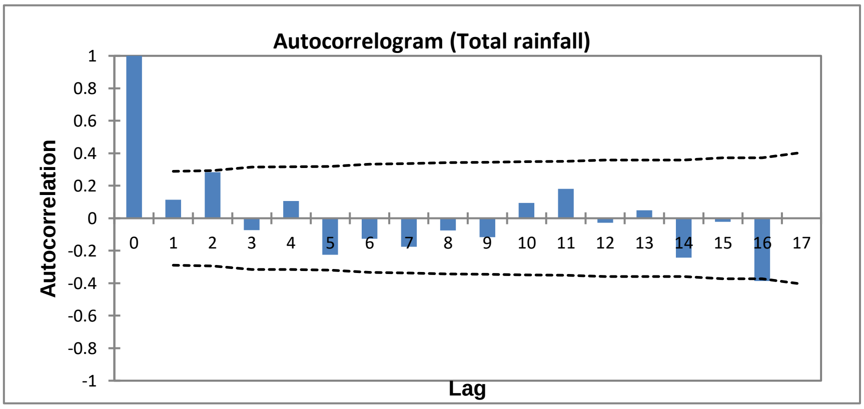

Figure 17.Autocorrelogram for average annual rainfall in Malawi, 1970-2015

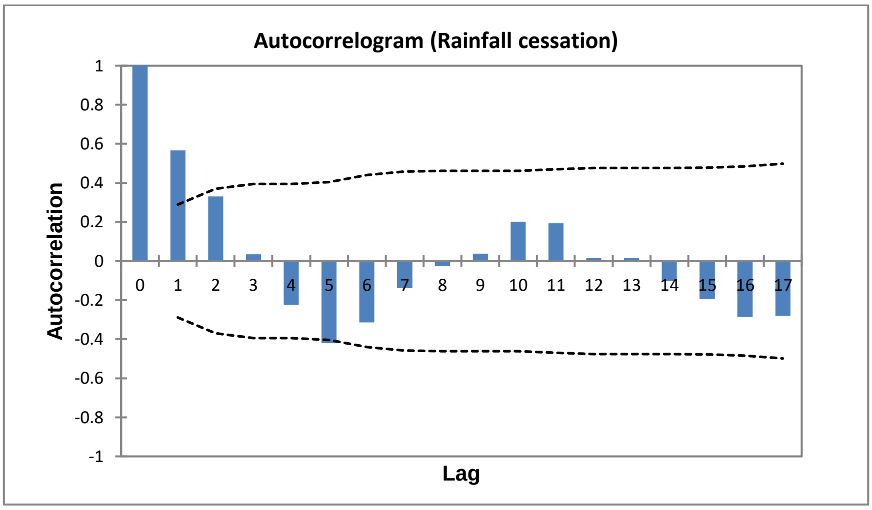

Figure 18.Auto-correlogram for annual rainfall cessation in Malawi, 1970-2015.

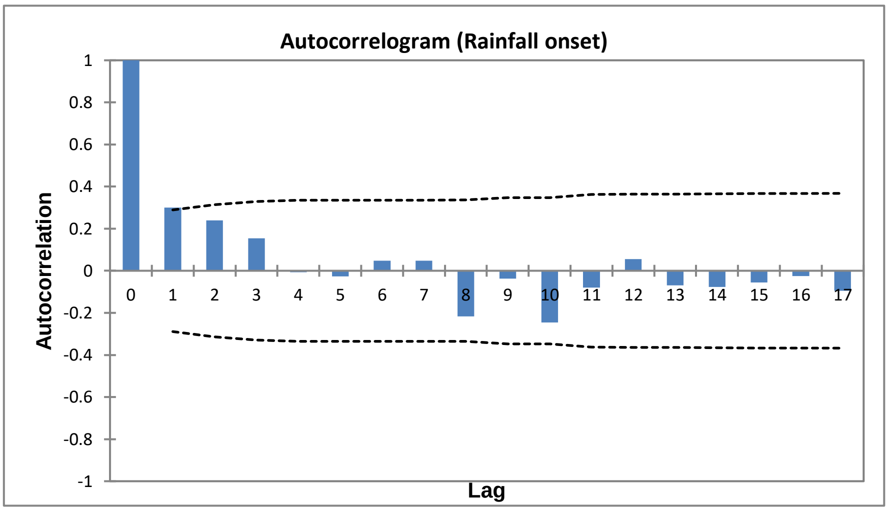

Figure 19.Auto-correlogram for annual rainfall onset in Malawi, 1970-2015

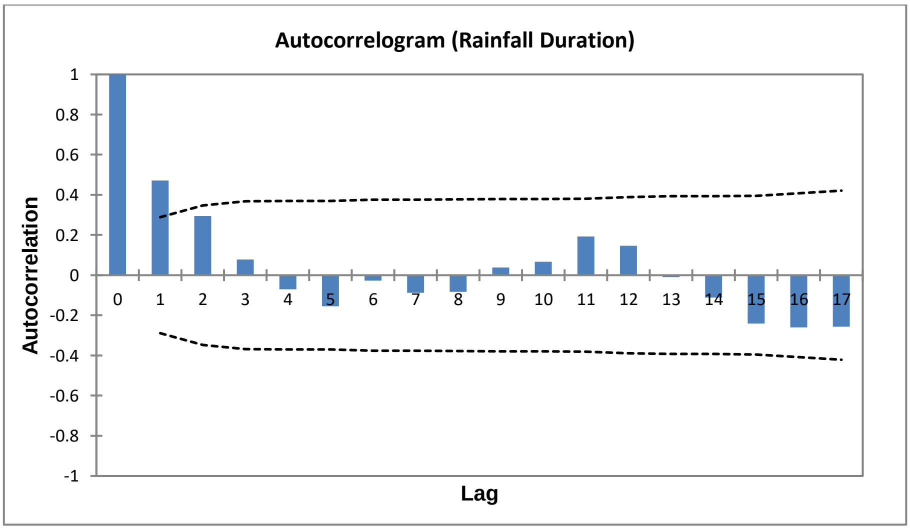

Figure 20.Auto-correlogram for annual rainfall duration in Malawi, 1970-2015

As can be noted from the autorrelograms above, all lags show that there is very small correlation in the residuals of the rainfall variables, ranging from -0.2 to 0.3 across all lags of the time series.

4.6. Discussion

This chapter presented results for quality assessment tests on climate data used in the study. This task was undertaken considering that station-based climate data is prone to natural and artificial errors emanating from various factors that affect the way data is collected and compiled. The task was also performed to provide guidance on methods that would be used to detect trends in selected climatic variables used in the analysis, considering that different analysis methods are robust for different types of data. Among the quality checks performed on the data series were normality tests, outlier data values detection, tests for homogeneity of the mean or variance of the data series, and tests on randomness and persistence in the data series. This section discusses results of the activity.

To begin with, results have shown that at an aggregate (national) level, all temperature and rainfall data series used in the study were not normally distributed. Results of Shapiro-Wilk tests and observations on histograms for time series average annual rainfall, average rainfall onset, cessation, duration and dry days were not normally distributed over the 45-year period. Similar results were noted for time series annual average minimum and maximum temperature data over the 43-year period of analysis.

According to Lloyd (2009) non-normality in temperature and rainfall data could arise from several factors, such as geophysical processes that drive rainfall variability i.e. topography. Further, reference periods of the data could also influence absence of normality in climate data series since events associated with such data pattern are not deterministic or predictable, leading to irregularity of patterns in occurrence and amplitudes, hence non-normality in the distribution (Jakuschné Kocsis and Anda 2018). In such conditions, detecting trends and homogeneity in the data distribution would require non-parametric methods since they are robust enough to cope with missing values and values under detection limit than parametric techniques (Muthoni, Odongo et al. 2018). Among such non-parametric trend detection methods is Mann-Kendall technique, while Pettitt's test is employed for homogeneity tests in time-series data.

Outliers are unusual points and values in patterns of data, which are introduced among other factors by human errors during data capturing and compiling, change in instruments and calibration for measure. (Weisent, Seaver et al. 2014). These lead to inflate error rates, forecasting inaccuracy and substantial distortions of parameter and statistical estimates of a given variable (Osborne and Overbay 2004). According to Osborne and Overbay (2004), not all outliers are illegitimate contaminants and not all illegitimate data values show up as outliers in a data series. As such, it is important to consider the range and causes that may be responsible for outliers in a given data set, as some might reflect a naturally occurring phenomenon in the series. Essentially, treatment of outliers in a dataset depends on why an outlier is illegitimately included in the data series, whether it has to be removed to avoid distorting the reality in the data series or left as such to reflect true anomalies in the series.

Results from the current data quality assessment show that at national level, no outliers were detected in time series average annual temperature and rainfall data variables selected for analysis in this study. This could be the effect of averaging the data series, since station level analysis of the data shows that 8 of the 27 stations had outlier average annual rainfall values, most of which occurred during the 1991/1992 rainfall year. Among the stations were Rumphi (595mm), Dedza (692mm), Balaka (586mm), Makoka in Zomba (742mm), Neno (427mm), Mwanza (533.2mm) and Makhanga station in Nsanje district (497.6mm).

However, although these values were detected as outliers in the series, they were not pulled out of the data series because disaster records and other reviewed studies i.e. Chabvungma, Mawenda et al. (2014) show and report that Malawi experienced a country wide drought in 1992/1993, which hit hard many southern region districts, represented by these stations. As such, these low rainfall values were a true reflection of naturally occurring climatic condition in the areas during this year and were not removed from the series, as doing so would be distorting a climatic reality of the time

Annual rainfall commencement in Malawi varies across regions, starting in the southern region around mid to end November, mid to end December in the central region and January to early February in the northern region. Warm-dry conditions commence in August, which become a precursor of the country's annual rainfall build-up (Ngongondo, Xu et al. 2011), where rainfall commences in November following sufficient heat and evaporation.

In the current study, onset of annual rainfall was defined as the number of days it took to determine that annual rainfall season had commenced, following after August or September as the month when Malawi's annual rainfall build-up commences. Outlier annual rainfall onset days were detected in few stations i.e. five out of 27 stations. Mchinji station (66 days from August, 1986 Nkhatabay; 12 days from August 1999, Ntcheu; 63 days from August 1996, Zomba; 77 days from August 2011 and Thyolo; 75 from August 1992. Considering that in the central region, annual rainfall commences end November to early December, Mchinji's rainfall onset in 1986 suggests that annual rainfall might have started early November, somehow earlier than normal.

However, though detected as outlier, there is no wide time difference between the normal commencement month of the rainfall; December, from the detected outlier month, November. However, Nkhata-bay's annual rainfall commencement days in 1999 is considered a genuine outlier because it suggests that the rains might have commenced in August, quiet unusual for the station, the northern region itself and the country at large. As such, an adjustment to this erroneous rainfall commencement period was made by taking the values for adjacent district i.e. Mzimba.

In this study, rainfall cessation days in a given rainfall year referred to number of days it took from August to record lowest rainfall for a given stretch i.e. three consecutive dekads with less than 20mm of rainfall. Outlier rainfall cessation days were detected in few stations in the country i.e. Rumphi in the northern region; 264 days in 2009, Balaka station in the southern region; 265 days in 1976, Neno; 297 days in 1976, Mwanza; 297 days in 196 and Chikwawa station; 252 days in 1992. Rumphi station's 264 rainfall termination days calculated from the month of August suggest an early termination in that rainfall year, as this falls in the month of April, uncharacteristic of this northern region district, where annual rainfall terminates late May or early June.

Results show that 1976 appears to be an interesting year for three of the five stations detected with outlier rainfall cessation days, where annual rainfall is noted to have terminated later than normal especially for Neno and Mwanza stations; May. According to Clay, Bohn et al. (2003) this was a La Nina year, where prolonged and high intense rainfall were recorded in the country, especially among southern region districts, hence the elongated rainfall season. As such, the detected outlier rainfall cessation values may not be artificial per se but true climatological events worth analysing.

On average, a normal annual rainfall duration in Malawi lasts 150-180 days, from its onset to cessation. Two out of 27 stations had outlier rainfall duration days, both in the central region; Mchinji; 63 days in 1996 and Dowa station; 61 days in 1994. However, Thomson, Abayomi et al. (2003), argues that southern African rainfall patterns for the years were affected by EL Nino which influenced drought conditions. Specific to Malawi, Nangoma (2007) reports that the 1994/1995 rainfall year is recorded among El Nino affected years associated with localised droughts across Malawi. Other drought rainfall years were 1953/54, 1972/73, 1982/84, 1992/93 rainfall seasons, where shorter annual rainfall duration was recorded. The 1994/95 annual El Nino and consequent drought conditions however were spatially sparse as evident in the current study (only two stations out of 27 stations). However, the result still represents an important climatic phenomenon whose effects i.e. shorter rainfall duration, cannot be considered artificial outlier.

Few stations were detected with outlier average annual maximum temperatures in this study; Nkhotakota and Mchinji stations in the central region, Machinga, Makoka in Zomba district, Phalombe and Chisombezi station in Chiradzulu district, southern region. Most outlier data were detected in Makoka station, extremely low values uncharacteristic of the months concerned. For instance, 15.5°C in March, 12.2°C in April, 17.3°C in December, Nkhotakota's 0°C in September 1998, Mchijnji's 17.9°C in January 2001 all of which are warm wet season months, when maximum temperatures are normally above 25°C (Warnatzsch and Reay 2019). Machinga, Chiradzulu and Phalombe's 38.6°C, 34.4. °C and 35.4°C in February and December respectively, and Mwanza's 37.5°C in October, were all unusually high temperatures for the warm wet season, although temperatures are expected to be high.

All these outliers were thought to originate from human error than meteorological factors. As such, they were adjusted using Winsorization method (Kwak and Kim 2017), which is a value modification method that allows replacement of outliers with the largest or second smallest values in the observations, excluding the outliers (Kwak and Kim 2017). The adjustments were done to prevent distorting various statistics of maximum temperature data for the stations i.e. mean and standard deviation, which have implications on trend and homogeneity in the series (Clay, Bohn et al. 2003).

Results for homogeneity tests showed that there has been an upward shift in the onset of annual rainfall, detected in 1991/92 rainfall year. This result indicates that over the analysed period, Malawi's rainfall commencement starts later than normal. Basically, annual rainfall onset is delaying. A significant downward shift in the duration of the annual rainfall was also detected in 1991/92, which suggests shortening of the rainfall period over the years of analysis. Meteorological records and other studies i.e. Coulibaly, Gbetibouo et al. (2015), Kachaje, Kasulo et al. (2016), Nash, Pribyl et al. (2018) report that the southern region of Africa experienced wide spread drought in 1991/92 which might have been a shifting point for November – April rainfall patterns for the region. This meteorological event might account for the shift in rainfall onset and duration detected in the current study. However, few stations reported significant shifts in average annual rainfall, its onset, cessation and duration over the period of analysis, suggesting that though 1991/92 is recognised as the major shifting point for rainfall in the southern African region, there are in-country variations, where these climatic signals are not spatially extensive.

Homogeneity tests results for time series average annual minimum and maximum temperature data indicate that both temperatures registered an upward shift in 1990/91. Unlike annual average rainfall, this upward shift was spatially extensive, with only few stations (5 out of 27) indicating significant downward shifts in the temperatures. This result highlights within-country spatial variations in surface temperature changes over time, which could be an influence of variations in geophysical processes i.e. topographic differentials in the placement of the stations (Ogwang, Chen et al. 2014) and also radiative force index in the southern African region (Manatsa, Morioka et al. 2015) in which Malawi is located.

Results on tests of randomness of average annual temperature and rainfall data series show that at an aggregate level, all the data series for the selected variables were uncorrelated. However, significant results were detected only on annual rainfall cessation, unlike average rainfall, its onset, cessation, duration, dry-days, minimum and maximum temperatures. No correlated series were detected at station level, indicating that the data were free from possible artificial or false trend detection (Ngongondo, Xu et al. 2011) characteristic of correlated data series.

4.7 Conclusion

In this study, results of quality assessment on time series temperature and rainfall data variables have shown that the data series are generally not normally distributed, and that at an aggregate (national) level, outliers were not detected, but at station level. A few of the analysed stations had outlier data values, mainly from human error, especially for temperature data series, and meteorological influences i.e. topography, for most rainfall variables. Outliers suspected of emanating from human error were adjusted to fit with the normal pattern using winsorization method, while those suspected of being meteorologically influenced were retained as such to avoid distorting a 'true' climatic reality of a given station and time. The non-normality of the data series entails that only non-parametric technique would produce valid results for any analysis performed on the data, as these methods are robust enough to handle missing values and outliers in the data series.

Few rainfall variables were detected with shifts in the patterns over time i.e. annual rainfall onset and duration, while both minimum and maximum temperatures had an upward shift, suspected of being influence of radiative forces influenced by global warming. This results suggests a possibility of generally increasing trends in the temperatures over time, a situation that augurs with current discussions about global warming and climatic changes.

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Chapter 5. Examining trends in Malawi's rainfall and temperature variables

5.1. Overview

This chapter presents results of analysis on assessment of trends in selected cropping season average temperature and rainfall variables for Malawi over a 45 and 43-year time period;1970-2015 and 1970-2013 respectively. The chapter addresses the first objective of the study, providing basis for subsequent analyses; assessing association of climatic variables with household food security and child nutritional status in the country. To assess the trends, a non-parametric trend detection technique; Mann-Kendall test was employed. This method has been used to detect monotonic upward or downward trends in time series environmental, climatic and hydrological data variables (Pohlert 2016). This technique was preferred because of its robustness in handling non-normally distributed data with outlier values and when examining trends in time series climate data variables (Hirsch and Slack 1984, Pohlert 2016). This was characteristic of temperature and rainfall data variables used in the current study, hence the choice of the technique.

This technique was also used by Ngongondo, Xu et al. (2011) in the analysis of spatial and temporal characteristic of rainfall in Malawi. Kachaje, Kasulo et al. (2016) also used this technique in the assessment of cropping season rainfall trends in Mulanje district, southern Malawi, while Kimaro and Sibande (2018) applied it in the assessment of trends in annual rainfall and temperatures in Malawi. In all these analyses, Mann-Kendall trend test technique was notably reliable in detecting trends in the respective time series temperature and rainfall variables.

5.2. Detecting trends in time series selected temperature and rainfall variables

A trend is defined as a tendency for successive values to increase or decrease over time (Machiwal and Jha 2012) either linearly or non-linearly, depending on patterns of the data variables. Methods for detecting trends in time series variables are classified into two groups; parametric and non-parametric methods. Parametric methods require normally distributed data that are free from outliers, while non-parametric methods are applied on non-normally distributed data which has some outlier values.

Among parametric methods are the Student's *t*-test, turning point, Kendall's rank, regression, Wald-Wolfwitz total number of runs, and sum of squared lengths (Shahin, Van Oorschot et al. 1993). Non-parametric trend detection methods include Mann-Kendall test for linear and non-linear trends, Hotelling-Pabst, Sen's test, Kruskal-Wallis, and Wilcoxon signed rank among others (Hipel and McLeod 1994). Mann-Kendall trend testing method measures the strength of a monotonic relationship between two variables: x_i and y_i. According to Wang, Van Gelder et al. (2005) the data values are evaluated as an ordered time series where each is compared to all subsequent values. The null hypothesis; $H°$ is that the data come from a population with independent realizations and are identically distributed (Pohlert 2016), while the alternative hypothesis H_a is that the data follow a monotonic trend. The initial value of the Mann-Kendall test statistic S, is assumed to be 0, meaning no trend. If a data value from a later time period is higher than a data value from an earlier time period, S is incremented by 1. If the data value from a later time period is lower than a data value sampled earlier, S is decremented by 1. S is derived as follows:

$$S = \sum_{i=j}^{n-1} \sum_{i=t+1}^{n} \operatorname{sgn}(x_i - x_j) \qquad (23)$$

$$\begin{Bmatrix} +1, \text{for } x_i - x_j > 0 \\ 0, \text{for } x_i - x_j = 0 \\ -1, \text{for } x_i - x_j < 0 \end{Bmatrix}$$

The net result of sum of all such increments and decrements yield the final value of S (the Mann-Kendall test statistic). x_i is a time series value i.e. annual rainfall at time i and x_j is a subsequent rainfall value at time j, n is length of the time series. According to Kendall (1975) S tends to normality for large probability (n) with the expected variance of S defined as:

$$E(S) = 0,$$

where variance (s) is given as:

$$V(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_p(t_p - 1)(2t_p + 5)\right. \qquad (24)$$

when the data distribution contain tied values (which is common with climatic data). t_p is the number of ties for the p^{th} value and q is the number of tied values (i.e. equal values).

The second term $2t_p$ represents an adjustment for tied data (Ghalhari, Dastjerdi et al. 2012). The standardized test statistic Z given by Hirsch and Slack (1984) is presented as follows;

$$z = \begin{cases} \frac{s-1}{\sqrt{\mathrm{Var}\,(s)}} & \text{if } s > 0, \\ 0 & \text{if } s = 0, \\ \frac{s+1}{\sqrt{\mathrm{Var}\,(s)}} & \text{if } s = < 0, \end{cases} \qquad (25)$$

The presence of a statistically significant trend is evaluated using the 'Z' value. Positive values of 'Z' indicate an increasing trend and negative values indicate a decreasing trend. In testing increasing or decreasing monotonic trend at significance level i.e. p= 0.05 the null hypothesis is rejected if the absolute value of 'Z' was greater than $Z_{1-p/2}$ where $Z_{1-p/2}$ was obtained from the standard normal cumulative distribution tables. In the current study, the Mann-Kendall test was performed in Excel Stat. V. 2016.

5.3 Results for trends analysis in selected temperature and rainfall variables

Results in table 10. shows that Malawi's average annual rainfall has had a negative trend over the period of analysis; Kendall's Tau -0.115 Sen's slope -1.996, suggesting that its amount is decreasing overtime, but not statistically significant; p-value 0.264.

Table 10.Mann-Kendall trend test results for temperature and rainfall variables

Variable	Kendall 'Tau	p-value	Sen's slope	Trend
Total rainfall	-0.115	0.264	-1.996	Negative
Rainfall onset	0.168	0.082	0.176	Positive
Rainfall cessation	-0.211	**0.042**	-0.167	Negative
Rainfall duration	-0.210	**0.043**	-0.164	Negative
Dry-days	-0.263	**0.011**	-0.183	Negative
Minimum Temp.	0.080	0.514	0.001	Positive
Maximum Temp.	0.356	**0.003**	0.216	Positive

A positive trend in the onset of rainfall in the country has been detected; Kendall's tau 0.168, Sen's slope 0.176, suggesting that annual rainfall is commencing later than normal i.e. delaying over time. However, this delay is not statistically significant, p-value 0.082. However, significant negative trends in rainfall cessation period have been detected; Kendall's tau -0.211, Sen's slope -0.167 and p-value 0.042. This indicate that annual rainfall have been terminating earlier than normal over the analysis period.

Further, the duration of annual rainfall over the period has been shortening, as evident Kendall's tau; -0.210, Sen's slope -0.164 and this trend is statistically significant; p-value 0.043. Significant increasing trends were detected in the country's maximum temperatures over the 43-year period, Kendall's tau; 0.356, p-value 0.003, suggesting that Malawi is getting warmer over time. Results have also shown that the trends have varied across stations as figure 21 shows.

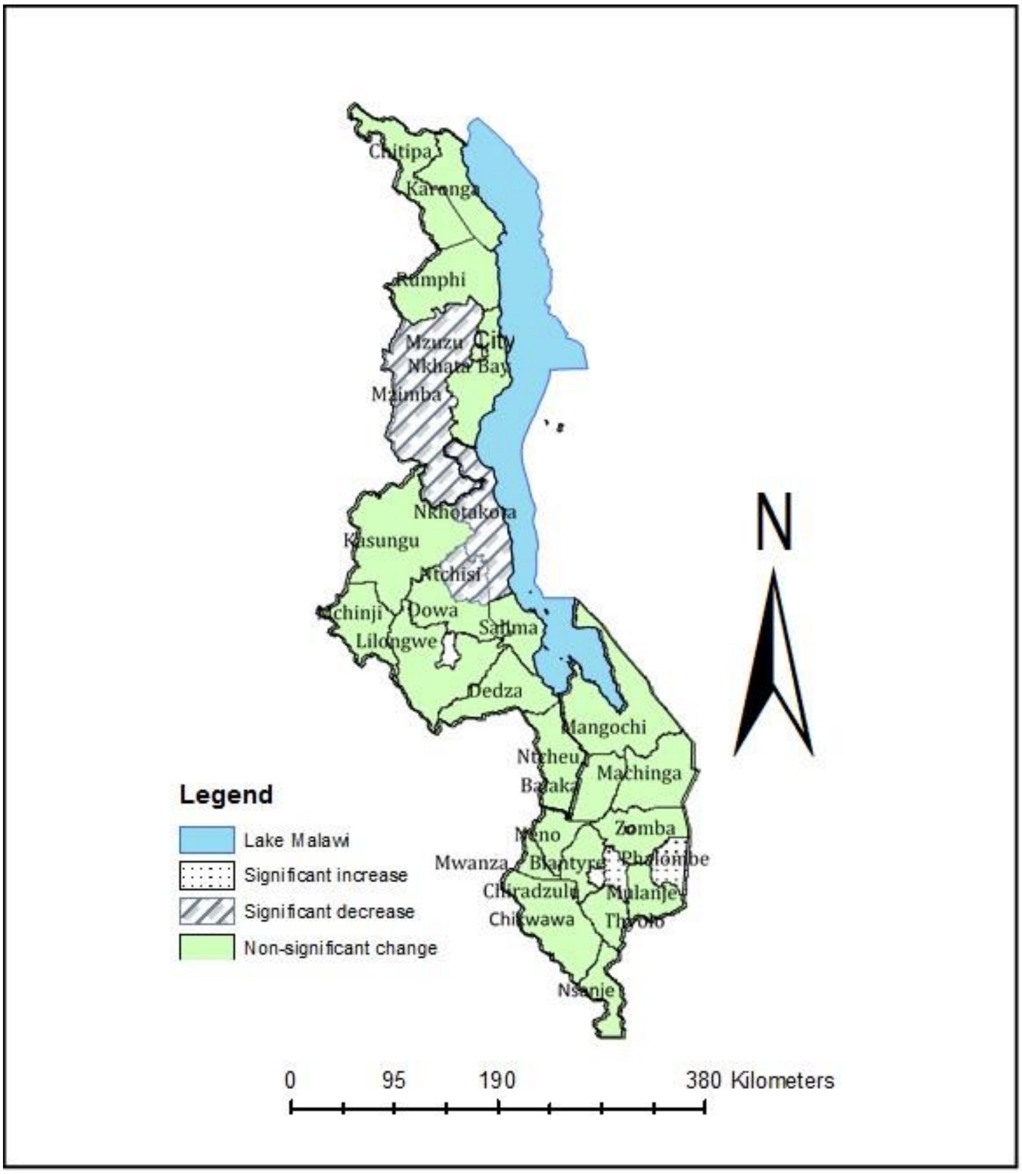


Figure 21. Annual rainfall trends by stations in Malawi, 1970-2015

The figure shows that in the northern region, Mzimba station, Ntchisi, and Nkhota-kota stations in the central region had statistically significant decreasing trends; Kendall's tau -0.360, P-value 0.000, and Kendall's tau -0.204, P-value 0.047, while Phalombe and Chiradzulu had significant increasing trends; Kendall's tau; 0.221, P-value 0.031 and Kendall's tau; 0.219, P-value 0.032.

Results further show that only five of the 27 stations had statistically significant positive trends in annual rainfall; Bolero station in Rumphi district Kendall's tau 0.230, P-value 0.028, Kasungu station; Kendall's tau 0.249, P-value 0.017, Chileka station in Blantyre district; Kendall's tau 0.212, P-value 0.044, Thyolo station; Kendall's tau 0.215, P-value 0.039 and Nchalo station in Chikwawa district Kendall's tau 0.290, P-value 0.006. Figure 22 shows geographical variation in onset of rainfall in the country.

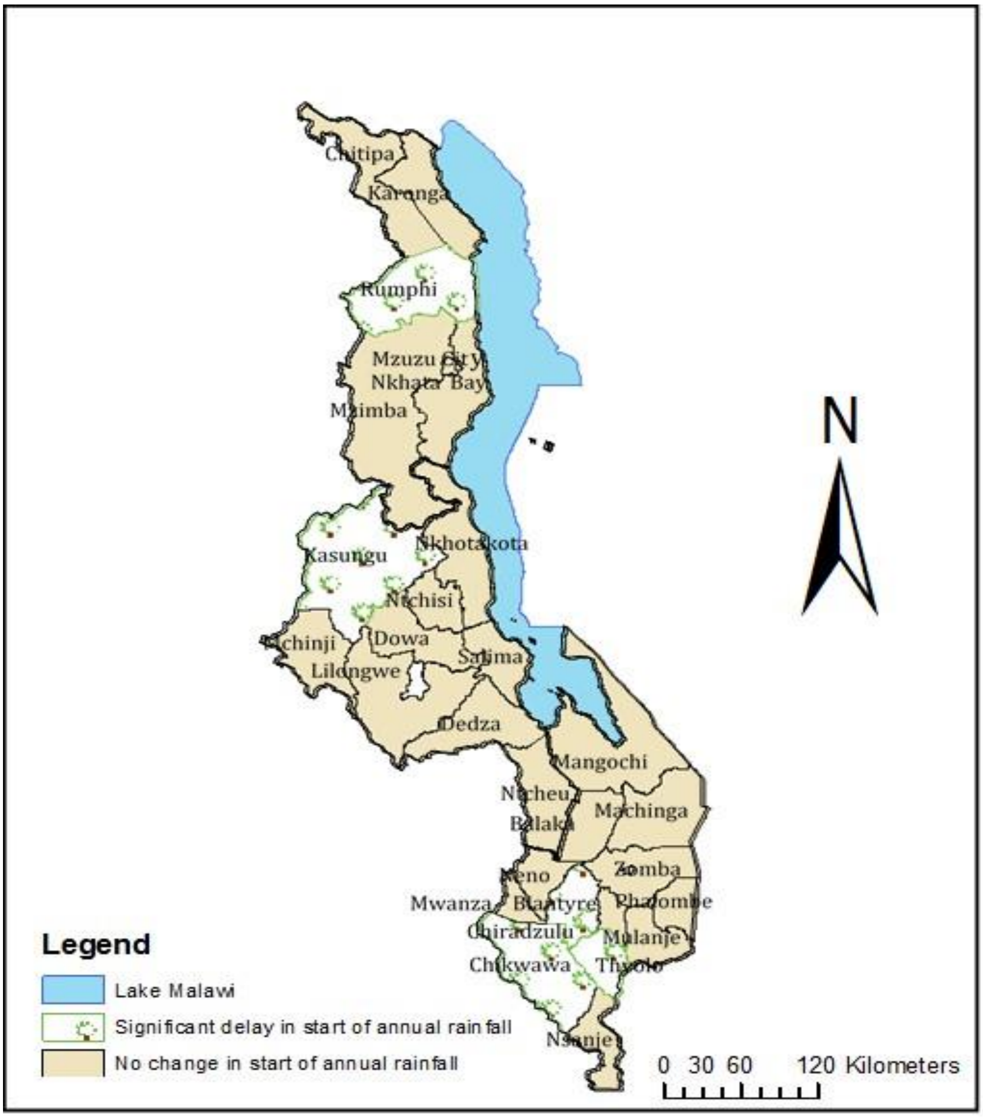


Figure 22.Annual rainfall onset trends by station in Malawi, 1970/2015

Few stations have shown significant negative trends in the cessation of annual rainfall in the country; Mzimba station; Kendall's tau -0.264, p-value 0.042, Nkhotakota in the station central region; Kendall's tau -0.260, P-value 0.013, and Balaka station in the southern region; Kandall's tau -0.357, P-value 0.001 respectively. The results entails that in these stations, annual rainfall has over the 45-year period been terminating earlier than normal.

Only one station showed statistically significant increasing trend in the cessation of annual rainfall; Chisombezi station in Chiradzulu district, Kendall's tau 0.328, P-value 0.002). Figure 23 shows that across the country, early rainfall cessation signal has been spatially sparse, with few stations showing significant delays in termination of annual rainfall over the studies period.

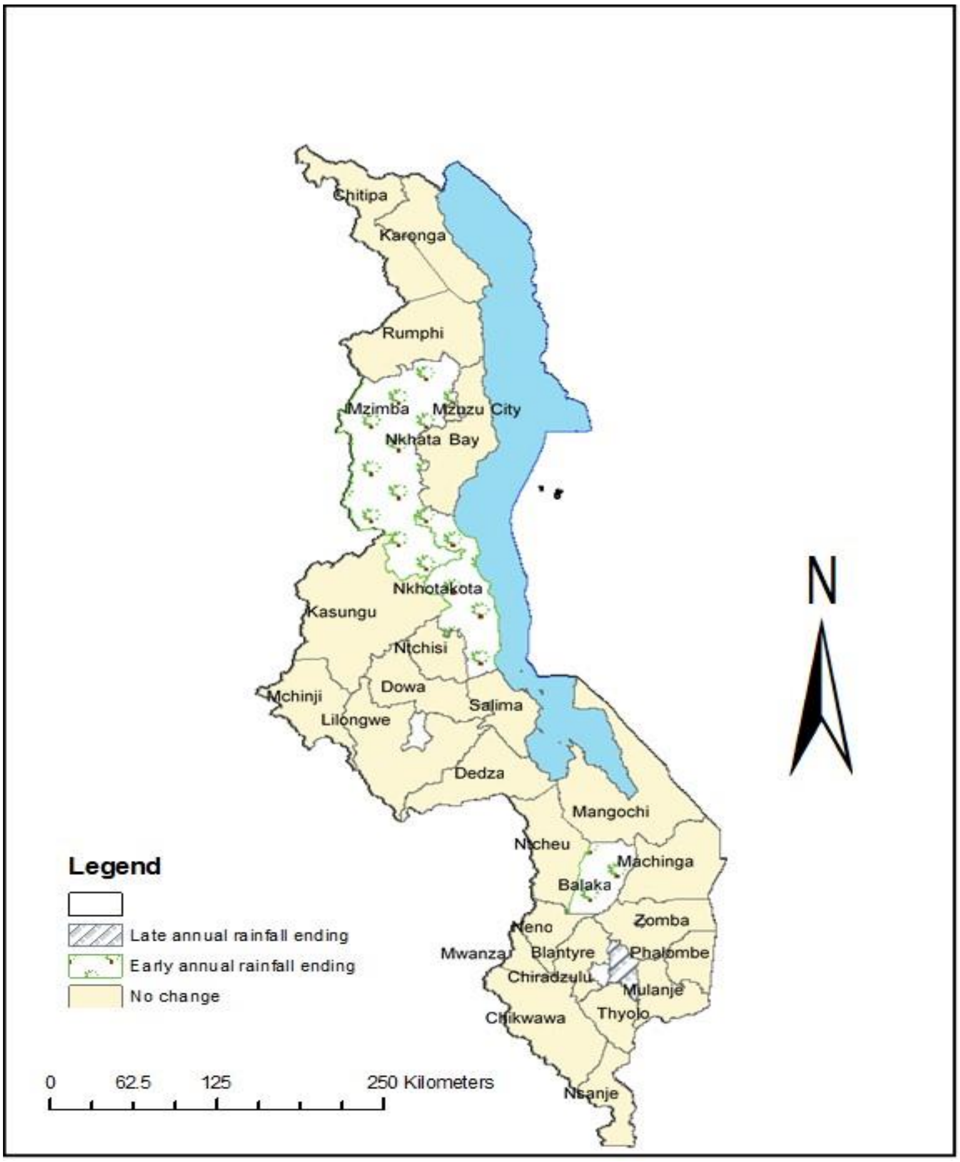


Figure 23. Annual rainfall cessation trends by station, 1970-2015

Results show that of all seven climatic variables analysed for trends in this study, average annual rainfall duration has been the only spatially extensive climatic variability signal in the country, with 10 of the 27 stations (37 percent) detected to experience significant short rainfall duration over the 45- year period. Figure 24 shows map of Malawi with stations in districts where significant shortening of annual rainfall duration was detected.

Among the stations experiencing shortening rainfall duration are; Mzimba, Mzuzu and Karonga stations in the northern region, Kasungu and Chitedze station in Lilongwe district, central region, Balaka, Chileka in Blantyre district, Nchalo in Chikwawa district, Chisombezi in Chiradzulu and Makhanga station in Nsanje district, in the southern region.

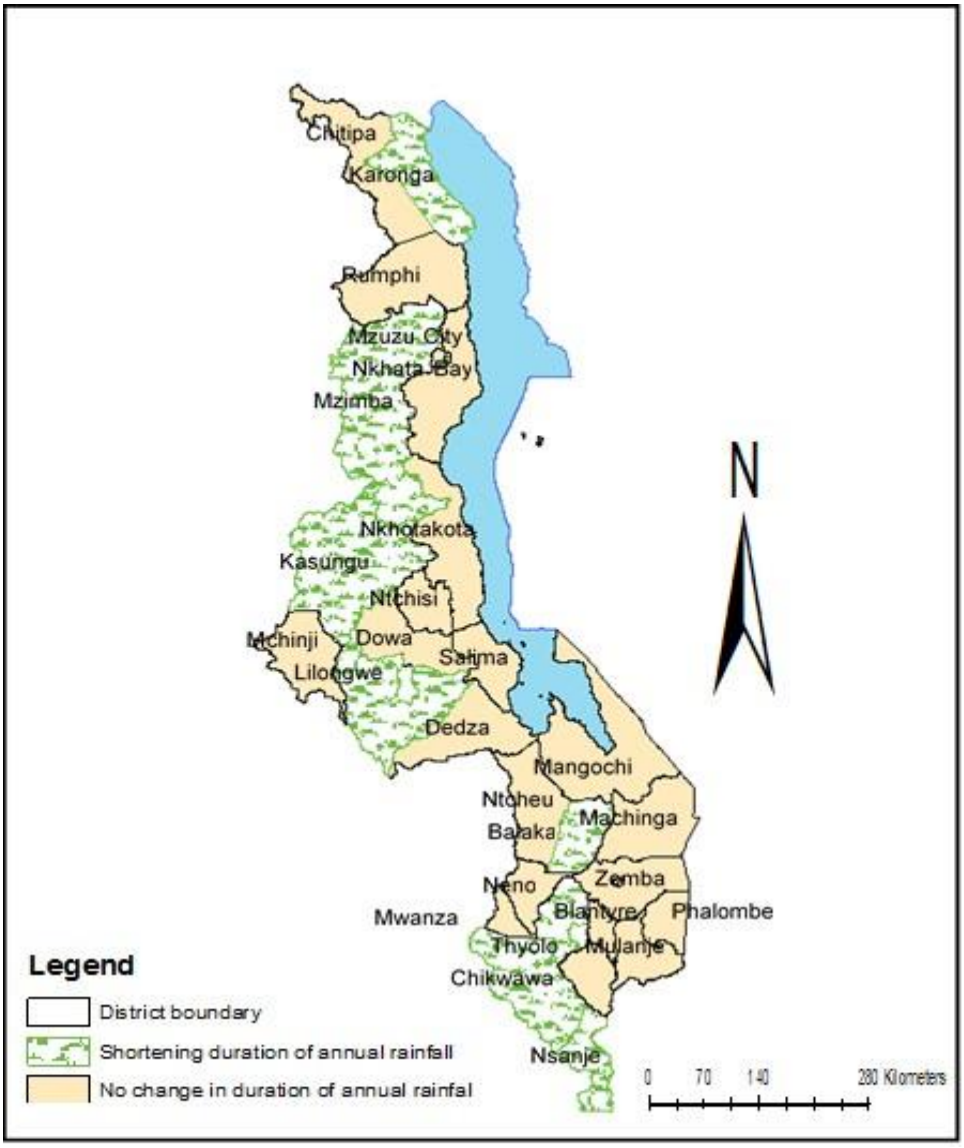


Figure 24.Annual rainfall duration trends by stations in Malawi rainfall 1970-2015

Further, there were few stations with statistically significant trends in average number of dry days in a rainfall year, although the general observed pattern is that of declining trend in dry-days during rainfall season. The two stations with significant results however show increasing trends in dry-days i.e. Phalombe station; Kendall's tau 0.229; p-value 0.003 and Mimosa station in Mulanje district; Kendall's tau 0.200, p-value 0.030. This result indicates a spatially weaker climatic variation signal in terms of dry spells during the rainfall season in the country.

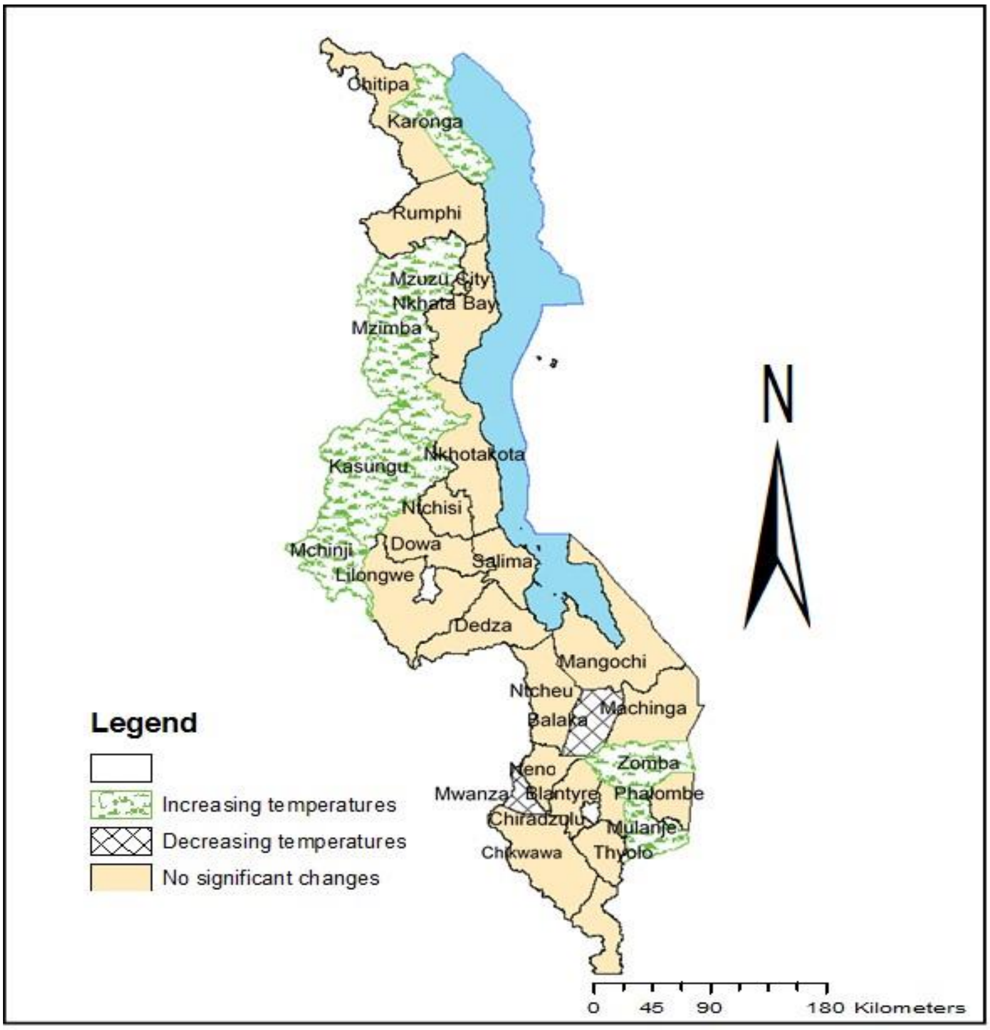


Figure 25.Trends in mean number of dry-days in a rainfall season by station in Malawi, 1970-2013

Analysis further shows that seven of these stations registered increasing minimum temperature trends and only two; Balaka and Mwanza experienced statistically significant decreasing trends over the analysed period (figure 23). A third of the analysed 27 stations in the country (7 out of 27) were detected with increasing average annual maximum temperatures. These were Karonga, Mzimba in the northern region, Kasungu and Ntchisi in the central region, Thyolo, Mwanza, Makoka and Mimosa station over the 43-year period of analysis.

5.4. Summary of Findings

The current chapter presented results of a trend analysis on selected temperature and rainfall variables over a 43 and 45-year period. Results have shown that Malawi's climatic variation signal has been spatially sparse, detected in few stations across the country. Few of the trends are statistically significant at national level. Specifically, the study has found:

- Non-statistically significant declining trend in average annual rainfall,
- Statistically significant early cessation trend in annual rainfall
- Statistically significant and spatially extensive shortening annual rainfall duration trend.
- Non statistically significant increasing average minimum temperatures
- A spatially extensive and increasing trend signal in average annual maximum temperatures.

5.5. Discussion

This chapter presented results on assessment of trends in selected temperature and rainfall variables in Malawi. The purpose was to provide background picture of Malawi's climatic conditions with respect to rainfall and temperature over time, prior to analysing association between these climatic variables and crop yield, household food security and under-five children's nutritional conditions. To examine the trends, Mann-Kendall (1945,1975) trend testing technique was applied on 45 and 43-year time-series temperature and rainfall data variables from 27 weather stations in 27 of the 28 districts of the country.

The data were assessed for quality by running different tests i.e. normality, outlier detection, homogeneity of the mean and temporal persistence. Results from the tests guided the researcher on choice of trend testing method to be used in the study, i.e. non-parametric or parametric methods. This section discusses findings on the assessment of trends in selected rainfall and temperature variables in Malawi, relating the findings to other analyses conducted at various spatial and temporal scales i.e. continental, regional and sub-regional, national and locally in Malawi. It also discusses the implications of the findings on the local context (Malawi) and research work that could be pursued to generate further understanding on the subject matter.

To begin with, Malawi's average annual rainfall has over a 45-year period (1970-2015) experienced decreasing trends, but not significantly. Essentially, annual rainfall amount has been decreasing but not substantially, though the decrease has extensive spatial coverage. There are spatial variations across stations with just a few showing significant decreasing rainfall trends, one station in the northern region, two in the central and southern regions of the country. The decline in annual rainfall concurs with observations of the IPCC 5th assessment report about rainfall patterns in the south-east African sub-continent, where Malawi is located. The report also notes a downward trend in summer rainfall (November to April) in southern and eastern Africa. This observation was also reported by New, Hewitson et al. (2006), Hoerling, Hurrell et al. (2006) and locally Ngongondo, Xu et al. (2011), who also noted decreasing annual rainfall in Malawi at varied spatial scales.

Among factors argued to account for this trend in the south-east African region are land cover changes influenced by wanton forests clearance to pave way for farming and human settlement (Longhurst and Sabates-Wheeler 2019). A long held hypothesis is that forest cover plays a much greater role in determining rainfall in that they generate large-scale flows in atmospheric water vapour, arguing no wonder high rainfall occurs in continental interiors such as the Amazon and the Congo river basis, because they have continuous forest covers from the interior to the cost (Sheil and Murdiyarso 2009). Deforestation disrupt hydrological cycles and ecosystems, leading to further disruptions in rainfall cycles, volume and intensity (Kotir 2011).

Another argument paraded as a factor to variation in climatic patterns is global ocean circulation changes associated with patterns of sea surface temperature and changing compositions of the global atmosphere (Hulme 1992). However, other researchers i.e. Tadross, Suarez et al. (2007) argue that anthropogenic effects have played significant role in shifting rainfall regimes in the continent, accounting for a mixed climatic pattern in different parts of the continent. These are evident in decreasing rainfall trends in the south-west while the south-eastern part of the continent experienced increasing trends. This position, however counters current study results which show decreasing annual rainfall trends in the south-eastern African region where Malawi is located.

Important in this finding though is the implication of such rainfall decreases to peoples' livelihood options such as farming, transmission of pests and diseases to crops, animals, and human populations at different spatial scales within the country, all of which affect quality of life.

Alongside decreasing annual rainfall trends in the country are delays in the onset and early cessation of the rainfall in almost all analysed stations across the country. Although the trends have not been statistically significant at country level, a few stations have shown significant trends in both delayed onset and early cessation of the rainfall. This result resonates with rainfall patterns in different parts of the African continent, even though there are spatial and temporal variations. In Ghana for instance Amekudzi, Yamba et al. (2015) noted a late onset of rainfall from the second dekad of April to the first dekad of May, associated with the Savanna zone. Early rainfall cessation dates of the coastal zone were also detected in the second and third dekad of October of the studied rainfall years.

In Cameroon, Guenang and Mkankam Kamga (2012) found a delayed rainfall onset of 1 pentad in the prevailing climatic conditions based on projections for 2082-2098 under SRES A2 carbon emission scenario. Further, an April 2017 FEWSNET report for mid-season rainfall anomalies between 1983-2009 in the Horn of Africa found that seasonal rainfall had delayed their onset, leading to below-average rainfall over many areas, which was associated with droughts in Somalia, North-east Kenya and south-eastern Ethiopia. In southern-eastern Africa, Shongwe, Van Oldenborgh et al. (2009) and Ngongondo, Tallakanse et al. (2014) have also detected delays in the onset of annual rainfall and their early cessation in some southern African countries i.e. Zambia, Zimbabwe and Malawi, a finding that concur with a general picture of changing annual and seasonal rainfall patterns generally observed in the region.

Nash (2017) explains that for regions where mean annual precipitation occur between October and March also regarded as summer rainfall zones (SRZ), i.e. south-eastern Africa, seasonal interplay between subtropical high-pressure systems and the migration of easterly flows associated with the ITCZ account for changes in annual rainfall patterns such as delayed onset and early cessation. However, the complexity of the climate system makes it difficult to firmly argue about a single influence as a factor behind observed and reported changes in patterns of its variables such as precipitation at varied spatial and temporal scales.

Although current study results indicate varying annual rainfall onset and cessation times over the analysed period, this climatic change signal is not strong enough in many districts, since only five of the 28 stations in the districts have had statistically significant results. This result might have been influenced by length of the period for the analysis, in that the changes many not have been substantive enough for the signal to cover the whole country during the period of analysis. Current study results however, indicate that amid claims that Malawi's rainfall patterns are changing over time, there is need to highlight that the signal of change with respect to some rainfall variables i.e. onset and cessation of annual rainfall, is generally not large scale and spatially significant. Essentially, it is important to consider spatial specifications in analysing the effects of climatic changes or variations with reference to annual rainfall in the country. This approach would enable detection of an accurate signal whose details would be important input for design and implementation of interventions to deal with the effects of such changes in rainfall patterns i.e. on farming calendar and crop production at a given spatial scale.

Delays in onset of cropping season rainfall and its early termination have been some of the characteristics of rainfall detected in this analysis. Significant increasing trends in its onset amid significant decreasing trends its cessation have resulted in significant decreasing trends in its duration. A regional analysis of duration of the summer rainfall in south-east Africa shows significant negative trends in the northern part of the Sahel region, parts of Tanzania and neighbouring Mozambique, indicating shorter rainfall duration (Vrieling, De Leeuw et al. 2013). In Malawi, shorter annual rainfall duration has been more pronounced, with all stations indicating negative trends in annual rainfall duration, statistically significant in 10 of the 27 stations.

The effects of this shortened rainfall duration on various issues depends on how critical water is with reference to the matter in question. For example, in terms of crop production, there are different phenological requirements for plant growth, development and yield, with different water indices. Some crops may react negatively to relatively short soil water while others might react positively depending on how crucial water is in their various phenological processes (Tao, Yokozawa et al. 2006). However, this rainfall signal extensive or not does have important implications on the country's food security posture, owing to its significance in crop production.

Considering mounting claims that southern Africa is one of the regions detected with warming trends since the 1960s (Nicholson and Flohn 1980, Tadross, Suarez et al. 2007) it would be expected to detect increasing minimum and maximum temperature trends across countries in the region. Analysis from the current study has shown that both minimum and maximum temperature trends have significantly increased in the country. However, there are variations across stations, with five of the 27 stations studied having decreasing minimum temperature trends, but statistically significant in three suggesting; Nkhatabay in the northern region of the country, Mchinji in the central region and Neno in the southern region. Statistically significant decreasing maximum temperature trends were also detected in Nchisi and Mchinji stations in the central region of the six stations detected with decreasing maximum temperatures.

Decreasing minimum and maximum temperature trends amid a general consensus that Malawi is generally undergoing significant warming spells the need for spatially detailed analysis of climatic conditions in order to detect a correct signal of variation or change, since getting a summary picture for the whole country might be misleading. In addition, significant decreases in both temperatures amid a general claim of warming in the country suggest the need for careful analysis of the effects such variations could have on various spheres of human lives in the country, in order to design target specific climate change or variation interventions, other than generalised approaches. It is also important to note from the analysis that the spatial variation in these climatic signals do not have regionality the trends are random in nature, despite topographic and environmental conditions stations from which the data was gathered might experience.

5.6. Conclusion

Although most studies on climatic patterns in Malawi have reported that the country is facing serious climatic changes with reference to rainfall, solar radiation and surface temperatures among other climatic variables analysed, the current study has found that the signal is not spatially extensive. Rainfall is decreasing non-significantly at national scale, with only five of the 27 districts showing statistically significant declines one showing significant increasing trends. This situation indicates that although there have been claims and reports of serious climatic changes with reference to annual rainfall in the country, analysis of station-based data used in this analysis has proved otherwise.

Not only has there been a spatially sparse climate variation signal in annual rainfall volumes, but other characteristics i.e. its onset though it is delaying, only few districts have reported significant trends. Few districts have had significant decreasing trends in its cessation, although the general pattern is such. However, more than a third have had significant decreasing trends in its duration, indicating shorter rainfall seasons over time. The scant trends in these rainfall variables counters the general pattern reported by other studies i.e. Nkomwa, Joshua et al. (2014) and Arndt, Schlosser et al. (2014) that Malawi is undergoing serious climatic changes, even the argument that the country faces rapid and intense climatic variation.

Further, the claim that Malawi is experiencing extensive global warming akin the south-east African region patterns might also require cross-examination, considering that results from station-based annual minimum and maximum temperature trend show a varied picture across the country, where other areas are experiencing decreasing temperature trends. While topography and other geophysical and socio-economic factors might account for variations, the result does stress the need for caution in generalizing climatic conditions at a given spatial and temporal scale, and call for lower spatial scale analysis which unearths details about climatic conditions other than generalized pictures. In essence, while there is indisputable evidence about global climatic changes, spatial variations in these changes ought to be given due 9-prominence in the discussion about climate change if appropriate and effective target specific counter interventions are to be designed and implemented.

Chapter 6. Examining association of rainfall and temperature variables with crop yield in Malawi

6.1. Overview

Among issues attracting global attention in the post-millennium years is how people's livelihoods are affected by variations in climatic conditions, especially in regions where climate play significant role in sustaining peoples' lives through farming i.e. sub-Sahara Africa (Coulibaly, Gbetibouo et al. 2015). In view of predictions about continued adverse global and regional climatic conditions (Gasparrini, Guo et al. 2017), the mismatch between global population growth and diminishing survival resources i.e. land (Zuberi and Thomas 2012) amid rising demand for food (Schmidhuber and Tubiello 2007, Margulis 2013), information on how crop yield associate with climatic conditions is important to design of interventions to counter-climate change effects on crop production.

Malawi is one of the countries reportedly experiencing variations in climatic conditions (Warnatzsch and Reay 2019), and it faces challenges on food availability amid widening poverty (Stevens and Madani 2016, Hall, Dawson et al. 2017). Studies contend that during the growing seasons, rainfall and temperature variations negatively affect production of food crops on the farm (Lipper, Thornton et al. 2014) which leads to insufficient food availability at national and household levels. This chapter examined the claim by assessing association of selected temperature and rainfall variables with maize yield, the country's staple food crop. Results of the analysis were envisaged to provide input for interventions addressing adverse climatic effects on crop production, in order to ensure food availability in the country. This chapter presents results of this analysis. It also describes the analytical framework used in addressing this subject matter, data and methods used in the analysis, and a discussion on implications of the findings on policy and future activities.

6.2. Analytical framework, data and methods of analysis used in the chapter

6.2.1. Analytical framework

The conceptual framework for the study was discussed in chapter two of the thesis. Figure 26 is an analytical framework for the current chapter extracted from the study's conceptual framework. The figure shows that one of the pathways through which variations in climatic conditions relate with crop yield is through farming.

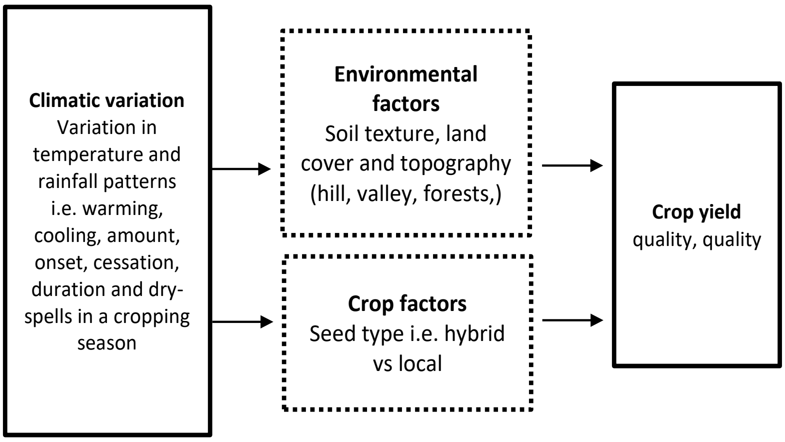


Figure 26.. Analytical framework for association of climate variables with crop yield

NB: variables in middle boxes (crop and environmental factors) were not included in the analysis.

The framework suggests that the amount, intensity and spatial distribution of rainfall and temperature ranges in a growing season are crucial to various processes in a crop's life, from seed germination to yield. For instance, these climatic variables provide water and warmth which are essential for plant food manufacturing and transporting of nutrients throughout the plants' parts, essential for growth and development. As such, these climatic elements influence quantity and quality of crop yield and consequently household food availability (Challinor, Watson et al. 2014). There are however intervening variables at environment level i.e. soil texture, land cover and topography (Kanianska 2016, Manda and Wanda 2017) through which variations in rainfall and temperature conditions wield their influence on crop yield. For instance, crop lands located in areas with vegetative cover suffer lesser plant loss during intense rainstorms compared to those with less vegetative cover (Zhang, Wenhong et al. 2010).

Topography of fields on which crops are grown determines the scale and intensity of surface run-off, influencing crop wash outs and consequently quantity of yield and food availability (Teshager, Gassman et al. 2016). Soil texture determines soil water retention ability and nutrients composition, important for nutrients transporting, and plant health respectively, essential for crop growth and yield. It also determines the extent to which dry-spells affect soil-water (Jalota, Singh et al. 2010). At a crop level, crop type and seed quality influence crop resilience to adverse climatic conditions such as dry-spells, directly influencing yield (Barron, Rockström et al. 2003). These intervening variables were however not included in the current analysis because their data was not available. To account for this limitation, crop yield data was de-trended in order to examine association of climatic variables with crop yield only. This process ensures that the distribution of yield data is free from the influence of other variables that might have influenced it, in the case of the current analysis, non-climatic variables such as land size, labour farm inputs like fertilizers and seed types, which affect both quantity and quality of crop yield.

6.2.2. Data and methods of used in examining association between crop yield and selected climatic variables

To examine association between climatic and crop variables in the study, temperature, rainfall and maize yield data were used. Temperature data comprised average minimum and maximum cropping season temperatures. Rainfall data was generated from average monthly rainfall during the growing season; November to April. Both data spanned 32 years; 1983 to 2015. Variables generated from rainfall data were; average rainfall, onset and cessation of rainfall, cessation, duration and dry days during the cropping season. There are different methods used to assess relationship between variables, based on among other characteristics the nature of data i.e. quantitative or qualitative, time to which the data refers i.e. cross-sectional, longitudinal or time-series. The methods are either graphical or statistical, depending on the objective of the analysis and data structure. Graphical methods involve plotting together the variables to observe how they are distributed together and the pattern they take (Miles and Gilbert 2005), which could either be positive or negative.

Scatter plots are the most commonly used form of graphical methods and they show distribution and pattern of relationship between two quantitative variables. The most common statistical methods used in testing association between variables are correlation and regression (Ali and Bhaskar 2016). Both methods show magnitude of relationship between variables, nature of relationship (positive or negative association) and its statistical significance. For correlation, a larger correlation coefficient on a scale of -1 to 1 shows strong relationship between variables. A perfect positive correlation gives the value of 1, and 0 shows no relationship between the examined variables. Chi-square tests technique is commonly used to test relationship between two categorical or qualitative variables. A higher chi-square value shown by Pearson's correlation coefficient on a scale of 0-1 shows a strong relationship while a low value shows weaker relationship between variables, at set significance level.

In the current study, both graphical and statistical methods were applied on the data in order to provide a visual picture of the relationship, its strength and statistical significance. First the data were plotted to show their distribution and pattern over time. This was done for each of the climatic variables i.e. total rainfall, its onset, cessation, duration, and temperatures against maize yield. The plots provided a visual indication of the relationships between each of the climatic variables used in the study and maize yield, especially the patterns of the distribution over time. The next step was performing correlation tests on the climate and crop variables using statistical techniques i.e. Spearman's correlation co-efficient, in order to assess and quantify the strength of the relationship and check statistical significance. The test was performed using Spearman's rank order correlation technique because it is robust in examining association of non-normally distributed data, which was characteristic of the data variables analysed in the current chapter.

Spearman's correlation test was specified as follows;

$$r_{ik} = \frac{n\,(\sum x_{ik}y_{ik}) - (\sum x_{ik})\,(\sum y_{ik})}{\sqrt{[n\sum x_{ik}^2 - (\sum x_{ik})^2]\,[n\sum y_{ik}^2 - (\sum x_{ik})^2\,]}} \ldots \qquad (26)$$

Where, $'r_{ik}'$ is the correlation function between the two variables i.e. cropping season rainfall and maize yield at time $'i'$ for district $'k'$, $'n'$ is number of observations or years the data refers to. $'x_{ik}'$ is a climate variable i.e. cropping season rainfall at time $'i'$ district $'k'$, $'y_{ik}'$ is a crop variable at time $'i'$ in district $'k'$.

Following this test, multiple linear regression models were fitted for each station or district to model relationship between the crop and climatic variables. De-trended maize yield was the dependent variable and the seven climatic variables i.e. total rainfall, its onset, cessation, duration, dry-days, minimum and maximum temperatures were independent variables. The model was specified as follows:

$$\hat{y} = \beta_{0i} + \beta_{1ik}x_{1ik} + \beta_{2ik}x_{2ik} + \cdots + \beta_{ikm}x_{ikm} + \varepsilon_i \qquad (27)$$

where $\hat{y}$ is the dependent variable i.e. de-trended maize yield, $'\beta_{0ik}'$ is the intercept of the model for station $'i'$. $'\beta_{1ik}'$ to $'\beta_{ikm}'$ are coefficients of independent climatic variables;$'x_1'$, $'x_2'$ up to $'x_m'$ for station $'i'$ time $'k'$ and $'\varepsilon_i'$ are residuals for the model at station $'i'$. The correlation tests and regression models were performed and fitted using the software statistical package for social scientists (SPSS) version 24. The SPSS output was exported to Microsoft excel where tables for results of the analysis were designed then exported to Microsoft word for presentation.

6.3. Results for assessment of relationship between temperature and rainfall variables with maize yield

6.3.1. Trends in maize yield and per-capita maize yield

Analysis results show that over a 32-year period (1983-2015), average maize yield per hectare in Malawi was 3,371.8kg. Figure 27 shows that Malawi's maize yield per capita has been decreasing over time from 1983/84 to 2004/05.

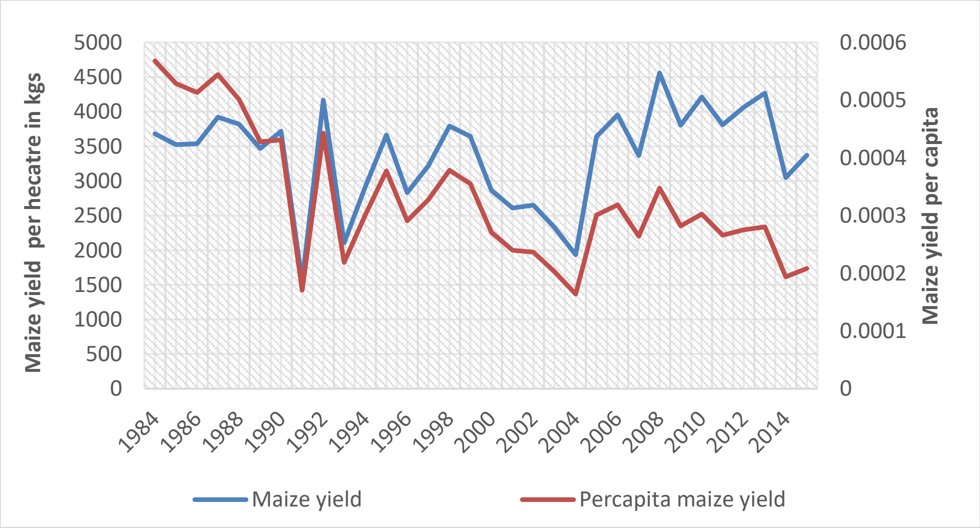


Figure 27.Time series distribution of average maize yield per hectare and per capita.

The lowest average yield per hectare was recorded in the 1991/92 cropping season, attributed to a country-wide drought that affected crops growth and consequently yield (Pauw, Thurlow et al. 2010). Maize yield per hectare was highest in the 2008/2009 cropping season; 4, 557.9 kg per hectare, and the trend maintained to 2012/13 growing seasons, with small variations. The sustained increase in yield per hectare was attributed to the universal farm input subsidy program (FISP) in which the Malawi government subsidised early maturing and drought resistant maize seeds and other farm inputs such as fertilisers and pesticides, in order to boost household level crop production (Holden and Lunduka 2010).

Per-capita, the country's maize yield per hectare has been decreasing over the period of analysis, indicating that population growth has through time not matched with maize yield. The United Nations estimates that Malawi's annual population growth rate between 1983 and 2015 was 2.5 percent per annum, among the highest in the SSA region(United Nations 2015). Such a rate of growth increases the possibility of food shortages in the population despite increasing maize yield (House and Zimalirana 1992, Stevens and Madani 2016). The situation is compounded by variable cropping season climatic conditions, which may be unfavourable to some phenological processes of crops, leading to low yield on the household.

Figure 26 shows a plot of selected rainfall variables and de-trended maize yield per hectare and one of the climatic variables, rainfall, in 32 years.

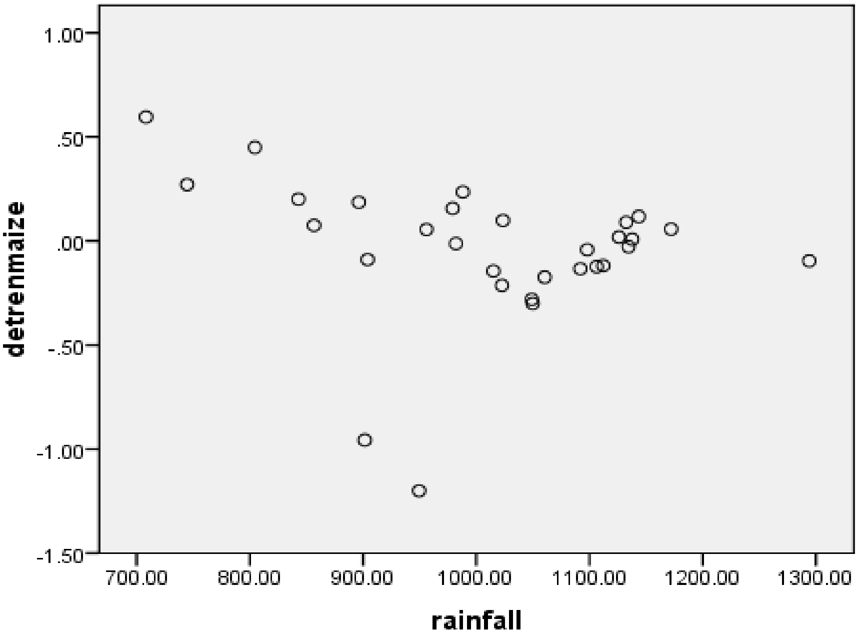


Figure 28.Plot of rainfall and de-trended maize yield per hectare in Malawi (1983-2015)

Figure 28 shows an inverse relationship where rainfall increases are associated with decreases in de-trended maize yield per hectare. Malawi's cropping rainfall has over the years been high in intensity (Longhurst and Sabates-Wheeler 2019), often leading to floods which wash out crops, directly lowering crop yield, as such the pattern of distribution in figure 26 could be evident of this situation. Figure 29 shows an inverse relationship between de-trended maize yield and average cropping season cessation days over a 32-year period.

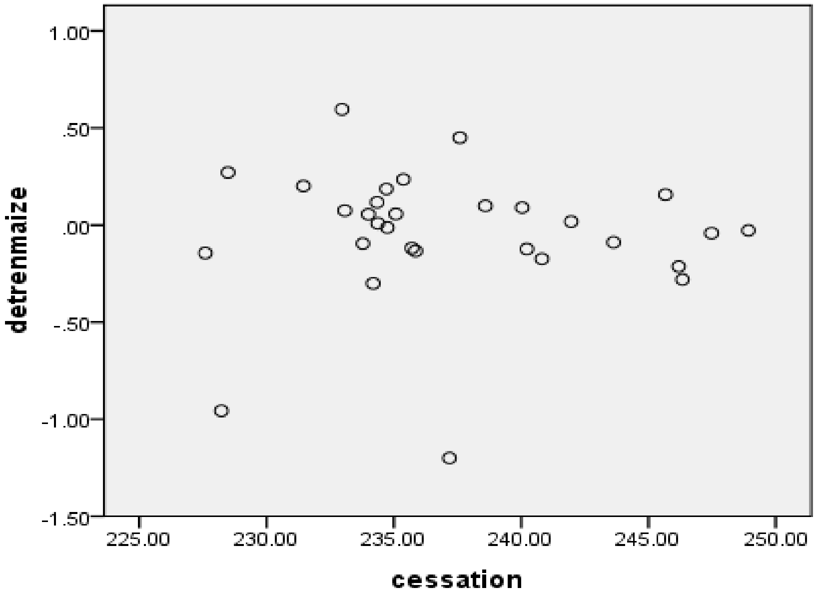


Figure 29.Plot of rainfall cessation days and de-trended maize yield per hectare (1983 2015)

Delays in termination of cropping season rainfall could mean high rainfall intensity, which could make soils water logged, affecting soil air and absorption of plant nutrients essential for growth and yielding. It could also facilitate higher incidence of crops' diseases thriving in moist conditions due to prolonged rainfall, a situation that would lower yield. Analysis further show an inverse relationship between rainfall duration and maize yield per hectare, where increasing duration of rainfall is associated with decreasing maize yield per hectare over time (Figure 30). A longer cropping season rainfall duration could be an indication of high amount of rainfall during the season, a situation where crops are likely to perform poorly as a result of imbalances between required water for various plant growth processes and the supply, hence the negative relationship.

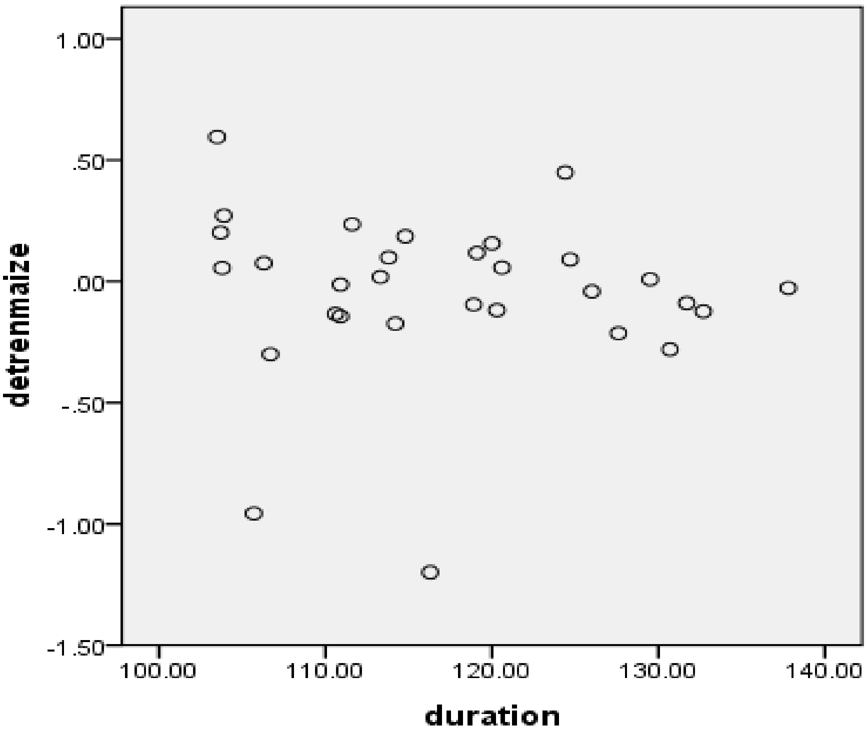


Figure 30.Plot of rainfall duration period and de-trended maize yield (1983-2015)

Results have also shown that average number of dry-days (dry-spells) in a cropping season have had an inverse relationship with maize yield per hectare. (Figure. 31).

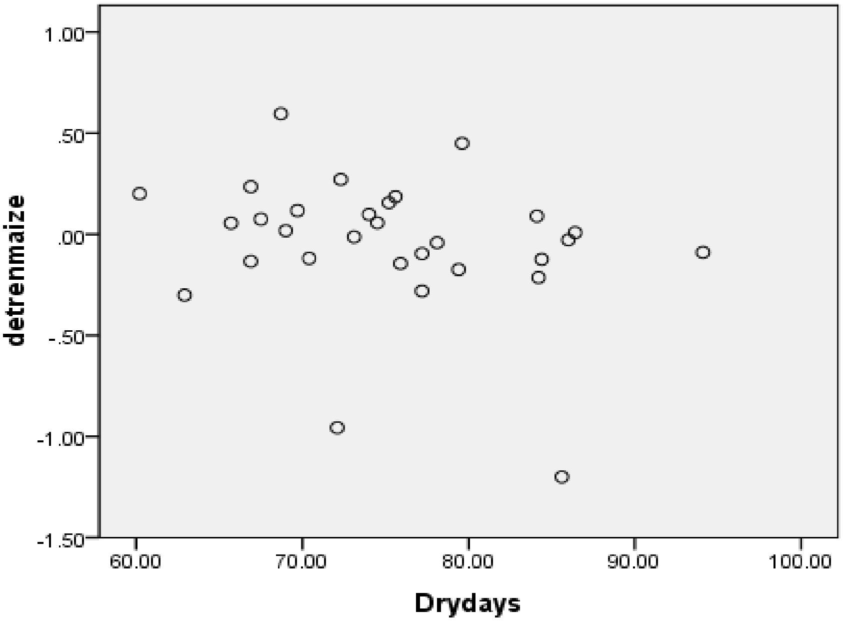


Figure 31.Plot of dry-days in a cropping season and maize yield per hectare (1983
2015)

Figure 31 shows that as dry-days increased, the average yield of maize per hectare decreased, suggesting a somewhat obvious pattern since dry-days entail days without rain or with rainfall below a certain threshold, good enough for plant growth in a cropping season.

This would obviously result in low yield, considering the prime importance of water to plant survival. A somewhat unexpected association is noted between cropping season maximum temperatures and de-trended maize yield per hectare, where increasing maximum temperatures are associated with increasing maize yield per hectare (figure 32).

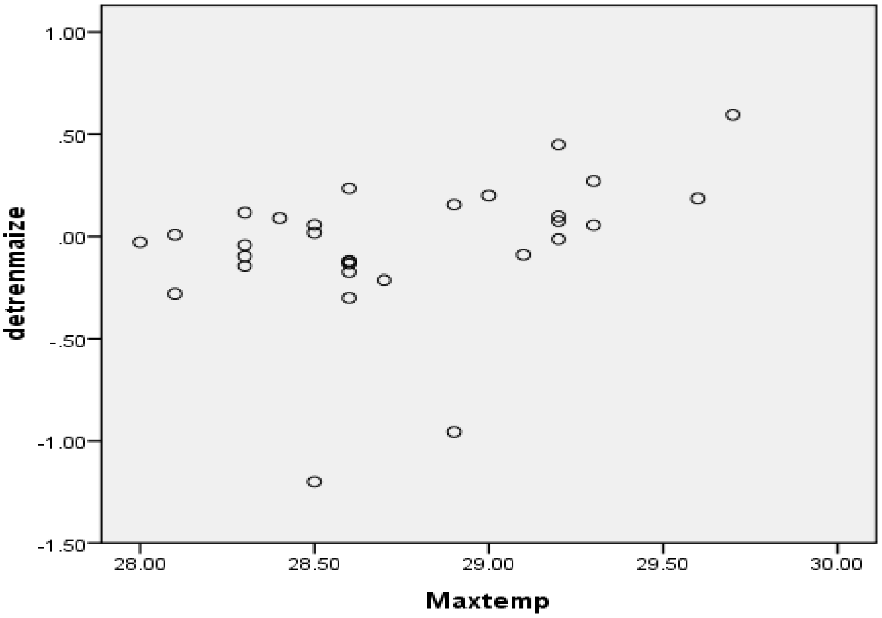


Figure 32.Plot of maximum temperatures and maize yield per hectare (1983-2015)

Maize is reportedly one of the cereal crops sensitive to warming temperatures, such that it is expected that under increasing maximum temperatures, yield would be low (Butler and Huybers 2015). However, the 32-year plot of maize yield per hectare and maximum temperatures for the country as figure 32 shows a somewhat contrary picture. Chapter 5 of the current thesis reported that trends of average annual maximum temperatures in the country indicate significant rises over a 45- year period. However, the positive association between increasing maximum temperatures and crop yield requires a deeper understanding about maize phenological processes, cultivars and their responses to warming conditions in different spatial and temporal contexts before current findings are considered, which is beyond the scope of the current study.

Apart from visual assessment of relationships between climatic variables and crop yield presented above, results for Spearman's Rank Order correlation showed that rainfall, its onset and its duration in a cropping season had a negative association with maize yield per hectare; r-0.239, -0.048, -0.180, similar to the plots presented above, but were all not statistically significant.

Correlation tests among the climatic variables themselves show strong significant positive correlations between rainfall duration and dry days, rainfall duration and its cessation (p-value <0.01), r: 0.826 and 0.777 respectively and strong significant negative correlation between rainfall duration and its onset; r: -0.869, rainfall and maximum temperatures; r: -0.805 (Table 11).

Table 11. Spearman's correlation test results for temperature and rainfall variables

Variables	onset	cessation	duration	Drydays	Mintemp	Maxtemp
Rainfall	-0.563**	0.395*	0.550**	0.282	-0.245	-0.805**
Onset		-0.452**	-0.869**	-0.821**	0.180	0.609**
Cessation			0.777**	0.575**	0.002	-0.348
Duration				0.826**	-0.094	-0.556**
Dry-days					-0.097	-0.384*
Min-temp						0.447*

**. Correlation is significant at the 0.01 level (2-tailed).*. Correlation is significant at the 0.05 level (2-tailed).

The negative correlations between variables indicate that the concerned variables could have opposing effects on the outcome variable in a regression model, such that it would be appropriate to retain them in the model examining association of climatic variables and maize yield per hectare. However, positively correlated variables are likely to have similar association with the outcome variable in a model, as such one was dropped to avoid multi-collinearity, which affects regression parameters i.e. coefficients and standard errors.

To predict the association of selected climatic variables with maize yield, a linear regression model was fit. This technique was chosen because both the independent and dependent variables used in the model were count variables. Multi-collinearity among independent variables was tested by assessing the Variance Inflation Factor (VIF) for each of the independent variables used in the model. A VIF range of 1 to 5 was set as the cut-off point for determining multi-collinearity among the independent variables used in the model. Any independent variable with a VIF above 5 was dropped out of the model. De-trended maize yield per hectare was the dependent variable and average cropping season rainfall, average onset days, average cessation days, average duration days, average number of dry-days in the rainfall season, minimum and maximum temperatures were independent variables. The fist fitted model was statistically significant; p-value 0.041 and 40 percent of variation in maize yield was explained by the seven independent climatic variables (Appendix C1).

However, none of the variables were significant in the model and cropping season rainfall had a zero coefficient. Cessation of rainfall, its duration and onset had high VIFs; 7.717, 16.090 and 23.432 respectively (Appendix C1).

In the second model, rainfall onset was dropped out as an independent variable since it was both non-significant and had high VIF. Although the model improved in terms of its significance i.e. p-value 0.039 from 0.041 in the previous model, only one out of the six independent variables was statistically significant; average maximum temperatures. Annual rainfall duration days still had VIF above 5 (Appendix C2), suggesting a higher degree of multi-collinearity. As such, in the third model, average annual rainfall duration, was dropped as an independent variable. The model significantly improved i.e. sig at p-value:0.020 and all independent variables had VIFs below the threshold of 5 (Appendix C3). However, total rainfall remained non-significant in the model and it still had a zero coefficient. This variable was removed in the follow-up model, where results in table 12 below show a significant mode with R^2 :0.398, indicating that still, 40 percent of variation in maize yield was explained by rainfall cessation, number of dry-days in the cropping season, minimum and maximum temperatures during the season. All the independent variables had a VIF less than 2, indicating that there was no multicollinearity among them.

Table 12. Linear regression results for association of maize yield and climatic variables

R^2	Model Sig (p-value)	Regression Variables	Standardized coefficients		Sig (p-value)	Collinearity statistics	
			B	Std. Error		Tolerance	VIF
0.395	0.009	Constant	10.104	5.458	0.1076		
		Cessation	-0.270	0.011	0.023	0.669	1.494
		Dry-days	0.210	0.008	0.016	0.705	1.418
		Min-temp	0.334	0.238	0.172	0.761	1.314
		Max-temp	-0.410	0.141	0.007	0.661	1.513

Dependent Variable: De-trended Maize

A unit increase in cessation days for the cropping season rainfall i.e. delay in cessation was associated with a 0.270 kg per hectare decrease in maize yield. A unit increase in number of dry-days in the season was associated with a 0.210 kg per hectare increase in maize yield, while a unit increase in maximum temperatures during the season was associated with a 0.410kg per hectare decrease in maize yield (Table 12).

However, when the temperature and rainfall variables used in the model were lagged by a month i.e. (minus one month) from commencement to end of the cropping season (October to March) instead of November to April (normal cropping season), rainfall onset, its cessation and duration still had higher VIFs (Appendix C5). Rainfall had zero coefficient and the model was not statistically significant, just like the first model with non-lagged independent climatic variables, and the amount of variation in maize yield attributed to the independent variables was slightly higher than the model with lagged variables; R^2 0.43.

Removing the variables with high VIFs i.e. onset and cessation of rainfall greatly improved the model as it became significant; p-value 0.012, but the amount of variation in maize yield explained by the remining variables reduced to R^2 0.39. Removing 'rainfall duration' as an independent variable in the model, though it had a high VIF made the model insignificant, as such it was retained. Unlike in the model with non-lagged independent variables, increase in number of dry-days in the cropping season was associated with decreased maize yield per hectare, while increase in the season's maximum temperatures was associated with increase in maize yield per hectare, contrary to results for a model with non-lagged variables (Appendix C5). This result indicates that lagging the climatic variables was associated with significant variations in crop yield, suggesting that changes in patterns of the variables in the season significantly could have significant influence on variations in maize yield.

Across the 27 districts in the country, different temperature and rainfall variables had different association with maize yield per hectare. Figure 33 shows that a unit increase in total cropping season rainfall was associated with a decreased in average de-trended maize yield per hectare in Lilongwe district in the central region and Machinga district in the southern region.

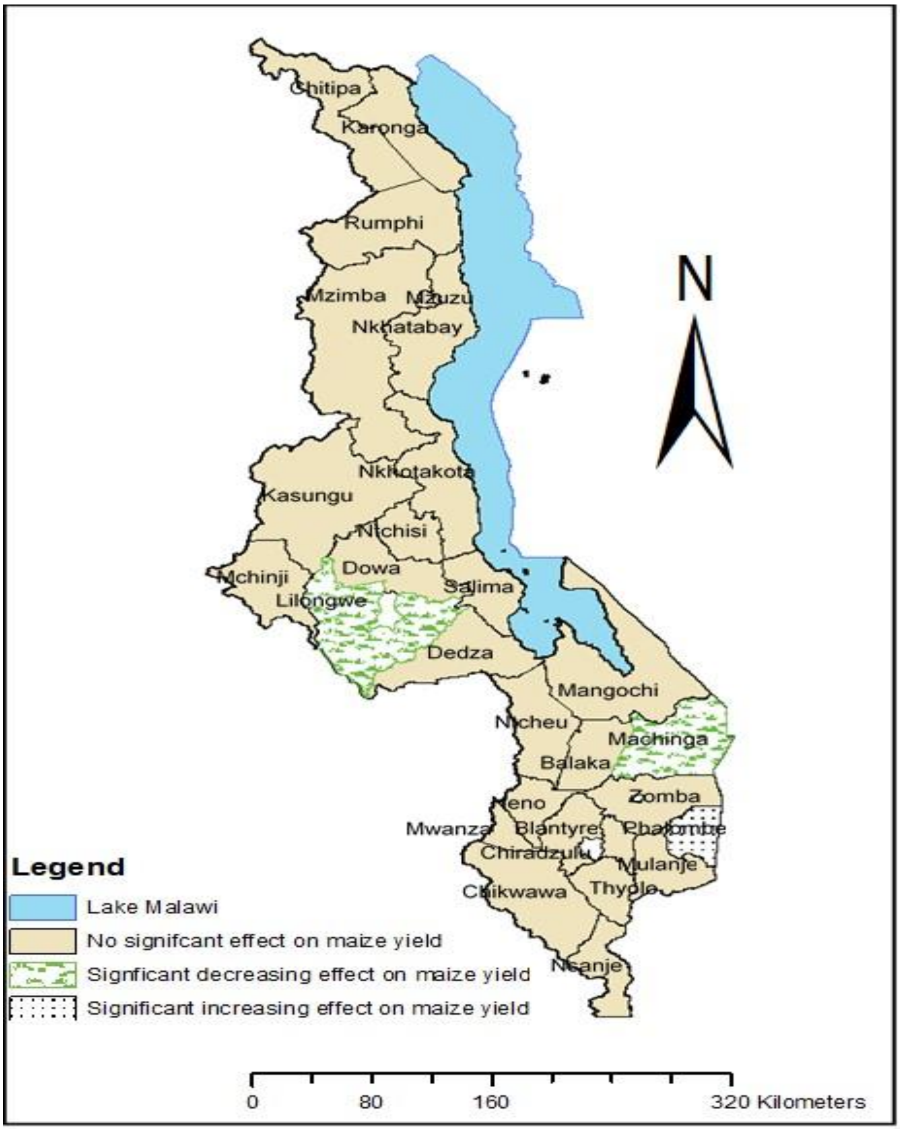


Figure 33. Map of Malawi showing association of average cropping season rainfall with average maize yield per hectare by district

A unit increase in the amount of rainfall was associated with an increase in maize yield per hectare in Phalombe district. The rest of the 23 districts had non-statistically significant results. A delay in onset of cropping season rainfall in the country significantly reduced average maize yield per hectare in Chitipa and Nkhata-bay in the northern region, Balaka and Zomba in the southern region. Only in one district did a unit delay in onset of average cropping season rainfall associated with a unit increase in maize yield per hectare; Mchinji in the central region (figure 34).

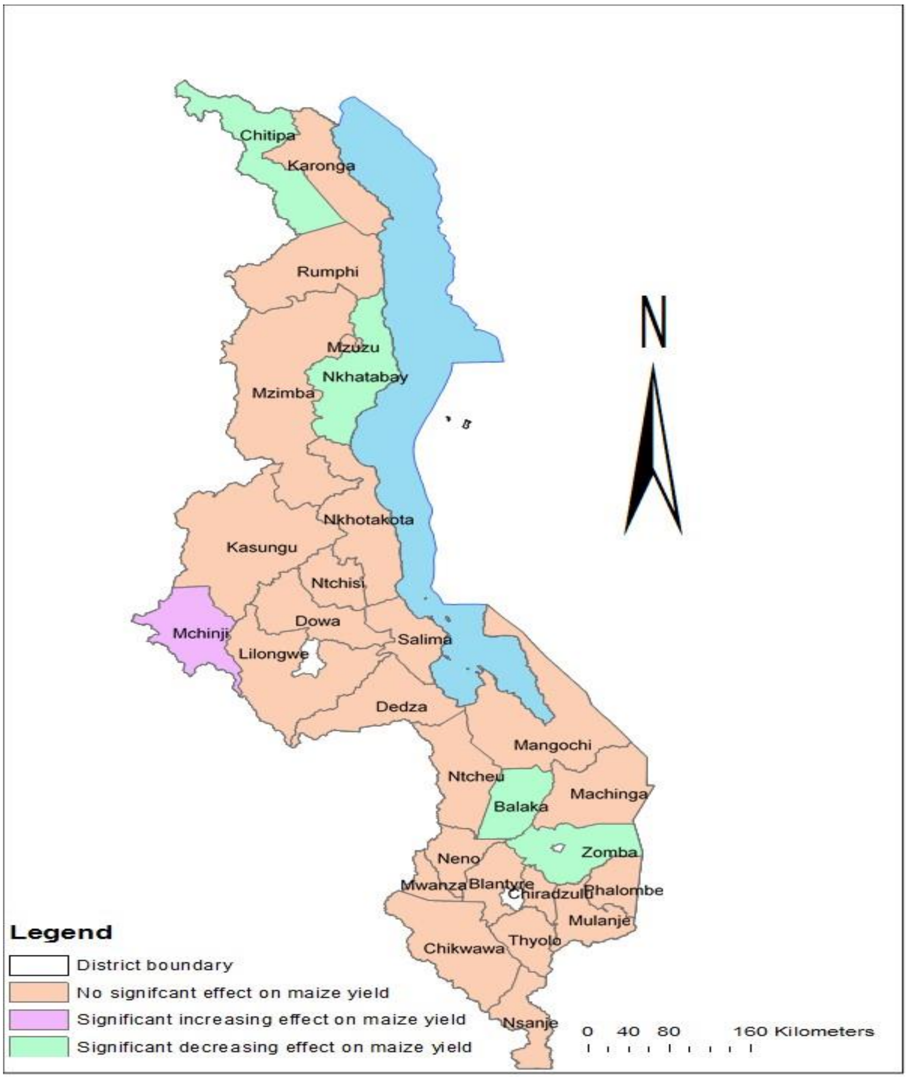


Figure 34. Map of Malawi showing association of rainfall onset with maize yield per hectare by district,

In the remaining 22 districts, there were no significant associations between the climatic variables in the regression models with average maize yield per hectare. However, a delay in termination of annual rainfall was significantly associated with decrease in average maize yield per hectare in four districts: Kasungu, Dedza, and Ntcheu in the central region and Mwanza district in the southern region (figure 35).

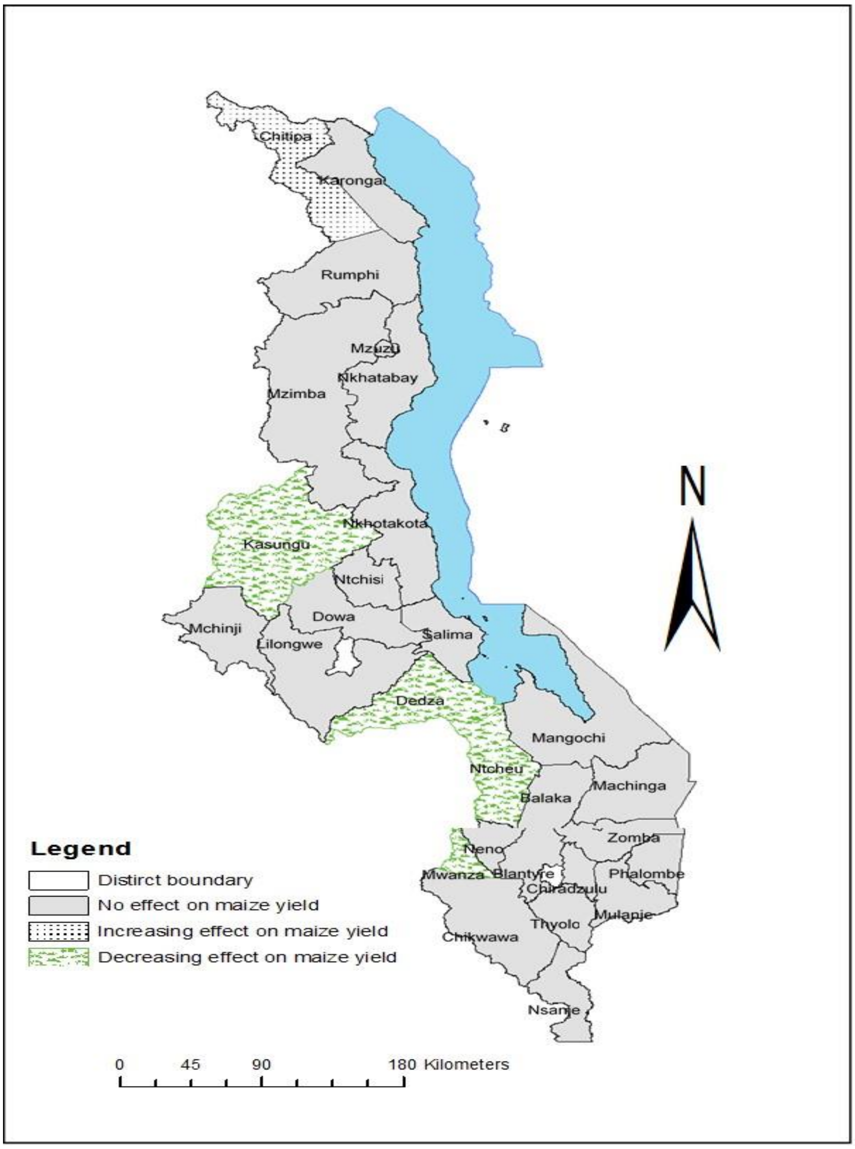


Figure 35.Map of Malawi showing association of rainfall cessation with maize yield per hectare

Only in one district in the country were delays in termination of annual rainfall significantly associated with increasing maize yield per hectare, Chitipa in the northern region, while no significant association were noted between the climatic variables and maize yield per hectare in the rest of the country's districts. Results further show that only few districts out of the 27 show significant change in average yield of maize associated with changes in cropping season rainfall duration, number of dry-days, minimum and maximum cropping season temperatures during the cropping season.

For instance, increasing annual cropping season rainfall duration was significantly associated with increases in average maize yield per hectare in Karonga district in the northern region and Ntcheu district in the southern region.

Increase in number of dry-days in a rainfall year had significant positive association with average maize yield per hectare in Dedza and Mchinji districts in the central region, and a negative association with average maize yield per hectare in Chitipa district in the northern region. Further, increasing maximum growing season temperatures were associated with increases in maize yield per hectare in Karonga, Chitipa and Nsanje districts, while increasing minimum growing season temperatures were associated with decreased maize yield per hectare in Phalombe district only.

6.4. Summary of results

This section summarises results of analysis on association of selected cropping season rainfall and temperature variables with maize yield per hectare, using data crop and climate data spanning 32 years (1983-2015). Results have shown that:

- Of the seven selected temperature and rainfall variables in this analysis, only four had significant association with average maize yield per hectare; average cropping season rainfall cessation days, average dry-days in the season and minimum and maximum cropping season temperatures, explaining 40 percent of variation in maize yield. The association varied across districts, indicating spatial differentials in signals of climatic variation on maize yield in the country.
- Independent variables which had significant association with maize yield per hectare show that:
    - Delayed cessation of the cropping season rainfall was associated with decreases in maize yield per hectare.
    - Increases in dry-days during the cropping season were associated with increases in maize yield per hectare,
    - Increases in maximum temperatures during the cropping season were associated with decreases in maize yield per hectare.
- Few districts had significant spatial variations signals on maize yield in the country, suggesting that controlling for other variables associated with maize yield, there is a sparse climate variation signal on maize yield in Malawi.

6.5. Discussion

Despite the importance of climatic conditions to farming in Malawi, few studies have analysed relationship of climatic variables with crop yield, even though the country is located in a region with higher climatic variation i.e. the SEA region (Verburg, Arets et al. 2010). To address this knowledge gap, the current chapter examined association between selected temperature and rainfall variables with maize yield as a proxy indicator for household food availability. It was envisaged that such analysis would augment efforts designed to help mitigate and adapt current farming practices, especially on maize, to prevailing climatic trends and ensure food availability. Results of analysis were envisaged to provide significant input in design of relevant context specific programs to counter climate change and variation and ensure sustainable food production practices amid increasing climatic adversity.

The analysis involved testing association between 32-year time series maize yield and selected temperature and rainfall variables in the country's 27 districts. Linear regression models were fit to assess the climate variables-crop yield relationship, where average cropping season maize yield was the dependent variable while cropping season rainfall, onset days, cessation days, dry-days, duration, minimum and maximum temperatures were independent variables. To account for non-climatic factors influencing maize yield, maize yield data was de-trended using the differencing method. This process was also applied in a study to examine association of rainfall and de-trended crop yield in Ghana (Choudhury, Jones et al. 2015). The purpose of de-trending maize yield data in the current study was to ensure that the model assessed association of crop yield and climatic variables without the influence of non-climate intervening factors affecting crop growth and yield. This chapter presented results of the analysis.

To begin with, earlier results on the assessment of trends in selected temperature and rainfall variables presented in Chapter 5 revealed that total cropping season rainfall has been declining over the 45-year period of analysis across almost all districts in the country, but with no statistical significance. Alongside this trend are significant early termination of rainfall and shortening duration during the cropping season. Current study results show that different climatic variables had different associations with maize yield per hectare in different districts.

At a national aggregate level, four of the climatic variables had statistically significant association with maize yield per hectare; average cropping season rainfall cessation days, average number of dry-days and average cropping season minimum and maximum temperatures. Delay in delayed cessation of cropping season rainfall and increase in maximum temperatures during the cropping season were associated with decreases in maize yield per hectare. There has however been a sparse climatic variation signal on maize yield in the country, with few districts showing significant association between the analysed climatic variables with average maize yield per hectare.

Late termination is mostly associated with spread of bacterial blights on already mature maize stand, supposed to dry following before harvesting (Bucheyeki 2012). Attacks from blights on the crops due to prolonged rainfall in the season are likely to reduce yield. There are however contradicting views on whether longer cropping seasons do have unique significant effects on yield as Li, Guan et al. (2019) contending that there are spatial variations in this relationship. According to the team, excessive rainfall in conjunction with poorly drained soil in cooler areas exacerbate yield loss due to high pre-season soil water storage.

The current study has however found that over the 45- year period (1970-2015), Malawi's cropping season rainfall is terminating earlier than normal, with spatial variations across districts, the majority of which trends have not been statistically significant. This suggests that other than experiencing low maize yield influenced by wet conditions due to delayed cessation of rainfall, which is argued to influence diseases attacks on maize stand hence decreasing yield, reported yield declines in the study could arise from other declining soil water in the season due to decreasing rainfall patterns. Though this climatic signal is spatially sparse, it still does call for targeted responses to counter declining seasonal rainfall water availability, in order to sustain plant growth, especially in areas with a significant rainfall decline signal. Such interventions could include enhancing irrigation of fields in affected areas to provide water for crops in order to ensure better yield.

Polade, Pierce et al. (2014) explains that number of dry-days in a rainfall year are likely to have significant alterations to precipitation regimes in different parts of the world as global climate systems experience changes resulting from global warming.

Such changes include increases and decreases in rainfall and water flows at various spatial and temporal scales in different regions. These events are augmented by altitude, global oceanic currents and air circulations. The changes are projected to have significant effects on crop yield especially in rainfall dependent cropping systems predominant in developing regions i.e. SSA, where yield of cereals crops such as maize, wheat and sorghum are projected to lower (Parry, Rosenzweig et al. 2004).

In the current study, regression analysis between lagged time series number of dry-days in a rainfall year and maize yield show that increasing dry-days were associated with decreasing maize yield per hectare. This is not surprising as dry-days in a rainfall season entail less or no water for crops, leading to premature deaths of plants and directly lower yield. However, across districts, results show mixed outcomes; associated with increase in maize yield per hectare in the three neighbouring central region districts; Dedza, Lilongwe and Mchinji and decreases in maize yield in Chitipa district up northern region. Increasing dry-days entail low rainfall intensity and in most cases poor soil-water balance, which affects various plant growth processes i.e. silking and grain filling (Butler and Huybers 2015), leading to low yield. In Zimbabwe Kuri, Murwira et al. (2014) regressed number of dry-dekads derived from vegetation condition index (VCI) against official ground-based maize yield estimates for over four seasons from 2009 to 2013. Results indicated that increasing dry-days in a dekad had significant decreasing effect on maize yield per hectare, as was the case in Chitipa district, northern Malawi as per results in the current chapter.

Another study examined long-term trends in climate variables and effects on crop productivity based on experimental data from 1965 to 1993 in the southern region of Mali (west Africa). The study found that increasing dry-days negatively correlated with cotton yield and increasing rainfall, and had a positive association with maize yield (Traore, Corbeels et al. 2013). In yet another study, Matiu, Ankerst et al. (2017) observed that apart from intensity of dry-days in a rainfall season effectively impacting crop yield, consecutive dry or warm years (suggesting elongated spells of dry-days in a cropping season) caused some spill over effects that reduced crop yield from one cropping season to another. In this study, yearly yield of maize, rice, soybeans and wheat of top producing countries were combined with growing seasons temperature and standardized precipitation evapotranspiration index (SPEI) dating 1961 to 2014 to assess the linkages between climatic variables and crop yield.

Results showed that heat and warming conditions associated with dry-spells reduced yield of maize and wheat unlike rice, attributed to high temperature and drought intensities in the studied countries. Results from this study suggests that while seasonal dry-days have a direct effect on crop yield i.e. affecting crop processes within a given growing condition, persistent dry conditions from one cropping season to another affects yield of cereal crops such as maize and wheat. In essence, changing patterns of dry-days in a rainfall season have significant effects on different crops at different time-periods and places. With reference to current study findings, the sparse association of prevailing trends in dry-days with maize yield in the central region districts could suggest that the intensity of dry-days in a rainfall season occurred at a time when maize yield was ready for harvest unlike the critical pollination and grain-filling phases, which would have negatively affected yield. Hence the positive effect on yield despite increasing dry-days trends entails the necessary conditions to avoid infections on maize, associated with persistent rainfall at a time the crop needed drying.

According to Hatfield and Prueger (2015), temperature is one of the primary climatic factors to plant's rate of growth. Warmer temperatures (which are expected to become extreme under climate change influences) have negative impacts on crop production through effects on plant growth and sensitive phenological processes such as pollination, which have direct effects on quantity and quality of crop yield. In the current study, maximum growing season temperatures had statistically significant effects on maize yield, where a unit increase in the temperatures was associated with decreasing maize yield per hectare, albeit with variations across districts in the country. At an aggregate national level, increasing temperatures were associated with decreasing maize yield per hectare.

However, increasing temperatures were associated with increasing maize yield per hectare in the southern and northern tip districts of the country, Nsanje, Chitipa and Karonga. These are generally warmer districts in Malawi. As has been the case with the other climatic variables used in the study, there has been a spatially sparse climatic signal on maize yield associated with maximum temperatures, with only a few districts having significant results in this analysis. The result is also somewhat surprising because increasing temperatures and warming conditions speed up plant growth periods necessary for optimum plant and grain size in maize (Hatfield and Prueger

2015), which is key to yield. Temperature increases during pollination influence crop failure and harsher thermos environment for maize influences early reproductive period, increasing the risk of heat and water stress, which affects various processes in plant life that require sufficient water, without which there would be poor crop yield (Harrison, Michaelsen et al. 2011). However, in the central region district, the situation is somewhat different since increasing temperatures are associated with increasing yield, perhaps the increases in the temperature thresholds have not been above the critical levels for maize phenological processes critical to yield, hence the positive effects. However, it has to be mentioned that different crops and their cultivars have different responses to changes in climatic variables at various spatial and temporal scales.

In this study, the varieties of maize were not considered since focus was on total maize yield response to temperature and rainfall conditions prevailing in the country over the studied period, irrespective of whether it was local or hybrid varieties. Despite this position however, Rurinda, Wijk et al. (2015) found that there was no difference by maize cultivars in the effect of climate change in Zimbabwe, where all three cultivars ; SC403 (131 days to maturity), SC513 (137 days to maturity) and SC635 (142 days to maturity) were given similar treatment i.e. planting dates and three fertilization rates in the study. Results showed no significant differences in the effects of various climatic conditions on maize yield cultivars. As such, the current study contends that it may not just be trends in the temperatures that affects crop yield, or extremes in the temperatures, but as Hatfield and Prueger (2015) observed, it is the timing of the unfavourable temperature threshold in a crop's development process that determines the effect of the temperatures on crop yield.

Based on their study on temperature extremes and effects on plant growth and development the two found that variability of maize yield was influenced by temperature extremes during pollination stage, where maize pollen was noted to decrease with exposures to temperatures above 35°c, since pollen viability is enhanced under high vapour pressure deficits. Further, potential maize plant kernel growth was reduced with temperatures above 35°c. The team maintains that temperatures above 30°c damage cell division and amytopast replication in maize kernels which reduces the size of the grain sink and ultimately yield.

For Malawi, current temperature trends indicate significant warming over time, a situation likely to negatively impact crop yield, especially maize. Although results in some districts suggest positive spins on maize yield associated with increasing temperature trends, there is still need for consideration about how such trends would affect future patterns of crop yield. This is in consideration of predictions about increasing temperatures across the SEA region in which Malawi is located. In essence, there is need for intensifying heat resistant maize cultivars in order to ensure better crop growth and development, essential for yield. Such interventions would help to avert the negative influence of adverse climatic conditions on food availability in the country.

6.6. Conclusion

This chapter assessed relationship between selected cropping season temperature and rainfall variables with maize yield in 27 districts of the country, guided by temporary matched crop and climate data. Results have shown that there is geographically a sparse significant association of these climate variables with maize yield in the country. There are also different associations for each of the temperature and rainfall variables with maize yield, indicating that trends and thresholds in different climatic variables have varying effects on yield of maize in the country. While maize yield is influenced by different variables i.e. climatic, socio-economic, geographic (topography and soil type) among others, the current study has found that prevailing temperature and rainfall trends have not had a significant extensive coverage in the country in terms of their association with maize yield. However, district focused studies would provide a detailed picture on the nature of association between climatic variations being experienced and crop yield. This would help development of area specific interventions to offset the negative effects associated with adverse climate variations on crop yield so as to ensure food availability for the growing population.

Chapter 7. Assessing association of temperature, rainfall variables with household foods' security status in Malawi

7.1. Introduction and Overview

Achieving global food security is one of the major objectives of the sustainable development goals program (SDGs) spanning 2016 to 2030 (Kates, Parris et al. 2005, Sachs 2012). Climate change, rapid population growth, poverty and inequality, political and social conflicts are reportedly some of the factors augmenting global food insecurity (Rosegrant and Cline 2003, Ericksen, Ingram et al. 2009, Godfray, Beddington et al. 2010). Approximately 842 million people around the world face food shortages (Zhou, Shah et al. 2017) many in regions with rapidly growing population, poverty and higher disease burden (Rukuni 2002, Wheeler and Von Braun 2013, Timmer 2014). Across regions, reports show that many people experience food insecurity in the eastern and southern Africa, the Horn and parts of western Africa (Moore, Alagarswamy et al. 2012), influenced by demographic, socio-economic, political and geographical factors. Adverse climatic patterns however add to the list thorough effects on agriculture productivity i.e. crop yield and livestock production, (Moore, Alagarswamy et al. 2012) causing wide spread hunger and threatening peoples' survival (Chakona and Shackleton 2017).

Addressing the effects of adverse climatic changes and variation on food security is one of major priorities for affected countries (Fields 2005). As such, research to understand how climatic change and variation relate with crop production and household food security status is therefore an urgent imperative (Parry, Rosenzweig et al. 1999) as it provides input for design of policies and interventions to combat food insecurity in the era of climatic adversity (Kang, Khan et al. 2009, Zhao, Liu et al. 2017). Malawi's has 17.5 million people, with a population rate of growth per annum of 2.9 percent (Malawi Government, 2018). The country experiences food insecurity (Harrigan 2008, Kakota, Nyariki et al. 2015) majorly influenced by poverty (Seaman, Sawdon et al. 2014), low agriculture technology and shortage of cultivable land (Koppmair, Kassie et al. 2017). Incidences of floods which wash out land and crops during the rainy season amid increasingly arid conditions all contribute to low crop yield, leading up to food insecurity (Stevens and Madani 2016).

Studies indicate that apart from extreme climatic events such as floods and droughts, variations in temperature and rainfall patterns at various spatial and temporal scales could also lower crop yield and households'' food security status (Asfaw, McCarthy et al. 2015). Mitigating the effects of such climatic trends is one of the goals highlighted in all editions of Malawi's Growth and Development Strategy (MGDS) 2005-2010, 2011-2016 (Miller, Tsoka et al. 2010, Dorward and Chirwa 2011, Íñigo, Ecker et al. 2014). This is in consideration that the country relies on subsistence agriculture especially crop production for food and livelihood (Matchaya, Nhlengethwa et al. 2014). However, there is limited information on how seasonal variation in such climatic variables associate with crop yield (Msowoya, Madani et al. 2016) and consequently household food security status (Arndt, Schlosser et al. 2014).

Although other studies have reported about global and regional changes in climatic patterns (Byass 2009, Stocker, Qin et al. 2013, Wheeler and Von Braun 2013) not much information is known about how these changes associate with households' food security, accounting for household level demographic and socio-economic factors, especially in the east African region, where Malawi is located (Moore, Alagarswamy et al. 2012). For Malawi, this knowledge gap exists despite its climate dependent agriculture system (Smale 1995, Arndt, Schlosser et al. 2014), which is key to food security and economic development. The current study attempted to address this knowledge gap by examining relationship between growing season temperature and rainfall variables with households' food security status. This chapter discusses the analytical framework, data, methods used in the analysis, results, policy and programmatic implications of the findings.

7.2. Analytical framework, data and methods used in the analysis

7.2.1. Analytical framework of the chapter

A conceptual framework presented in chapter 2 of the thesis explained that among other factors, household food security status is influenced by both climatic and non-climatic factors operating at different levels, but linked in a given context. Among household level factors are income, labour, farmland size, seeds, fertilizers, technological equipment and knowledge. In concert with climatic factors i.e. cropping season temperature and rainfall, these factors influence crop yield (Zeller, Diagne et al. 1998, Chirwa 2005). Figure 36 is the analytical framework for the chapter.

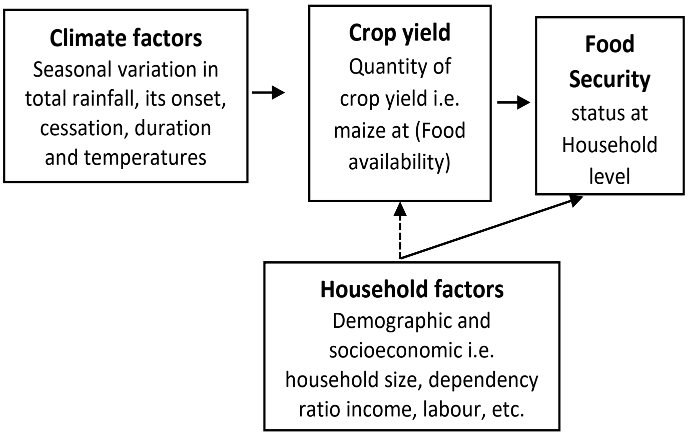


Figure 36. Analytical framework for examining association of climatic and household level actors on households' food security status

In figure 36, climatic factors i.e. cropping season rainfall and temperature variation have a direct association with crop yield, where variations in rainfall onset, cessation, duration and dry spells during the cropping season directly affect quantity and quality of yield on the farm, on account of the role these factors play in plant growth processes and ultimately yield. Further, crop yield has a direct association with household food security status, where low crop yield entails shortage or non-availability of food on the household. Crop yield also directly relate with household food security status i.e. access to other food resources needed on the household, considering that farm produce is sometimes sold for income which is used to acquire additional food resources on the household, hence augmenting household food security status. Household level demographic and socioeconomic factors i.e. household size, dependency ratio, income and labour also associate with households' food availability and food security status, by providing enabling factors i.e. labour and income which help in the production of food on the farm. In the current chapter, only climatic and household level socioeconomic and demographic factors were included in the analysis.

7.2.2. Data used in the analysis

In this study, the relationship between climatic variables and household food security status in Malawi was examined using temperature and rainfall data for a cropping season (November to April) and demographic and socio-economic data for the same reference period, obtained from the Integrated Household Survey data (IHS). This survey was conducted in Malawi between March 2010 and March 2011 as part of the World Bank's Living Standards Measurement Surveys (LSMS).

The survey is conducted at 4-5 year intervals and it was based on a nationally representative sample of 12,271 households, collecting data from 56,403 people. Modules covered in the survey included household members' demographics, social and socio-economic characteristics, agriculture, food security, health, education and housing conditions of households. The temperature and rainfall data used in this analysis was obtained from 27 stations available in each of the 27 districts of the country, provided by the Department of Climate Change and Meteorological Services (DCCMS) in Malawi.

According to Adamgbe and Ujoh (2013) and Matsui (2016), there are different rainfall characteristics which influence crop yield in a growing season. Among such are amount of rainfall, when it starts, when it stops, its length, and dry spells during the rainfall season. Five rainfall variables were generated from daily rainfall data for the crop growing season (November to April) as described in chapter 5 of the thesis. Household's food security status was assessed using questions that focused on four main components of food security; access, availability, utilization, and stability of food resources (described in chapter 2), and coping mechanisms in times when food was not available or insufficient for the household as table 12 shows. A series of questions were posed to the household head about the food situation seven days prior to the survey. According to how food security was measured in the survey, a household was categorised as highly food secure if there was no:

a. Worry about food during the reference period.
b. Change of food consumption pattern due to the food situation.
c. Borrowing money to substantiate a food situation that was not good.

A household was classified as moderately foods secure if the head:

a. Worried about a food situation over the reference period
b. Did not alter consumption pattern due to the food situation
c. Restricted consumption to older members on account of the food situation
d. Borrowed food from other people to substantiate the household's food stocks.

Table 13. Questions used to assess household food security status in IHS2010/11

Module H: Food security								
H01.	H02					H03.		H04
In the past 7 days, did you worry that your household would not have enough food?	In the past 7 days, how many days have you or someone in your household had to:					How many meals, including breakfast taken per day in your household?		In the last 12 months, have you been faced with a situation when you did not have enough food to feed the household?
	a. Rely on less preferred food and /or less expensive food?	b. Limit portion size at meal times? (Days)	c. Reduce number of meals eaten in a day? (Days)	d. Restrict consumption by adults in order for small children to eat? (Days)	e. Borrow food, or rely on help from a friend or relative? (Days)	a. Adults (No.)	b. Children (6-59 months) Number	

A household was categorised as low food secure if it:

a. Worried about its food security situation over the reference period
b. Relied on less preferred food to cushion the food situation
c. Did not alter its food consumption pattern in response to the food situation

A very low food secure household was one in which the head:

a. Worried about having insufficient food in the reference period
b. Relied on less preferred and expensive food to survive low food availability
c. Limited portions of food during consumption due to the food situation
d. Reduced number of meals in a day to ensure food was sufficient
e. Restricted consumption of food to small children only due to insufficient food
f. Borrowed food or relied on a friend or relative to augment food resources

7.2.3. Methods of analysis

In the assessment of relationship between climatic, demographic and socioeconomic variables with households' food security status, what was essentially analysed was the risk of a household being food secure as opposed to being food insecure. As such, the response variable (household food insecurity) had two categories i.e. food secure or not food secure. In this regard, odds ratios were used to interpret the likelihood of a household being food secure given the demographic, socio-economic characteristics of the household, temperature and rainfall conditions for the place where the household was located during the crop growing season of the survey year. This involved fitting a multilevel binary logistic regression model to assess variation in household food security status on account of household level factors and climatic conditions at district level. This technique was also used by Arene and Anyaeji (2010) when assessing determinants of household food security in Enugu state, Nigeria and Hagos, Lunde et al. (2014) on a similar analysis in some Ethiopian ecological zones.

Zhou, Shah et al. (2017) argues that when analysing relationship between variables where one (the outcome) is binary (having two possible responses) the linear probability model (LPM) is not appropriate. This is on account that the LPM is plagued with heteroscedasticity of the error term and the possibility that the estimated value of the response variable 'y' could lie outside the range (0, 1).To avoid this problem, Zhou, Shah et al. (2017) suggests the relationship of independent variables x_i x_2, $x_{3,}$..., x_k. and the dependent variables y_i be modelled in such a way that y_i is an unobservable variable, given as:

$$\begin{aligned} Y_i &= 1 \text{ if } y_i > 0 \\ Y_i &= 0 \text{ if } y_i < 0 \end{aligned} \qquad (28)$$

In the current study, binary logistic regression model was presented as:

$$g(\pi_i) = \beta_0 + \beta_1 x_{1i} +, \ldots, \beta_{mi} x_{mi}$$

$$g(\pi_i) = log_e \left(\frac{\pi_i}{1-\pi_i}\right) \qquad (29)$$

$$\frac{\pi_i}{1-\pi_i} = \text{odds of success}$$

where the logit link: $g(\pi_i)$ was a function modelling the probability that household i was food secure. β_0 is the intercept, β_1 to β_m are coefficients for explanatory variables x_1 to x_m for the household i.

The explanatory variables x_1 to x_m may be factors directly related to the household (operating at a lower level) i.e. demographic and socio-economic factors or indirectly related to the household (operating at an upper level) i.e. cropping season temperature and rainfall. Literature (Frongillo Jr, de Onis et al. 1997, Garrett and Ruel 1999) has shown that factors associated with household food security status operate at different levels depending on the variables involved and the objective of the analysis. In the current study, there were two levels at which independent variables used in the analysis operated, household level (level 1) and station or district level (level2). Level 1 independent variables were demographic and socio-economic i.e. residence, poverty status, size and mean annual food expenditure, household dependency ratio, gender, age, marital status of the household head and education level attained. Total annual rainfall, onset, cessation, duration, dry-days, minimum and maximum temperatures comprised level 2 (climatic) variables used in the analysis.

Since the outcome variable 'food security status' was assumed to be influenced by variables operating at two levels of analysis, the normal binary logistic regression was extended to multi-level multivariate logistic regression model. According to Khan and Shaw (2011), when variations in an outcome variable is influenced by predictors at different levels, there is possibility of multi-level dependency or correlation originating from several levels of the variables. To make valid inferences from multi-level or clustered data, multilevel models are preferred because they take into account variability occurring at different levels of independent variables in influencing the outcome variable. The technique allows analysis to take account of the levels of hierarchical structure in the population so that a sample population is treated as random, and can allow specification and fitting a wide range of multi-level models in order to understand where and how the effects are occurring (Fisher and Lewin 2013, Nyangasa, Buck et al. 2019). A two-level binary logistic regression model with a random intercept was specified as:

$$
\begin{aligned}
&logit\left(P_{ij}\right) = \beta_0 x_{oij} + \beta_n x_{nij} + u_{oj} x_{oij} + e_{ij} \\
&u_{oj} \sim N\left(0, \tau_o^2\right) \qquad (30) \\
&e_{ij} \sim \boldsymbol{N}\left(0, \sigma_o^2\right)
\end{aligned}
$$

Where:

$logit\ (P_{ij})$ is the log odds for household i in district j

$\beta_0 x_{oij}$ is the random intercept for household i in district j

$\beta_n x_{nij}$ are fixed effects of each level 1 predictor variable

u_{oj} is the random group or district level residual

e_{ij} is the random household level residual

τ_u^2 is the variance between districts.

σ_e^2 is the variance within households.

β_n are fixed effects such that each household in level 1 is under the same fixed effect of level 1 explanatory variables and only the effects at district level are allowed to vary. Similar to a standard logistic regression, it is possible to obtain average predicted probabilities for household i within level 2 using the formula:

$$log_e\left(\frac{\pi_i}{1-\pi_i}\right) = \frac{\exp(\bar{\beta}_n x_{nij} + u_{oj} x_{oij} + e_{ij})}{1+(\bar{\beta}_n x_{nij} + u_j x_{oij} + e_{ij})} \qquad (31)$$

Where $log\ \frac{\pi_i j}{1-\pi_{ij}}$ are the odds of household i in district j being food secure against being food insecure.

7.2.4. Building the model to assess factors associated with household food security status

Analysis started with an empty model based on the intercept or constant, specified as:

$$log_e\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \beta_0 + u_{oij} + e_{ij} \qquad (32)$$

Where $log_e\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right)$ represents the log odds of a household i in district j being food secure and β_0 is the overall mean across districts, u_{oj} is the random effect at district level referred to as level 2 (district) residuals, following a non-normal distribution with mean zero and variance $N(0, \tau_u^2)$ and e_{ij} being household level residuals. The second model involved the outcome variable with level 1 predictors only and the random part i.e. district level effect. The model intended to assess variables that significantly influenced households' food security status among the studied households whilst considering variance at district level.

This model was specified as:

$$log_e\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \beta_{00} + \beta_{10}x_{ij} + e_{ij} \qquad (33)$$

where x_{ij} refers to a level one variable i.e. household residence area (urban or rural). β_{10} is the fixed slope of x_{ij} (overall effect of food security). β_{00} is the intercept. This is a constrained immediate model, which does not include cross level interactions.

Having established variation of level 1 predictor variables after considering random effects at level 2 (district level) and assessed changes in the size of unexplained variance in the model (by comparing model 2 variance with variance in the empty model) based on level two effects, another model (3) was fit which included both level 1 and level 2 independent variables in order to assess which variables at both levels significantly influenced household food security. This model was compared with the former (model 2) by examining significance of the differences of the likelihood ratios to see if the later model was a better fit, variance estimate changes at level 2, and the regression coefficients for level one variables, especially their sizes after including level two variables in the model.

Other model fit diagnostics included Bayesian Information Criterion (BIC) and Akaike Information Criterion (AIC) which were used as deviance measuring statistics to assess fit of the model. The smaller the AIC and BIC, the better the fit the model provides (Holden, Kelley et al. 2008). Changes in size of unexplained variances were also checked to see if inclusion of level 2 variables reduced unexplained variation in households' food security status at the upper level. A pseudo R^2 was also used to assess model fit. This was presented as:

$$R^2 = \frac{\sigma^2_{\varepsilon 0} - \sigma^2_{\varepsilon M}}{\sigma^2_{\varepsilon 0}} \qquad (34)$$

Where $\sigma^2_{\varepsilon 0}$ is the population error variance for the baseline model (empty model) and $\sigma^2_{\varepsilon M}$ is the population error variance for more the rich model (e.g. straight line change) model. Model 4, followed from model 3, where among level 1 and 2 predictors was an interaction term generated from the product of one level 1 and one level 2 variable.

The specification of the model was:

$$log_e\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \beta_{00} + (\beta_{10}+u_{1j})\, x_{ij} + \beta_{01}\, X_{ij} + \beta_{11}\,(x_{ij} * X_j) + u_{0j} \quad (35)$$

Where all other parameters were as explained earlier but β_{11} was a coefficient associated with a cross-level interaction, X_j was level 2 variable i.e. total annual rainfall for district j representing climatic variables and x_{ij} is level 1 variable i.e. average annual household food expenditure for household i in district j. This model was compared with the preceding one using all the goodness of fit statistics i.e. variance change, pseudo R^2, BIC and AIC, as well as change in coefficients of independent variables used in the model following introduction of the interaction term.

7.2.5. Interpretation of model results

In this study, results of analysis were presented using various parameters guided by the nature of the study and the methods used. Presentation of results was by statistical tables and graphs to show magnitude of estimates and patterns of relationships among variables respectively.

7.2.5.1. Total model variance unexplained

In statistics, variance provides an average picture of how far each of the observation in a data distribution is from the overall mean of the distribution. Hosmer and Lemesbow (1980) explains that in logistic regression there is no true R^2 value as in ordinary least squares regression analysis. However, since deviance (difference between the observed and predicted value) also shows how poor the model fits the data (lack of fit between observed and predicted values), an analogy is made to sum of squares in the ordinary least squares. The proportion of variance unaccounted for which is expected to decrease with addition of predictors in the model is the same as the proportion of variance accounted for or R^2. Multilevel models have different components of variance, influenced by levels at which predictor variables operate to influence an outcome.

For instance, a multi-level model containing one level 1 predictor, one level 2 predictor and a cross-level interaction, there are three levels of variance i.e. within group variance, intercept variance and slope variance which could be explained (LaHuis, Hartman et al. 2014). In the current study, only the slope and intercept variance are reported, on account that the study's interest was to examine variation of household food security status considering levels at which factors influencing it operate, i.e. household and district or station levels.

7.2.5.2. Goodness of fit: Likelihood ratio test

Hosmer and Lemesbow (1980) explains that the most common assessment of overall model fit in logistic regression analysis is the 'goodness of fit test (G), and this is the chi-square difference between the null model and the model containing one or more predictors. This test uses the likelihood ratio test between two nested models and it assess the improvement of fit between predicted and observed values of y, the outcome variable in a regression, by adding predictors to the model. Logistic regression models seek to find a set of parameter estimates that maximises the likelihood of a condition. Buse (1982) observes that most regression analysis use the log of the likelihood rather than the likelihood itself which is always negative. The higher values i.e. closer to zero indicate a better fit of the model and lower values a poor fit. The specification of the likelihood ratio test is as follows:

$$LR = -2\ln \frac{L(m1)}{L(m2)} = 2(ll(m2) - ll(m1)) \qquad (52)$$

Where $L(m\,*)$ denotes the likelihood of the respective model (either model 1 or 2) and $ll(m\,*)$ the natural log of the model's final likelihood i.e. the log likelihood, and $(m1)$ is the more restrictive model and $(m2)$ is the less restrictive model, i.e. one with one or more predictor variables. The resulting statistic is a distributed chi-square with degrees of freedom equal to the number of parameters that are constrained. When a Likelihood ratio has been calculated, tables are used to check whether the test statistic is statistically significant at a set p-value. In the current analysis the goodness of fit of the models was assessed by comparing size of the likelihood ratio test from baseline model to subsequent models. Another test for goodness of fit for the multi-level models is assessed is by using penalised-likelihood information criteria such as the Akaike's Information Criterion (AIC) and the Bayesian Information Criterion (BIC).

These elements are also used for model selection as they provide a picture about sensitivity and specificity of models, which relates to having enough parameters to accurately fit the model and not over-fitting the model or suggesting non-existing relationships (Dziak, Coffman et al. 2017). These goodness of fit testing techniques penalise models to control over-fitting and provide standardised way to balance sensitivity and specificity. The techniques are often discussed in a unified way as log-likelihood functions with simple penalties on the model. The simplest criteria of the best fit model involves choosing a model with the best penalised log-likelihood i.e. the highest value of $l - A_{nP}$. Where l is the log-likelihood and A_{nP} is some constant or function of the sample size n and p is the number of parameters in the model. The lower the size of the AIC and BIC test statistics as the models compare, the better the fit of the model.

7.2.5.3. Effect size

In statistics, effect size is described as a way of quantifying the magnitude of a phenomenon i.e. relationship between or among variables. Among the examples are correlation between variables, the regression coefficient in a regression model, the mean difference and risks that something or some condition would occur. Effect size is therefore a standard measure that is calculated from statistical outputs to see how large an effect of something is on another. Among the parameters used to measure effects size are chi-square tests of independence, odds ratios, rate ratio, risk ratio (relative risk ratio). In the current chapter, effects size was measured using odds ratios, which are a measure of association between an exposure and an outcome. Odds ratios represent the odds that an outcome will occur given particular exposure (represented by other variables). The odds are also used to determine whether a particular exposure is a risk factor for a particular outcome (Szumilas 2010). The interpretation of odds ratio is as follows:

OR = 1 means that exposure does not affect the odds of outcome

OR >1 means that exposure is associated with higher odds of outcome

OR<1 means that exposure is associated with lower odds of outcome.

The confidence interval is used to estimate precision of odds ratios. A large confidence interval indicates lower level of precision of the odds ratio, whereas smaller confidence intervals indicate higher precision of the odds ratios at a set significance level.

7.2.6. Bivariate analysis

Bivariate analysis involved testing association among independent variables and between the dependent and independent variables used in multi-level logistic regression model. Graham (2003) and Vatcheva, Lee et al. (2016) explain that in regression analysis, testing association among variables reduce the possibility of producing inaccurate estimates and large standard errors arising from the effect of strongly correlated independent variables or variables with weak and non-significant associations. Both Pearson'S Chi-square test and Pearson's correlation coefficient techniques were used since the variables involved in this analysis were categorical and numerical. Pearson's Chi-square test only shows whether the variables concerned have significant association, unlike the Pearson's correlation coefficient technique which shows size, direction i.e. positive or negative, and significance of the association between variables. Results for the correlation tests helped in selecting variables to include in the 2-level binary logistic regression model to ensure accurate and significant results. Table14 shows variables used in the models.

Table 14.Variables used in fitting multilevel logistic models for household food security

Variable	Type	Classification
Dependent variable		
Food security status	Categorical	1 food secure (Ref),0 otherwise
Independent variables		
Level 1. (Household)		
Household size	Count	
Poverty status	Categorical	1 Poor, 0 non-poor (Ref)
Residence	Categorical	1 Urban (Ref), 2 Rural
food expenditure	Count	1 above mean(ref) 0 otherwise
Dependency ratio	Count	
Maize yield	Count	
Gender of household head	Categorical	1 Male (Ref), 2 Female
Education level of head	Categorical	1None (Ref), 2 Primary 3 Sec. 4 Tertiary
Marital status of head	Categorical	1 Married (Ref) 2 Divorced 3.Widowed, 4 Never
Level 2. (District)		
Total annual rainfall	Count	
Onset of annual rainfall	Count	
Cessation of annual rainfall	Count	
Duration of annual rainfall	Count	
Minimum temperature	Count	
Maximum temperature	Count	

7.2.7. Results of analysis

In this study, preliminary analysis involved examining background characteristics of the sampled households before fitting the two-level binary logistic regression model. Table 15. shows that 82 percent of the sampled households were in the rural. Over half (52 percent) had 4 or less members and more than three-quarters (76 percent) were headed by males.

Table15. Demographic and socio-economic characteristics of households IHS2010/11

Characteristics	Percentage	(N)
Residence		
Urban	18.2	2233
Rural	81.8	10038
Total	100	12271
Household size		
≤4	52.3	6420
5-7	29.3	3597
>7	18.4	2254
Total	100	12271
Gender of household head		
Male	75.9	9319
Female	24.1	2952
Total	100	12271
Poverty status		
Poor	57.2	5246
Non-poor	42.8	7025
Total	100	12271
Food security situation		
Felt food insecure over the past seven days	31.8	3898
Relied on less preferred or less expensive food	30.9	3786
Limit portion size at meal times	23.7	2910
Reduced number of meals eaten	18.0	2211
Restricted consumption by adults to give to children only	13.7	1684
Limited and restricted meals, and borrowed money	40.0	4904
Food security classification		
Food secure	57.9	7104
Marginal food insecure	2.1	263
Low food insecure	7.6	934
Very low food insecure	32.4	3970
Total	100	12271
Annual household food expenditure		
Mean	137,450	12271
Household food expenditure by categories		
Below mean	64.2	7883
Above	35.8	4388
Household food expenditure by residence (Kwacha)		
Urban	213,139	2233
Rural	120,613	10038

Over half of the households (57.3 percent) were poor and the mean annual household food expenditure was K137, 450.17, with 64.2 percent of households spending below the mean annually.

Results showed that at the time of the survey, 40 percent of the sampled households were food insecure and 60 percent were food secure, more in the rural than urban; 43 and 27 percent respectively (Table 16).

Table 16.Percentage of food insecure households and their characteristics,IHS2010/11

Background variables	Categories	Low food secure households	(N)
Residence	Urban	26.5	592
	Rural	43.0	4312
Household size	≤4 members	38.3	2462
	5-6	41.9	1506
	≥7	41.5	936
Gender of household head	Male	37.6	3507
	Female	47.3	1397
Age group of household head	≤24	9.3	454
	25-34	30.2	1483
	35-44	22.0	1080
	45-54	14.3	703
	55+	24.1	1184
Mean annual household food expenditure	Below mean	46.2	3645
	Above mean	28.7	1259
Poverty status	Non-Poor	31.0	2181
	Poor	51.9	2723
Marital status of household head	Married	37.9	3406
	Separated/divorced	45.3	606
	Widow/widower	50.0	772
	Never married	30.1	119
Education level of household head	None	45.1	3872
	Primary	36.7	460
	Secondary	26.1	533
	Tertiary	9.0	34

More poor households were food insecure at the time of the survey compared to non-poor ones; 52 percent against 38 percent. More households with five to six members were food insecure (41.9 percent) compared to those with equal to or less than four members (38.3 percent) and more female than male headed households were food insecure; 47 percent against 38 percent. Food insecurity was high among households whose heads were separated or divorced and widowed; 45 and 50 percent respectively compared to never married; 30 percent and married; 38 percent. More households with non-educated heads (45 percent) were food insecure compared to those with heads that had secondary (26 percent) and tertiary education (9 percent).

Across districts, the proportion of low food secure households was higher in the south and south-western districts i.e. Nsanje, Blantyre, Neno and Balaka, above 50 percent (Figure 37).

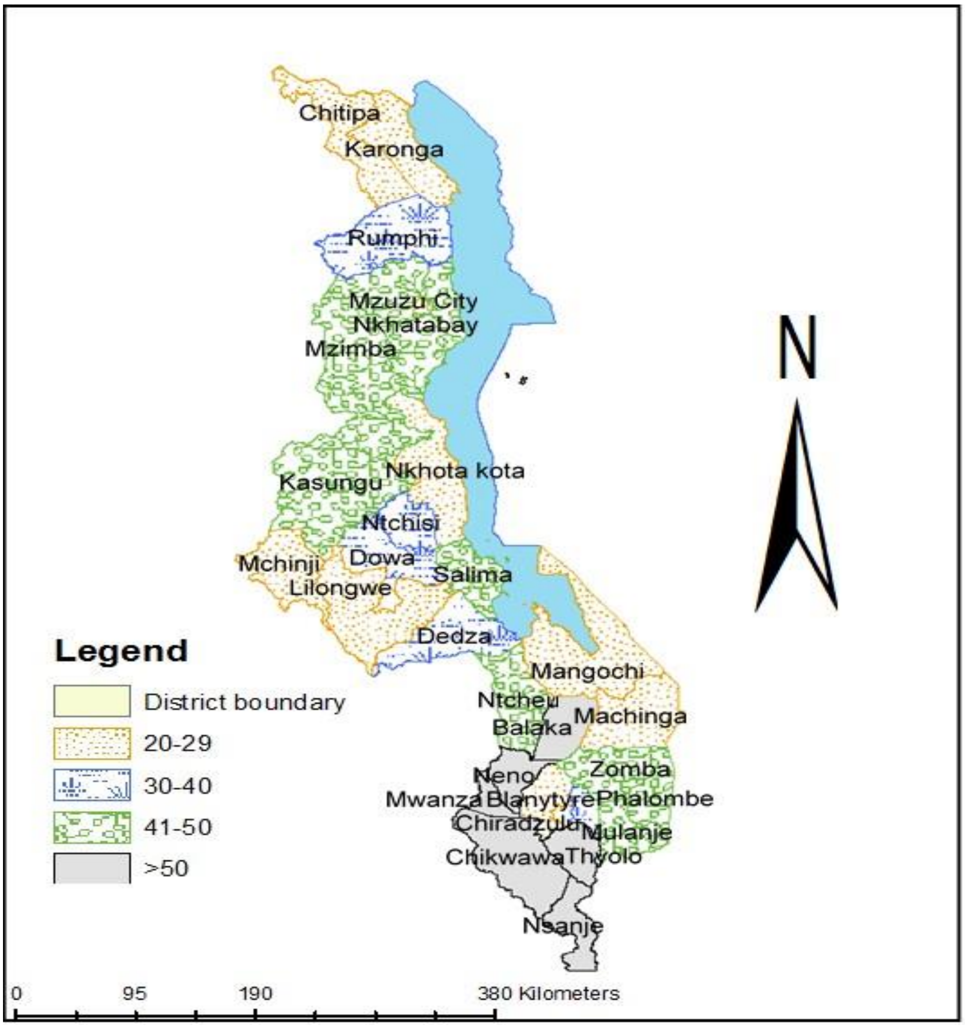


Figure 37.Map of Malawi showing percentage of low food secure households by district 7days prior to the IHS2010-2011

The figure further show that 41-50 percent of households in Zomba, Mulanje, Phalombe districts in the south-eastern part of the country, Ntechu, Salima and Kasungu in the central region and Mzimba in the northern region had low food security status at the time of the survey. Lower proportion of low food secure households i.e. 20-29 percent were found in Mangochi and Machinga districts in the southern region, Lilongwe, Mchinji and Nkhotakoka in the central region, Chitipa and Karonga in the northern region.

Chi-square tests results in Table 17, show that there were statistically significant associations between a household's food security status and its size, residence, poverty status, annual food expenditure and characteristics of the household head.

Table 17.Chi-square test results for variables used in food security analysis

Variables	Chi-Square Test	Degrees of freedom	P-value
Household level variables			
Residence (Urban /Rural)	205.9	1	0.000
Household size	14.7	2	0.001
Poverty status (Poor /Non Poor)	544.7	1	0.000
Age of household head	14.1	4	0.007
Gender of household head (Male/female)	87.5	1	0.000
Education level of household head	414.7	3	0.000
Marital status of household head	113.4	3	0.000
Mean household food expenditure	380.5	1	0.000
Climatic /district level variables			
Total annual rainfall	21.03	2	0.000
Rainfall Onset	21.0	2	0.000
Rainfall Cessation	155.4	1	0.000
Rainfall Duration	70.9	2	0.000
Number of Dry days	4.52	2	0.104
Maximum temp	246.6	2	0.000
Minimum temp	118.4	2	0.000

No of valid cases 12,271. P = <0.05

Age, gender, marital status, education level of a household head also had significant associations with food security status. Among climatic variables, the amount of growing season rainfall, its onset and cessation, duration, minimum and maximum temperatures, were all significantly associated with a household's food security status.

7.2.8. Binary and multilevel logistic regression models results on factors associated with households' food security status

Prior to fitting multi-level models in this analysis, a binary logistic regression model was fit to identify socioeconomic and demographic variables that had significant association with household food security status in Malawi. Results in table 18 show that dependency ratio, gender and age of the household head were not significantly associated with household food security status. This is somewhat surprising considering existing gender and age based disparities on access to resources for acquiring food i.e. land, income in the SSA region reported in other studies i.e. Quisumbing, Brown et al. (1995). Dependency ratio indicates household's productive ability against its consumption level, as such is expected to have significant association with households' food security status. However, results of the model shows otherwise.

Table18.Logistic regression results for household factors affecting food security status

Independent variables	Odds ratio	P-value	95% Conf. Interval
Dependency ratio	0.999	0.587	0.999 - 1.000
Urban (Ref)			
Rural	0.808	0.016	0.679-0.961
Non-poor (Ref)			
Poor	0.590	0.000	0.533-0.654
Household size	0.923	0.000	0.895-0.951
Annul food expenditure	1.000	0.000	1.000-1.000
Harvested maize(yield)	1.203	0.000	1.000-1.000
House head ed. Level			
None (R)			
Primary	1.097	0.211	0.948-1.269
Secondary	1.516	0.000	1.310-1.754
Tertiary	3.399	0.000	1.956-5.905
Marital status of head			
Married			
Separated, divorced	0.77	0.077	0.665-0.891
Widow or widower	0.66	0.064	0.567-0.768
Never married	0.709	0.127	0.477-1.052
Age of Household head			
15-19 (Ref)			
20-29	1.152	0.573	0.703-1.890
30-39	1.298	0.303	0.790-2.134
40-49	1.354	0.238	0.818-2.237
50+	1.35	0.237	0.820-2.222
Gender of household head			
Male (Ref)			
Female	1.0387	0.068	0.687-0.961
Constant	1.197	0.506	0.705-2.033

However, poverty status of the household, education level attained and marital status of the head, residence, household size, its annual food expenditure and quantity of maize yield produced in the growing season, were all significantly associated with households' food security status. Although dependency ratio, age and gender of the head were not statistically significant in the binary logistic regression, they were still included in the multilevel models on account that in concert with other independent variables, they could play a significant role in influencing household food security status. Multi-level logistic regression models were then fit to assess whether there was variation in household food security status across districts and assess climatic factors associated with such variation. Key questions in this analysis were:

1. Are there variations in households' food security status across districts?
2. Do the district level variations in household food security status remain after controlling for household level factors?
3. How much variation in households' food security status is due to district and household level differences?

Model one was an empty or null model, with an outcome variable (households' food security status) and a group level variable i.e. station or district and no predictors at any level. The purpose was to find out whether there were significant district level effects associated with household's food security status, and assess average odds of a household becoming food insecure when no predictors are included in the model. This model determined whether fitting a multi-level model would be necessary in assessing factors associated with household food security in the country. Results in table 19a show that there was significant variation in households' food security status on account of district or station level factors. The random effect parameter was 0.407, statistically significant; p-value:0.000.

Table 19a.Multilevel logistic regression models on food security status in Malawi

	Empty		**Model 1**		**Model 2**		**Model 3**		**Model 4**	
Model Parameters	Model (Null)		(Random intercept with level 1.variables)		(Random intercept with level 1 and 2 variables)		(Random intercept with level 1 and 2 variables cross-level variable		(Random intercept with sig. predictors, and cross-level variable)	
Variance and fit statistics	**Estimate**	**P-value**	**Estimate**	**P-value**	**Estimate**	**P-value**	**Estimate**	**P-value**	**Estimate**	**P-value**
District level	0.407	0.000	0.349	0.000	0.288	0.000	0.290	0.000	0.234	0.000
Intra class correlation										
District level	0.11		0.096		0.081		0.081		0.081	
Model fit										
Likelihood ratio test	659.1	0.000	531	0.000	3623	0.000	0.366	0.000		0.000
AIC	1221		1116		1063		1062		1061	
BIC	1223		1129		1081		1081		1078	
R^2	0.000		0.109		0.117		0.136		0.137	

Comparison between the null model with ordinary logistic regression model indicate that fitting a multilevel model would be appropriate, as the log likelihood ratio statistic was significant; 659.17 p-value 0.000. There was a decrease in the random effect estimate with inclusion of level one independent variables in model 1, to 0.349, then 0.288 in model 2 upon inclusion of both level one and two independent variables, 0.288 in model 3 where a cross-level variable (from rainfall and quantity of maize yield) was included. The random effect estimate lowered more to 0.234 in model 4, where only statistically significant level 1 and level 2 independent variables and a cross-level variable were included in the model.

Results also show low intra-class correlation coefficient; 0.11 in the null model suggesting that there was no correlation among household food security status within districts. The ICC estimate; 0.095 in model one, reduced to 0.081 in model two to three and 0.066 in model four. Model fit diagnostics show decreasing AIC and BIC estimates from 1221 and 1223 in model one to 1061 and 1078 in model 4 respectively, indicating that including level 1, level 2 and cross-level independent variables as the model progressed improved its fit. This was also evident in the R^2 value; 0 in the null model to 0.137 in model 4 where variables from both levels and a cross-level variable were included in the model.

Results in table 19b the final model show that among level one variables, household size, annual food expenditure, poverty status of the household, marital status, education level of the household head and quantity of maize yield harvested were all significantly associated with household food security status. In this model an increase in household size lowered the odds of the household being food secure by 0.926, p-value 0.000. An increase in household annual food expenditure increases the odds of a household being food secure by 1.230 (p-value 0.000). Being separated and divorced lowered the odds of a household being food secure by 0.797 (p-value 0.0004) and being widowed reduced the odds of a household being food secure by 0.655 (p-value 0.000). Having secondary and tertiary education increased the odds of a household being food secure by 1.5 (OR:1.491, p-value 0.000) and 3.0 (2.93, p-value 0.000) respectively. An increase in household's maize yield during the growing season increased the odds of a household by 1. (OR:1.300, p-value, 0.000).

Table19b Multilevel logistic regression models on food security status in Malawi

Model Parameters	**Empty** Model (Null)		**Model 1** (Random intercept with level 1.variables)		**Model 2** (Random intercept with level 1 and 2 variables)		**Model 3** (Random intercept with level 1 and 2 and cross-level variable		**Model 4** (Random intercept with sig. level 1 and two and cross-level variables)	
	Odds ratio	**P-value**	**Odds ratio**	**P-value**	**Odds ratio**	**P-value**	**Odds ratio**	**P-value**	**Odds ratio**	**P-value**
Household size			0.918	0.000	0.914	0.000	0.913	0.000	0.926	0.000
Residence										
Urban (Ref)										
Rural			0.861	0.259	0.816	0.155	0.814	0.15	0.809	0.136
Food expenditure			1.20	0.000	1.230	0.000	1.23	0.000	-	-
Poverty										
Poor (ref)										
Non-Poor			1.433	0.000	1.432	0.000	1.427	0.000	1.432	0.000
Sex of House head										
Male (ref)										
Female			0.987	0.89	0.964	0.712	0.968	0.739	-	-
Marital status										
Married (ref)										
Separated /Divorced			0.803	0.044	0.802	0.046	0.800	0.045	0.797	0.004
Widowed			0.655	0.000	0.639	0.000	0.634	0.000	0.655	0.000
Never married			0.776	0.230	0.845	0.444	0.855	0.478	0.804	0.316
Head education										
Never educated (ref)										
Primary			1.164	0.051	1.18	0.041	1.177	0.045	1.158	0.069
Secondary			1.553	0.000	1.519	0.000	1.518	0.000	1.491	0.000
Tertiary			3.791	0.000	2.969	0.000	2.968	0.000	2.973	0.000
H/head age										
15-19 (ref)										
20-29			1.200	0.489	1.067	0.811	1.063	0.824	-	-
30-39			1.349	0.258	1.201	0.507	1.194	0.522	-	-
40-49			1.423	0.188	1.284	0.37	1.279	0.379	-	-
50+			1.406	0.199	1.254	0.413	1.246	0.427	-	-
Household maize yield			1.025	0.000	1.027	0.000	1.049	0.000	1.065	0.000
Dependency Ratio			0.999	0.525	1.000	0.659	0.999	0.739	-	-

Across level two variables, results show that none of the variables had significant association with household food security status across the four models fitted. An attempt was made to fit the model with categorical than count climatic variables to see if the variables would be significant. As such, total growing season rainfall was categorised as low, medium and high. Rainfall onset was categorised as early normal or late onset. Rainfall cessation was categorised as early, normal and late cessation, while rainfall duration was categorised as short, normal and longer, temperatures; low, average and high categories.

However, the results were not significantly different from the earlier approach since of the seven variables, only one category of ‘total rainfall’ was significantly associated with household food security status.

19c Multilevel logistic regression models on climate variables and food security

Model Parameters	**Empty**		**Model 1**		**Model 2**		**Model 3**		**Model 4**	
	Model (Null)		(Random intercept with level 1.variables)		(Random intercept with level 1 and 2 variables)		(Random intercept with level 1 and 2 and cross-level variable		(Random intercept with sig. level 1 and two and cross-level variables)	
Climate variables (level two)	**Estimate**	**P-value**	**Estimate**	**P-value**	**Estimate**	**P-value**	**Estimate**	**P-value**	**Estimate**	**P-value**
Rainfall onset	-	-	-	-	0.719	0.356	0.717	0.353	0.715	0.346
Rainfall cessation	-	-	-	-	0.890	0.841	0.894	0.846	0.888	0.837
Rainfall duration	-	-	-	-	1.121	0.709	1.128	0.699	1.131	0.686
Dry days	-	-	-	-	0.989	0.979	0.99	0.82	0.981	0.964
Max temperature	-	-	-	-	0.634	0.713	0.665	0.714	0.667	0.716
Min. temperature	-	-	-	-	164.5	0.142	1.611	0.145	1.652	0.142
(Rainfall *Yield)	-	-	-	-	-	-	1.036	0.008	1.039	0.007

However, a cross level variable involving total rainfall in a growing season and household quantity of maize yield was highly significant in the model; OR: 1.039, p-value 0.007. This result indicates that on their own, temperature and rainfall variables do not have a direct association with household food security status, but rather through the interaction with maize yield (i.e. crop production).

7.3. Summary of results

The current analysis has found statistically significant variation in household level food security status on account of district or station based factors as evident from random estimates parameters, from the null model to the fourth model. Higher amount of variation in households’ food security status in the models was contributed by household level than district level factors. Climatic factors i.e. selected temperature and rainfall variables (which were at district level) were not statistically significant in each of the fitted four models, although random estimates parameters still indicated significant variation in the outcome variable on account of district level factors. Modifying the climatic variables from count to categorical to show ranges i.e. for rainfall; high, medium and low, for the reference growing season did not improve the significance of the variables in the models.

However, a cross-level variable involving total rainfall at district level and total maize yield produced by the household was noted to be highly significant across all the four models. Among level 2 variables (household level) in the final model, and controlling for climatic and other household level variables, households that were poor, had higher number of members, heads with lower education level attainment, heads who were divorced or separated, and those which had lower quantity of maize yield harvested during the reference season, had lower odds of being food secure. This was in comparison to non-poor households, those with fewer members, those whose heads had attained secondary or higher education, those who were married, and those who had produced high amount of maize yield in the reference season. Dependency ratio of the household, gender and age of the household head and residence i.e. rural or urban were not significant across the four models.

7.4. Discussion

This section discusses findings of analysis about factors associated with household food security status in Malawi, addressing the third objective of the study; examining association of climatic, demographic and socioeconomic variables with households' food security status in the country. The discussion highlights key findings of the analysis corroborated with literature from other studies. It also provides suggested explanations for the results and their implications on policy and interventions addressing climatic variation and food security in the country. It will finally highlight limitations of the findings and propose future research on the subject.

Literature i.e. Rose and Charlton (2002) and Arriola (2015) shows that there are various macro and micro level factors influencing household food security within a given geographic and socio-economic context. Macro level factors operate at an aggregate level influencing general conditions within which food is made available on the household i.e. food and market policies, climatic conditions (Timmer 2014) while micro level factors operate at a most basic level i.e. household, to influence food resources utilization (Kowaleski-Jones 2011, Timmer 2014). In this analysis, climatic factors i.e. cropping season temperature and rainfall variables were macro-level factors while demographic and socio-economic conditions of the household were micro-level factors.

Multi-level logistic regression models were fitted to examine how these factors relate with household food security and how it varied across these levels, a key input for target specific interventions addressing food insecurity in the country. An intercept only model fit at the beginning of the analysis showed significant variations in household food security on account of district level effects. This finding relates to an observation by Bartfeld and Dunifon (2005) on assessment of state-level predictors of food security and hunger in the USA, where contextual factors i.e. availability and accessibility to federal nutrition assistance programs, states' economic and social characteristics were associated with household food security.

In Nigeria, Lamidi (2017) also found complex but significant relationships involving household and community level factors influencing food security, stressing the importance of macro level contextual factors on household food security status. Along these findings, current study results imply that limiting assessment of household food security to lower level (demographic and socioeconomic) factors masks understanding of variations in households' food security status on account of higher level factors. Such a situation could compromise design of policy and programmatic interventions to address food insecurity in the country.

A follow-up model in this analysis included level 1 (households level) predictors alongside a random intercept at level two (district level). The purpose was to observe variations in households' food security status on account of selected demographic and socio-economic factors, whilst considering variation in unknown aggregate contextual district level variables. Results showed that the considered demographic and household level factors had significant association with food security status. Level 2 variance significantly decreased following inclusion of level 1 variables in the model, indicating that despite variations of contextual factors, household level factors were still important to household' food security status.

In a study examining individual and community level factors' roles in determining stunting among children in Ethiopia, Alemu, Sileshi et al. (2014) also noted statistical significance in household level factors when community level factors were allowed to vary. Current findings hence suggest that interventions addressing household food insecurity in Malawi ought to consider household level factors i.e. education level of the household head, its marital status, poverty status of the household, food expenditure and maize production, apart from upper level (climatic factors).

A subsequent model fitted intended to observe how household's food security status varied when both level 1 and 2 variables were included in the model, allowing variation of factors at level 2 i.e. cropping season temperature and rainfall variables. Results showed that level 1 variables significant in the previous model i.e. poverty status, expenditure on food, education level and marital status of the household head were again significant in this model. However, none of the 7 level 2 count (climatic variables) included in the model had significant association with household food security status. However, when the climatic variables were categorised i.e. low, medium and high rainfall, temperatures or into early normal and late onset and cessation of cropping season rainfall, or long, short or normal duration of rainfall during the season, only rainfall was the significant climatic variable.

Households in districts that experienced higher total annual rainfall above 1499mm had lower odds of being food secure compared to those that experienced average amount of rainfall i.e.700-1499mm. This finding relate with a study by Niles and Brown (2017) who performed a multi-country analysis on effects of varying rainfall conditions on small holder households' food security status. Results showed that households that experienced a normal or average cropping season rainfall range were more likely to be food secure than those that experienced below and above normal rainfall. According to Kane (2009), in the east African region, above cropping season average and high intensity rainfall cause floods, leading to land and crop wash-outs, directly causing loss of crop and sometimes lower yield. These events lead to lower food availability among families and consequently food insecurity. Results in chapter 5 of this study have shown that Malawi's cropping season rainfall is decreasing, though not statistically significant. However, its onset during the season is significantly delaying and duration shortening, conditions which will impact crop growth and yield, leading to low food availability.

The ministry of agriculture and other sectoral players therefore ought to ensure that food security policy interventions take into account these climatic patterns in order to mount a targeted and matched response in districts experiencing significant rainfall decreases. Among such is building capacity of local farmers to diversify livelihood strategies so as to ensure multiple sources of income with which to augment food resources, apart from farming, which is affected by increasingly variable rainfall conditions.

Such multipronged approaches will cushion farming households from perennial food insecurity ((MalawiGovernment 2017) influenced by adverse climatic conditions in the country. Despite the finding that only one climatic variable was statistically significant in the model, a cross-level variable involving level 1 and 2 variables i.e. total rainfall and maize yield included in the subsequent model was significantly associated with household food security status, controlling for household level and other climatic variables. This result suggest that climatic variables do not have a direct influence on household food security status, but rather through crop production as the source of food. In essence, addressing the influence of climatic variation on food security status among households in Malawi ought to be looked at not in isolation of crop production, as it is through crop production that climatic factors impact household food security.

In the final model of this analysis, results showed that controlling for household and climatic variables included in the model, poverty status of the household was significantly associated with food security status. Poor households had lower odds of being food secure compared to non-poor households. This result has also been reported by other studies on this matter. For instance in a study on factors influencing household food security in Niger (west Africa), Zakari, Ying et al. (2014) found that poor households had significantly lower odds of being food secure compared to their non-poor counterpart. In south Africa, a review of literature on household food security status by Altman, Hart et al. (2009) revealed that poor households experienced deeper food insecurity compared to non-poor and high income households.

Examining food insecurity in the USA, Nord (2010) found the prevalence of food insecurity among households below the poverty line four times more than those above the poverty line. In yet another study examining the link between poverty and food insecurity in a population survey Wight, Kaushal et al. (2014) found that the incidence of food insecurity declined as the income-to-needs ratios increase, suggesting that lower income influenced food insecurity. Among other explanations, poverty (proxy for low income) limits access to food resources, whereby people experience low capability to produce and buy food or exchange for other assets, a situation that leads to food insecurity (Longo 2016, Alwang, Gotor et al. 2017). Poor people also face greater risk and vulnerability to shocks i.e. climatic, higher food prices, making them more prone to food insecurity (Gregory, Ingram et al. 2005) and are less capable of cushioning themselves against such, let alone rebuilding themselves after loss.

Over half of Malawi's population is classified as poor (MalawiGovernment 2017), suggesting that the majority is vulnerable to food insecurity. Current results suggest the need for targeted safety nets and social protection programs aimed at cushioning the poor from food insecurity, while building their capacity to produce own food or generate income with which to access food resources.

Although dependency ratio has been suggested as much better variable than household size when assessing household food security status, on account that it shows how many people are available to provide for how many, than household size which only looks at 'mouths' to be fed than 'hands' to provide food, it was not statistically significant in all four models fitted in the current analysis. Results from the current analysis showed that household size was a highly significant variable influencing household food security status. Higher households size was associated with lower odds of food security. Obayelu (2012) found similar results from a study examining household food security in north-central Nigeria, where increase in household size lowered household prospects for food security. In South Africa, Chakona and Shackleton (2017) noted disparities in household food security status influenced by household size, where households with more members had lower likelihood of being food secure compared to those with less members.

According to Silvestri, Sabine et al. (2015) and Ahmed, Ying et al. (2017) high household size puts pressure on households food resources due to more people to be fed. This is worse in households with few income earners and food producers since a thin resource base fails to meet households' food demand. Malawi's mean household size is still high 4.7 members (MalawiGovernment 2017), indicating that most households experience food insufficiency, compounded by poverty and poor infrastructure through which food could be accessed, sanitation and hygiene among others. Reducing population growth whilst improving farm productivity and income could be an important policy and programmatic priority for addressing food insecurity among Malawian households.

Education is a key socio-economic variable in the model world as it determines income and quality of life (Frost, Forste et al. 2005, De Muro and Burchi 2007). Well educated individuals are likely to find higher income jobs that would enable them meet their day to day needs including health and personal development (Bhardwaj 2016).

The benefits of education accruals not only to the individual themselves but also people around (Türkkahraman 2012). Multilevel regression analysis results in this study showed that controlling for selected climatic, demographic and socio-economic variables in the final model, education status of the household head has significant association with households' food security status. The higher the education level attained by the household head, the higher the odds of the household being food secure compared to a household with non-educated head. This result has also been reported by other studies examining factors influencing household food security status, i.e. De Muro and Burchi (2007), Bashir and Schilizzi (2013) and In Kenya, Mutisya, Ngware et al. (2016).

Education enhances productive capacities essential for gainful employment and higher income, important for accessing sufficient quantity and quality food on a household (De Cock, D'Haese et al. 2013). It also enhances capacity for resource mobilization, improves technology acceptability for bolstering crop yield, food availability and farm-based income in societies dependent on farming for livelihoods (Abu and Soom 2016). A descriptive analysis in the current study showed a higher proportion of household heads with no education attained, suggesting that the majority of population in Malawi are less capable to earn more income. This situation among others result in persistent food insecurity in the country as it limits their ability to acquire and produce food for their households.

The education sector should therefore enhance accessibility to education for all, prioritising the rural population often hard hit by food insecurity and other socio-economic ills i.e. poor health. Targeted interventions such as adult literacy programs ought to be enhanced as well as agricultural extension services support to build households' abilities to cushion themselves against food insecurity. Government should consider tailor made community based income generating activities and technical skills development targeting young people and other vulnerable households. Such initiatives will not only build capacity among household members to avert food insecurity but also enhance productivity in other facets of life.

Hanson, Sobal et al. (2007) notes that socioeconomic factors have dominated literature on correlates of household food security, leaving out equally important factors at societal level.

In the current study, marital status of the household head was included as a social variable on the assumption that it connotes extent of responsibility in terms of number of people under someone's care with regard to food provision among other responsibilities. Divorced, separated and widow headed households had lower odds of being food secure compared to households with married heads. Asefach and Nigatu (2007) in southern Ethiopia, Obayelu (2012) in north-central Nigeria and Tantu, Gamebo et al. (2017) in Ethiopia have also reported similar results on their analysis of social factors associated with household food security status.

Among other explanations, Hanson, Sobal et al. (2007) suggests that married household heads jointly work with their partners in sourcing food for the household unlike single, separated, divorced and widowed heads who have none to cooperate with in sourcing and augmenting food resources for the household. The current study finding points to a significant policy intervention for the ministries of gender and finance, economic planning and development in Malawi, in that safety nets and social protection interventions during lean periods should purposively target vulnerable population groups such as widows, divorced and separated people observed to be vulnerable to food insecurity among all others in the population.

Maize is one of the strategic food crops in sub-Saharan Africa, and its production has been argued to be crucial for not only food availability in many African countries but also income resources following sale of farm proceeds (Mango, Makate et al. 2018). In the current analysis, maize yield has been noted to have a significant association with households' food security status. Increase in maize yield on the household was associated with higher odds of food security, suggesting that lower maize yield was associated with lower odds of household food security status. Essentially, controlling for climatic i.e. temperature and rainfall patterns during a growing season, and other demographic and socioeconomic characteristics of the household, lower maize production entails food insecurity in the country. As a country relying on maize as the main source of household food, targeted policy interventions on maize ought to be enhanced in order to ensure that households have enough food. Among such could be encouraging use of subsidized high yielding maize yield among local farmers in order to bolster productivity and households' capability to feed themselves.

Household expenditure on food has been argued to be a significant factor to food security, where in some instances higher food expenditure indicates higher food available, and of good quality (Cromwell and Kyegombe 2005). In the current study, the higher the expenditure of the household on food resources, the higher the odds of the household being food secure. Considering that almost two-fifth of Malawian households are poor, with lowly educated household head and a higher member size, it is unlikely that their expenditure on food would be sufficient enough to meet the demand. As such, targeted safety net interventions ought to be expanded to carter for households with lower food expenditure in order to augment their food security status.

7.5. Limitations of the analysis in the chapter

One of the limitations of this study is that assessment of household food security status was based on a 7-day household food experience recall. The 2010 integrated household survey from which data about households' food security status was obtained captured information about household's food security experience at different time periods from March 2010 to March 2011. As such some responses about household food security status pertained to harvest period where households are likely to be food secure, while others responses pertain to the lean period, where households are prone to food insecurity. This situation might have affected estimates and probabilities of households' food security status, depending on what proportion of the sampled households was interviewed during the lean or food secure seasons reported to be food secure or insecure.

The implication of this limitation to the findings of the analysis can only be established if proportions of food secure and insecure households for the two season are compared to assess under or overestimates. In essence, estimating household food security according to seasons as done by Chikhungu and Madise (2014) could have provided further clarity on estimates and probability of a household being food secure or insecure. However, this could not be done since the data for the survey available to the researcher did not have details about date of interviews for respondents, and efforts to access this kind of data were futile. Further, although analysis on factors associated with household food security status is important for interventions to address food insecurity in the country.

Understanding causes of household food insecurity would have provided more useful input for policy. This is the case because in a resource constricted country like Malawi, the need for target specific and impact oriented programs to address socio-economic problems is imperative, such that ‘causality’ other than ‘association’ would have more implications on policy. However, this requires depth and breadth of the subject matter, which calls for longitudinal other than cross-sectional analysis, with robust techniques to isolate the contribution of each factor to the outcome. This could not be done in the current study because there was no longitudinal data on socio-economic characteristics of households in Malawi which would have permitted such analysis.

Future research ought to consider longitudinal research focusing on establishing causal links between food security and its associated factors for effective policy input. In addition to the above limitations, this analysis did not exhaust all factors associated with household food security in Malawi, since the variables included in the analysis were limited to the type of data collected i.e. socio-economic and demographic data from the IHS2010, cropping season temperature and rainfall variables as per temperature and rainfall data obtained from the MET office.

Food security in itself is such a comprehensive and dynamic concept with many factors associated with it other the socio-economic, demographic and climatic factors. For instance, crop production from which Malawians obtain their food resources relies on climatic, socioeconomic and topographic factors among others. Soil structure and quality, seed varieties, land sizes, labour input, fertilizer and pesticides are among other non-climatic and non-socioeconomic variables influencing crop yield and ultimately household food security (Chirwa 2005, Moore, Alagarswamy et al. 2012, Munodawafa 2012). Interpretation of current study results is therefore limited to the data and variables used in the study only. Future research should consider including these factors in the analysis in order to provide a fuller picture on the subject.

7.6. Conclusion

Climate change is one of the major development challenges facing the 21st century world. Wide spread poverty, increasing human population amid low technological absorption among developing countries in sub-Saharan region pose significant concerns on responses to changes in climatic patterns whose effects are well spelt in the food security posture of households.

Understanding the scale at which human societies are confronted with the effects of changing temperature and rainfall variables on the food security status of households relying on farming is an urgent research imperative. This calls for accurate data and methodologies within which various assumptions regarding relationship of factors associated with food security at different levels of influence could be tested and validated. The current chapter attempted to examine the association of changes in climatic variables i.e. temperature and rainfall on household food security in Malawi, based on the Integrated Household Survey 2010/11.

A 2-level binary logistic regression was used to assess the odds of a household being food secure accounting for household level socio-economic and demographic variables and climatic variables at district level. Results showed existence of district level climatic effects influencing variation in household food security status as evident from temperature and rainfall variables i.e. total annual rainfall which was significant in the model if used as a categorical than count variable, while adjusting for equally significant household level variables. Interaction of predictor variables from both levels showed significant influence on household food security throughout the models. This suggests that in Malawi, household food security status is influenced by factors operating at different levels of analysis, both independently and jointly. This result highlight the need to factor in climatic variables in the analysis of household food security bearing in mind Malawi's food availability is predominantly farm based, dependent on patterns of climatic variables such as temperature and rainfall during the growing season, which affects maize yield and ultimately food availability.

Considering that Malawi like many countries in sub-Sahara Africa is undergoing significant changes in its climatic patterns, with possible implications on its food security posture, current study results signal the need for an integrated policy framework that addresses the association of household and district level factors on food security. In essence, despite limitation in resources and technologies, policies to address food insecurity ought to consider variability in climatic patterns amid variations in demographic and socio-economic conditions within which households across districts are found. Such an approach will ensure target specific interventions, responding to the varied socio-economic, demographic and climatic terrain within which food security programs operate.

Chapter 8. Examining factors associated with under-five children's nutritional status in Malawi

8.1 Introduction and Overview

Under-five children are among population groups vulnerable to changing climatic conditions around the world due to their underdeveloped physiology and weak immune systems (Urke, Bull et al. 2011, Ghani, Zubair et al. 2017). These conditions make them unable to withstand adverse socio-economic and environmental conditions that predispose them to poor health. Studies indicate that due to global climate change and variation, intense rainfall, floods, warm to hot temperatures and droughts facilitate spread of infectious diseases and disability around the world, with under-five children bearing the heavy burden of these misfortunes (Xu, Sheffield et al. 2012, McMichael 2013, Milton, Lusha et al. 2015). Apart from infectious diseases, poor household food security status and poor food consumption patterns, exacerbated by among other factors, poor household crop production due to climatic variation and change especially in climate dependent food production systems, have been argued to influence poor health outcomes among under-five children (Phalkey, Aranda-Jan et al. 2015).

Poor nutritional conditions among under-five children has negative lifelong effects such as poor cognitive abilities, which extend to low education attainment and low skills acquisition, resulting in low economic productivity in later life, which creates a cycle of ill-health and poverty (Haines, Kovats et al. 2006, Sheffield and Landrigan 2011, Billah, Saha et al. 2017). Despite this understanding, there is limited information on how changes in climatic conditions i.e. temperature and rainfall, associate with child nutritional status especially in sub-Saharan African region, let alone pathways through which such association operates (Haines, Kovats et al. 2006, Costello, Abbas et al. 2009). Addressing child malnutrition is one of the major development goals highlighted in Sustainable Development Goals (SGDs) 2016-2030, and locally in Malawi Growth and Development Strategy III (MGDSIII), 2016-2022, on account that malnutrition contributes to higher disease burden among half of under-five children (Bowie 2006, Lelijveld, Seal et al. 2016, MalawiGovernment 2017).

Literature reviewed in this study i.e. Stevens and Madani (2016) Parry, Rosenzweig et al. (1999) reveal that for countries like Malawi which rely on rain fed agriculture for food production, variations in climatic conditions affect food availability, which is key to better nutritional status (Olson 1999, FAO 2015). A conceptual framework for the current study suggested that apart from childhood infections and diseases leading to under-five child malnutrition in Malawi, poor crop yield and food insecurity influenced by changes in climatic conditions could be another significant pathway explaining child malnutrition. However, evidence linking changes in climatic variables to child malnutrition through this pathway is scanty, yet the south East African sub-continent where Malawi is located is increasingly experiencing climatic variability (Kula, Haines et al. 2013, Stocker, Qin et al. 2013). Such information gap affect design and implementation of policy interventions to address child malnutrition in the era of climate change. The current chapter attempted to address this gap by examining association of variations in selected cropping season temperature and rainfall variables with under-five children's nutritional status in Malawi, accounting for some households' demographic and socioeconomic conditions.

8.2. Analytical framework, data and methods used to examine factors associated with under-five children's nutritional status

8.2.1. Analytical framework

Figure 38 is the analytical framework for this chapter, showing type of data used, level at which the data were aggregated, variables used in the analysis and the outcomes. In the figure, there are two groups of variables; demographic and Socio-economic variables, and climatic variables i.e. temperature and rainfall. Climatic variables were aggregated at meteorological station level in each district, while demographic and socioeconomic variables were at household level. The variables at station level were total rainfall, its onset, its cessation, duration and dry-days in a cropping season, minimum and maximum temperatures, all for the cropping season matched with the IHS2010/11 demographic and socioeconomic data. Climatic variables were thought to have a direct association with food availability through crop yield on the farm, where seasonal changes have varying effects on plant growth processes and ultimately yield.

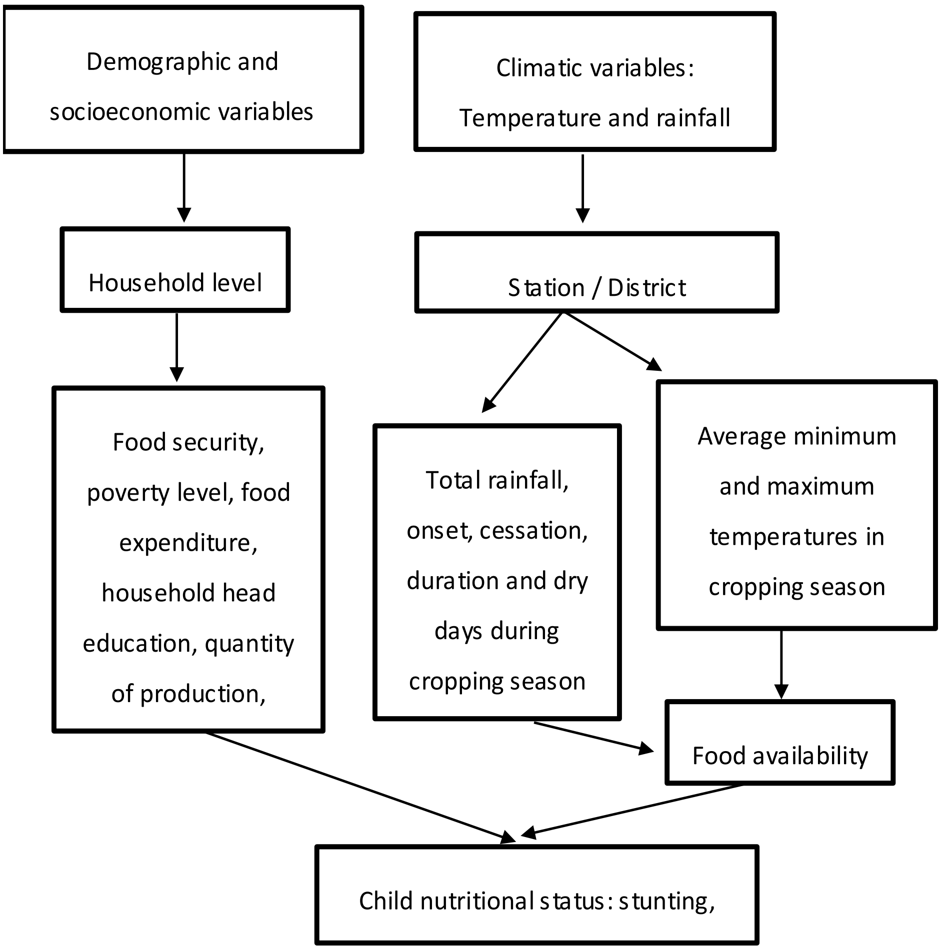


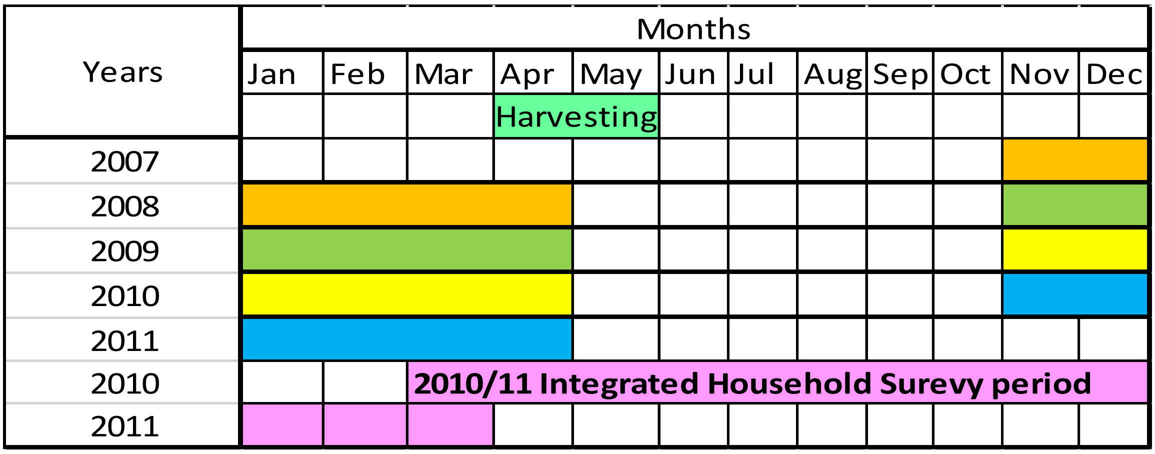
Figure 38.Analytical Framework for examining factors associated with under-five children's nutritional status in Malawi.

In Malawi, crop yield directly relates to food availability on the household because it is the major source of food. This ultimately influences quantity of food available to the household as well as its quality, both of which affects the patterns of consumption, key to nutritional conditions of household members. Demographic and socioeconomic factors associated with nutritional conditions operate at household level, i.e. characteristics of the household head (age, sex) household size, poverty level, expenditure on food among others. These factors modulate food production, acquisition and consumption patterns on the household, all of which could be associated with nutritional outcomes among members.

8.2.2. Data used in the analysis

Daily temperature and rainfall data were averaged to monthly for Malawi's cropping season, which in a normal rainfall year runs from November when rainfall commences, to April when harvest of staple food crops commences. The cropping season is thus an overlapping one i.e. November of one calendar year to April of another calendar year. Climate data used in the analysis were restricted to the 2008/09, 2009/10 and 2010/11 cropping seasons as shown in Table 20, to coincide with assessment of household food security situation during the survey period; March 2010 to March 2011.

Table 20. Schedule of Malawi's cropping seasons and IHS2010 survey



Years	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
				Harvesting								
2007											🟧	🟧
2008	🟧	🟧	🟧	🟧							🟩	🟩
2009	🟩	🟩	🟩	🟩							🟨	🟨
2010	🟨	🟨	🟨	🟨							🟦	🟦
2011	🟦	🟦	🟦	🟦								
2010			**2010/11 Integrated Household Surevy period**									
2011	🟪	🟪	🟪									

Colour Key:
Cropping seasons

🟧	2007/08
🟩	2008/09
🟨	2009/10
🟦	2010/11

Since the 2010/11IHS started in March 2010 ending in March 2011, households interviewed in March 2010 reported about the food situation influenced by rainfall and temperature conditions on crop yield harvests from the 2008 to 2009 cropping season, whether from own production or purchases (Table 21). Households interviewed in April to October 2010 reported about their food situation through crop yield and harvest influenced by temperature and rainfall patterns for the 2009 to 2010 cropping season. Households interviewed between November 2010 to March 2011 reported about their food situation influenced by temperature and rainfall conditions on crop yield for the 2010/11 cropping season.

This approach was adopted to match temperature and rainfall data used in this analysis with the period of the IHS2010/11, since focus of the analysis was assessment of association between patterns of these climatic variables with nutritional conditions of children using cross-sectional survey and climate data. Some studies i.e. Bose, Biswas et al. (2007) and Onis (2006) observed that some forms of child malnutrition take longer to detect i.e. stunting, suggesting that a cross-sectional (seasonal) assessment of climatic influences on malnutrition may not provide plausible results since the period of household exposure to the influence of inordinate climatic conditions that could influence crop yield and food availability leading to malnutrition is short.

However, this study argues that other forms of malnutrition i.e. wasting could be detected within the period of analysis since this condition is an immediate result of severe food deficiency or frequent, severe illnesses (Linneman, Matilsky et al. 2007, Briend, Khara et al. 2015) within a short time, which can cause malnutrition. As such, it was envisaged possible to detect other forms of nutritional conditions from a cross-sectional analysis because in a country like Malawi, a seasonal crop failure due to climatic hazards could negatively alter household food consumption patterns, which could facilitate poor nutritional conditions among children under-five.

Temperature and rainfall data used in the analysis were aggregated at met station or district level for the 27 districts covered in the analysis. This involved summing daily rainfall for a given district i.e. Blantyre, for the entire cropping season. For other variables i.e. temperature, a cropping season average for the station/district was used to generate the variables. Seven variables were generated from these data i.e. total cropping season rainfall, its onset, cessation, duration, number of dry days, minimum and maximum temperatures during the season. This file was merged to the IHS2010 household file which had information about demographics and socioeconomic conditions of the households including child anthropometric information. The new file was then merged with the food security information, making one data file comprising climatic, demographic and socio-economic, food security and child anthropometry variables.

Studies have reported that there are various socio-economic and demographic factors which influence under-five children’s nutritional conditions (Urke, Bull et al. 2011, Bain, Awah et al. 2013).

Among demographic factors are age of the child, age of the mother, sex of the child and that of the household head, household size and residence of the household (Martorell and Habicht 1986, Ruel and Menon 2002, Frost, Forste et al. 2005). Socio-economic factors include food security and poverty status of the household, education level attained by the household head and mother of the child and residence (rural/urban/subnational) among others (Frost, Forste et al. 2005, Urke, Bull et al. 2011). The current analysis used some of these variables as Table 21 shows.

Table 21 Household level factors associated with child nutritional status

Type of variable	Name	What it measures	Rationale for inclusion in analysis	How it affects child nutritional status
Demographic	Age of child	Physiological growth, essential for determining physical, cognitive and psycho-social growth (Taveras et al,2015)	Age related physiological growth is key to nutritional outcomes (Foster &Garibala,2005). Need to investigate whether it also applies to Malawi.	Demand and utilization of food by the body depends on physiological growth (age), hence key to analysis of nutritional disorders.
	Sex of child	Sex of a child is a biological associate of nutritional status	Sex based disparities on under-five nutritional status have been reported in many studies i.e. Capananza et al, (2018), need to find out whether they apply to Malawi and factors responsible.	Modulated by social and cultural factors i.e. sex influences parental preference in quality of care of children leading to sex-based differentials in nutritional outcomes (Pande, 2003)
Socio-economic	Education of mother	Ability to provide sufficient care to child for growth and development	Educated mothers have economic, biological and technical know-how on child care, essential for good child health and development (Duncan et al, 1991)	Educated mothers have economic access to food, know how on its preparation and feeding practices utilize under-five growth monitoring services important for proper child growth (Duncan et al, 1991)
	Education of household head	Ability to provide sufficient resources i.e. food for child care and development	To measure households' conditions essential for better child health i.e. medical care (Villieries 2013)	Educated household heads provide a conducive environment for proper child growth i.e. food, medication, shelter (Villieries 2013)
	Poverty status of household	Measures economic access to resources on the household	Key indicator of household conditions essential for child health capability to	Studies have shown that poor households have lower chances of having well-nourished

			access food, medical services growth and development services for the child (Zere, et al 2003)	children, hence an important factor to child health especially malnutrition (Zere, et al 2003).
Social	Residence of child's household	Measures access to economic and health services essential for child growth and nutritional status	Residence is one of the key determinants of access to health services i.e. urban settings have better health services essential for child growth than rural.	Areas with better health facilities are likely to have healthy children (Ruel, et al 2002) hence the need to assess disparities in nutritional outcomes on residence.
	Marital status of head	Marital status is considered a social determinant of food access, influencing consumption patterns and nutritional outcomes	Studies i.e. Appoh and Kerkling (2005) have noted significant association with nutritional outcomes hence need to assess this link in Malawi	Married people have a better resource mobilization base with which households acquire food essential for child health (Appoh and Krekling, 2005).

8.2.3. Methods of analysis

8.2.3.1 Assessment of malnutrition among under-five children

Among indicators of children's nutritional status are biochemical, clinical and anthropometric measures (Onis 2006, Uthman 2008). Commonly used anthropometric measurements include mid-upper arm circumference, triceps skin fold, body mass index, weight for height, age for weight, and height for age (Uthman 2008). A weight for age (underweight) index measures body mass relative to age of a child. It shows growth faltering, caused by acute infectious disease and poor nutritional intake. Height for age, (stunting) measures cumulative effects of under-nutrition and infections even before birth (WHO, 2006). Wasting indicates recent and severe process of weight loss often associated with acute starvation or severe disease (Corsi, Subramanyam et al. 2011). Interpretation of these anthropometric measures is based on comparison with standard reference population groups of the same age and sex using Z-scores (standard deviation scores), percentiles, and percent of median (Onis 2006).

The WHO global database on Child Growth and Malnutrition uses a Z-score cut-off point of <-2SD and <-3SD to classify low weight for age, low height for age and low weight for height as moderate and severe malnutrition respectively (de Onis and Habicht 1996, Urke, Bull et al. 2011).

In the current study, Z-scores were used to express anthropometric values as a number of standard deviations below or above the reference mean value, using the formula:

$$Z_i = \frac{X_i - \bar{X}}{S} \quad (36)$$

Where X_1 is the observed (i.e. height for age of a child in the sample), $\bar{X}$ is the sample mean and S the standard deviation of the reference population group. Child nutritional status was assessed by comparing IHS2010 sample of under-five children's (6-59 months) height for age, height for weight and weight for age to the reference population of the WHO Multicentre Growth reference study group developed in 2006. To compute height for age z-scores and weight for age z-scores, data on weight, height, age and sex of children sampled in the study was imported into Anthro software. The weight of children greater than 36kg or less than 0.9kgs were set to missing and heights greater than 138cm or less than 38cm were set to missing to avoid producing implausible results. This approach was also done by Chikhungu and Madise (2014). Once the z scores were computed, any height for age z score greater than 6 or less than -6 was set to missing and any weight for age z scores greater than 5 or less than -5 was also set to missing as per WHO recommendations since these data distort results.

8.2.3.2. Examining association of climatic and household level variables with child nutritional status

There are many factors associated with under-five children's nutritional conditions in different contexts. Table 22 provides a description of variables used in this analysis. The dependent variables were three commonly used indicators for child malnutrition; stunting, wasting and underweight. All these were categorical variables. For stunting, 'not stunted' was the reference category in the analysis, and for wasting 'not wasted' was the reference category, while for underweight, 'not underweight' was the reference category. Independent variables were classified in two levels; individual and household level variables. Among individual variables were child sex, child age, and mother's education level attained. Among household level variables were residence i.e. rural or urban, where the later was the reference category, poverty status i.e. poor and non-poor household, where the later was the reference category, while for food security status; 'food insecure' was the reference category. Other household level variables in the analysis were household size, child's mother education attained, food expenditure, marital status and educational level of the household head.

Climatic variables included in the analysis were total rainfall, its onset, cessation, duration, dry days, minimum and maximum cropping season temperatures.

Table 20.Climatic and household variables for assessing child nutritional status

Variable Type	Name	Categories
Dependent variables	Stunting	Stunted
		Not stunted (ref)
	Wasting	Wasted
		Not wasted (ref)
	Underweight	Underweight
		Not underweight (ref)
Independent variables		
Individual variables	Child sex	Male (ref)
		Female
	Age	
	Mother's education	None (ref)
		Primary
		Secondary & above
Household variables	Residence	Rural
		Urban(ref)
	Poverty status	Poor
		Non-poor (ref)
	Household food sec. status	Food secure(ref)
		Food insecure (ref)
	Household size	
	Food expenditure	
	Educational level of head	None(ref)
		Primary
		Secondary
		Tertiary
	Marital status of head	Married(ref)
		Separated /Divorced
		Widowed
		Never married
Climate variables	Minimum temperature (low, medium, high-Ref)	
	Maximum temperature (low, medium, high-Ref)	
	Total rainfall (low, medium, high-Ref)	
	Rainfall onset (early, normal, late)	
	Rainfall cessation (early, normal, late)	
	Rainfall duration (short, normal, long)	
	Dry-days (short, normal, long)	

8.2.3.3. Bivariate analysis

Bivariate analysis involves analysing two variables often denoted X, Y in order to determine the empirical relationship between them. There are different types of bivariate inference methods amongst which are Student's t-test, Mann-Whitney U test and Chi-square test for normal, skewed and categorical data respectively (Zhang 2016). The current analysis used both Chi-square and Pearson's correlation test to assess association of dependent and independent variables used in the fitted models, because not all variables used were categorical, as some were count variables. Chi-square method compares the frequency of each category of the nominal (independent) variables across categories of the binary (independent) variables in a contingency table. The task involves calculating the expected values of the nominal variables, using the Chi-square formula to test the independence of the variables from each other. For two nominal variables, the expected values are found using the statistical formula:

$$\mathrm{E}_{ij} = \frac{\sum_{k-1}^{l} O_{ij} \sum_{k-1}^{l} O_{kj}}{N} \quad (37)$$

where

E_{ij}= Expected value of the nominal variable
$\sum_{k-1}^{l} O_{ij}$ = Sum of the i_{th} column
$\sum_{k-1}^{l} O_{kj}$ = sum of the k_{th} column
N = Total number of variables

After calculating the expected value, the following formula is applied to calculate the value of the chi-square test of independence between each of the pairs of the variables.

$$x^2 = \sum_{i-1}^{r} \sum_{j-1}^{l} \frac{(O_{ij}-E_{ij})^2}{E_{ij}} \quad (38)$$

Where:

x^2 = Chi-Square test of independence
O_{ij} = Observed value of two nominal variables
E_{ij} = Expected value of two nominal variables

The null hypothesis in the analysis was that there was no association between child, household and district (climatic) variables with stunting, underweight and wasting. This hypothesis was tested by comparing the critical value of the Chi-square distribution to the test statistic, determined by the level of statistical significance i.e. <0.05 p-value (95 percent confidence interval).

If the observed Chi-square test statistic was greater than the critical value, the null hypothesis was rejected, suggesting that the nominal variables are not independent of each other i.e. there is a significant association between the variables. STATA SE14 was used to test the association between each of the independent variables with each of the three dependent variables used in the models assessing factors associated with under-five nutritional status.

8.2.3.4 Multivariate analysis

Multivariate analysis is a statistical procedure for analysing data involving more than one measurement or observation. This procedure may involve solving problems where more than one dependent variable is analysed simultaneously with other variables that are independent (Martinsen and Grimnes 2011). The two general types of multivariate techniques involve analysis of dependence and interdependence, and they are both selected depending on the type of data and the reason for the analysis (Kumar, Singh et al. 2013). Among common multivariate techniques are cluster analysis, principal component analysis, discriminant analysis and logistic regression analysis. Cluster analysis involves identifying separate groups of similar cases. It is also used in summarising data by defining segments of similar cases. Discriminant analysis involves classifying individuals or objects into mutually exclusive and exhaustive groups on the basis of a set of independent variables.

Factor analysis or multiple factor analysis describes variability among observations in terms of potentially lower number of unobserved variables called factors (Kumar, Singh et al. 2013). Principal component analysis decomposes a data table with correlated measurements into a new set of uncorrelated variables called principal components, factors, eigenvectors, singular vectors or loadings depending upon the context (ibd). Regression analysis involves modelling and analysing several variables when the focus is on the relationship between a dependent variable and one or more independent variables (Kumar, Singh et al. 2013). In the current analysis, logistic regression was used to examine association of climatic variables with child nutritional status, controlling for demographic and socio-economic factors. Although linear discriminant analysis (LDA) could have been used, there were some limitations associated with its models which made it not a better option in the current analysis. For instance, LDA requires normally distributed data and violating this assumption affects model parameters i.e. coefficients, standard errors and model fit.

This is uncharacteristic of logistic regression model, which is capable of handling non-normally distributed data variables, a characteristic of independent variables used in the current analysis. Further, the current analysis intended to identify factors associated with under-five children's nutritional status, whether they were significant individually or collectively in the models. In this regard, principal component analysis was not a suitable technique in this analysis as its focus is on identifying key components of factors associated with an outcome variable. In this study, multi-level logistic regression models enabled examining of variance across the levels of predictors, and how it changed with inclusion of various model parameters i.e. random intercept and random coefficients, thus a modelling technique fitting current analysis as it enabled proportioning variance in the levels at which the independent variables used in the model operate, unlike in PCA. By determining how much variation in the outcome variable was contributed by factors at what level i.e. station / district level or household level, the technique was essential in identifying factors which would have to be addressed in interventions to reduce malnutrition among under-five children in the country.

8.2.3.5. Fitting multi-level logistic regression models

The conceptual framework for the study presented in chapter 2 of the thesis shows that factors associated with under-five children's nutritional status are multi-faceted and interlinked, operating at different levels in different contexts. In the current analysis, three levels were considered; child, district and household levels. According to Peugh (2010), multilevel models ensure that model estimates are robust by accounting for model coefficients and variation at different levels of predictor variables unlike ordinary regression analysis. Figure 39 shows levels of variables used in the analysis.

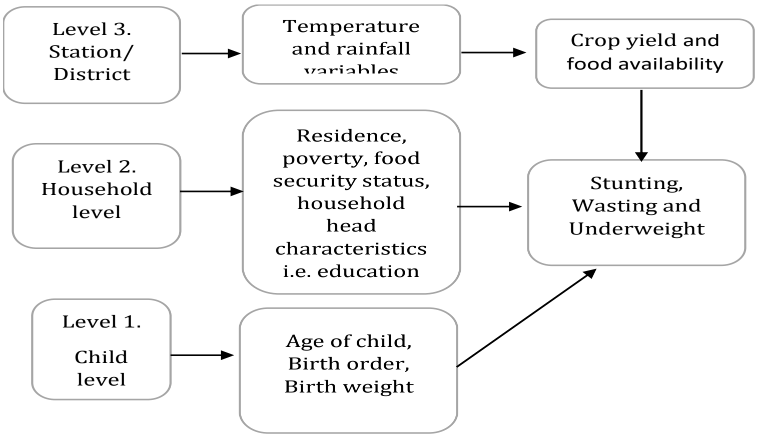


Figure 39.Hierarchy of factors associated with child nutritional status used in the study

In the current analysis, fitting multi-level models enabled examining changes in model estimates at different levels upon inclusion of different model components i.e. fixed and random effects and random intercepts. Logistic regression model was used because the outcome variables had two possible outcomes coded 0 and 1, where 0 stood for failure of the condition i.e. child is not stunted, underweight or wasted, and 1 stood for success of the condition i.e. child is stunted, wasted or underweight. The child level logistic regression model was presented as follows:

$$g\ (\pi_i) = \beta_0 + \beta_1\ X_1 + \beta_2\ X_{2,} + \cdots, + \beta_{mi} X_i \qquad (39)$$

$$\text{where}\ \ g\ (\pi_i) = log_e \left(\frac{\pi_i}{1-\pi_i}\right)\ \text{and} \qquad (40)$$

$$log_e \left(\frac{\pi_i}{1-\pi_i}\right)\ \text{ is odds of success and}$$

$g\ (\pi_i)$ is a function that models the probability that a child is either stunted, wasted or underweight (code =1). β_0 is the constant, and β_1, β_2 and β_{mi} are coefficients of explanatory variables $X_1, X_{2,}$ to X_m. The explanatory variables X_1 to X_m may be factors directly related to the child like age, sex, and those related to the mother i.e. mother's education. The model was extended to include level 2 (household level) variables i.e. residence whether rural or urban, poverty, food security status and size of the household, sex, education level and marital status of the head. The statistical notation for the random intercept model for child i within household j was;

$$log_e \left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \beta_{0j} + \beta_1\ X_{1ij} +, \ldots, + \beta_{mij} X_{mij} \qquad (41)$$

$$\text{Where}\ \beta_{0j} = \beta_0 + u_{0j} \qquad (42)$$

β_{0j} is the random intercept and u_{0j} is the random effect at level 2 (household). The random effect represents the variation of nutritional status for children from different households. Like the standard logistic regression model, it is possible to obtain averaged predicted probabilities for child i within level 2 being stunted, wasted and underweight using the formula and the parameters as explained earlier:

$$\pi_{ij} = \frac{exp(\widehat{\beta_0} + \widehat{\beta_{1\imath\jmath}} +, \ldots, \widehat{\beta_{m\imath\jmath}}\ X_{mij})}{1 + exp\ (\widehat{\beta_0} + \widehat{\beta_{1\imath\jmath}} +, \ldots, \widehat{\beta_{m\imath\jmath}}\ X_{mij})} \qquad (43)$$

Considering that climatic factors i.e. temperature and rainfall variables are at district level, a third multilevel logistic regression model was performed. The level three of the model comprised of district level climatic variables and it was represented as follows for child i in household j and district k.

$$\pi_{ij} = \frac{exp(\widehat{\beta_0}+\widehat{\beta_{1\imath\jmath k}}+,\ldots,\widehat{\beta_{m\imath k\jmath}}\, X_{mijk})}{1+ exp\,(\widehat{\beta_0}+\widehat{\beta_{1\imath\jmath k}}+,\ldots,\widehat{\beta_{m\imath\jmath k}}\, X_{mijk})} \tag{44}$$

This multi-level model could be extended to include a random coefficient at a higher level than the child itself i.e. household, where the variation of the group level factor is significantly different across households. For a child i in household j the model is represented as follows:

$$log_e\left(\frac{\pi_{ij}}{1-\pi_{ij}}\right) = \beta_{0j} + \beta_{1ij}\, X_{1ij}+,\ldots,+\beta_m X_{mij} \tag{45}$$

Where $\beta_{0j} = \beta_0 + u_{0j}$ (46)

$\beta_{1j} = \beta_1 + u_{1j}$ (47)

Where β_0 is the random intercept and u_{0j} is the random error at level 2. β_{1ij} is the random coefficient and u_{1j} is the random error at level 1. Models at level 2 and level 3 have group specific interpretation i.e. the interpretation of coefficients is either at household level or district level.

The variance is partitioned into two levels i.e. τ_u^2 which is district level variance and σ_e^2 which is household level variance. The term variance partitioning coefficient refers to the percentage of variance explained by the higher level i.e. district, represented as:

$$\text{VPC} = \frac{\tau_u^2}{(\sigma_e^2+\tau_u^2)} \tag{48}$$

An alternative way to present this VPC is using an intra-class correlation coefficient (ICC) which in this analysis was the correlation of child stunting, wasting and underweight in the same higher level unit, i.e. district, presented as follows:

$$ICC = \frac{\tau_u^2}{(\sigma_e^2+\tau_u^2)} = vpc \tag{49}$$

In this analysis, the multi-level logistic regression model was fitted in sequence to observe changes in model parameters following inclusion and exclusion of different model attributes i.e. random intercept, level 1 and level 2 predictors.

Among the parameters observed were changes in effect size i.e. odds for predictor variables on the outcome variables, variance explained, significance of predictor variables and goodness of fit. The null model was fit to check average model variance at both household and district levels with respect to the outcome variable. It also showed average odds of a child being stunted, wasted and underweight without considering factors associated with these conditions. Results were compared with subsequent models following adjustments in relation to levels of variation i.e. district or household and effect sizes, significance of predictors and model fit.

The analysis of co-variance (ANCOVA) compares one or more variables in two or more groups taking into account or to correct for variability of other variables or co-variates. The ANCOVA model involved level one predictors i.e. household and child level factors treated as fixed effects whose slope was not predicted by level 2 and it included a random intercept at district level. The purpose of fitting the model was to find out how estimates of child nutritional status varied on account of variability at a higher level, i.e. district level. Essentially, the model predicted the level one intercept (but not the slope of the covariates) as a random effect of the level 2 grouping variable i.e. district.

The random intercept regression model was fit so that the variance of the random intercept model predicts level 1 intercept on the basis of the level 2 grouping variable and one or more level 2 predictors i.e. total annual rainfall, rainfall onset days. Level 1(household level) predictor variables included child age and sex, mother's education level attained, residence of the household, food security sand poverty status of households among others. Results showed the amount of variance introduced by including level two predictors and changes in the effect sizes of level 1 variables following introduction of level 2 predictors. It also showed predictors at the two levels significantly associated with stunting, wasting and underweight.

In a standard regression model, the parameters i.e. slope or intercept are fixed to a single value on the assumption that the sample of the data came from a population with a single slope. However, this assumption can be altered by allowing the slope to vary across individuals and predicted by other co-variates, thus becoming a random slope. This is called a random coefficient model (Garson 2013). In multi-level modelling, the model is also called the 'intercepts-and-slopes-as outcomes model' because level 1 slopes and intercept are modelled not only by the level two grouping variable as a random factor but also by one or more other level 2 variables (ibid).

For instance, the difference in child nutritional status at level 1 (household level) may be analysed, predicting level 1 intercept and the slope of level 1 predictor variable i.e. mother's education level, in terms of groups effect and level 2 (district) variables such as total rainfall. This model was also fit, and assessments on best fit based on model parameters were made to determine variances across the levels of independent variables, effect sizes (odds ratios), standard errors, and pseudo r-squares.

8.3. Results of the analysis

This section presents results of the analysis in this chapter. First presented is distribution of stunting, wasting and underweight among under-five children across demographic and socio-economic characteristics of the sample. Second are results of bivariate analysis on relationship between child nutritional status measures and demographic and socio-economic characteristics of the sampled children. Third are results of multilevel models assessing climatic, demographic and socioeconomic factors associated with child nutritional status in the study.

8.3.1. Prevalence of stunting, wasting and underweight among the sampled under five children

Results in Table 23 show that 61.1 percent of under-five children were stunted, 12.5 percent were wasted and 32 percent were underweight. Among those stunted, 13.4 percent were severely stunted, 17.8 percent were moderately stunted and 29.8 percent were mildly stunted. Only 1 percent of the sampled under-five children were severely wasted, 2.6 percent moderately wasted and 9 percent mildly wasted. Further, 1.3 percent of the children were severely underweight, 5.1 percent were moderately underweight and 25.6 percent were mildly underweight. More male children were stunted, wasted and underweight: 33, 7 and 17 percent respectively, compared to female children; 30, 6 and 15 percent respectively. Higher proportions of stunting were noted among children aged between 12-47 months, while for wasting higher proportions were noted among children aged 36-47 months. The prevalence of underweight children increased with increasing age of the child.

Higher proportion of malnourished children (stunting, wasting and underweight) were recorded in rural than urban areas, among children in poor than non-poor households, those in food insecure households and those whose average annual household food expenditure was below the sample average (Table 23).

Table 21. Percentage of stunting, wasting and underweight in Malawi, 2010/11

Demographic	Categories	Stunted	Wasted	Underweight
Prevalence	**Overall**	**61.1**	**12.5**	**32.0**
	Severe	13.4	1.0	1.3
	Moderate	17.8	2.6	5.1
	Mild	29.8	8.9	25.6
	Healthy	39.0	87.5	68.0
	Total	**100**	**100.0**	**100**
Sex	Male	31.6	6.9	17.1
	Female	29.5	5.6	14.9
	Total	**61.1**	**12.5**	**32.0**
Age in months	6-11	4.2	1.3	2.2
	12-23	12.7	2.7	5.6
	24-25	14.9	2.5	7.4
	36-47	15.4	3.1	8.1
	48-59	13.9	2.9	8.7
	Total	**61.1**	**12.5**	**32.0**
Residence	Urban	8.9	1.4	3.8
	Rural	52.2	11.1	28.2
	Total	**61.1**	**12.5**	**32.0**
Poverty status	Non-Poor	26.7	5.0	12.9
	Poor	34.4	7.5	19.1
	Total	**61.1**	**12.5**	**32.0**
Food security	Food secure	26.2	5.7	14.1
	Food insecure	34.9	6.8	17.9
	Total	**61.1**	**12.5**	**32.0**
Food exp.	Below average	39.4	8.7	21.4
	Above average	21.7	3.8	10.6
	Total	**61.1**	**12.5**	**32.0**
Mother ed.	None	51.1	10.5	27.4
	Primary	5.1	1.1	2.7
	Secondary+	4.9	0.9	1.9
	Total	**61.1**	**12.5**	**32.0**
Father ed.	None	43.8	9.4	24.4
	Primary	6.6	1.2	3.2
	Secondary	9.8	1.8	4.0
	Tertiary	0.9	0.1	0.4
	Total	**61.1**	**12.5**	**32.0**
Marital S.	Married	52.4	10.7	27.2
	Separated, divorced	5.2	1.2	3.0
	Widow or widower	3.3	0.5	1.7
	Never married	0.2	0.1	0.1
	Total	**61.1**	**12.5**	**32.0**

p-value :0.05

Higher proportion of stunting, wasting and underweight were noted among children whose head of the household had no education level attained: 44 percent for stunting, 9 percent for wasting and 24 percent for underweight. Table 24 shows that among demographic variables, child sex and residence were significantly associated with the three anthropometric measures, while child age was significantly associated with stunting and underweight, not wasting.

Table 22.Chi-square test of independence results for variables use in the models

		Stunting		Wasting		Underweight	
Category	Variable	Chi^2 statistic	P-value	Chi^2 statistic	P-value	Chi^2 statistic	P-value
Demographic	Age of child	100.8	0.000	6.7	0.151	99.1	0.000
	Mother ed.	34.2	0.000	5.2	0.073	47.5	0.000
	Sex of child	13.4	0.000	14.8	0.000	18.2	0.000
Soc-economic	Food exp.	0.1	0.806	20.5	0.000	10.6	0.001
	Household size	0.9	0.630	2.0	0.373	2.5	0.294
	Food sec.status	0.0	0.832	4.6	0.032	3.3	0.068
	Marital Status.	10.5	0.015	5.4	0.144	15.3	0.002
	Head. Ed.	30.1	0.000	13.3	0.004	56.3	0.000
	Poverty status.	4.8	0.028	8.5	0.004	29.1	0.000
	Residence	9.6	0.002	15.5	0.000	37.1	0.000
Climatic	Max. temp.	4.8	0.089	1.9	0.396	1.9	0.396
	Min. temp.	33.3	0.000	2.5	0.293	28.9	0.000
	Total rainfall	75.3	0.000	32.8	0.000	37.7	0.000
	Onset days	68.9	0.000	3.0	0.224	1.2	0.543
	Cessation days	7.7	0.006	4.8	0.028	14.5	0.000
	Duration days	66.4	0.000	3.3	0.192	0.1	0.958
	Dry days	17.3	0.000	0.4	0.834	3.1	0.217

p-value :0.05

Poverty status of the household, marital status of the household head, residence and education level attained by the household head were significantly associated with child stunting. Households' mean annual food expenditure, food security status, education level attained by the household head, poverty status and residence of the household had significant associations with child wasting. Minimum growing season temperatures, total rainfall and its cessation had significant associations with underweight, while total rainfall and its cessation had significant associations with wasting. Total rainfall, its onset, cessation, duration, dry days and minimum crops growing season temperatures were significantly associated with child stunting.

8.3.2. Results for multivariate analysis on factors associated with child nutritional status.

Prior to fitting multilevel logistic regression models, ordinary logistic regression models were fitted to examine association of selected demographic and socio-economic factors with stunting, wasting and underweight. Results provided a picture about demographic and socio-economic variables significantly associated with the three anthropometric measures. Table 25. shows results of the analysis, where mother's education was significantly associated with stunting and underweight (category secondary school and over) unlike wasting. For stunting, the higher the education level attained by the mother (primary to secondary school), the lower the odds of stunting for the child; OR 0.76, CI:0.64-0.90, compared to a mother with no education at all. Only after the mother attained secondary school do the odds of being underweight among the children significantly lower, compared to when the mother had no education, OR 0.72, CI:0.57-0.90.

Education level of the household head was significantly associated with stunting when the head attained tertiary education and with underweight when the head attained secondary school education. The odds of a child being stunted were lower if the head attained tertiary education, OR 0.66, CI:0.42-0.88, and the odds of a child being underweight were lower if the head of the household attained secondary school education; OR 0.78, CI:0.66-0.92 (Table 25). Only wasting and underweight were significantly associated with residence of the child. Children residing in rural areas had higher odds of being wasted and underweight compared to those residing in urban areas; OR 1.35, CI:1.07-1.71, and OR 1.28, CI:1.01-1.50 respectively. Household size was only significant with child stunting when household members totalled 7 or more but non-significant to wasting and underweight. Mean annual household expenditure on food was significantly associated with wasting in the studied children and not stunting and underweight. Children living in households spending below the sample's mean annual expenditure on food had higher odds of being wasted compared to those whose households spent above the sample's mean annual food expenditure; OR1.27, CI:1.06-1.53.

Table 23.Logistic regression model results on factors associated child nutritional status, IHS2010

Predictors	Stunting		Wasting		Underweight	
	OR (95% CI)	*p-value*	OR (95% CI)	*p-value*	OR (95% CI)	*p-value*
Child level factors						
Sex						
Male (Ref)						
Female	0.83(0.76-0.91)	0.000	0.76(0.66-0.88)	**0.000**	0.80(0.86-0.88)	0.000
Child age						
6-12 (Ref)						
11.23	1.63(1.36-1.95)	**0.000**	0.87(0.69-1.17)	0.422	1.06(1.18-1.77)	0.609
24-35	2.12(1.77-2.54)	**0.000**	0.77(0.59-0.99)	**0.044**	1.45(1.18-1.77)	**0.000**
36-47	2.20(1.84-2.63)	**0.000**	0.94(0.72-1.21)	0.628	1.60(1.30-1.96)	**0.000**
48-59	2.11(1.75-2.53)	**0.000**	1.00(0.77-1.31)	0.968	2.07(1.67-2.54)	**0.000**
Mother education						
None (Ref)						
Primary	0.76(0.64-0.90)	**0.001**	1.05(0.81-1.37)	0.705	0.97(0.80-1.17)	0.722
Secondary & over	0.78(0-64-0.95)	**0.012**	1.03(0.75-1.41)	0.856	0.72(0.57-0.90)	**0.005**
Household level factors						
Urban (Ref)						
Rural	1.08(0.93-1.23)	0.316	1.35(1.07-1.71)	**0.010**	1.28(1.01-1.50)	**0.002**
Poverty status						
Poor (Ref)						
Non-poor	1.03(0.75-1.40)	0.863	1.03(0.93-1.25)	0.741	0.89(0.78-1.02)	0.097
Food security status						
Food secure (Ref)						
Food insecure	1.20(0.94-1.52)	0.148	1.08(0.93-1.25)	0.302	1.01(0.91-1.12)	0.860
Household size						
4 or less (Ref)						
5-6	0.93(0.83-1.05)	0.225	0.930(0.78-1.15)	0.413	0.06(0.90 -1.16)	0.744
7 and over	0.85(0.74-0.97)	**0.016**	0.94(0.77-1.14)	0.551	0.07(0.85-1.13)	0.758
Mean food expenditure						
Above mean exp'ture (Ref)						
Below mean exp'ture	1.13(0.99-1.29)	0.063	1.27(1.06-1.53)	**0.010**	0.99(0.87-1.13)	0.858
HH Education level						
None (Ref)						
Primary	1.03(0.88-1.21)	0.694	0.84(0.66-1.08)	0.178	0.90(0.76-1.07)	0.242
Secondary	0.92(0.79-1.07)	0.261	0.88(0.70-1.11)	0.304	0.78(0.66-0.92)	**0.003**
Tertiary	0.66(0.42-0.88)	**0.008**	0.56(0.27-1.16)	0.118	0.72(0.55-1.13)	0.154
Marital status						
Married (Ref)						
Separated/Divorced	1.23(0.94-1.35)	0.205	1.13(0.89-1.45)	0.317	1.22(1.02-1.47)	**0.032**
Widowed	1.20(0.96-1.51)	0.104	0.852(0.61-1.19)	0.350	1.02(0.81-1.29)	0.841
Never married	0.66(0.30-1.46)	0.305	1.52(0.51-4.50	0.452	0.85(0.33-2.16)	0.728

Results in table 25 show that sex of a child had significant association with the three anthropometric indicators, where female children had lower odds of being stunted, wasted and underweight compared to their male counterpart; OR 0.83, CI: 0.76-0.91, OR 0.76, CI:0.66-0.88, and OR 0.80, CI:0.86-0.88 respectively. All ages of a child were significantly associated with stunting, but for wasting, significant association was noted at 24-35 months. For underweight, significant association with age of a child was noted from age 24-35 months through 48-59 months. Figure 40 and 41 shows that child stunting and underweight increased with increasing age, decreasing after age 35-47 for stunting.

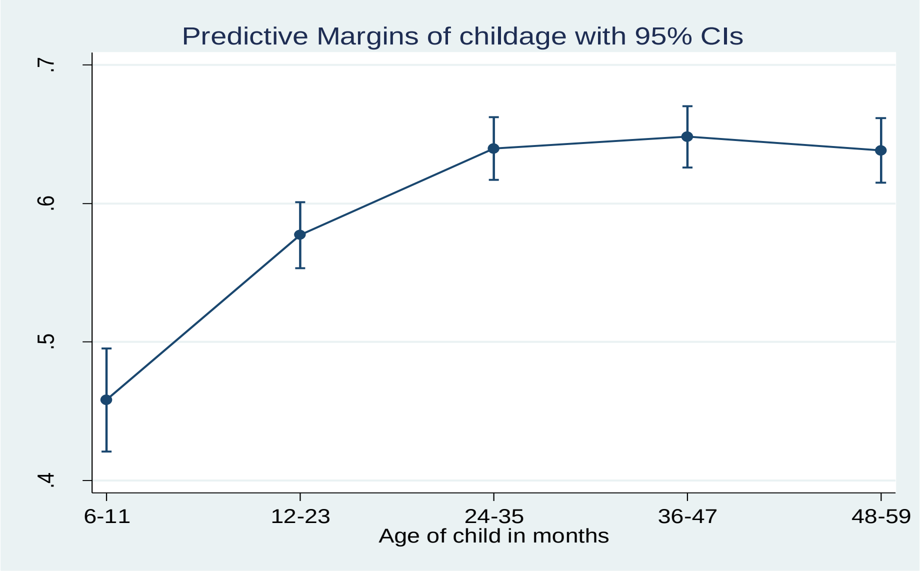


Figure 40.Predicted probabilities of stunting among under-five children by age of child

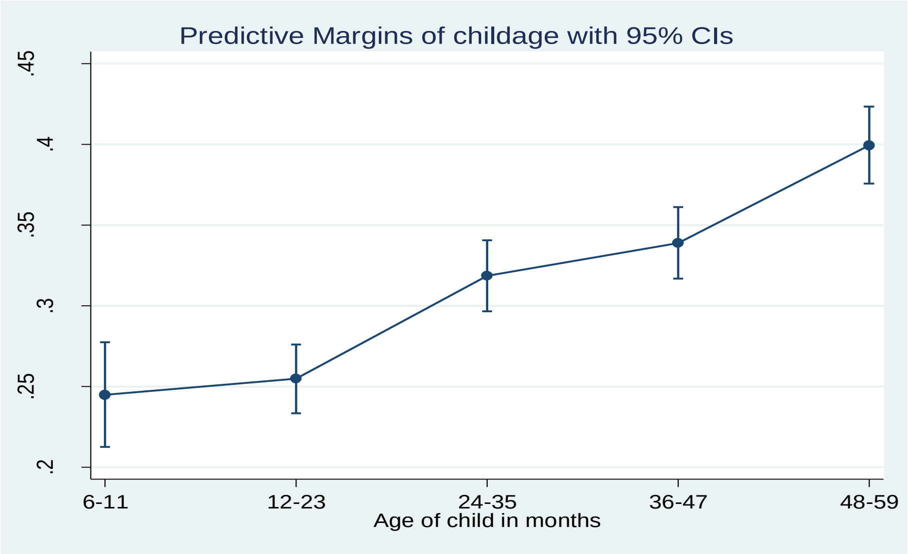


Figure 41.Predicted probabilities of underweight in children by age in months based on individual level predictors

8.3.3. Multilevel model results on climate and household level factors associated with child stunting

Results for the null model on stunting show that comparison between the likelihood ratio of the null model to the ordinary least squared regression model showed a Chi^2 value of 532.37, significant at p-value 0.000 (Table 26). A non-significant Chi^2 result entails upper level variation does not affect the outcome of the model. In that situation, ordinary least squared regression model would be fit. However, current results show that the likelihood ratio test was statistically significant, indicating significant variation in stunting on account of district level factors. In this situation a random intercept model is essential in the analysis.

Diagnostics for goodness of fit for the model show average unexplained variance of 0.571, CI: 0.330-0.998 at district level (level 2) and 1.921, CI: 1.342-2.600 at household level (level1) (Table 26). The total variance in the model was 2.492, and the variance partitioning coefficient was 0.2291, indicating that the proportion of variance at level 2 is 23 percent. The result suggests that more variation in child stunting is influenced by household than district level factors. The average intra-class correlation coefficient (ICC) at district level was 0.10, CI: 0.06-0.16 and at household level, 0.431, CI: 0.361-0.502). As in ordinary Pearson's correlation coefficient, these two ICC coefficients indicate that on average the extent of shared variance in stunting among the sampled children at both levels was generally low.

Results of the second model; with a level 2 (district) random intercept component and level 1 variables show a lower residual intra-class correlation coefficient; 0.088, CI: 0.054-0.1414, suggesting a low shared variance on children's odds of stunting on account of level 2 factors (table 26). The district level variance decreased from 0.571 in the null model to 0.318 in the random intercept model. The AIC also decreased from AIC 9497.7 in the null to 9449.1 in the random intercept model. The Chi^2 statistic of the likelihood ratio test versus the logistic regression model was 408.74, statistically significant at p-value 0.000. The decreases in the model fit diagnostics statistics and the significant Chi^2 statistic of the likelihood ratio test demonstrate that accounting for level 2 variation in assessing child stunting in this analysis was appropriate.

Table 26 Results for multi-level logistic regression modes on of factors associated with child stunting in Malawi

Variables and Level of analysis	Model 1. (Intercept only)		Model 2: Random Intercept (Child and Household variables included)		Model 3. Random intercept : Child, Household and Climate variables included		Model 4. Random intercept and coefficient Model: Child, Household & Climate variables included	
	OR(95% CI)	*SE*	OR (95% CI)	*p-value*	OR (95% CI)	*p-value*	OR(95% CI)	*p-value*
Child level								
Sex								
Male (Ref)								
Female			0.82(0.74-0.90)	**0.000**	0.87(0.77-0.96)	**0.018**	0.83(0.49-0.98)	**0.025**
Child age								
6-12 (Ref)								
12-23			1.71(1.42-2.06)	**0.000**	1.70(1.87-2.12)	**0.000**	2.05(1.49-2.83)	**0.000**
24-35			2.31(1.91-2.76)	**0.000**	2.24(1.78-2.82)	**0.000**	3.18(2.29-4.41)	**0.000**
36-47			2.30(1.91-2.77)	**0.000**	2.22(1.76-2.79)	**0.000**	3.05(2.21-4.22)	**0.000**
48-59			2.28(1.88-2.75)	**0.000**	2.21(1.76-2.79)	**0.000**	3.12(2.24-4.35)	**0.000**
Mother education								
None (Ref)								
Primary			0.84(0.70-0.84)	0.057	0.84(0.68-1.03)	0.101	0.77 (0.56-1.05)	0.097
Secondary & over			0.82(0.70-0.82)	**0.050**	0.75(0.60-0.95)	**0.017**	0.68(0.48-0.97)	**0.031**
Household level								
Urban (Ref)								
Rural			1.10(0.87- 1.41)	0.414	1.09(0.77-1.55)	0.615	1.12(0.67-1.89)	0.664
Poverty status								
Poor (Ref)								
Non-poor			0.83(0.72-0.95)	**0.008**	0.85(0.71-1.00)	**0.050**	0.81(0.63-1.04)	0.102
Food security status								
Food secure (Ref)								
Food insecure			1.00(0.90-1.11)	0.965	0.98(0.86-1.11)	0.713	1.00(0.82-1.21)	0.965
Household size								
4 or less (Ref)								
5-6			0.89(0.79-1.01)	0.067	0.95(0.82-1.10)	0.482	0.92(0.74-1.14)	0.446
7 and over			0.84(0.73-0.96)	**0.014**	0.86(0.72-1.02)	0.080	0.80(0.62-1.04)	0.094
Mean food expenditure								

Above mean exp (Ref)						
Below mean exp	0.83(0.72-0.94)	**0.004**	0.07(0.75-1.03)	0.115	0.84(0.66-1.04)	0.146
Education level of head						
None (Ref)						
Primary	1.13(0.95-1.34)	0.161	1.19(0.97-1.46)	0.092	1.32(0.73-1.44)	0.076
Secondary	1.00(0.85-1.17)	0.961	1.01(0.84-1.22)	0.913	1.02(0.78-1.35)	0.865
Tertiary	0.66(0.45-0.96)	**0.029**	0.73(0.48-1.10)	0.130	0.59(0.32-1.09)	0.093
Marital status of head						
Married (Ref)						
Separated/Divorced	1.09(0.90-1.32)	0.394	1.05(0.83-1.05)	0.699	1.03(0.73-1.44)	0.885
Widowed	1.31(1.04-1.70)	**0.023**	1.18(0.88-1.59)	0.263	1.24(0.81-1.92)	0.327
Never married	0.70(0.31-1.60)	0.378	0.71(0.30-1.66)	0.432	0.61(0.18-2.11)	0.438
District level variables						
Minimum temperature						
Average(ref)14-20°C						
High:≥21°C			1.51(0.86-2.67)	0.150	1.85(0.81-4.27)	0.147
Low:15≤°C			0.38(0.23-0.65)	**0.000**	0.27(0.12-0.61)	**0.001**
Maximum temperature						
Average(ref):24-26°C						
above average:≥27°C			0.92(0.54-1.57)	0.758	0.87(0.39-0.37-)	0.730
below average:≤23°C			3.99(1.91-8.33)	**0.000**	6.38(1.40-1.92)	**0.001**
Total rainfall						

Average(ref)700-1499mm								
above average:≥1500mm					1.32(0.78-2.24)	0.301	1.44(0.67- 3.08)	0.349
below average: ≤699mm					0.40(0.28-0.58)	**0.000**	0.28(0.16-0.48)	**0.000**
Rainfall onset								
Average: 120-130dys								
above average:≥131dys					1.34(0.93-1.93)	0.122	1.52(0.88-2.61)	0.129
below average :≤199					1.16(0.86-1.57)	0.333	1.26(0.81- 1.98)	0.308
Rainfall duration								
Average(ref)120-135								
above average:≥136					1.39(0.81-2.36)	0.230	1.59(0.71-3.56)	0.260
below average :≤120					1.84(1.30-2.61)	**0.001**	2.37(1.41-4.01)	**0.001**
Dry-days								
Average(ref) 81-90dys								
above average: ≥90					1.10(0.63-1.91)	0.737	1.13(0.49-2.57)	0.775
below average:≥80					1.04(0.75-1.50)	0.804	1.05(0.64-1.72)	0.853
Model diagnostics								
Variance parameters								
District level	0.57(0.33- 1.00)	0.160	0.03(0.19-0.54)	**0.09**	0.12(0.05-0.27)	**0.050**	0.26(0.11-0.60)	0.111
Household level	1.92(1.42 -2.60)	0.296					2.45(1.73 - 3.48)	0.438
Likelihood ratio test	532.37	0.000	408.74	0.000	56.83	**0.000**	150.21	**0.000**
Intra-class correlation								
District level (ICC& Std Error)	0.10(0.06-0.16)	0.024(SE)	0.09(0.05 -0.14)	**0.02**	0.03(0.02-0.08)	**0.014**	0.043(0.02-0.09)	
Household level	0.43(0.36- 0.50)	0.036(SE)					0.45(0.37- 0.54)	
Model fit Statistics								
AIC	9497.7		9449.1		6423.6		6332.2	
BIC	9518.4		9594.5		6639.1		6554.4	

In the third model, level 2 variables i.e. cropping season total rainfall, onset, cessation and duration of the rainfall, minimum and maximum temperatures were included, having maintained the random intercept and level 1 variables. Results of the model showed that the residual intra-class correlation coefficient decreased from 0.088 in the random intercept model with fixed effects, to 0.03, CI: 0.02-0.080 in the random intercept model with fixed effects and level 2 variables. There were decreases in unexplained variance at district level from 0.318 in the previous model to 0.119, CI: 0.05-0.27 in the current model, and for the AIC and BIC, from 9449.1 and 9594.5 in the previous model to 6423.6, and to 6639.1 respectively. The Chi^2 statistic of the likelihood ratio also drastically decreased from 408.7 to 56.8 in the current model, p-value 0.000. These decreases in model diagnostics indicated that the model with a random intercept at level 2, level 1 and 2 variables was a better fit than the one before.

The fourth model involved a random intercept at level 2 and random coefficient at level 1, with level 1 and level 2 predictors. Results show that including random coefficient component in the previous model more than doubles the size of unexplained variance at district level, increased from 0.12 in the previous model to 0.26, CI: 0.11-0.60 in the current model. The likelihood ratio test almost triples from 56.83 in the previous model to 150.21 in the current. However, there were decreases in the AIC and BIC statistics from the previous to the current i.e. 6423.6 and 6639 in the previous model to 6332.22 and 6554.4 in the current model respectively. The VPC decreased from 0.23 in the first null model to 0.095 in the fourth model. In essence, allowing variation of the model parameters at district and household level reduces district level variance to 10 percent, suggesting that more variation in child stunting occurs at household level.

There were increases in the size of odds of a child being stunted across age of the child in the current model compared to the previous model. Children aged 12-23 months had 2 times the odds of being stunted, OR 2.05, CI: 1.49-2.83, compared to those aged 6-11 months, almost double the odds in the previous model. Children aged 24-35 months had 3 times as much odds of being stunted compared to those aged 6-11 months, OR 3.18, CI: 2.29-4.41, and those aged 36-47 months also had 3 times the odds of being stunted OR 3.05, CI: 2.21-4.22 compared to those aged 6-12 months. Children aged 48-57 months had 3 times the odds of being stunted, OR 3.12, CI: 2.24-4.35 compared to those aged 6-11 months.

Among climatic variables, the odds of stunting for a child whose household was in a district with below average cropping season minimum temperatures (<23°C) were lower; OR 0.27, CI: 0.13-0.60 compared to one whose household was located in a district that experienced average minimum cropping season temperatures during the cropping season (24-26°C). A child from a household in a district with short rainfall duration during the cropping season (<120 days) had 2 times the odds of stunting, OR 2.37, CI: 1.41-4.01, compared to one from a household in a district with average rainfall duration during the season (>120-135 days).

8.3.4. Multilevel model results on climate and household level factors associated with child wasting

Among the sampled children, the null model for wasting shows an average variance of 0.251, CI: 0.13-0.49 at district level and 1.44, CI: 0.89-2.34 at household level (Table 27), with a VPC of 0.148, indicating a 15 percent variation in child wasting occurring at district level. Like stunting, there is more variation in child wasting at household than district level. The intra-class correlation coefficient of the residuals were 0.05, CI: 0.002-0.009 at district level, and 0.34, CI: 0.25-0.45 at household level, suggesting lower correlation of wasting among children across households and districts, somehow higher at household level. The likelihood ratio Chi^2 test (comparing the null and the ordinary logistic regression) was 108.8, statistically significant at p-value 0.000, and the AIC and BIC were 5411.9 and 5432.6 respectively.

Results for a random intercept model showed a lower residual intra-class correlation coefficient; 0.047, CI: 0.024-0.089, indicating no correlation in the odds of child wasted at district level. Level 2 variance decreased from 0.251 in the null model to 0.162, CI: 0.08-0.32 in the current model (Table 27). The likelihood ratio test Chi^2 statistic also decreased from 108.9 in the null model to 61.04 in the random intercept model with fixed effects and no level 2 predictors. However, unlike with stunting, the AIC and BIC statistics moderately increased in the random intercept model compared to the null; 5411.9 and 5432.6 in the null model to 5420.8 and 5565.5 in the model with a random intercept, fixed effects and no level 2 predictors.

Table 27 Results for multi-level logistic regression models on of factors associated with wasting in Malawi

Variables and Level of analysis	Model 1. (Intercept only)		Model 2: Random Intercept (Child and Household variables included)		Model 3. Random intercept : Child, Household and Climate variables (District level) included		Model 4. Random intercept and coefficient Model (Child, Household & Climate variables) included	
	OR(95% CI)	*SE*	OR (95% CI)	*p-value*	OR (95% CI)	*p-value*	OR(95% CI)	*p-value*
Child level factors								
Sex								
Male (Ref)								
Female			0.78(0.67-0.89)	**0.000**	0.83(0.70-0.99)	**0.035**	0.79(0.65-0.97)	**0.025**
Child age								
6-12 (Ref)								
12-23			0.89(0.68-1.16)	0.392	0.96(0.68-1.36)	0.814	0.947(.63-1.42)	0.793
24-35			0.78(0.58-1.02)	0.070	0.94(0.67-1.33)	0.732	0.93(.62-1.38)	0.715
36-47			0.93(0.72-1.22)	0.610	1.21(0.86-1.70)	0.273	1.23(0.83-1.81)	0.295
48-59			1.00(0.77-1.32)	0.943	1.17(0.83-1.65)	0.372	1.18(0.79-1.75)	0.415
Mother education								
None (Ref)								
Primary			1.08(0.82-1.40)	0.590	1.14(0.83-160)	0.408	1.17(0.80- 1.70)	0.421
Secondary & over			1.05(0.77-1.45)	0.750	1.36(0.93-1.97)	0.110	1.43(0.92-2.22)	0.111
Household level factors								
Urban (Ref)								
Rural			1.34(0.96-1.87)	0.078	1.83(1.01-3.32)	**0.045**	2.03(1.02-4.04)	**0.042**
Poverty status								
Poor (Ref)								
Non-poor			1.05(0.87-1.29)	0.566	0.97(0.76-1.24)	0.806	0.96(0.72- 1.29)	0.785
Food security status								
Food secure (Ref)								
Food insecure			1.06(0.91-1.23)	0.455	1.13(0.94-1.36)	0.210	1.16(0.93-1.45)	0.192

Household size						
4 or less (Ref)						
5-6	0.94(0.79-1.12)	0.510	0.87(0.70-1.08)	0.200	0.84(0.65-1.09)	0.191
7 and over	0.98(0.81-1.20)	0.880	0.86(0.67-1.10)	0.231	0.83(0.61-1.12)	0.231
Mean food expenditure						
Above mean exp (Ref)						
Below mean exp	1.33(1.11-1.61)	**0.002**	1.36(1.08-1.72)	**0.010**	1.40(1.06-1.85)	**0.018**
Education level of head						
None (Ref)						
Primary	0.88(0.68-1.13)	0.310	0.79(0.58-1.08)	0.135	0.76(0.53- 1.10)	0.151
Secondary	0.92(0.73-1.17)	0.500	0.80(0.60-1.07)	0.131	0.78(0.55- 1.10)	0.155
Tertiary	0.58(0.28-1.21)	0.146	0.38(1.54-0.92)	**0.032**	0.34(0.13-0.92)	**0.034**
Marital status of head						
Married (Ref)						
Separated/Divorced	1.15(0.90-1.48)	0.262	0.97(0.71-1.32)	0.830	0.97(0.66-1.41)	0.867
Widowed	0.88(0.63-1.23)	0.458	0.85(0.55-1.32)	0.470	0.81(0.48- 1.35)	0.419
Never married	1.50(0.50-4.50)	0.471	1.11(0.32-3.89)	0.865)	1.17(0.27-5.06)	0.830
District level variables						
Minimum temperature						
Average(ref)						
above average			1.62(0.88-2.99)	0.120	1.74(0.86- 3.52)	0.122
below average			1.38(0.71-2.69)	0.349	1.47(0.66- 3.29)	0.342
Maximum temperature						
Average(ref)						
above average			0.86(0.45-1.62)	0.638	0.85(0.41-1.77)	0.666
below average			1.46(0.61-0.3.52)	0.394	1.56(0.55-4.41)	0.403
Total rainfall						
Average(ref)						
above average			0.46(0.23-0.93)	**0.031**	0.40(0.17-0.90)	**0.027**
below average			0.62-(0.40-0.97)	**0.036**	0.56(0.34-0.95)	**0.032**
Rainfall onset						

Average								
above average					0.96(0.62-1.48)	0.842	0.96(0.57- 1.61)	0.875
below average					0.86(.587-1.24)	0.413	0.81(0.52-1.25)	0.342
Rainfall duration								
Average(ref)								
above average					0.919(.43-1.98)	0.829	0.927(0.37-2.30)	0.871
below average					1.85(1.22-2.79)	**0.004**	2.06(1.27- 3.34)	**0.003**
Dry-days								
Average(ref)								
High					1.29(0.61- 2.69)	0.506	0.60(0.60-3.54)	0.402
Low					0.93(0.67-1.42)	0.754	0.94(0.59-1.53)	0.829
Measures of variation								
Model diagnostics								
District level	0.251(0.13-0.49)	0.085	0.162(0.08-0.32)	SE:0.015	0.10(0.04-0.28)	SE:0.053	0.13(0.044- 0.37)	SE:0.068
Household level	1.44(0.89-2.34)	0.354					1.34(0.72- 2.50)	SE:0.427
Likelihood ratio test	108.82	sig(0.00)	61.04 (Sig:0.000)		15.97(Sig:0.000)		34.05 (Sig:0.000)	
Intra-class correlation								
District level (ICC&SE)	0.05(0.02-0.09)		0.047(0.024-0.089)		0.029(0.01-0.08)		0.03(0.09-0.07)	
Household level	0.34(0.25-0.45)		0.33(0.21-0.46)		0.32(0.20-0.46)		0.31(0.20-0.45)	
Model fit Statistics								
AIC	5411.901		5420.753		3602.57		3586.50	
BIC	5432.588		5565.506		3817.42		3807.85	

The third model included level 2 predictors in the random intercept model with fixed effects. Results showed decreased district level variance from 0.162 in the model without level 2 variables to 0.10, CI: 0.04-0.28 in one with level 2 predictors, with decreased significant likelihood ratio test;15.97 (p-value 0.000). The AIC and BIC statistics increased; 5420.75 and 5565.50 from 5411.9 and 5432.58 respectively, indicating that introducing level 1 variables affects the model fit. However, ICC decreased at both district and household levels.

In the fourth model, each district had its own intercept and the coefficients of level one variables were allowed to vary and all level 1 and 2 predictors were included. Results show decrease in level 2 variance from 0.148 in the previous model to 0.088. This represents a 9 percent variance in district level wasting among children (Table 27). The likelihood ratio Chi^2 test doubled from 15.97 in the previous model to 34.05 but the AIC and BIC decreased from 3602.6 and 3817.42 the previous model to 3586.50 and 3807.85, indicating the model was a better fit than the previous one.

Across climatic variables, the odds of children wasting for households in districts that experienced shorter rainfall duration were twice as much the odds of children in households whose districts experienced a normal or average rainfall duration. Like it was for stunting models, a female child had lower odds of being wasted compared to a male child, OR 0.79, CI: 0.65-0.97. Rural based children had twice the odds of being wasted compared to urban-based children, OR2.03, CI: 1.02-4.04. Children in households with below average mean annual food expenditure had 1.4, (CI: 1.06-1.85) times the odds of being wasted than those whose household's annual mean food expenditure was above the samples' average. Children whose household head had attained tertiary education had lower odds of being wasted compared to those whose head had no education 0.34 (CI: 0.13-0.92).

8.3.5. Multilevel model results on climate and household level factors associated with child underweight

Results from the null model on underweight show that average variance was higher at household level; 1.48, CI: 1.06-2.07 compared to district level; 0.23, CI: 0.12- 0.41 (Table 28). The total variance was 1.71, and level 2 variance estimate was 0.1345, indicating a 13 percent of variation in child stunting associated with district level factors.

There was no correlation in the odds of a child becoming underweight at district and household level; district level ICC 0.05, CI: 0.03-0.079, household level ICC 0.34, CI: 0.27-0.42. The likelihood ratio Chi^2 statistic for this model was 233.4, statistically significant. Results also show the AIC and BIC of 8973.2 and 8993.9 respectively. Results of the second model showed decreased variance at district level from 0.23 in the null model to 0.12, CI: 0.07-0.23 in the random intercept model. There was a slight decrease in the AIC from 8973.2 in the null model to 8885.7 in the current model, suggesting that the model with a random intercept had a better fit that the null. The ICC still showed no correlation in underweight among children at district level; ICC 0.04, CI: 0.02-0.06. In the third model (random intercept model with level 1 and level 2 predictor variables) district level variance decreased from 0.06, CI: 0.02-0.16, to 0.12 in the previous model. The likelihood ratio Chi^2 test statistic was also significant, decreasing from 0.253 in the previous model to 19.93 in the random intercept model with level 1 and 2 predictors. Decreases were also noted in the AIC and BIC statistics, 8885.7 in the previous model to 6030.9 in the current model. The BIC also decreased from 9030.6 to 6224.9 in the current model.

Table 28 Results for multi-level logistic regression models on of factors associated with understanding in Malawi

Variables and Level of analysis	Model 1. (Intercept only)		Model 2: Random Intercept (Child and Household variables included)		Model 3. Random intercept: Child, Household and Climate variables (District level) included		Model 4. Random intercept and coefficient Model (Child, Household & Climate variables) included	
	OR (95% CI)	*SE*	OR (95% CI)	*p-value*	OR (95% CI)	*p-value*	OR(95% CI)	*p-value*
Child level factors								
Sex								
Male (Ref)								
Female			0.80(0.73-0.89)	**0.000**	0.84(0.74-0.95)	**0.006**	0.70(0.68-0.93)	**0.005**
Child age								
6-11 (Ref)								
12-23			1.03(0.84-1.29)	0.727	1.17(0.90-1.53)	0.233	1.18(0.85-1.18)	0.323
24-35			1.45(1.17-1.79)	**0.001**	1.65(1.27-2.13)	**0.000**	1.85(1.34-2.55)	**0.000**
36-47			1.59(1.29-1.96)	**0.000**	1.74(1.35-2.25)	**0.000**	1.98(1.44-2.75)	**0.000**
48-59			2.10(1.71-2.59)	0.000	2.28(1.76-2.95)	**0.000**	2.76(1.99-3.83)	**0.000**
Mother education								
None (Ref)								
Primary			1.01(0.84-1.22)	0.923	1.01(0.81-1.26)	0.933	0.99(0.74-1.33)	0.931
Secondary & over			0.75(0.59-0.95)	**0.015**	0.810.62-1.06)	0.122	0.73(0.51-1.03)	0.076
Household level factors								
Urban (Ref)								
Rural			1.34(1.05-1.70)	**0.018**	1.64(1.11-2.43)	**0.012**	1.93(1.15-3.21	**0.012**
Poverty status								
Poor (Ref)								
Non-poor			0.91(0.79-1.04)	0.168	0.94 (0.76-1.07)	0.250	0.89(0.70-1.12)	0.314
Food security status								
Food secure (Ref)								
Food insecure			1.00(0.90-1.12)	**0.07**	1.03(0.90-1.19)	0.713	1.04(0.87-1.25)	0.648

Household size						
4 or less (Ref)						
5-6	0.63(0.91-1.17)	0.633	1.03(0.88-1.20)	0.675	1.02(0.83-1.25)	0.836
7 and over	0.95(0.80-1.14)	0.948	0.95(0.80-1.14)	0.598	0.92(0.72-1.17)	0.507
Mean food expenditure						
Above mean exp (Ref)						
Below mean exp	1.03(0.90-1.17)	0.697	1.01(0.85-1.19)	0.923	1.00(0.80-1.25)	0.997
Education level of head						
None (Ref)						
Primary	0.94(0.79-1.15)	0.461	0.94(0.76-1.17)	0.564	0.91(0.69-1.20)	0.509
Secondary	0.82(0.69-0.97)	**0.020**	0.77(0.63-0.94)	**0.011**	0.72(0.55-0.94)	**0.015**
Tertiary	0.76(0.48-1.20)	0.234	0.69(0.41-1.14)	0.144	0.66(0.35-1.26)	0.212
Marital status of head						
Married (Ref)						
Separated/Divorced	1.24(1.03-1.50)	**0.023**	1.101(0.88-1.39)	0.371	1.14(0.84-1.55)	0.410
Widowed	1.08(0.85-1.36)	0.542	1.03(0.77-1.39)	0.832	1.04(0.700-1.56)	0.833
Never married	0.88(0.34-2.26)	0.792	0.75(0.27-2.09)	0.585	0.70(0.19-2.58)	0.594
District level variables						
Minimum temperature						
Average(ref)						
above average			1.78(1.13-2.81)	**0.013**	2.14(1.19-3.86)	**0.011**
below average			0.95(0.37-1.09)	0.102	0.60(0.30-1.22)	0.157
Maximum temperature						
Average(ref)						
above average			1.04(0.66-1.64)	0.857	1.09(0.61-1.97)	0.767
below average			3.17 (1.60-6.29)	**0.001**	4.27(1.7-10.43)	**0.001**
Total rainfall						
Average(ref)						
above average			1.00(0.60-1.52)	0.850	0.87(0.47-1.61)	0.653
below average			0.53(0.38-0.72)	**0.000**	0.44(0.29-0.66)	**0.000**

Rainfall onset								
Average								
above average					1.15(0.83-1.58)	0.398	1.20(0.78-1.83)	0.405
below average					0.85(0.65-1.12)	0.245	0.80(0.56-1.15)	0.236
Rainfall duration								
Average(ref)								
above average					0.78 (0.46-1.35)	0.370	0.77(0.78-1.58)	0.482
below average					1.61(1.19-2.16)	**0.002**	1.81(1.23-2.66)	**0.002**
Dry-days								
Average(ref)								
above average					0.39(0.83-2.42)	0.204	1.62(0.79-3.32)	0.188
below average					0.15(0.70-1.29)	0.759	0.97(0.65-1.42)	0.857
Model diagnostics								
Variance parameters								
District level	0.23(0.12-0.41)	0.069	0.12(0.07-0.23)		0.06(0.02-0.16)	0.000	0.09(0.03-0.26)	SE:0.05
Household level	1.48(1.06-2.07)	0.253					1.63(1.08-2.45)	SE:0.03
Likelihood ratio test	233.29	Sig(0.00)	121.89	sig:0.000	19.93	0.000	74.55	0.000
Intra class correlation								
District level (ICC&SE)	0.05(0.03-.079)	0.013	0.04(0.02-0.06)		0.02(0.01-05)	SE0.000	0.02(0.007-050)	SE:0.01
Household level	0.34(0.27-0.42)	0.036	0.33(0.26-0.40)		0.33(0.26-0.40)	SE0.001	0.34(0.26-0.44)	SE:0.05
Model fit Statistics								
AIC	8973.2		8885.7		6030.941		5978.316	
BIC	8993.9		9030.6		6245.935		6199.826	

The decreases in the random part of the model and other model fit assessment statistics i.e. LR test, AIC and BIC all indicate that including level 2 variables in the model made it a better fit than the previous one. As was the case with wasting and stunting, cropping season rainfall duration had significant association with underweight among the sampled children. Children from households whose districts experienced shorter rainfall duration had higher odds of being underweight compared to those from households whose districts had average cropping season rainfall duration, OR1.61, CI: 1.19-2.16 (Table 28). Children in households whose districts experienced above average minimum cropping season temperatures had higher odds of being underweight compared to children in households whose districts had experienced average minimum cropping season temperatures, OR 1.78, CI: 1.13-2.81.

The fourth model involved a random intercept at district level and random coefficient at household level. The variance component of the models showed a slight increase at district level, from 0.06 in the previous model to 0.09, CI: 0.03-0.26 in the current model. The household level variance was 1.63, CI: 1.08-2.45, up from 1.48 in the null model. This shows slight increase in the size of unexplained variance at these two levels compared to the previous one, possibly influenced by the changes introduced i.e. random coefficient. The likelihood ratio Chi^2 test statistic rose from 19.93 in the random intercept model to 74.6 in the random intercept and random coefficient model. However, the AIC and BIC decreased from 8885.7 in the previous model to 5978.3 in the current model for AIC, and BIC dropped from 6245.9 in the third model to 6199.8 in the random intercept and random coefficient model. These statistics i.e. the Likelihood ratio test, the variance component suggest that including a random coefficient makes the model not a better fit than the one preceding it.

However, the type of association of level 1 and 2 variables with the outcome did not change. For instance, among household level factors results showed that female children had lower odds of being underweight compared to their male counterpart, OR 0.70, CI: 0.68-0.93. As has been the case with stunting and wasting, the odds of a child being underweight increased with age, as figure 42 shows.

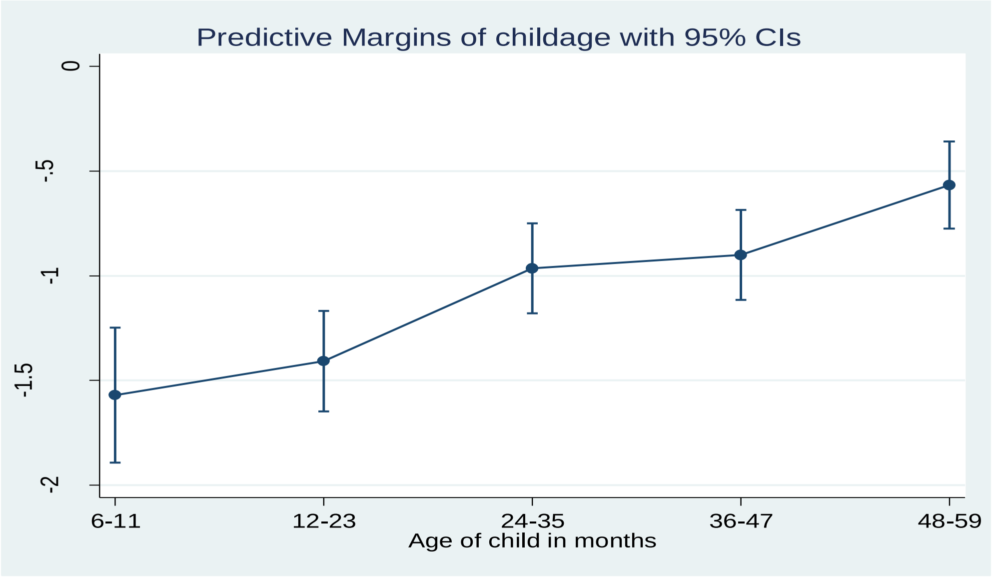


Figure 42.Predicted probabilities of underweight among studied children by age

Children aged 24-35 months had higher odds of being underweight compared to those aged 6-11 months, OR 1.85, CI: 1.34-2.55. Those aged 36-47 months also had higher odds of being underweight compared to those aged 6-11 months, OR 1.98, CI: 1.44-2.75, and those aged 48-59 months had almost 3 times the odds of being underweight compared to those aged 6-11 months, OR 2.76, CI: 1.99-3.93. Further, children in rural based households had almost twice the odds of being underweight compared to those in urban based households; OR: 1.93, CI: 0.70-1. Children from households whose head had attained secondary education had lower odds of being underweight compared to those whose household head had not attained any education level, OR 0.72, CI: 0.55-0.94.

As was the case with stunting and wasting, across the climatic variables children from households in districts that experienced shorter rainfall duration had close to twice the odds of being underweight compared to those from households in districts that experienced average length of the cropping season, OR1.81, CI: 1.23-2.66 (table 26). Children from households whose district experienced below average cropping season maximum temperatures had 4 times the odds of being underweight compared to those in households whose districts experienced average maximum cropping season temperatures, OR 4.27, CI: 1.74-10.44.

8.4. Summary of results

Analysis results in this chapter shows that:

- For all the three measures of child nutrition status, measures of model variance, random effects estimates (log-likelihood ratio) have been decreasing upon introduction of a random intercept in model 2, random intercept with level 1 predictors in model 3, and random intercept, random coefficient, level 1 and level 2 predictors in model, 4. This indicates that introducing these model parameters significantly improved the model fit.
- The proportion of variance across the models i.e. intercept only model, random intercept model, and random intercept and random coefficient model was generally lower at level 2 (district level) compared to level 1 (Household level) of the predictors, suggesting that more variation in child nutritional status was influenced by factors operating at household than district level, although there was significant variation in child nutritional measures on account of district level factors.
- Further models diagnostics showed consistent decreases in the intra-class correlation coefficients at both level 1 and level 2 variables throughout the four models, suggesting lower correlation of children's nutritional status at household level and across districts, lowest at district levels.
- Controlling for other temperature, rainfall, demographic and socio-economic variables used in the model: shorter rainfall duration was associated with increased odds of stunting, wasting and underweight. Children in districts that experienced shorter rainfall duration had higher odds of stunting, wasting and underweight compared to those in districts which experienced an average rainfall duration during the cropping season.
- High minimum temperatures were significantly associated with underweight among the studied children. Under-five children resident in districts with above average cropping season minimum temperatures had higher odds of being underweight compared to those in districts with average minimum cropping season temperatures.

- Child sex was significantly associated with stunting, wasting and underweight. Female children had lower odds of being stunted, wasted and underweight compared to male children.
- The odds of a child becoming stunted and underweight increased as the child grew.
- A mother's education attainment was significantly associated with wasting and stunting. The higher the level of education attained by the mother, the lower the odds of the child being stunted or underweight.
- The odds of a child being wasted and underweight were lower if the household head had attained secondary and tertiary education.
- Residence was a significant factor to child wasting and underweight only. Rural based children had higher odds of being wasted and being underweight compared to their urban counterpart.
- Children from households with low annual food expenditure had higher odds of being wasted compared to those with higher annual household food expenditure.

8.5. Discussion

This chapter addressed the fourth objective of the current study; examining association of climatic variables with child nutritional status, controlling for selected demographic and socio-economic factors. The analysis used a dataset comprising climate variables (temperature and rainfall) for the cropping season prior to and during the IHS2010/11 and demographic and socio-economic data from the IHS2010/11. Considering differences in levels at which factors associated with child nutritional status operate, it was decided that a multi-level logistic regression model be fitted to assess variation in the regression estimates associated with levels at which factors influencing under-five children's nutritional status operate i.e. district and household level. Model results showed that there was significant variation in stunting, underweight and wasting on account of district level factors. However, the amount of variance at this level was smaller compared to the household level across the fitted models i.e. from the null model to the last model, the random intercept and random coefficient model.

Across all models of the three anthropometric measures, district level variance decreased with introduction of different model attributes such as random intercept at level 2 variables i.e. district factors, and introduction of a random coefficient at household level among others. These results are similar to ones from a multilevel analysis of individual and community effects on chronic childhood malnutrition in Nigeria by Uthman (2008). In this study, upper level variance decreased much lower than individual (lower) level variance across the model sequence i.e. null, random intercept and random coefficient models. In the current models. the decreases in model variance estimates at station/district level suggest that lower level factors had higher influence on child health outcomes than district level factors. As such, efforts addressing child malnutrition in Malawi should concentrate on addressing household level factors and conditions more than district level factors, though they are also important.

In the current study, climatic variables that had significant association with child nutritional status were total cropping season rainfall and its duration, minimum and maximum cropping season temperatures. Analysis has shown that children in districts which had shorter than average duration of cropping season rainfall had higher odds of stunting, wasting and underweight, almost double the odds for those children in districts which had an average duration of the rainfall. A 45-year trend in cropping season rainfall duration reported in chapter 5 of the thesis has shown significant decrease in length of cropping season rainfall, with detrimental results on crop yield as reported in chapter 6 of the thesis.

The significant association between shorter cropping season rainfall with higher odds of stunting, wasting and underweight among studied children noted in the current study could suggest that among other factors, this relationship is effected through the rainfall patterns-crop yield relationship pathway as noted in the current chapter. Poor crop yield causes food shortages among households, leading to poor food consumption patterns and consequently malnutrition among household members especially children under-five. This assertion concurs with study findings by Felix and Romuald (2012) on rainfall shocks, food prices vulnerability and food security among 25 sub-Saharan African countries, where rainfall volatility affected food security availability.

A result similar to this finding was reported in Tanzania by Msongaleli, Tumbo et al. (2017) who also observed that decreasing length of growing season rainfall was associated with decreasing cereals yield i.e. sorghum. For Malawi, results in the current chapter indicate that cropping season rainfall duration trends could enhance poor child health outcomes, especially on nutritional conditions. Considering that malnutrition has irreversible life-long effects on productivity, efforts to avert climatic influences on nutritional outcomes, especially through the food production pathway ought to be given utmost priority in the country's development endevours, in order to ensure better nutritional health for children.

Current study findings have also shown that children in districts that experienced lower than average cropping season maximum temperatures i.e. 24°C, had lower odds of stunting than those in districts that experienced average maximum temperatures during the season. Essentially, lower temperatures were associated with better nutritional outcomes, with respect to stunting. Malawi's temperature trends as revealed from analysis results presented in Chapter 5 of the thesis show general increase across the country, with sparse spatial variations. A negative association was noted between increasing temperatures and maize yield, reported in Chapter 6 of the thesis. Hatfield and Prueger (2015) explains that above normal temperatures for crops like maize adversely affect phenological processes such as pollination, leading to low yield.

Derso, Tariku et al. (2017) further explains that in food production systems dependent on climatic patterns i.e. seasonal farming, low yield of food crops such as maize has direct implications on households' food availability, enhancing wasting among children. McMichael (2013), also reports about significant association between increasing temperatures and child stunting among eastern African countries such as Kenya since 1975. Current study results in chapter 7 of the thesis indicate that Malawi's temperature trends are not favourable to maize production, a situation that will directly impact household food availability, given the significant association between maize yield and food security reported in the findings. The situation spells significant implications on children's nutritional status, as prevailing cropping season temperatures lower crop yield and consequently food availability among households. This could result in unhealthy food consumption patterns, which could predispose under-five children to malnutrition.

Among household level factors associated with child nutritional status as noted from the current study is child sex. Male children have had higher odds of stunting, wasting and underweight than female children. Similar findings have been reported by Adair and Guilkey (1997) and Wamani, Åstrøm et al. (2007) in nutritional assessment studies conducted in sub-Saharan Africa. However, a study conducted in India by Pande (2003) somewhat contradicts this finding. In this study, female children had higher probability of being malnourished and having poor immunization record compared to males. Among other explanations, preference for sons among couples plunged many female children into poor care and improper feeding practices that enhanced poor nutritional status. Other studies however i.e. Martínez Pérez and Pascual García (2013) and Aboud (2011) highlight the influence of cultural beliefs and practices in sub-Saharan African region driving child feeding practices which tend to favour girls than boys, the latter being perceived in need of less attention with regards to childhood food requirements and care. It is not established in Malawi yet why male under-fives appear to trail their female counterpart in nutritional health outcomes, suggesting the need for specific studies to unearth sex based disparities in nutritional outcomes among children. This would provide relevant input for interventions to address malnutrition in the country.

In the current study, age of a child has had significant association with stunting and underweight. The older the under-five child (especially after 24 months and between 35-47 months), the higher the odds of being stunted and underweight. This observation was also made by Bose, Biswas et al. (2007) from a study conducted among under-five children in West Bendal, India, where stunting among under-fives increased with increasing age for both sexes particularly among those aged 36-47 months. Akombi, Agho et al. (2017) explains that in many socio-economic contexts, mothers' attention on a child decreases with increasing age of the child, especially after 24 months following weaning, as the mother engages in productive tasks apart from child care. Such situations increase vulnerability to poor feeding practices among other effects, and increased susceptibility to diseases as a result of compromised child care, which later on affects its growth and development.

Among interventions to address malnutrition among under-five children on account of this factor in Malawi would be promoting attendance to growth monitoring services at health facilities for mothers, where they learn about importance of child care practices beyond the weaning age, and its implications on child health outcomes such as nutritional conditions.

Current analysis results show that not all child anthropometric measures are sensitive to age of the child. For instance, there has been no significant association between wasting and child age. This result resonates with another study conducted in Ethiopia by Alemu, Sileshi et al. (2014) which assessed factors influencing wasting among children aged 6-59 months in Guto Gida district. Controlling for other covariates i.e. sex and number of children in the household, the study found no significant association between child age and wasting. The result is somewhat surprising considering that age is generally a significant factor in child malnutrition, where food uptake and care practices are critical at this formative stage of life (Nyaradi, Li et al. 2013, Nurliyana, Shariff et al. 2016).

Current findings however suggest that different factors have different influences on different child nutritional indicators, a situation also noted in a study by Mukatay, Kalenga et al. (2010), where stunting was mostly associated with child level factors such as age, sex and number of children in a family while Chikhungu and Madise (2014) noted that female children's nutritional status is affected by age unlike male children's. These observations suggest the need for careful assessment of factors influencing children's nutritional status for each of the nutritional status indicators, to ensure appropriate factors are analysed for each nutritional assessment measure. This would then inform policy interventions with which to avert each of the malnutrition measures among under-five children.

Mother's and household head's attainment of some level of education is one of the most reported correlates of under-five children's nutritional status. Findings from the current study show that different levels of education attainment were associated with different measures of child nutritional status across the fitted models. There were lower odds of a child being stunted and underweight if its mother had attained secondary education and over. No significant association was noted with any of mother's education attainment levels with wasting.

Studies i.e. Ruel and Menon (2002) Urke, Bull et al. (2011) explain that an educated mother has economic resources and know-how with which to support her child than one with lower or no education attainment at all.

Further, children whose household heads had attained secondary and tertiary education had lower odds of being stunted, but the introduction of level 3 variables and random coefficient in the model made this variable lose significance in the model (for wasting) and underweight (in the final model). Analysis from other studies i.e. Urke, Bull et al. (2011) suggest that an educated household head has more economic ability to provide necessities such as food, medical care and even pay for child care, all of which are important for a child' nutritional status (even in the absence of the mother).

For countries like Malawi with generally low education attainment i.e. 70 percent of people aged 15 years and above have no education qualification (MalawiGovernment 2017), current study results, (supported by other studies) suggest higher possibility of perpetrated malnutrition among under-five children, associated with low economic status among household heads, on account of low education level. Adult literacy programs targeting non-educated households would therefore be an important intervention to address not only low education attainment among adults, but also enhance economic capabilities of households to mobilise resources including food for their members, especially vulnerable ones such as under-five children.

Among social variables associated with child nutritional status examined in this analysis is marital status of household head, where results have shown that children from widowed households had higher odds of being stunted compared to those from married household heads. This findings was also noted in a study assessing association between socio-economic variables and under nutrition in India, by Subramanyam, Kawachi et al. (2010). In this study, children living with non-married household heads had higher odds of underweight, stunting and wasting compared to those from households whose heads were married. An analysis of the burden, causes and prospects of malnutrition in sub-Saharan Africa by Bain, Awah et al. (2013) also found that marital status of the household head was one of the significant correlates of stunting, wasting and underweight.

Among other explanations, married household heads have the support of their spouses in providing care and augmenting household food and income resources which is essential for child nutritional condition, growth and development. Whilst Malawi has a social protection and safety nets intervention in place since 2005 (Devereux and Macauslan 2006), emphasis has been on providing support to households hard hit by food insufficiency as a result of adverse climatic conditions causing low yield among rural populations. However, current study results suggest that among population classified as food insecure due to crop failure are widows, who socio-economically could be vulnerable to food insecurity even without being exposed to climatic risks, hence in need of special assistance. Such targeting requires proper profiling of the population in order to provide target specific interventions, with which to address their problematic situations.

In this study, average annual household expenditure on food was significantly associated with wasting among the sampled under-five children. Children in households with low or below the sample's average annual expenditure on food had higher odds of being wasted compared to those in households whose average annual expenditure on food was above the sample's average. A study by Thapa G (2017) also noted association between household expenditure on food and nutritional outcomes among under-fives in Nepal. In this study, monthly food expenditure had positive impact on the expected height for age Z-scores among the studied children. In another study, Humphries, Dearden et al. (2017) found that household food group expenditure index was associated with significant increases in child height for age in Ethiopia, India and Vietnam. Total food expenditures were significantly associated with increases in body mass index in India, Peru and Vietnam.

Among other explanations for these associations, household food expenditure was argued to provide insights into household food purchasing patterns which significantly predicted stunting and body mass index on children. Results from the current study therefore suggest that increasing income and income opportunities among households i.e. through social cash transfers (Asfaw, Pickmans et al. 2015) could help to address nutritional disorders among under-five children in Malawi, hence the need for government to consider widening the scope of the current social cash transfer programs in Malawi to carter for income and resource constrained households.

8.6. Conclusion

This chapter has presented and discussed results of analysis on association of temperature and rainfall with child nutritional status, controlling for demographic and socio-economic factors also associated with child nutritional status. The analysis addressed the fourth objective of the study answering the question: how do climatic temperature and rainfall relate with under-five children's nutritional status.

It involved fitting multi-level logistic regression models to account for variance in child nutritional status emanating from different levels at which factors influencing child nutritional status operate. In this regard, random intercept and random coefficient models were fitted in sequence. Results of the analysis have added on to the evidence that changes in temperature and rainfall characteristics; especially during the cropping season have significant effects on children's nutritional outcomes. This relationship is assumed to operate through the food availability pathway, where unfavourable temperature and rainfall conditions influence low crop yield and therefore low household food availability, which in turn affects food consumption patterns. These conditions, coupled with other household socio-economic and demographic factors influence poor child nutritional status, resulting in poor health.

Appropriate policy programs on child growth and development ought to consider how changes in climatic variables, especially those relating to cropping season temperature and rainfall and other household level dynamics associate with child nutritional status. Among such could be providing safety nets through social cash transfer programs, practicing climate sensitive agriculture i.e. use of early maturing, drought resilient and heat tolerant varieties of maize as staple food crop in the country, whilst improving the socio-economic conditions of the population.

Chapter 9. Discussion

9.1. Introduction

Climate change and variation are some of the major development challenges confronting the 21st century world. Their effects on human survival and wellbeing are broad and multifaceted (Kjellstrom 2009, Adger 2010). Among such are increased incidences of communicable and non-communicable diseases influenced by rising temperatures, intense rainfall, floods and droughts in various parts of the world (McMichael, Woodruff et al. 2006). There are also reports about crop failure, growth and spread of pests and diseases affecting crops and livestock, and reduced agriculture productivity, which are influenced by adverse climatic variation and change (Gregory, Ingram et al. 2005, Schlenker and Lobell 2010, Guan, Sultan et al. 2015).

Against this background, few studies have examined how spatial and temporal variations in climatic conditions affect households' food security and nutritional status of its members. This knowledge gap is more pronounced in regions and countries where climatic conditions are significant to food production on the farm and have higher disease burden, malnutrition and poverty (Schmidhuber and Tubiello 2007, Schlenker and Lobell 2010, Wheeler and Von Braun 2013), i.e. the SSA region and Malawi respectively. These problems exist against a background of projected increase in climatic variability, likely to negatively affect peoples' lives with increasing magnitude.

The current study attempted to address the identified knowledge gap by examining how changes in selected climatic variables in a cropping season relate with household food security and child nutritional status, controlling for demographic and socio-economic factors operating at household level in Malawi. The analysis used temperature and rainfall data spanning 45 and 43 years i.e.1970-2015 and 1970-2013 respectively, and household level socio-economic data from the 2010/11 Malawi Integrated Household Survey (IHS2010). It was envisaged that results from the analysis would provide important input for policy and programs addressing adverse effects of climatic variation on household food security and nutritional status of under-five children in Malawi. This chapter discusses findings of the study, their implications, and further research that could be undertaken to provide more insight on the subject.

The discussion will follow objectives and findings of the study, beginning with assessment of Malawi's temperature and rainfall trends over time, relationship of temperature and rainfall trends with crop yield, association of temperature, rainfall, household level demographic and socioeconomic factors with household food security and under-five children's nutritional status.

9.2. Trends in cropping season rainfall and temperatures in Malawi

A trend analysis of selected temperature and rainfall variables using Mann-Kendall (1945,1975) trend testing method, has shown that over the last 46 years (1970-2015), Malawi's total rainfall during cropping season has been decreasing but not significantly. This result has remained even when analysis was lowered at station level across the 27 districts considered in the study. The result concurs with a regional trend analysis reported by New, Hewitson et al. (2006) and Hoerling, Hurrell et al. (2006) who noted a downward trend of summer rainfall (October to April) in the eastern and southern African region. A similar observation was reported by Ngongondo, Xu et al. (2011) in a study about spatial and temporal characteristic of rainfall in Malawi, where declining but non-significant annual rainfall trends were observed.

Among the factors argued to account for this decreasing rainfall pattern in the SSA region are land cover changes, global ocean circulation changes associated with patterns of sea surface temperature and changing compositions of the global atmosphere (Hulme 1992). However, other researchers i.e. Tadross, Suarez et al. (2007) argue that anthropogenic effects have played significant role in shifting rainfall regimes in the region, accounting for mixed climatic patterns, i.e. decreasing rainfall trends in the south-west of the continent and increasing trends in the south-eastern part. These trends are likely to have significant implications on peoples' lives, considering the importance of rainfall in livelihoods such as farming, predominant in Africa, which depend on climatic conditions such as temperature and rainfall. Alongside the decreasing rainfall trends in the country are delays in onset and early cessation of rainfall in the cropping season in almost all analysed stations. Although the trends have not been statistically significant at national scale, regional results show statistically significant delays in onset of rainfall in the central region.

The southern and northern regions exhibit similar but not statistically significant trends. However, for rainfall cessation, results have been statistically significant at national scale and regionally in the north and non-significant in the central and southern regions. The delays in onset of annual rainfall and its early termination during the cropping season resonates with rainfall patterns in some parts of the African continent, even though there are spatial and temporal differences in the analyses and factors behind such changes. For instance in Ghana (west Africa) Amekudzi, Yamba et al. (2015) found that late onset of rainfall start from the second dekad of April to the first dekad of May, associated with Savanna zone. Early rainfall cessation dates of the coastal zone were also detected in the second and third dekad of October of the studied rainfall years.

In Cameroon, Guenang and Mkankam Kamga (2012) found a delayed rainfall onset of 1 pentad based on projections for 2082 -2098 under SRES A2 carbon emission scenario. A FEWSNET April 2017 report for mid-season rainfall anomalies between 1983-2009 in the Horn of Africa also found that seasonal rainfall had delayed their onset, leading to below-average rainfall over many areas and droughts among countries in the region i.e. Somalia, North-east Kenya and south-eastern Ethiopia. In southern-eastern Africa, Shongwe, Van Oldenborgh et al. (2009) and NGONGONDO, TALLAKSEN et al. (2014) have also detected delays in the onset and early cessation of annual rainfall in Zambia, Zimbabwe and Malawi.

Nash (2017) explains that for African regions where mean annual precipitation occur between October and March, also known as summer rainfall zones (SRZ), seasonal interplay between subtropical high pressure systems and the migration of easterly flows associated with the ITCZ account for rainfall patterns as detected in the current study. Although there is general consensus that anthropogenic warming trends are influencing changes in global climatic patterns, natural influences by ocean temperature changes, solar radiation and air pressure systems within the regions also contribute to reported regional climatic patterns, which could be directly influenced by greenhouse gases. However, for Malawi, although current study results indicate changing annual rainfall, onset and cessation times over the analysed period, this climatic signal is not strong enough spatially, since only five of the 28 stations in the country have had statistically significant trends in cropping season rainfall onset.

This result stresses the argument about spatial variations in climatic conditions across areas, where there are different climatic patterns influenced by varied factors i.e. topography, geophysical and socioeconomic processes among other factors. Current study results however indicate that amid claims that Malawi's rainfall patterns are changing and highly variable, there is need to highlight that with respect to some rainfall variables i.e. onset and cessation of annual rainfall, the signal is generally sparse. This finding highlights the importance of micro level spatial analysis of variations in climatic variables to ensure that an accurate climatic signal for a specific spatial scale and context is detected. Such approaches would provide important input for spatially targeted interventions to deal with adverse effects of such rainfall patterns on various aspects of people's lives.

Delays in onset of cropping season rainfall and subsequent early termination during the season entail a short rainfall duration. This has been characteristic of cropping season rainfall duration trends in Malawi, which have decreased over time. Other studies have also reported similar findings. For instance, a regional analysis of duration of annual rainfall shows significant negative trends in the northern part of the Sahel region, parts of Tanzania and Mozambique, which are Malawi's direct neighbours (Figure 1) (Vrieling, De Leeuw et al. 2013). For Malawi, this climatic signal has been more pronounced, with all stations indicating negative trends, though some had non-significant trends.

The negative effects of shortened rainfall duration depend on how critical water is with reference to a particular element in a given temporal and spatial scale. For crop production, different plant phenological processes require different water levels at various stages i.e. seed germination, stalk and leaf development, flowering, pollination and yield. Some of these processes may react negatively to relatively low or high soil water, others positively, depending on how crucial water is in the plant's growth process. Essentially, decreasing cropping season rainfall duration trends, even non-significant, but occurring at critical plant growth stages could have important implications on crop yield, which might affect food availability for the people. As such, efforts are required to assess how such trends are impacting various aspects of peoples' lives i.e. crop production, domestic water availability at a micro level.

Considering mounting evidence that southern Africa is one of the regions detected with warming trends since the 1960s (Nicholson and Flohn 1980, Tadross, Suarez et al. 2007) amid delayed onset, early cessation and shortened duration, it would be expected to detect increasing minimum and maximum temperature trends across countries in the region. However, analysis from the current study has shown that in Malawi, only maximum temperature trends have significantly increased over the period of analysis. There have also been pockets of decreasing trends in some stations across the country. This result indicates that amid the global warming observation, where regional studies have affirmed increased warming in southern and eastern Africa, there are lower spatial scales experiencing the opposite of such globally proven climatic realities. As such, sustained efforts are required to generate lower level picture of climatic patterns if appropriate and effective interventions to address the adverse effects associated with such patterns are to be designed and implemented.

9.3. Relationship between selected cropping season temperature and rainfall variables with maize yield in Malawi

Despite the importance of climatic conditions to Malawi's food production and its agro-based economy, few studies have analysed association of climatic variables and crop yield in the country, even though the country is reportedly experiencing adverse climatic variation. The current study attempted to address this knowledge gap by examining relationship between temperature and rainfall variables with maize yield, considering the importance of maize production to households' food security status in the country. Linear regression models were performed using 32-year de-trended maize yield data as the dependent variable and 32 year selected time series cropping season rainfall and temperature independent variables. It was envisaged that findings from the analysis would provide important input for interventions aimed at improving crop production amid detected climatic variability in the country, to ensure households' food availability.

Results have shown that over the period of analysis, different climatic variables had different associations with maize yield per hectare in different districts. Four of the seven climatic variables; onset of cropping season rainfall, cessation, duration and minimum growing season temperatures had statistically significant association with maize yield per hectare in different districts of the country. A unit increase in cropping season rainfall amount was positively associated with maize yield per hectare in Lilongwe district in the central region and Machinga district in the south-east.

However, an increase in cropping season rainfall was negatively associated with maize yield per hectare in Phalombe district, south-eastern Malawi. The result shows that the rainfall variation signal on maize yield has been spatially sparse in the country as few districts show significant association of the rainfall trends with maize yield. Further, the type of association across districts has also been different, positive in two districts and negative in one. Results similar to these were noted in a study conducted in south Africa on effects of annual rainfall on maize yield, in which Akpalu, Rashid et al. (2011) found that increasing precipitation trends marginally associated with increases in maize yield. Another study simulated rainfall trends to assess association with maize yield in Pietermaritzburg (South Africa), Duffy and Masere (2015) and results showed that within-season total rainfall distribution positively associated with maize yield.

Current study results and the two South African studies suggest that rainfall patterns could have different influences on crop yield at different spatial scales within a country, although the general trend could be similar i.e. decreasing or increasing rainfall patterns over time. This could happen on account that decrease in seasonal rainfall may not occur at similar time periods and with similar magnitude in different spatial scales in a given cropping season, suggesting that water limitations or supply in the crop development processes might have different influences on crop yield, also at varied spatial scales, as has been the case in the current study.

Omoyo, Wakhungu et al. (2015) explains that maize experiences extreme sensitivity to water deficits during a very short critical period i.e. from flowering to the beginning of grain-filling phase. In this period, Maize experiences the highest water demand when maximum leaf area index combines with the highest evaporative demand. It is also in this period that main yield components i.e. number of ears per plant and number of kernels per ear are determined. These processes might occur at varied temporal intervals in a growing season in different areas, even though the general rainfall trends could be similar in a larger spatial context. Hence, differences in maize yield - rainfall association patterns across districts are likely, as the current study shows.

The results however stress the need for lower level spatial scale analysis in determining how prevailing climatic trends with reference to rainfall are associated and possibly impacting crop yield, rather than relying on spatially extensive studies, preferred due to non-availability of data at lower spatial scales.

Such attempts would help in developing context specific interventions to address adverse climatic conditions associated with crop yield in order to avert poor crop production and food shortages among the people.

Further, although non-statistically significant decreasing rainfall trends detected in the current study may not be worrisome at first sight, there could be concerns in other aspects of human lives considering the importance of water to human sustainability, be it through farm production or domestic utility. For instance, a study by Koo and Cox (2014) found that in sub-Saharan Africa region, yield of maize tended to correspond to seasonal fluctuations of rainfall. However, the year to year fluctuations of yield were bigger in magnitude compared to rainfall variations. Essentially, although the year to year fluctuations of rainfall might have been non-significant in magnitude, the effects on crop yield was higher than expected. This could be so because crops react differently to different water indexes at different stages of their development, leading to varied response to prevailing rainfall patterns.

Current study results therefore entail that much as the rainfall declines have been non-significant, there could be important concerns on crop production on the farm, which might affect food crop availability for farming households. Essentially, studies on effects of rainfall and water requirements in various phenological processes of plants at different periods of plant development processes is crucial in determining how prevailing rainfall patterns relate and affect crop yield, especially in current times when rainfall variability is projected to increase in the country and the SEA region at large.

As alluded to in Chapter 2 of the thesis, there are different factors accounting for variation in maize yield at varied spatial scales in the country, other than amount of cropping season rainfall. For instance in Lilongwe district Malawi, MacColl (1989) found that high rainfall at the beginning of the growing season reduced maize yield on one type of soil, while high rainfall at late silking reduced yields for other soil samples. This finding suggests that apart from intensity and timing of annual rainfall in the plant’s phenological processes, environmental factors such as soil type also explain variations in crop yield. Malawi has of late experienced a spate of floods during the growing season that has resulted in loss of farm lands and good quality soils, influenced by intense rainfall during the season, amid increasing variability. Decreasing rainfall trends could also mean less soil water over time, which would affect soil quality, resulting in poor crop yield.

Essentially, trends in climatic conditions do not operate in isolation of environmental factors in influencing crop yield, suggesting the need for multi-pronged counter-climate variation interventions to avert their adverse effects on maize yield. Like total rainfall, maize yield per hectare was associated with trends in onset of cropping season rainfall in few districts of the country, 6 out of 24. In half of these; Blantyre, Zomba and Balaka located in the southern region, delayed cropping season rainfall was associated with yield reduction. In Chitipa and Nkhata-bay in the northern region and Mchinji in the central region, increase in maize yield per hectare was associated with delayed onset of the cropping season rainfall. First these results show that onset of these seasonal rainfall did not show significant effect on maize yield per hectare on an extensive geographical scale in the country. The finding could suggest a weaker rainfall variation signal with reference to this characteristic. Second, the response of maize yield to delays in annual rainfall onset even for these few districts varied; associated with increasing yield in some and decreasing yield in others, a situation that attest to spatial variations in response of crops to rainfall conditions.

However, decreasing yield following delayed onset of cropping season rainfall appears to be a most likely outcome for maize since without water, few seeds would germinate or grow, hence low yield. Waha, Müller et al. (2013) studied effects of temperature and precipitation change on maize yield in the sub-Sahara African region for mid to 21st century. Results showed that low grain yield was associated with high water stress resulting from an unusual delayed onset or early break of the rainy season in the Sahel, southern and central African regions. Current study results hence indicate that prevailing cropping season rainfall onset trends could have significant implications on the country's staple food crop, a situation that calls for targeted and matched counter responses in order to address the adverse effects of such rainfall trends on the country's food crop. Such initiatives could include introducing water resilient maize varieties which would stand prevailing rainfall trends, and practicing conservation farming which would ensure soils retain moisture enough to sustain crops from season to season, amid increasing variability of the seasonal rains.

Current study results have also shown that an elongated cessation of the rainfall during the cropping period associated with increased maize yield in a few districts, i.e. Ntcheu, Dedza, and Kasungu in the central region, and Chitipa in the northern region, 4 districts out of the 27. A 45-year trend analysis of annual rainfall cessation days for the country indicates a decreasing pattern which entails early rainfall termination.

However, like earlier discussed rainfall variables i.e. total annual rainfall and its onset, analysis show no significant association on maize yield arising from such trends in a majority of districts in the country. This result could mean that without accounting for non-climatic factors influencing maize yield, even though the seasonal rainfall is significantly terminating earlier, the time at which the rains terminate does not affect critical phenological processes of maize crop i.e. flowering, ear formation and grain filling, hence no associated lowering of yield in many spatial scales. Huho, Ngaira et al. (2012) examined changing rainfall patterns and their associated impacts on agriculture in a district located east of Kenya. Based on annual rainfall data from 1976-2005, the team observed decreasing trends in termination of seasonal rainfall in the two growing seasons associated with rainfall; October to November and the one in March to May.

Results further showed that early termination of growing season rainfall reduced yield of both maize and beans, suggesting that predicted and persistent early cessation trends in the east African region could be detrimental to crop production and food security. However, the team observed that the effect of changing rainfall patterns on the crops might have been influenced by timing of onset and cessation of growing season rainfall, other than late or early cessation. This is perceived as such on account that a plant's response to changing rainfall patterns in a given area is effectively based on timing of the changes in relation to water requirement phases during critical stages of plant growth.

In a similar study conducted in Tanzania, Msongaleli, Tumbo et al. (2017) found a mix of significant and non-significant trends in onset, cessation and length of growing season which had varied effects on yield of cereal crop. According to the team, simulated model results for three different varieties of sorghum attest to the importance of rainfall distribution during a growing season to yield of crops at various critical stages. Yields of crops in 1998 were compared to 2008 and results showed marked differences where the 1998 crop yield was lower for all sorghum varieties, attributed to water stress as a result of early rainfall cessation. Moeletsi, Walker et al. (2011) argues that early growing season rainfall cessation shortens growing season period, which affects long season crop varieties while late rainfall cessation may favour some crop varieties.

According to the Climate change fifth assessment report (Christensen, Hewitson et al. 2007) southern and eastern Africa precipitation projections indicate increasing growing season rainfall variability which is projected to decrease crop yield especially cereals on which the population in the region depend for sustenance. Malawi as a country in this region is therefore likely to experience changes in maize yield if the severity of growing season rainfall variation with respect to its cessation intensifies. Essentially localised studies on the association and effects of these projected rainfall trends would be important to provide detailed picture on how best to address their effects on crop production and food security in the country.

Results from the current study have also shown that increasing growing season length (marked by duration of rainfall) did not affect maize yield per hectare in a majority of districts across the country, with only Ntcheu's maize yield per hectare increasing following a longer rainfall duration. This result is somewhat surprising in that a trend analysis of annual rainfall duration in the country show decreases over time among almost all districts. This suggests that maize is likely to suffer since a shortened rainfall duration entails less water availability for plant growth. However, it is important to know that there are two conditions that account for shorter duration of growing season rainfall; late or delayed onset of rainfall followed by early cessation, or early onset followed by early cessation. The effect of both conditions depends on the period in maize plant growth processes at which water availability is below the required growth process threshold, such that the critical stages that determine yield would be affected. This explanation however may count in situations where non-climatic variables are not considered in the analysis, since results could be different if such variables are included in the regression model.

Furthermore, the current study did not also consider the period at which growing season rainfall terminates, soil characteristics and soil water balance in each of the districts of the country and stage of maize plant growth at the time rainfall terminated. Such information would provide a fuller picture on the association of rainfall duration with maize yield at various spatial and temporal scales in the country. The information would provide critical input for interventions to address the effects of changes in annual rainfall duration on different types of crops and cultivars, in order to ensure availability of food. Polade, Pierce et al. (2014) explains that number of dry-days in a rainfall year are likely to have significant alterations to precipitation regimes in different parts of the world as global climate systems experience changes resulting from global warming.

Such changes include increases and decreases in rainfall and water flows at various spatial and temporal scales in different regions, augmented by altitude, global oceanic currents and air circulations. These changes are projected to have significant effects on crop yield especially in rainfall dependent cropping systems predominant in developing regions i.e. SSA, where yield of cereals crops such as maize, wheat and sorghum are projected to lower (Parry, Rosenzweig et al. 2004). In the current study, linear regression analysis between time series number of dry-days in a cropping season and maize yield per hectare show that increasing dry-days had mixed results; a positive association in the three neighbouring central region districts; Dedza, Lilongwe and Mchinji, and a negative in Chitipa district up northern region.

Although spatial variations in rainfall patterns could explain differences in the associations with maize yield, the result could be somewhat interesting because increasing dry-days entail low rainfall intensity and in most cases poor soil-water balance which would affect various plant growth processes i.e. flowering in maize. The current result could therefore suggest that increasing dry-days in a rainfall year could show that soil conditions may be highly water logged such that dry conditions would enhance soil air and moderate conditions for absorption of nutrients for plant growth, leading to better yield. A result as noted in the three central region districts could suggest this explanation, although a detailed analysis of soil texture, periods and intensity of dry-days in the districts have not been examined in the current study.

However, studies indicate generally negative correlation between increasing dry-days in a rainfall season and yield of crops, which makes current study results interesting. In Zimbabwe Kuri, Murwira et al. (2014) regressed number of dry-dekads derived from vegetation condition index (VCI) against official ground-based maize yield estimates for over four seasons from 2009 to 2013. Results indicated that increasing dry-days in a dekad had significant negative association with maize yield per hectare, as was the case in Chitipa district in northern Malawi. A related study examining long-term trends in climate variables and effects on crop productivity were based on experimental data from 1965 to 1993 in the southern region of Mali (west Africa). The study found that increasing dry-days negatively correlated with cotton yield (Traore, Corbeels et al. 2013). In yet another study, Matiu, Ankerst et al. (2017) observed that apart from intensity of dry-days in a rainfall season effectively impacting yield of crops, consecutive dry or warm years (suggesting elongated spells of dry-days in a cropping season) caused some spill over effects that reduced crop yield from one cropping season to another.

In this study, yearly yield of maize, rice, soybeans and wheat of top producing countries were combined with growing season temperature and standardized precipitation evapotranspiration index (SPEI) dating 1961 to 2014, to assess the linkages between climatic variables and crop yield. Results showed that heat and warming conditions associated with dry-spells reduced yield of maize and wheat unlike rice, attributed to high temperature and drought in the studied countries. The study suggests that while seasonal dry-days have a direct effect on crop yield i.e. affecting crop processes within a given growing condition, persistent dry conditions from one cropping season to another do damage yield of cereal crops such as maize and wheat.

In essence, changing patterns of dry-days in a rainfall season have significant associated effects on different crops at different time-periods and places. With reference to current study findings, the sparse effect of prevailing trends in dry-days during a rainfall season on maize yield in the central region districts could suggest that the intensity of dry-days in a rainfall season occurred at a time when maize yield was ready for harvest unlike the critical pollination and grain-filling phases, which would have negatively affected yield. The positive effect on yield despite increasing dry-days trends could also entail the necessary conditions to avoid maize being attacked by blights associated with persistent rainfall and moisture, at a time the crop needed drying.

According to Hatfield and Prueger (2015) temperature is one of the primary climatic factors to plant's rate of growth. Warmer temperatures (which are expected to become extreme under climate change influences) have negative impacts on crop production through effects on plant growth and sensitive phenological processes such as pollination, a key determinant of crop yield. For regions whose temperature trends are predicted to continue warming amid increases in incidence of extreme heat such as sub-Saharan African region, this argument is obviously worrisome. This is so when considering the climate dependent crop production systems on which millions of people already experiencing food and nutrition insecurity in the region survive.

In the current study, minimum growing season temperatures had statistically significant association with crop yield, where a unit increase in the temperatures was associated with increasing maize yield per hectare in the southern and northern tip districts of the country, Nsanje, Chitipa and Karonga. There was no statistically significant association between maize yield per hectare and cropping season maximum temperatures in the remaining 22 districts studied.

The results could be a reflection of trends in the two temperature variables over a 45-year period. The significant association of the minimum temperatures with maize yield in the three districts was therefore a reflection of the prevailing trends observed across the country, only that the impact was rather strong in the southern and northern tip districts of the country. The results indicate that like all other previously discussed climate variables, increases in growing season temperatures have a geographically sparse association with maize yield in the country, and possibly a weaker negative influence on maize yield. However, different crops have different responses to changes in climatic variables at various spatial and temporal scales, and including non-climatic factors in the analysis could have produced different results.

In this study, the varieties of maize were not considered since focus was on total maize yield response to prevailing temperature and rainfall conditions, irrespective of whether it was local or hybrid varieties. While this argument may stand, other studies i.e. Rurinda, Wijk et al. (2015) found that there was no difference by maize cultivars in the effect of climate change in Zimbabwe, where all three cultivars ; SC403 (131 days to maturity), SC513 (137 days to maturity) and SC635 (142 days to maturity) were given similar treatment i.e. planting dates and three fertilization rates. Using an APSIM crop model, yield and biomass output from observed climate data simulations showed yield reduction of 13 percent for all cultivars, suggesting that the response of maize crop variety to observed climatic trends did not differ by cultivars.

Further, it is not just trends in the temperatures that affects crop yield, or extremes in the temperatures, but as Hatfield and Prueger (2015) observed, it is the timing of the unfavourable temperature threshold in a crop's development process that determines the effect. Based on their study on temperature extremes and effects on plant growth and development the two found that variability of maize yield was influenced by temperature extremes during pollination stage, where maize pollen was noted to decrease with exposures to temperatures above 35°c. This was on account that pollen viability is enhanced under high vapour pressure deficits. In addition, potential maize plant kernel growth was reduced with temperatures above 35°c. The team maintains that temperatures above 30°c negatively affects cell division and amytopast replication in maize kernels, which reduces the size of the grain sink and ultimately yield. For Malawi, current temperatures trends have not shown statistically significant increases associated with yield reduction in maize yet, but persistence in the trends as projected in the region entails that maize would be affected, leading to lower yield and food shortages in the region.

Appropriate interventions therefore are called for to avert this simmering negative climatic feedback of temperatures on crop yield in the country.

9.4. Association of selected cropping season temperature and rainfall variables with household food security status in Malawi

As of 2016, approximately 842 million people faced food shortages around the world, (Zhou, Shah et al. 2017), many in regions with rapidly growing population, wide spread poverty, higher disease burden, political and social conflicts (Rukuni 2002, Wheeler and Von Braun 2013, Timmer 2014). The sub-Saharan African region, eastern and southern Africa, the Horn and parts of western Africa are among the regions experiencing wide spread food insecurity, exacerbated by demographic, socio-economic, political and geographical conditions among other factors (Moore, Alagarswamy et al. 2012, FAO 2015). Climate variation and change is argued one of the major problems facilitating and augmenting food insecurity in the regions (Rosegrant and Cline 2003, Ericksen, Ingram et al. 2009, Godfray, Beddington et al. 2010).

In the current study, understanding the association between climatic variables i.e. temperature and rainfall with household food security involved performing a series of multi-level logistic regression models involving variables operating at different levels i.e. household and district levels. Random component results indicated that there was significant variation in household food security status on account of selected temperature and rainfall variables, operating at higher level i.e. district. This result concurs with findings from a cross-country analysis of 5299 households in Latin America, Africa and Asia assessing climate shocks and smallholder household's food insecurity by Niles and Salemo (2018).

Households that experienced climatic shocks during the study period were 1.73 times more likely to be food insecure than those which did not experience such climatic events across all studied countries in the continent. Current study results and reviewed literature indicate that apart from household level factors, upper level i.e. (district) climatic factors explain variations in households' food security status across the world. These findings suggest that while interventions addressing household food insecurity in Malawi emphasize household level factors, focus should also be put on aggregate district level factors in order to effectively and comprehensively address factors operating at both micro (household) and macro (district) levels in addressing households'' food insecurity.

Results from the current study have shown that total cropping season rainfall had significant association with household food security status. Above average cropping season rainfall was associated with higher odds of a household becoming food secure. The positive association between above normal cropping season rainfall with household food security status in the country seems to reflect the positive association and feedback of decreasing total rainfall trends (reported in chapter 5) with maize yield. Even if rainfall is above average in a season, yield may not be affected because there is need for water anyway (which is not beyond the crop's phenological requirement) to facilitate crop growth. Hence households are likely to have better crop yield and food availability.

While this argument might hold, studies indicate that higher than normal cropping season rainfall are detrimental to crop yield, especially in regions dependent on rainfall for food production on the farm. For instance, in Zimbabwe Manyeruke, Hamauswa et al. (2013) noted that increased intensity of rainfall caused floods which affected crop yield, resulting in many households becoming food insecure. Another study conducted in Ghana by Ndamani and Watanabe (2015) also found an inverse relationship between annual rainfall and crop production for all assessed crops, associated with decreasing annual rainfall. However, the decreasing rainfall trends reported in the current study might suggest decreasing rainfall intensity which normally could have resulted in floods and crop washouts, causing food insecurity among households. As such, rainfall decreases could in some instances be associated with better household food security status as the rainfall trend may be getting normal in the season, good for crop conditions and leading to better yield.

Apart from climatic influences on household food insecurity, demographic and socio-economic factors of households also influence its food security posture. Results from this study showed that the higher the education level of the household head, the higher the odds of the household becoming food secure. This concurs with findings from another study undertaken by Mutisya, Ngware et al. (2016) in Kenya's informal urban settlements which investigated the effect of education on household food security situation. Results showed that the probability of a household being food insecure decreased with increasing levels of education attainment.

According to Acker, Gasperini et al. (2009) education improves and widens opportunities for employment and skills, fosters resilience and competitiveness with which people engage in livelihood activities that generate income on the household, in order to be food secure. As such, higher education of the household head is likely to have a positive association with household's food security status, since the head becomes productive enough to meet the food needs of the household. Appropriate interventions to enhance education status and skills among household members, particularly those responsible for the day to day needs of households ought to be enhanced in order to increase households' capability to secure food for its members in the country, given few adults in Malawi have secondary and much fewer tertiary education.

The current study has further found that household size and not its dependency ratio was significantly associated with its food security status, where bigger households i.e.> seven members had higher odds of being food secure compared to smaller size households. This result was somewhat confusing in that most studies have documented that in so far as household size influence food security, larger households are most often food insecure compared to smaller households. (Ajao, Ojofeitimi et al. 2010, Silvestri, Sabine et al. 2015, Farzana, Rahman et al. 2017). Fisher and Lewin (2013) explain that it is not only household size per se that determines its food security status, but its structure in terms of age and sex distribution of the members, as well as their socio-economic status i.e. employment or education, that matters when it comes to food acquisition and distribution within the household.

Grobler (2016) contends that a larger household whose members are male and all engaged in active economic labour is likely to be more food secure as members pool their resources for a common good. However, a household with younger and elderly members who are less active and contribute little to the household's economic resource base might be more prone to food insecurity than the former. This explanation could suggest that households in the IHS2010 though large and potentially detrimental to their food security status might have been pooling their labour together to source food because they would have been active enough compared to younger member households.

In essence, rather than household size, it is the dependency ratio of the household that might have influenced the odds of it being likely to be food secure other than mere size, however, this variable was not statistically significant in the study.

In the current study, non-poor households had lower odds of being food secure compared to their poor counterpart. This observation has been reported by various studies examining correlates of food security in Africa and other parts of the world i.e. Omotesho, Adewumi et al. (2010) Ali Naser, Jalil et al. (2014) Harris-Fry, Shrestha et al. (2017). Poverty status is a significant factor to food security status as it determines ability of households or individuals to access sufficient and good quality food meeting their dietary requirements for health. Half of the population in Malawi are classified as poor (living below the $1.90 a day) and so prone to food insecurity (MalawiGovernment 2017). The third Malawi Growth and Development Strategy (MDGS2016-22) has strategies to spur economic growth in the country in order to offset widespread poverty. Despite investments in productive sectors such as mining, tourism and manufacturing, there is need for enhanced and well targeted safety nets and social protection programs to reduce food insecurity among people, influenced by poor production associated with climatic changes in the country.

9.5. Association of selected cropping season temperature and rainfall variables with under-five children's nutritional status

In Malawi, addressing malnutrition is one of the development goals pursued by the government, highlighted in the overarching growth and development strategy (MDGS2016-2022). Malnourished children have poor growth potential which limit their physical and mental ability essential for productive life in future. They are therefore likely to maintain a cycle of poverty and poor health, which is not conducive for human capacity development, crucial for Malawi's economic growth and development. Studies i.e. Jankowska, Lopez-Carr et al. (2012), (Tirado, Crahay et al. 2013) have maintained that adverse changes in climatic conditions i.e. rainfall and temperatures influence malnutrition due to crop failure associated with unconducive cropping conditions i.e. too much or insufficient rain, higher or too low temperature. Current study findings (Chapter 5) indicate that Malawi is undergoing variations in cropping season rainfall and temperature conditions at different spatial scales.

Coupled with poor household socio-economic conditions i.e. poverty, low education attainment of head, such conditions affects household food security, leading to poor nutritional status among household members especially under-five children.

Results from the current study have shown significant variation in child stunting, wasting and underweight influenced by contextual (district level) climatic factors such as shortened duration of cropping season rainfall and increasing minimum temperatures during the season. The result suggests that apart from lower level factors i.e. household poverty level, education attained by the child's mother, there are significant contextual factors influencing child nutritional conditions in the country. This observation was also noted in other studies i.e. Adekanmbi, Kayode et al. (2013), whose multilevel modelling analysis found higher variation in stunting among under-five children contributed by upper level factors i.e. community level factors. As such, efforts to address child malnutrition in Malawi and indeed among African countries must include identification of contextual factors which predispose children to poor nutritional status at various spatial scales. Such an approach will ensure that strategies and policies for reducing malnutrition in the country include essential factors in their proper contexts for effective policy interventions.

Among contextual factors examined for association with child nutritional status in the current study were cropping season rainfall duration and temperatures, both of which significantly influence child nutritional status as measured by stunting, wasting and underweight. For instance, below average rainfall duration was associated with higher odds of stunting, wasting and underweight among the studied children. Below average rainfall and maximum temperatures were also associated with lower odds of stunting among under-five children studied. A study by Hagos, Lunde et al. (2014) assessed climatic change, crop production and child under-nutrition in Ethiopia and found that decrease in temperatures during the cropping season was associated with decrease in moderate stunting. Explaining the result, the team suggests that the association between climatic variables and child nutritional conditions operate through the crop production pathway, where lower crop yield as a result of unfavourable climatic conditions causes food insecurity among households, predisposing children to malnutrition. According to Burke, Lobell et al. (2009) and Schlenker and Roberts (2009) higher temperatures reduce soil water crucial for various plant growth and development processes, resulting in low crop yield and household food shortage.

In concert with other factors, these conditions lower a child's nutritional status. In this understanding, decreasing temperatures (within the crop's phenological requirement) in a cropping season may provide favourable conditions for crops, leading to better yield and household food availability, essential for good nutritional status. In that regard, as was the case in the current study and one by Hagos, Lunde et al, 2014, decreasing temperatures in a cropping season are likely to influence positive crop yield outcome, which could be an indicator of adequate food availability on the household, essential for better nutritional conditions among children under-five.

In Malawi, floods have been singled out as one major factor influencing poor crop production, food insecurity and poor nutritional outcomes among households (Devereux 2002, Kari Pauw 2010). Current study results have noted significant association between below average rainfall, (which could entail reduced rainfall intensity) and lower odds of a child being stunted and underweight. Considering the two pathways through which climatic conditions influence poor nutritional conditions among children i.e. the crop-yield food security pathway and the infections and diseases pathway, decreasing rainfall trends in the country could entail reduced rainfall intensity, leading to less floods occurring. Such a situation among other non-climatic factors could be conducive for crop yield, leading to household food security, thereby reducing the odds of household members being malnourished.

Further, decreasing rainfall intensity could also entail decreasing availability of stagnant water which harbour vectors for infectious diseases such malaria and diarrhoea, which are among the major influencing factors for malnutrition among under-five children in Africa (Nel 2010, Wilson, Bradley et al. 2018). Decreased incidences of childhood infections and diseases such as these could therefore suggest that children's bodies are able to make efficient use of food nutrients essential for their growth and development (Baingana and Bos 2006), lowering poor nutritional conditions. As such, current rainfall and temperature trends in some parts could be an important factor to better child health outcomes in the country.

Among demographic and socioeconomic factors associated with child nutritional status in the current study, sex of the child, the child's age and maternal education had significant association with stunting and underweight in the final models of these measures. Female under-five children had lower odds of being stunted and underweight compared to male under-five children.

The odds of a child becoming stunted were higher at 24-35 months compared to all other categories of child age, and the odds were higher for underweight at 48-59 months. A child from a mother who had attained secondary education and over had lower odds of being stunted and underweight compared to one whose mother had not attained any education. Rural under-five children had higher odds of being underweight and wasted compared to their urban counterparts, and children from poor households had higher odds of being stunted than those from non-poor households.

These findings relate with studies conducted in different parts of the world on factors associated with child nutritional conditions. For instance in India, Jawaregowda and Angadi (2017) found gender based differences in nutritional status of under-five children. Controlling for other factors, the prevalence and odds of stunting were higher among male than female children. Similar findings were reported in a study assessing socioeconomic factors associated with nutritional status of infants aged 0-23 months in Pangkep, where prevalence of stunting was reportedly higher among males than females. Differential child care practices influenced by gender preferences of children by the parents is argued to be one of the reasons accounting for gender based disparities in nutritional outcomes among children.

In a study on parental education, gender preferences and child nutritional status in four developing countries, Novella (2013) noted that household allocation of resources varied with gender of the child and the parents. Maternal power had larger effects on girls than boys' health outcomes in Peru and Vietnam, while no difference in child care based on sex was observed in Ethiopia. For Malawi, other than social and cultural factors associated with sex differentials in child nutritional status, Madise and Mpoma (1997) suggests that biological frailty of male children from birth could account for poor nutritional outcomes compared to female under-fives. Targeted interventions to avert sex based disparities in nutritional outcomes are therefore called for in the country. For instance, promoting child growth monitoring services targeting mothers and carers of under-five children, where early detection of malnutrition could be made and appropriate recuperative services provided to affected children.

Revisiting cultural factors influencing gender based differential child care practices among mothers and designing appropriate policy interventions directly addressing gender-based disparities in nutritional conditions of under-five children could also be an important policy prescription to the problem.

Studies across the world have highlighted significant age differences in child malnutrition, with children aged 24-35 months noted to experience higher malnourishment than all other age categories of under-five children. In Ghana, Jawaregowda and Angadi (2017) study on dietary diversity and child malnutrition found that the prevalence of stunting among under-five children increased with increasing age of the child, highest at 35 months. A similar study examining association of demographic characteristics with malnutrition among children less than 24 months by (Abubakar, Uriyo et al. 2012) found statistically significant differences in stunting across age of children, with those aged 12-24 months being worse off than those aged 6-11 months.

Among other factors explaining age-based differentials in child nutritional status is weaning age. Children are weaned from breast feeding at different ages depending on various factors as observed by Bewket Zeleke, Welday Gebremichael et al. (2017). It is at weaning age that mother's care practices become a critical factor to a child's nutritional status, as they introduce supplementary foods. Poor hygiene at this stage result in frequent infections such as diarrhoea which predispose the child to poor nutritional outcomes as the body fails to make effective use of consumed food due to reduced body absorptive capacity (Ogbo, Agho et al. 2017). Further, striking an appropriate balance between child care demands and productive work following weaning period by the mothers has an important bearing on nutritional outcomes on the child as women prioritise productive tasks than child care, exposing the child to poor feeding practices that affects its nutritional status (Chikhungu and Madise 2014).

Promoting growth monitoring services at health facilities for women with under-five children would be an important strategy where women are told about child care practices to avoid exposing the child to poor health outcomes such as malnutrition. Augmenting household survival resources for poorer mothers who would be tempted to compromise their quality of child care on account of productive work in order provide for the family could also be another important socioeconomic investment for the country.

For instance, reduced under-five sicknesses following proper care practices by mothers would reduce the country's disease burden which takes a higher proportion of finances to provide for curative and preventive service for under-fives. Such funds would be channelled to productive sectors of the economy in order to spur economic growth that can provide more social security services for the population. The country's population pyramid in figure 3 of the thesis shows a broad base, indicating that there is higher proportion of under-five children, who if well cared for in terms of proper growth monitoring and development would cut the proportion of governments expenditure on health services. Savings from health services could be re-directed to pro-economic growth investments that could ensure better employment for the population and hence better incomes with which to meet their day to day needs for their households including under-five child health, crucial for human capital development for the country.

Mothers' education status has been reported by many studies to be an important associate of child nutritional conditions around the world i.e. Stamenkovic, Djikanovic et al. (2016) in Serbia, Abuya, Ciera et al. (2012) in Kenya, and especially sub-Saharan Africa region, where child care is considered to be the domain of women, yet women form the majority of low educated population in the continent (Suen 2013). An educated mother is associated with enough resources such as income as they engage in productive and non-farm income which enhances access to materials for quality child care, with which to augment their abilities to provide care for their children (Akombi, Agho et al. 2017). Educated mothers also have the ability to make plausible decisions over a child's care when ill i.e. when and where to seek medical support, which is crucial for child health (Wamani, Tylleskär et al. 2004).

Current study findings showed somewhat surprising results in that children from mothers who had tertiary education had higher odds of being wasted and underweight compared to those whose mothers had no education. Among the factors accounting to this is failure to strike a balance between professional demands to which highly educated mothers are exposed, and proper child care. Tertiary education level women often spend more time at work, leaving their children with less capable and experienced child minders, who barely meet the required child care needs, i.e. proper sanitation and hygiene when feeding the child, attendance to growth monitoring services, among others.

Such situations compromise the quality of health for the child, making it susceptible to infections and poor nutritional health. As such, children born to highly educated women are likely to suffer poor nutritional conditions. Appropriate policy interventions could be ensuring accommodative working conditions in professional jobs, where women would be allowed more time off from work to care for their babies up to a time they are out of age related risks of diseases, infections and mortality to ensure their survival.

In the current study, rural based children had twice the odds of being wasted compared to urban-based children. Uthman (2008) found similar results in a study on community and individual effects associated with chronic malnutrition in rural Nigeria and so did Kanjilal, Mazumdar et al. (2010) and Fotso (2007) when investigating why children in rural areas were more malnourished than those in urban areas among African countries. Rural households have limited economic access to food and child care resources compared to their urban counterparts (Srinivasan, Zanello et al. 2013), hence children in rural settings are unlikely to have better nutritional health due to poor household economic status.

However, other studies i.e. Van de Poel, O'Donnell et al. (2007) have found that children in urban households had higher probability of stunting compared to their rural counterparts. Rises in food costs and compromised care quality for the children were among the factors associated with poor nutritional outcomes in the urban areas, as parents especially mothers prioritise productive activities than baby care, exposing the children to poor nutritional health outcomes. For Malawi, enhancing access and provision of growth monitoring services in rural settings is an important policy and programmatic response to this problem, considering that the majority of the population reside in rural settings. Such interventions would help reduce malnutrition and heavy costs for health service provision as most rural people rely on government support for their health services.

Results in this study have also shown that children whose households spend lower on food had higher odds of being wasted compared to those whose households spent more. Zere and McIntyre (2003) found similar results from a study on inequities in under-five child malnutrition in South Africa, where households in provinces with higher expenditure on food had lower malnutrition rates compared to households in poor provinces which spent lower on food.

Amount of expenditure on food determines both quantity and quality of food available to the household and its members (French, Wall et al. 2010). Insufficient food among households would influence poor nutritional outcomes especially among under-five children, hence households with low food expenditure having higher rates of child malnutrition. Significant efforts to augment household incomes such as social cash transfers for poor households would be a better policy strategy as it will enhance households' ability to acquire sufficient and good quality food for its members, especially under-five children.

9.6. Conclusion

This chapter has discussed findings of the study on Malawi's trends in selected temperature and rainfall variables, relationship between maize yield and selected temperature and rainfall variables in a cropping season, assessment of association between selected temperature and rainfall variables with households' food security and under-five children's nutritional status. Attempts were made to discuss the results within the context of other studies conducted in different parts of the world, with a focus on Africa, a continent known to experience severe climatic variability with adverse effects on people's livelihoods, food security and health.

Results show that Malawi is undergoing significant variation in some cropping season temperature and rainfall variables, which have significant association with maize yield, households' food security status and under-five children's nutritional conditions. This finding entails that efforts to address household food insecurity and malnutrition in the country ought to consider significant associations existing between climatic variables in a cropping season and household level demographic and socio-economic factors noted to be associated with household food security and child nutritional status. Such an approach will ensure design and implementation of target specific and impact oriented interventions to address effects of climatic variation on maize production, households' food insecurity and under-five malnutrition conditions in the country.

Chapter 10. Conclusion and study implications

10. 1. Introduction

This study examined trends in selected temperature and rainfall variables, relationship between cropping season temperature and rainfall variables with crop yield i.e. maize, association of selected temperature and rainfall variables with household food security and under-five children's nutritional status in Malawi. The study intended to address the knowledge gap on understanding how variations in cropping season temperature and rainfall variables relate with crop yield, household food security and nutritional status of members in the country, given current climatic trends. The study was premised on the background that Malawi and most of the countries in the sub-Saharan African region rely on temperature and rainfall for the sustenance of the population through farming, be it crop or livestock production (Stevens and Madani 2016). Although there are significant non-climatic factors important for farming i.e. availability and size of land, climatic patterns for variables such as temperature and rainfall in a cropping season have been argued to be key to crop yield, household food security and child nutritional status.

Considering that global climatic conditions are experiencing variations augmented by global warming at various temporal and spatial scales, it was considered important to examine relationship between changes in selected climatic variables on households' food security and nutritional outcomes among children, taking into account socio-economic and demographic factors also argued to influence household food security and human nutritional status. It was envisaged that findings of the study would provide relevant input for evidence based policies and interventions to address the negative influences of changing and varying climatic conditions on household food insecurity and malnutrition, to enhance the country's human capital development.

First in the analysis was assessment of trends in selected cropping season temperature and rainfall variables i.e. total rainfall, its onset, cessation, duration, number of dry days, minimum and maximum temperature, using data from weather stations available in 27 districts of the country. This provided background information about Malawi's temperature and rainfall patterns over 45 and 43 years respectively, which shed light on understanding relationship of these climatic variables with crop yield, household food security and nutritional conditions of under-five children.

Second, linear logistic regression models for each of the districts (stations) were run to examine how maize yield related with the selected climatic variables over three decades. The purpose was to assess how variations in these climatic variables related with maize yield over time, so as to detect a climate variation signal on crop yield in the country, taking the case of maize. Third, multi-level logistic regression models were fitted to assess association of growing season temperature and rainfall variables, households' demographic and socioeconomic variables with household food security and under-five children's nutritional conditions in Malawi. This technique allowed assessment of variation in household food security status and child nutritional conditions at different levels i.e. household and district, depending on factors reported to influence these outcomes, as argued by other studies i.e. Grace et al, (2012), Jankowska et al (2012).

Prior to fitting the models, bivariate analysis was performed to examine relationship between independent variables themselves i.e. household level demographic socio-economic variables and climatic variables, and with dependent variables i.e. crop yield, households' food security status, child nutritional conditions i.e. stunting, wasting and underweight. Descriptive statistical analysis was also performed to examine distribution of household food security and children's nutritional status by socio-economic and demographic characteristics of households. These analyses provided contextual references on how results of regression models would be understood and interpreted. The following sections discuss key findings of the study and their implications in various policy areas.

10.2. Assessment of temperature and rainfall trends in Malawi

A 45-year rainfall trend analysis revealed that the amount of annual or cropping season rainfall is decreasing over time. This decrease is occurring alongside delayed onset, early termination and shortened duration of rainfall during the season. However, there are few districts or stations with statistically significant trends in these rainfall variables. The result suggests that with reference to rainfall, the climate variation signal is not geographically extensive in the country. However, of all five rainfall variables examined, geographically extensive significant trends have been noted in duration of the rainfall, which is becoming shorter over time.

Over a third of the country (10 out of 27 districts) was noted to experience significant shorter duration of annual rainfall over the 45 years. This finding shows that with reference to rainfall, a significant climate variation signal is more pronounced in its duration during the cropping season. Results have also shown spatially sparse statistically significant increasing trends in minimum cropping season temperatures, with only 8 districts indicating this pattern. Like rainfall, these changes have important implications on various sectors policy programs and activities in the country. For the agriculture sector, shortening rainfall duration entails that phenological processes such as flowering and grain filling are speeded, adversely affecting crop yield (Bergamaschi, Wheeler et al. 2007).

The government of Malawi has for long recognised significant effects rainfall changes pose to the agriculture sector, especially on food availability as highlighted in the three growth and development strategies; 2005-2010, 2011-2016 and currently the 2016-2020 strategy. The introduction of the ‘Green Belt’ initiative in 2010 was a response to decreasing water availability during cropping seasons due to shorter rainfall durations. This initiative focused on mechanised food crop farming including irrigation to millions of farm lands lying within 20km radius of the country’s three lakes and 13 perennial rivers. The overall goal was to enhance food security and self-food sufficiency on the plan that harvest from the interventions would provide food crops for households in areas where cropping season rainfall had been poor, (Chinsinga 2017). However, the project has been affected by land and crop prioritization issues involving local farmers in the areas and multinational and local cooperative investments i.e. sugar manufacturing, whose priority focus is cash rather than food crop farming, leaving subsistence farmers suffering. This has led to dismal progress towards addressing climate variation influenced food insecurity in the country.

Current study results have localised areas experiencing significant shortening of rainfall during the cropping season, likely to experience lower crop yield, consequently low food availability i.e. Mzimba, Kasungu, Lilongwe, Machinga, Chikwawa and Nsanje districts, which are not lakeshore districts but could benefit from perennial rivers irrigation initiatives, which are also free from multinational interests. The ministry of agriculture ought to undertake evidence based target specific identification of irrigation project areas if crop production and food self-sufficiency is to be realised by the interventions.

Such an approach would also ensure cost effectiveness of the intervention since focus is directed to areas where significant effects of climatic variation on crops are experienced.

In Malawi, seasonal rainfall is the main recharge strategy for water bodies such as rivers, dams, boreholes and wells, from which the majority of the population derive water for their day to day domestic usage. Changes in rainfall patterns therefore pose considerable concerns on water availability. Decreasing trends in duration of rainfall as detected in the current study suggest diminishing water availability over time. Increasing household access to safe drinking water and sanitation is a long standing development goal for Malawi, highlighted in its overarching development strategy since 2005. Current estimates show that 71 percent of the rural population, (which accounts for 82 percent of the population) rely on tube wells as their main source of both drinking and sanitation (MalawiGovernment 2015). Decreasing rainfall influenced by shortened duration during the cropping season signifies potential threats of diseases such as diarrhoea, adding on to already increased high disease burden in the country.

Improving provision of hygienic sources of water i.e. tap water in rural areas is therefore a significant intervention in the water sector in view of the changing rainfall patterns. Significant investments in the health and water sectors must be dedicated to ensuring that rural populations have safe sources of water to ensure that water borne diseases are minimized. At a household and community level, rainwater harvesting is suggested in this research study as a viable option to overcoming shortages of water emanating from decreased length of rainfall season. This would ensure that however shorter a rainfall duration, households have secured water that could have been lost through surface runoff and conserve it for future domestic and farm use by channelling uphill rainfall water fall into dams as water reservoirs.

Current study findings also have important implications on the energy sector of the country. The main source of power in Malawi is hydro-electricity, which depends on water from the Shire river, Lake Malawi's outlet. Rainfall plays a significant role in maintaining water levels and volume along the river course to maintain appropriate runoff enough to drive the turbines generating electricity at the power plant (Gamula, Hui et al. 2013).

Over the last 5 years, Malawi has been experiencing intermittent power supply attributed to many factors amongst which is climate variation, mostly associated with floods causing siltation and low rainfall affecting water levels in the Shire river. Almost 98 percent of all industries in the country rely on electricity for their productive activities (Malawi Government, 2012). Frequent power outages have crippled industrial productivity and further affecting 13 percent of the population relying on electricity for domestic use (Taulo, Gondwe et al. 2015). Poor electricity output, which is also accessible to few households in the country entails continued reliance on unsustainable energy resources such as charcoal from trees by 87 percent of the population, a situation that exacerbates environmental degradation and climatic changes. Although siltation due to flooding of the Shire river has been reported as the cause of intermittent power supply in the country (Gamula, Hui et al. 2013) current study findings on decreasing rainfall amount following shortening rainfall season suggests that prevailing rainfall trends will have significant effects on water levels in the Shire river which will affect power generation in the country.

Among other suggestions, developing alternative energy sources would minimize power problems emanating from decreasing rainfall duration and insufficient water available for hydro-electricity generation. The current climate change policy stresses the need for diversification of energy sources, moving away from hydroelectricity to other renewable and low carbon energy sources. However, 87 percent of the country already use biomass energy resources (Malawi Government, 2017), a situation that has resulted in destruction of the country's natural vegetative resources and already fragile ecosystems. Coupled with low technological use, dependency on farming as main livelihood strategy and increased population pressure on environmental resources, the country's energy situation in a precarious state. This study proposes investment in country wide government supported solar (energy) based power generation system. The positioning of the country within the tropics (where sunlight is received for longer periods in a day unlike in polar regions) entails Malawi can harness this energy resource to offset the current energy crisis, augmented by rainfall variations. Although this is a huge investment for the energy sector, its benefits outweigh the cost of continued power problems exacerbated by continued climatic variations in the country.

Investing in renewable energy resources will not only overcome climate variation influenced power problems but also ensure sustainability of Malawi's fragile ecosystems i.e. rivers water which are already hard hit with poor water recharge systems i.e. decreasing rainfall, but also ensure generation of cleaner and sustainable energy for the country. This program proposition does not necessarily declare current hydroelectric system redundant but rather augment provision and availability of alternative power sources accessible to the local population, while giving due priority to the industrial sector in order to spur economic growth.

10.3. Association of temperature and rainfall variables with crop yield

The next objective in this study was to assess a climate variation signal on crop yield using the case of Malawi's staple food crop, maize. This involved fitting linear regression models on de-trended maize yield per hectare as the outcome variable and selected temperature and rainfall variables as independent variables. De-trending time series maize yield data was done to remove effects of non-climatic factors on maize yield trends, such as fertiliser inputs, as in Kumar, Raju et al. (2011). Results for the analysis showed that of the 7 independent climatic variables used in the model, only four were significantly associated with maize yield per hectare; total rainfall, its onset, cessation and duration.

Delay in cessation of rainfall, increases in dry days during the cropping season were associated with decreases in maize yield per hectare, while increases in rainfall duration and maximum temperatures were associated with increases in maize yield per hectare. There were variations in the relationship of these climatic patterns with maize yield across districts, where in some districts, delays in cessation of rainfall and increases in dry days during the season were associated with increases in maize yield per hectare while in others, there were significant decreases in maize yield per hectare. As argued by Munodawafa (2012), higher rainfall intensity due to intense and delayed rainfall cessation is associated with floods which erodes plants and soils leading to poor yield. Although longer rainfall season (late cessation) and longer rainfall duration have been associated with increased yield of traditional cultivars (Guan, Sultan et al. 2015) they also provide necessary conditions for thriving of disease causing organisms which affect quantity and quality of crop harvests (Hardwick 2002) which finally enhances food insecurity (Linneman, Matilsky et al. 2007, Weber, Haensler et al. 2018).

Increases in dry-days during a cropping season in many south-east African countries (including Malawi) are likely to persist owing to increasingly arid conditions occurring in the region, exacerbated by regional climatic changes (Barron, Rockström et al. 2003) Although policy programs and projects are in place to enhance irrigation in the agriculture sector in Malawi, most farmers do not have sufficient financial resources to access small scale irrigation equipment such as water pumps, let alone maintain the equipment, with which to augment water availability for their crops. It is argued in this study that just like the government provides subsidy on farm inputs to rural farmers i.e. seeds and fertilizers in order to augment production of maize (Chirwa, Matita et al. 2011) there is need to provide support to subsistence farmers to access irrigation equipment with which to enhance water availability for maize production, so as to avert poor crop yield on account of increasingly decreasing rainfall. This ought to be a targeted intervention considering that different areas in the country experience difference rainfall patterns and trends, with varying effects on maize yield. Further, communities ought to be trained in the use and maintenance of accessed equipment in order to ensure long life and optimum utility.

The water sector would also do well to encourage local approaches in conserving water, such as community-based water management initiatives. These could include construction of community-based water reservoirs to be used for irrigation of small-scale farms when rain fails in order to spur maize production. Although the current water policy and the national irrigation policy lays out various strategies for water resources management, not much is mentioned specifically addressing the need for extensive community-based initiatives to conserve and manage water for irrigation with a purpose of responding to decreasing water availability influenced by adverse climatic conditions.

Further, most of the interventions in the water sector have focused on provision of clean water to address infections arising from use of untreated water mostly in rural areas. For instance, USAID has supported various water and sanitation programs from 2004 to 2013 in Malawi. Others include Water Aid and Population Services International (PSI), which provide portable and water treating chemicals for urban and rural households in the country. However, not much effort has been invested in equipping and building capacity of local communities to sustainably manage available water resources, which are facing adverse climatic effects, hence unlikely to be sustained. Effective management of community-based water resources in view of varying rainfall patterns would be an important policy intervention in the water sector.

10.4. Association of temperature and rainfall variables with households' food security status in Malawi

The third objective of the current study examined association of different rainfall and temperature variables with households' food security status, controlling for non-climatic factors argued to influence households' food security status. This involved performing multi-level binary logistic regression models to assess variation in households' food security status on account of factors operating at different levels.

Results showed that controlling for household level demographic and socio-economic factors and some cropping season rainfall and temperature variables, increases in rainfall significantly increase the odds of a household being food secure while increases in maximum temperatures during a cropping season lowered the odds of household food security. This association is envisaged to operate through crop yield where among other factors, temperature and rainfall influence seed generation, growth and consequently yield, which determines household food availability. Increasing temperatures are associated with high evapotranspiration rates which robe the soil off water, causing plants to suffer water stress at various phenological periods, leading to low yield (Moeletsi, Walker et al. 2011).

Considering that Malawi's rainfall trends show a decrease (as reported in the current study), increasing rainfall are likely to be beneficial for crop yield, especially maize in the country. Although there are spatial variations in the temperatures across the country, trend analysis results showed increases in most districts of the country, suggesting that crops such as maize are likely to suffer, since Malawi's temperatures are generally high due to its tropical location. Further, results have shown that even when household level socio-economic conditions improve, significant attention ought to be focused on patterns of climatic variables such as cropping season temperature and rainfall, which have in themselves been the two key climatic variables providing significant evidence of climate variation in many African countries. These results have different policy implications. For instance, Malawi launched a Food Security Action Plan in 2008 in response to perennial food shortages.

Inadequate farming technology among subsistence farmers, land shortages, degenerating soil conditions and variations in rainfall patterns were notable influencing factors (Government of Malawi, 2008). Strategic activities to address food insecurity focused on universal subsidy of farm inputs, commenced in 2005 (Chirwa 2005), which were not financially sustainable given the country's poor economic base. Although the plan recognised the contribution of variable climatic patterns on crop failure, there was no effective strategic activities geared towards addressing effects of varying rainfall patterns on crop production, which even in the presence of universal access to improved farm inputs (majorly seeds and fertilisers) would not address food insecurity among the people. Current study results reveal that increasing temperatures and decreasing rainfall adversely affects household food security status. For the agriculture sector, government should consider intensifying irrigation services to local farmers in order to offset the effect of shortage of water for maize production, being a strategic food crop in the country.

Further, there is need for targeted provision of social protection and safety nets for households in districts that experience decreasing rainfall trends i.e. Mzimba, Nkhotakota, Kasungu and Ntchisi to ensure efficiency in addressing the food insecurity problem. This could be done while providing lasting support that will build resilience and capacity to communities i.e. diversifying crop production by focusing on less water demanding and heat resilient food crops, and improving access of farmers to technological equipment for irrigation at lower levels i.e. communities in districts affected by decreasing rainfall trends.

Responding to the food insecurity problem in Malawi, the food and agriculture organisation (FAO) has from 2008 to 2015 also engaged in activities to improve food security and nutrition in the country, in response to calls by government for assistance on the problem (FAO 2015). Among the areas targeted were Mzimba and Kasungu districts, where various activities such as training farmers on new farming knowledge and practices, business skills, diversified agriculture, income generating activities, environment, soil and water conservation, water and sanitation have been implemented. However the Malawi vulnerability assessment reports for subsequent years 2015,2016, and 2017 still mentions Mzimba, Nkhatabay, Karonga and Likoma (Northern region districts) as being food insecure every year (MalawiGovernment 2015, MalawiGovernment 2017).

Current study results have shown that the northern part of the country is experiencing decreasing rainfall, which suggests that key policy and programmatic interventions must among others address water shortages during the cropping season in the region, in order to spur crop production and avert hunger. Current study results have shown that poor, larger size, child and single headed households i.e. widowed, separated and divorced are prone to food insecurity in Malawi. Social protection initiatives i.e. cash transfers (MalawiGovernment 2016) currently underway ought to have a clear population profile if appropriate assistance is to be directed to deserving people as the current study suggests. Efforts to address increasing population i.e. encouraging family planning in order to reduce family sizes while enhancing its capability to produce enough for its members, although current study findings have shown that increasing household size is associated with household food security status. This calls for sectoral linkages between the Ministries of Finance, Agriculture and Health, where appropriate intervention packages ought to be implemented alongside efforts to address food insecurity in the affected areas.

10.5. Association of temperature and rainfall variables with Under-fives' status in Malawi

Results from the current study have shown that in Malawi, a significant amount of variation in child nutritional status is explained by climatic factors i.e. patterns of cropping season temperature and rainfall variables. Model results show that controlling for household level socio-economic, demographic factors and other rainfall and temperature variables used in the analysis, shorter duration of cropping season rainfall is associated with higher odds of stunting, wasting and underweight among under-five children. Above average cropping season minimum temperatures are associated with higher odds of underweight among children under-five. As other studies i.e. (Hagos, Lunde et al. 2014, Phalkey, Aranda-Jan et al. 2015) have argued, in Africa association of climatic variables with human nutritional outcomes operates through crop production, which provides food for households essential for good nutritional status of its members.

Current study results have some policy implications in various sectors. For instance, in Malawi discussions about the effects of climate change or its variation on food security and health of the population have majorly concerned policies and strategies on averting effects of climatic shocks such as floods and droughts on household food security situation. The introduction of the social protection and safety nets programs in 2006, the Agriculture Sector-Wide approach project activities (ASWAP) in 2011 and the social support program (2018-2023) have all been aimed at strengthening households' capabilities to respond to climatic shocks i.e. floods and droughts, food insecurity and poverty. However, evidence of progress in these initiatives have been contrary to the objectives, proportion of food insecure and poor populations continue to rise (MalawiGovernment 2017).

Despite the understanding that floods and droughts are the more pronounced climatic risks affecting household food security and poverty in Malawi, changes in cropping season climatic patterns i.e. decreasing rainfall and increasing temperatures also affect crop yield, leading to shortage of food and in some instances poverty among households in the country. Significant policy interventions ought to consider how best to respond to these climatic anomalies which have implications not only on food security status of households, but also on nutritional outcomes for under-five children, as the current study reveals. Essentially, government through the agriculture ministry should consider rolling out subsidized early maturing maize varieties to subsistence farmers in areas hard hit by these climatic conditions as shown in the current study. Further, there is need for households to be encouraged and supported to diversify food crops production in order to ensure that they cultivate alternative food crops during the cropping season despite failure of maize, which has been noted to be highly sensitive to climatic variation.

Literature i.e. Wright, Garland et al. (2014), (Martins, Toledo Florêncio et al. 2011) and Devereux (2007) shows that the effects of climate change on human nutritional status in sub-Saharan African region have focused on explaining how changes in climatic patterns influence spread of infectious diseases such as malaria, diarrhoea and cholera. These are reportedly facilitated by floods and droughts influenced by adverse rainfall and temperature conditions. For under-five children, frequent bouts of infections such as these erode the body's capacity to absorb nutrients essential for good nutritional status (Boko 2007, Katona and Katona-Apte 2008). Current study results have shown that despite this pathway through which malnutrition operates, adverse temperature and rainfall patterns during the cropping season reduce crop yield and household food availability (and security), resulting in poor food consumption patterns and malnutrition children.

In view of this finding, Malawi's health sector response to adverse climatic variations ought to include understanding of climate variation-human nutrition linkages, and formulation of strategies that would offset malnutrition, influenced by food insecurity due to seasonal crop failure, apart from influence of infectious diseases, as the conceptual framework for the current study suggested. Essentially, targeted interventions by the health sector ought to focus on ensuring that households in areas experiencing adverse cropping season rainfall and temperature patterns are given nutritional support for under-fives upon appropriate screening. This is on the understanding that such areas are likely to experience food insecurity, alterations in food consumption patterns by household members, which would cause or influence malnutrition among under-five children.

10.6 Study implications on policy and programmatic intersection of climatic issues with food security and nutrition

Results from the current study have shown that there are inter-connections between variation in some climatic variables, households' food security and under-five children's nutritional status in Malawi. For instance, adverse climatic conditions i.e. decreasing cropping season rainfall have negative association with households' food security status. Shortening rainfall duration and increasing temperatures have associations with stunting, wasting and underweight among under-five children. This result indicates that there could be a policy and programmatic intersection involving climate issues, food security and human nutrition in the country.

However, the country's climate change policy does not consider food security or nutritional health as priority strategic areas. These issues are only mentioned as population problems, other than real policy goals within the realm of climate change discussions. Instead family planning and reproductive health have been mentioned within the broader strategic goal of slowing down population growth in order to limit environmental degradation associated with increasing demand and use of land resources for the population's survival. Essentially, climate change policy interventions ought to include strategies for addressing household food security as well as malnutrition. Similarly, efforts to address food insecurity and malnutrition in the country ought to recognise the influence of varying climatic conditions on household food security and nutritional conditions.

This recognition ought to focus on pathways through which climate change and variation associate with food security and nutritional conditions, especially among under-five children. Fundamentally, there is need for multipronged policy strategies addressing the multifaceted effects of climatic change and variation on households' food security status, whilst addressing nutritional problems associated with such adverse climatic conditions. Such policy objectives will ensure that efforts on adaptation and mitigation of adverse climatic effects on human survival are given due priority in the country's development endevours.

10.7. Limitations of the study

The current study assessed association between climatic variables, household food security and under-five children's nutritional condition in Malawi. Maize is a staple food crop for Malawi and its availability is synonymous to food availability (Chinsinga, Chasukwa et al. 2012). As such, the negative association between maize yield and trends in cropping season temperature and rainfall variables observed in this study suggests a negative relationship between changes in these climatic variables and food availability in the country. However, literature indicates that different crops react differently to different temperature and rainfall patterns in a cropping season (Ali, Liu et al. 2017). Much as poor maize production has been associated with low food availability and insecurity in the country as argued by Mazunda and Droppelmann (2012) and also noted in the current study results, there could be other food crops which could have an entirely different relationship with current temperature and rainfall trends. This could mean a different conclusion on the climate variables- crop yield relationship noted in the study.

The current study's limitation in this regard is that only one food crop was considered for this analysis. This was because there was no time series data for other major food crops matching the period of analysis with climatic variables used in this study i.e. 32 years. However, although maize is a widely used food crop in Malawi, it does not in essence entail that its poor response to current climatic conditions represent the response of all other food crops in the country, such that it would be conceived that current climatic trends are negatively influencing food availability in the country as current results show.

An appropriate approach in this regard would have been including main food crops in the analysis to assess how they react to these climatic conditions. Current study findings hence provide a part picture of how in Malawi food crops associate with climatic conditions.

There are so many factors influencing production of crops i.e. land size, quality, farm inputs such as seeds, fertilizers, pesticides, labour availability and expertise, and climatic conditions. Examining how each of these factors relate with crop yield requires a careful consideration and isolation of all other factors. The current study assessed relationship of temperature and rainfall variables with crop yield. However, non-climatic factors i.e. use of farm inputs were not controlled for in the analysis because time series data matching the period of analysis (32 years) from which these variables could have been generated at districts or household level was not available. To address the above situation in the study, time series maize yield data was de-trended to account for fluctuations in maize yield as a result of non-climatic factors (Lu, Carbone et al. 2017) such as use of universal fertilizer subsidy program implemented in the country from 2005 (Dorward and Chirwa 2011).

However, including actual non climatic variables in the regression would have enabled observation of changes in regression coefficients adjusting for these factors. This approach would have presented a comprehensive picture on the relationship between cropping season temperature, rainfall variables and maize yield accounting for non-climatic variables in the analysis. Research by the ministry of agriculture, food security, water development and irrigation should therefore consider including time series non-climatic variables in such analysis in order to isolate the climatic influence on maize yield in the country effectively. Further, results from analysis where these climatic variables were accounted for by de-trending maize yield could be compared with those from an analysis where the actual non-climatic variables were included in the models to assess how prevailing climatic trends are influencing crop yield in the country, key to review of the current food security policy.

One of the gaps in studies examining relationship between climate change and food security is focus on adverse climatic variables such as floods and droughts other than seasonal changes in patterns of temperature and rainfall as key climatic variables influencing crop yield. Although the current study has provided insight about relationship between seasonal temperature and rainfall patterns and household food security status, a complete picture could have emerged had floods and drought variables been included in the models, since climatic patterns involve extremes such as floods and droughts, and gradual changes over time such as periodic increases or decreases in the climatic variables. However, time series data on droughts and floods matching the period of analysis as was for temperature and rainfall was not available.

Generating a fuller picture about how climatic trends associate with food security in the country requires long term data variables in order to examine changes in regression coefficients over time. This requires a longitudinal other than a cross-sectional study. Research activities in the ministry of agriculture should therefore ensure that analysis of this nature includes both climatic and household level socio-economic data variables over a longer period in order to examine patterns of the association over time. Such information provides a comprehensive perspective of this association, which is essential for design of interventions to address influence of variation in climatic variables on food insecurity in the country.

Another approach could have been performing the analysis at different time points over a longer period of time. For instance, following the intervals of the integrated household surveys in Malawi i.e. 1998, 2004 and 2010, matching it with temperature and rainfall variables for the same years. However, the modules providing variables to be used in the analysis i.e. food security variables were available in two surveys only, the IHS 2004 and 2010. This made it difficult to analysis relationship between climatic variables and household food security over a longer period of time. This limitation affected provision of a comprehensive picture on how changing climatic patterns are associated with household food security status, which could have different results from the current cross-sectional approach used in the study. Research activities in the ministry of agriculture ought to consider this methodological gap in order to show changes in patterns of association in climatic variables and households' food security over time, relevant for policy and interventions on both climate change effects mitigation and aversion as well as ensuring sustainable households' food security.

The conceptual framework for the current study outlined two pathways through which under-five children's nutritional conditions could be influenced. First is the food security pathway, where crop production in addition to household level variables i.e. poverty, household size and residence influence under-five children's nutritional status. Second is the infections and disease pathway, where frequent illnesses reduce the body's capability to absorb essential elements in foods, resulting in malnutrition on the child. Reviewed literature i.e. Knox, Zafonte-Sanders et al. (2003) shows that under-five children's nutritional status is affected by other factors apart from poor food consumption. Amongst these are infections associated with poor hygiene i.e. diarrhoea, and environmental conditions i.e. floods and droughts (Dhara, Schramm et al. 2013).

However, the current study only addressed the food security pathway, where temperature and rainfall variables were associated with crop yield, thereby lowering household food availability. This situation was assumed to result in poor food consumption among its members including under-five children, whilst accounting for household and individual level demographic and socio-economic factors envisaged to affect under-five children's nutritional status. The approach was adopted because there was no data on incidences of illnesses such as diarrhoea and malaria during the cropping season. This data could have provided control variables in the analysis, in order to provide an isolated picture of how changes in climatic variables influence malnutrition. As such, results of the current analysis ought to be understood within the context where the association of climatic variables with child nutritional condition was studied along the food security pathway only.

Further study on this subject matter ought to consider both pathways in order to provide a comprehensive picture about how climatic conditions in both pathways are influencing malnutrition among under-five children. Research on the influence of climatic variables on under-five children's nutritional conditions by the ministry of health and sector organisations ought to be tailored towards consideration of both food security and disease and infections pathways in examining under-five children's nutritional status, controlling for demographic and socio-economic factors associated with malnutrition.

Such an approach will ensure that the observed associations between climate variation and under-five children's nutritional status in Malawi accounts for these main pathways through which malnutrition operates. This approach would enable design of targeted interventions to address the influence of climatic variation on malnutrition in Malawi.

10.8. Originality, academic and research contribution of the PhD study

10.8.1. Research originality

Literature review has shown that studies linking long term changes in climatic variables such as temperature and rainfall to crop yield, household food security and under-five children's nutritional status have not been intense among countries in the sub-Saharan African region, let alone in Malawi. Most of the studies on this subject have discussed association of climatic trends and food security i.e. Adhikari, Nejadhashemi et al. (2015) and (Gregory, Ingram et al. 2005), association of climatic trends with human health, with a focus on infectious diseases such as diarrhoea and malaria (Lake, Hooper et al. 2012), and association of climatic conditions with crops yield, with a view of detecting a climatic change signal on crop yield and household food availability (Ali, Liu et al. 2017). However, the current research study has linked all these three components: climate change, food security and nutrition by examining the association of seasonal climatic trends with crop yield, household food security and nutritional outcomes, with a focus on under-five children. This is an independent and original research contribution of the current PhD study since no study as this has been conducted in Malawi.

10.8.2. Academic contribution

The current study has been cross-disciplinary in its design; involving geography, agriculture and health. The assessment of climatic trends concerns geography. Crop yield as one of the proxy measures of household and national food security in Africa and Malawi concerns agriculture, and nutritional assessment is an essential element of human health. Reviewed literature about climate change, food security and health issues in African and indeed Malawian social research work has shown few attempts i.e. (Lake, Hooper et al. 2012) on cross-disciplinary research undertaking such as the current one.

As such, the current study makes a methodological contribution to the academic world by demonstrating linkages existing across the three disciplines on the subject focused in the study, through use of statistical methods i.e. multi-level multi-variate regression methods. Further, engaging in a multi-disciplinary approach showed depth of the PhD study and broader application of its findings across sectors as the discussion section has shown. This is another important academic contribution of the research.

10.8.3. Research area contribution

Despite more claims that climate change or its variation will affect food security and nutrition conditions of people in developing regions especially sub-Saharan African region (Rosenzweig, Iglesias et al. 2001, Boko 2007) few attempts are engaged to provide evidence for this claim. The current study has contributed towards efforts providing evidence about how variation in climatic variables within the realm of climatic change are associated with poor households' food security and nutritional status of its members. Variations in patterns of some climatic variables in a cropping season i.e. temperature and rainfall have been noted to have significant influence on household food security and nutritional outcomes among under-five children. This result is significant for policies and interventions about food security and malnutrition in the country, as well as those aimed at addressing the negative effects associated with adverse temperature and rainfall changes in Malawi. In this regard, the current PhD provides a significant research contribution.

Further, although there have been various studies examining climatic patterns in Malawi, there has not been focus on cropping season temperature and rainfall variables i.e. total rainfall, onset, cessation, duration, minimum and maximum temperatures, despite their significance to crop yield and food availability. The analysis and results of trends in these climatic variables as presented in this PhD fills a knowledge and information gap regarding the influence of these climatic variables on food crop production, controlling for non-climatic factors. This is an essential piece of policy and programs as it provides input for target specific policy interventions. The current PhD results further indicates which rainfall and temperature variables have varied in Malawi over time, direction of variation over time, and influence on crop yield, food security and under-five nutritional conditions.

Such information is a significant contribution of the PhD to the three research areas i.e. climate change, food security and nutrition in Malawi and Africa, important for design of policies to offset negative effects of climatic conditions on household food security and under-five nutritional conditions.

10.8.4 Future work

In the immediate future i.e. after completing final corrections of the PhD, the researcher intends to develop for publication the substantive chapters of the PhD i.e. on assessing temperature and rainfall trends, examining association of factors associated with food security, and the other one on assessing climatic and household level socioeconomic factors associated with child nutritional status in Malawi. Further, as part of future work following this PhD, the researcher plans to address some of the gaps discussed in the PhD to improve the current work. For instance, other than using a single cross-sectional survey i.e. the 2010 Integrated Household Survey data, the research will attempt to perform similar analysis on different time series of the survey i.e. 2014, 2019, matching the population and socioeconomic data in the three surveys with climatic data for the same years. This will enable assessing changes in climatic and household level factors associated with food security and child nutritional status in the country over time, and provide relevant and updated policy and programmatic input in concerned sectors.

Among other improvements to the models used in the current PhD, the researcher will in this work include other independent variables in each of the analyses in order to provide a comprehensive picture about factors associated with crop yield, food security and child nutritional conditions on the household i.e. adding crops such as pulses, tubers (which provide food to the country) including geospatial characteristics of the areas i.e. altitude, soil types, fertiliser input as other factors important in the assessment of factors associated with crop yield. The author also intends to examine the other pathway through which child malnutrition is influenced i.e. infections and diseases affecting the child, apart from the food security pathway used in the study. Such an approach will provide a broader picture on the overall factors influencing child nutritional status as argued by other researchers and conceptual frameworks, and so offer rich policy and programmatic input in the concerned sectors.

REFERENCES

Aboud, F. E. (2011). "Cultural perspectives on the interactions between nutrition, health, and psychological functioning." Online Readings in Psychology and Culture **10**(1): 2.

Abraham, J. P., J. Cook, J. T. Fasullo, P. H. Jacobs, S. A. Mandia and D. A. Nuccitelli (2014). "Review of the consensus and asymmetric quality of research on human-induced climate change." Cosmopolis **1**: 3-18.

Abram, N. J., M. K. Gagan, J. E. Cole, W. S. Hantoro and M. Mudelsee (2008). "Recent intensification of tropical climate variability in the Indian Ocean." Nature Geoscience **1**(12): 849.

Abu, G. A. and A. Soom (2016). "Analysis of factors affecting food security in rural and urban farming households of Benue state, Nigeria." International Journal of Food and Agricultural Economics **4**(1): 55.

Abubakar, A., J. Uriyo, S. E. Msuya, M. Swai and B. Stray-Pedersen (2012). "Prevalence and risk factors for poor nutritional status among children in the Kilimanjaro region of Tanzania." International journal of environmental research and public health **9**(10): 3506-3518.

Abuya, B. A., J. Ciera and E. Kimani-Murage (2012). "Effect of mother's education on child's nutritional status in the slums of Nairobi." BMC pediatrics **12**(1): 80.

Acker, D., L. Gasperini, U. Ite, J. Cock, P. D. Eyzaguirre, K. Dvorak, J. B. Smith, A. Goldman, A. Mareck and K. JH Dvorak (2009). Education for Rural People. The role of education, training and capacity development in poverty reduction and food security, CIAT, Cali (Colombia) CIP, Lima (Perú) IITA, Ibadán (Nigeria) UNDP, New York, NY (EUA).

Adair, L. S. and D. K. Guilkey (1997). "Age-specific determinants of stunting in Filipino children." The Journal of nutrition **127**(2): 314-320.

Adamgbe, E. M. and F. Ujoh (2013). "Effect of variability in rainfall characteristics on maize yield in Gboko, Nigeria." Journal of Environmental Protection **4**(09): 881.

Adekanmbi, V. T., G. A. Kayode and O. A. Uthman (2013). "Individual and contextual factors associated with childhood stunting in Nigeria: a multilevel analysis." Maternal & child nutrition **9**(2): 244-259.

Adger, W. N. (2010). "Climate change, human well-being and insecurity." New Political Economy **15**(2): 275-292.

Adhikari, U., A. P. Nejadhashemi and S. A. Woznicki (2015). "Climate change and eastern Africa: a review of impact on major crops." Food and Energy Security **4**(2): 110-132.

Adler, P. B., J. Leiker and J. M. Levine (2009). "Direct and indirect effects of climate change on a prairie plant community." PLoS One **4**(9): e6887.

Adu-Prah, S., S. Appiah-Opoku and D. Aboagye (2017). "Spatiotemporal evidence of recent climate variability in Ghana." African Geographical Review: 1-19.

Ahmad, N. H. and S. M. Deni (2013). "Homogeneity test on daily rainfall series for Malaysia." Matematika **29**: 141-150.

Ahmed, U., J. Arnold-Jellis, S. Lunt and K. Rostami (2015). "Analysis of the completion trends of the malnutrition universal screening tool (MUST) across directorates within a District General Hospital." Clinical nutrition ESPEN **10**(5): e202.

Ahmed, U. I., L. Ying, M. K. Bashir, M. Abid and F. Zulfiqar (2017). "Status and determinants of small farming households' food security and role of market access in enhancing food security in rural Pakistan." PloS one **12**(10): e0185466.

Ajao, K., E. Ojofeitimi, A. Adebayo, A. Fatusi and O. Afolabi (2010). "Influence of family size, household food security status, and child care practices on the nutritional status of under-five children in Ile-Ife, Nigeria." African journal of reproductive health **14**(4).

Akombi, B. J., K. E. Agho, D. Merom, J. J. Hall and A. M. Renzaho (2017). "Multilevel analysis of factors associated with wasting and underweight among children under-five years in Nigeria." Nutrients **9**(1): 44.

Akpalu, W., H. M. Rashid and C. Ringler (2011). "Climate variability and maize yield in the Limpopo region of South Africa: Results from GME and MELE methods." Climate and Development **3**(2): 114-122.

Alemu, A., G. Sileshi, F. Habtamu and G. Wondu (2014). "Prevalence's of wasting and its associated factors of children among 6-59 months age in Guto Gida District, Oromia Regional State, Ethiopia." Journal of Food Processing and Technology **5**(1).

Alexander, L. V. (2016). "Global observed long-term changes in temperature and precipitation extremes: a review of progress and limitations in IPCC assessments and beyond." Weather and Climate Extremes **11**: 4-16.

Alexandersson, H. and A. Moberg (1997). "Homogenization of Swedish temperature data. Part I: Homogeneity test for linear trends." International Journal of climatology **17**(1): 25-34.

Ali Naser, I., R. Jalil, W. Muda, W. Manan, W. Nik, W. Suriati, Z. Mohd Shariff and M. R. Abdullah (2014). "Association between household food insecurity and nutritional outcomes among children in Northeastern of Peninsular Malaysia." Nutrition research and practice **8**(3): 304-311.

Ali, S., Y. Liu, M. Ishaq, T. Shah, A. Ilyas and I. U. Din (2017). "Climate change and its impact on the yield of major food crops: Evidence from Pakistan." Foods **6**(6): 39.

Ali, Z. and S. B. Bhaskar (2016). "Basic statistical tools in research and data analysis." Indian journal of anaesthesia **60**(9): 662.

Alley, R. B. (2000). "Ice-core evidence of abrupt climate changes." Proceedings of the National Academy of Sciences **97**(4): 1331-1334.

Alley, R. B. (2010). "Reliability of ice-core science: historical insights." Journal of Glaciology **56**(200): 1095-1103.

Altman, M., T. Hart and P. Jacobs (2009). "Household food security status in South Africa." Agrekon **48**(4): 345-361.

Alwang, J., E. Gotor, G. Thiele, G. Hareau, M. Jaleta and J. Chamberlin (2017). "Pathways from research on improved staple crop germplasm to poverty reduction for smallholder farmers." Agricultural Systems.

Amekudzi, L. K., E. I. Yamba, K. Preko, E. O. Asare, J. Aryee, M. Baidu and S. N. Codjoe (2015). "Variabilities in rainfall onset, cessation and length of rainy season for the various agro-ecological zones of Ghana." Climate **3**(2): 416-434.

Anning, A. K. and B. C. McCarthy (2013). "Long-term effects of prescribed fire and thinning on residual tree growth in mixed-oak forests of southern Ohio." Ecosystems **16**(8): 1473-1486.

Anyah, R. O. and W. Qiu (2012). "Characteristic 20th and 21st century precipitation and temperature patterns and changes over the Greater Horn of Africa." International Journal of Climatology **32**(3): 347-363.

Aquino, R. d. C. d. and S. T. Philippi (2011). "Identification of malnutrition risk factors in hospitalized patients." Revista da Associação Médica Brasileira **57**(6): 637-643.

Aragie, E., K. Pauw and V. Pernechele (2018). "Achieving food security and industrial development in Malawi: Are export restrictions the solution?" World development **108**: 1-15.

Araújo dos Santos, C., C. de Oliveira Barbosa Rosa, A. Queiroz Ribeiro and R. de Cássia Lanes Ribeiro (2015). "Patient-Generated Subjective Global Assessment and classic anthropometry: comparison between the methods in detection of malnutrition among elderly with cancer." Nutricion hospitalaria **31**(1).

Arene, C. and J. Anyaeji (2010). "Determinants of food security among households in Nsukka Metropolis of Enugu State, Nigeria." Pakistan Journal of Social Sciences **30**(1): 9-16.

Arndt, C., A. Schlosser, K. Strzepek and J. Thurlow (2014). "Climate change and economic growth prospects for Malawi: An uncertainty approach." Journal of African Economies **23**(suppl_2): ii83-ii107.

Arriola, N. B. (2015). "Food Insecurity and Hunger Experiences and their Impact on Food Pantry Clients in the Tampa Bay."

Asefach, A. and R. Nigatu (2007). "Correlates of household food security in densely populated areas of Southern Ethiopia: does the household structure matter?" Studies on Home and Community Science **1**(2): 85-91.

Asfaw, S., N. McCarthy, L. Lipper, A. Arslan, A. Cattaneo and M. Kachulu (2015). Climate variability, adaptation strategies and food security in Malawi.

Asfaw, S., R. Pickmans and B. Davis (2015). "Productive Impacts of Malawi's Social Cash Transfer Programme–Midline Report." PtoP project report, forthcoming, FAO, Rome.

Atinmo, T., P. Mirmiran, O. E. Oyewole, R. Belahsen and L. Serra-Majem (2009). "Breaking the poverty/malnutrition cycle in Africa and the Middle East." Nutrition reviews **67**(suppl_1): S40-S46.

Auvinen, J. (1997). "Political conflict in less developed countries 1981-89." Journal of Peace Research **34**(2): 177-195.

Avila, F. B., S. Dong, K. P. Menang, J. Rajczak, M. Renom, M. G. Donat and L. V. Alexander (2015). "Systematic investigation of gridding-related scaling effects on annual statistics of daily temperature and precipitation maxima: A case study for south-east Australia." Weather and climate extremes **9**: 6-16.

Babu, S. C. and E. Chapasuka (1997). "Mitigating the effects of drought through food security and nutrition monitoring: lessons from Malawi." FOOD AND NUTRITION BULLETIN-UNITED NATIONS UNIVERSITY- **18**: 71-83.

Bader, D. C., C. Covey, W. J. Gutowski Jr, I. M. Held, R. L. Miller, R. T. Tokmakian and M. H. Zhang (2008). "Climate models: an assessment of strengths and limitations."

Bain, L. E., P. K. Awah, N. Geraldine, N. P. Kindong, Y. Siga, N. Bernard and A. T. Tanjeko (2013). "Malnutrition in Sub–Saharan Africa: burden, causes and prospects." Pan African Medical Journal **15**(1).

Baingana, F. K. and E. R. Bos (2006). "Changing patterns of disease and mortality in Sub-Saharan Africa: an overview."

Bamwesigye, D., P. Hlavackova, S. A. Darkwah and N. Verter (2019). "Deforestation, Climate Change and Food Security Nexus in Sub-Sahara Africa: Content Analysis."

Barbier, E. B. and J. P. Hochard (2016). "Does land degradation increase poverty in developing countries?" PloS one **11**(5): e0152973.

Barrett, C. B. (2010). "Measuring food insecurity." Science **327**(5967): 825-828.

Barron, J., J. Rockström, F. Gichuki and N. Hatibu (2003). "Dry spell analysis and maize yields for two semi-arid locations in east Africa." Agricultural and forest meteorology **117**(1-2): 23-37.

Bartfeld, J. and R. Dunifon (2005). State-level predictors of food insecurity and hunger among households with children, Economic Research Service.

Bashir, M. K. and S. Schilizzi (2013). "Determinants of rural household food security: a comparative analysis of African and Asian studies." Journal of the Science of Food and Agriculture **93**(6): 1251-1258.

Bell, W. F., E. Saltzman and J. Coates (2016). "Accuracy of Self-Reported Dietary Intake in Low-and Middle-Income Countries: A Review of the Literature." The FASEB Journal **30**(1_supplement): lb417-lb417.

Ben-Gal, I. (2005). Outlier detection. Data mining and knowledge discovery handbook, Springer**:** 131-146.

Beniston, M. and M. M. Verstraete (2001). Remote sensing and climate modeling: synergies and limitations, Springer.

Bennett, S. D., S. A. Lowther, F. Chingoli, B. Chilima, S. Kabuluzi, T. L. Ayers, T. A. Warne and E. Mintz (2018). "Assessment of water, sanitation and hygiene interventions in response to an outbreak of typhoid fever in Neno District, Malawi." PloS one **13**(2): e0193348.

Bensassi, S., J. C. Stroeve, I. Martínez-Zarzoso and A. P. Barrett (2016). "Melting ice, growing trade?" Elem Sci Anth **4**.

Bergamaschi, H., T. R. Wheeler, A. J. Challinor, F. Comiran and B. M. M. Heckler (2007). "Maize yield and rainfall on different spatial and temporal scales in Southern Brazil." Pesquisa Agropecuária Brasileira **42**(5): 603-613.

Bewket Zeleke, L., M. Welday Gebremichael, Y. Mehretie Adinew and K. Abebe Gelaw (2017). "Appropriate Weaning Practice and Associated Factors among Infants and Young Children in Northwest Ethiopia." Journal of nutrition and metabolism **2017**.

Bhardwaj, A. (2016). "Importance of Education in Human Life: a Holistic Approach." International Journal of Science and Consciousness **2**: 23-28.

Bickton, F. M. (2016). "Climate change as the biggest threat to public health in southern Africa and measures to reduce its impacts." Malawi Medical Journal **28**(2): 70-72.

Billah, S. M., K. K. Saha, A. N. S. Khan, A. H. Chowdhury, S. P. Garnett, S. El Arifeen and P. Menon (2017). "Quality of nutrition services in primary health care facilities: Implications for integrating nutrition into the health system in Bangladesh." PloS one **12**(5): e0178121.
Bimerew, T. G. and F. Beyene (2014). "Factors influencing rural household food insecurity: The case of Babile district, East Hararghe Zone, Ethiopia." Journal of Development and Agricultural Economics **6**(4): 149-158.
Blössner, M., M. De Onis and R. Uauy (2006). "Estimating stunting from underweight survey data." J Hum Ecol **14**: 145-152.
Boko, M., I. Niang, A. Nyong, C. Vogel, A. Githeko, M. Medany, B. Osman-Elasha, R. Tabo and P. Yanda, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., (2007). "Africa. Climate Change

2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental

Panel on Climate Change,." Cambridge University Press, Cambridge UK, 433-467.
Bose, K., S. Biswas, S. Bisai, S. Ganguli, A. Khatun, A. Mukhopadhyay and M. Bhadra (2007). "Stunting, underweight and wasting among Integrated Child Development Services (ICDS) scheme children aged 3–5 years of Chapra, Nadia District, West Bengal, India." Maternal & child nutrition **3**(3): 216-221.
Bowie, C. (2006). "The burden of disease in Malawi." Malawi Medical Journal **18**(3): 104-110.
Bowles, D. C., C. D. Butler and S. Friel (2014). "Climate change and health in Earth's future." Earth's Future **2**(2): 60-67.
Branscombe (2018). "The benefits and vulnerabilities of a warming Europe." Climate Change research spotlight.
Briend, A., T. Khara and C. Dolan (2015). "Wasting and stunting—similarities and differences: policy and programmatic implications." Food and nutrition bulletin **36**(1_suppl1): S15-S23.
Bucheyeki, T. L. (2012). Characterization and genetic analysis of maize germplasm for resistance to northern corn leaf blight disease in Tanzania.
Burchi, F., J. Fanzo and E. Frison (2011). "The role of food and nutrition system approaches in tackling hidden hunger." International journal of environmental research and public health **8**(2): 358-373.
Burke, M. B., D. B. Lobell and L. Guarino (2009). "Shifts in African crop climates by 2050, and the implications for crop improvement and genetic resources conservation." Global Environmental Change **19**(3): 317-325.
Busby, J. W., T. G. Smith and N. Krishnan (2014). "Climate security vulnerability in Africa mapping 3.01." Political Geography **43**: 51-67.
Buse, A. (1982). "The likelihood ratio, Wald, and Lagrange multiplier tests: An expository note." The American Statistician **36**(3a): 153-157.
Butler, E. E. and P. Huybers (2015). "Variations in the sensitivity of US maize yield to extreme temperatures by region and growth phase." Environmental Research Letters **10**(3): 034009.
Byass, P. (2009). "Climate change and population health in Africa: where are the scientists?" Global Health Action **2**(1): 2065.
Campbell-Lendrum, D., L. Manga, M. Bagayoko and J. Sommerfeld (2015). "Climate change and vector-borne diseases: what are the implications for public health research and policy?" Philosophical Transactions of the Royal Society B: Biological Sciences **370**(1665): 20130552.
Capaldo, J., P. Karfakis, M. Knowles and M. Smulders (2010). "A Model of Vulnerability to Food Insecurity."
Carniel, M. P., D. Santetti, J. S. Andrade, B. P. Favero, T. Moschen, P. A. Campos, H. A. Goldani and C. T. Dornelles (2015). "Validation of a subjective global assessment questionnaire." Jornal de Pediatria (Versão em Português) **91**(6): 596-602.
Carr, L. T. (1994). "The strengths and weaknesses of quantitative and qualitative research: what method for nursing?" Journal of advanced nursing **20**(4): 716-721.

Carter, M. A., L. Dubois, M. S. Tremblay and M. Taljaard (2012). "Local social environmental factors are associated with household food insecurity in a longitudinal study of children." BMC public health **12**(1): 1038.

Caswell, J. A., A. L. Yaktine and N. R. Council (2013). Individual, household, and environmental factors affecting food choices and access. Supplemental Nutrition Assistance Program: Examining the Evidence to Define Benefit Adequacy, National Academies Press (US).

CDC (2019). "Burden of Disease, Malawi. Centre for Disease Control."

Chabvungma, S., J. Mawenda and G. Kambauwa (2014). drought conditions and management strategies in Malawi, UNW-DPC-NDMP–Country Report.

Chakona, G. and C. M. Shackleton (2017). "household Food insecurity along an agro-ecological gradient influences children's nutritional status in south africa." Frontiers in nutrition **4**: 72.

Chakrabarti, S., D. Dinesh and J. Garrett (2017). "The Nutrition Advantage: Harnessing nutrition co-benefits of climate-resilient agriculture."

Chakraborty, S., R. Pandey, U. Chaube and S. Mishra (2013). "Trend and variability analysis of rainfall series at Seonath River Basin, Chhattisgarh (India)." International Journal of Applied Sciences and Engineering Research **2**(4): 425-434.

Challinor, A. J., J. Watson, D. B. Lobell, S. Howden, D. Smith and N. Chhetri (2014). "A meta-analysis of crop yield under climate change and adaptation." Nature Climate Change **4**(4): 287.

CHH (2013). "The State of Health in the Commonwealth, Malawi."

Chikhungu, L. C. and N. J. Madise (2014). "Seasonal variation of child under nutrition in Malawi: is seasonal food availability an important factor? Findings from a national level cross-sectional study." BMC Public health **14**(1): 1146.

Chilowa, W. (1998). "The impact of agricultural liberalisation on food security in Malawi." Food Policy **23**(6): 553-569.

Chilton, M. and D. Rose (2009). "A rights-based approach to food insecurity in the United States." American Journal of Public Health **99**(7): 1203-1211.

Chinsinga, B. (2017). "The Green Belt Initiative, Politics and Sugar Production in Malawi." Journal of Southern African Studies **43**(3): 501-515.

Chinsinga, B., M. Chasukwa and L. O. Naess (2012). "Climate change and agricultural policy processes in Malawi."

Chirwa, E. W. (2005). "Adoption of fertiliser and hybrid seeds by smallholder maize farmers in Southern Malawi." Development Southern Africa **22**(1): 1-12.

Chirwa, E. W., M. Matita and A. Dorward (2011). "Factors influencing access to agricultural input subsidy coupons in Malawi."

Chirwa, E. W. and H. P. Ngalawa (2008). "Determinants of child nutrition in Malawi." South African Journal of Economics **76**(4): 628-640.

Choi, G., D. Collins, G. Ren, B. Trewin, M. Baldi, Y. Fukuda, M. Afzaal, T. Pianmana, P. Gomboluudev and P. T. T. Huong (2009). "Changes in means and extreme events of temperature and precipitation in the Asia‐Pacific Network region, 1955–2007." International Journal of Climatology **29**(13): 1906-1925.

Choudhury, A. H., J. R. Jones and A. D. Spaulding (2015). "Association of Rainfall and Detrended Crop Yield Based on Piecewise Regression for Agricultural Insurance." Journal of Economics and Economic Education Research **16**(2): 31.

Choy, L. T. (2014). "The strengths and weaknesses of research methodology: comparison and complimentary between qualitative and quantitative approaches." IOSR Journal of Humanities and Social Science **19**(4): 99-104.

Christensen, J. H., B. Hewitson, A. Busuioc, A. Chen, X. Gao, R. Held, R. Jones, R. K. Kolli, W. Kwon and R. Laprise (2007). Regional climate projections. Climate Change, 2007: The Physical Science Basis. Contribution of Working group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, University Press, Cambridge, Chapter 11**:** 847-940.

Christiaensen, L. J. and R. N. Boisvert (2000). "On measuring household food vulnerability: Case evidence from Northern Mali."

Clapp, J., P. Newell and Z. W. Brent (2018). "The global political economy of climate change, agriculture and food systems." The Journal of Peasant Studies **45**(1): 80-88.

Clark, M. and D. Tilman (2017). "Comparative analysis of environmental impacts of agricultural production systems, agricultural input efficiency, and food choice." Environmental Research Letters **12**(6): 064016.

Clarke, R. T. (2010). "On the (mis) use of statistical methods in hydro-climatological research." Hydrological Sciences Journal–Journal des Sciences Hydrologiques **55**(2): 139-144.

Claussen, M., L. Mysak, A. Weaver, M. Crucifix, T. Fichefet, M.-F. Loutre, S. Weber, J. Alcamo, V. Alexeev and A. Berger (2002). "Earth system models of intermediate complexity: closing the gap in the spectrum of climate system models." Climate dynamics **18**(7): 579-586.

Clay, E., L. Bohn, E. B. de Armas, S. Kabambe and H. Tchale (2003). "Malawi and Southern Africa: climatic variability and economic performance."

Clover, J. (2003). "Food security in sub-saharan Africa: feature." African security review **12**(1): 5-15.

Coates, J. (2013). "Build it back better: Deconstructing food security for improved measurement and action." Global Food Security **2**(3): 188-194.

Combs Jr, G. F. and J. P. McClung (2016). The vitamins: fundamental aspects in nutrition and health, Academic press.

Connolly-Boutin, L. and B. Smit (2016). "Climate change, food security, and livelihoods in sub-Saharan Africa." Regional Environmental Change **16**(2): 385-399.

Copenheaver, C. A., E. A. Pokorski, J. E. Currie and M. D. Abrams (2006). "Causation of false ring formation in Pinus banksiana: a comparison of age, canopy class, climate and growth rate." Forest Ecology and Management **236**(2-3): 348-355.

Corsi, D. J., M. A. Subramanyam and S. Subramanian (2011). "Commentary: Measuring nutritional status of children." International journal of epidemiology **40**(4): 1030-1036.

Costello, A., M. Abbas, A. Allen, S. Ball, S. Bell, R. Bellamy, S. Friel, N. Groce, A. Johnson and M. Kett (2009). "Managing the health effects of climate change." The Lancet **373**(9676): 1693-1733.

Coulibaly, J., G. Gbetibouo, G. Kundhlande, G. Sileshi and T. Beedy (2015). "Responding to crop failure: Understanding farmers' coping strategies in Southern Malawi." Sustainability **7**(2): 1620-1636.

Crépin, A.-S., M. Karcher and J.-C. Gascard (2017). "Arctic Climate Change, Economy and Society (ACCESS): Integrated perspectives." Ambio **46**(3): 341-354.

Creswell, J. W. (2013). Research design: Qualitative, quantitative, and mixed methods approaches, Sage publications.

Cromwell, E. and N. Kyegombe (2005). "Food security options in Malawi: good neighbours make good friends." Country Food Security Options Paper **2**.

Cunha, A. J. L. A. d., Á. J. M. Leite and I. S. d. Almeida (2015). "The pediatrician's role in the first thousand days of the child: the pursuit of healthy nutrition and development." Jornal de pediatria **91**(6): S44-S51.

Dawson, R. (2011). "How significant is a boxplot outlier." Journal of Statistics Education **19**(2): 1-12.

De Cock, N., M. D'Haese, N. Vink, C. J. Van Rooyen, L. Staelens, H. C. Schönfeldt and L. D'Haese (2013). "Food security in rural areas of Limpopo province, South Africa." Food Security **5**(2): 269-282.

De Lima, M., S. Carvalho and J. de Lima (2010). "Investigating annual and monthly trends in precipitation structure: an overview across Portugal." Natural Hazards and Earth System Sciences **10**(11): 2429-2440.

De Muro, P. and F. Burchi (2007). "Education for rural people and food security." A Cross Country Analysis. Food and Agricultural Organization of the United Nations, Rome.

De Onis, M., D. Brown, M. Blossner and E. Borghi (2012). "Levels and trends in child malnutrition. UNICEF-WHO-The World Bank joint child malnutrition estimates."

de Onis, M. and J.-P. Habicht (1996). "Anthropometric reference data for international use: recommendations from a World Health Organization Expert Committee." The American journal of clinical nutrition **64**(4): 650-658.

de Onis, M., A. W. Onyango, E. Borghi, C. Garza and H. Yang (2006). "Comparison of the world health organization (WHO) child growth standards and the national center for health statistics/WHO international growth reference: implications for child health programmes." Public Health Nutr **9**.

de Sassi, C. and J. M. Tylianakis (2012). "Climate change disproportionately increases herbivore over plant or parasitoid biomass." PLoS One **7**(7): e40557.

De Souza, K., E. Kituyi, B. Harvey, M. Leone, K. S. Murali and J. D. Ford (2015). Vulnerability to climate change in three hot spots in Africa and Asia: key issues for policy-relevant adaptation and resilience-building research, Springer.

Derso, T., A. Tariku, G. A. Biks and M. M. Wassie (2017). "Stunting, wasting and associated factors among children aged 6–24 months in Dabat health and demographic surveillance system site: A community based cross-sectional study in Ethiopia." BMC pediatrics **17**(1): 96.

Detsky, A. S., J. Baker, N. Johnston, S. Whittaker, R. Mendelson and K. Jeejeebhoy (1987). "What is subjective global assessment of nutritional status?" Journal of parenteral and enteral nutrition **11**(1): 8-13.

Devereux, S. (2002). "The Malawi famine of 2002." IDS bulletin **33**(4): 70-78.

Devereux, S. (2007). "The impact of droughts and floods on food security and policy options to alleviate negative effects." Agricultural Economics **37**(s1): 47-58.

Devereux, S. and I. Macauslan (2006). "Review of social protection instruments in Malawi." Report for DFID. Brighton, IDS.

Dhara, V. R., P. J. Schramm and G. Luber (2013). "Climate change & infectious diseases in India: Implications for health care providers." The Indian journal of medical research **138**(6): 847.

Dijkshoorn, J., J. Leenaars, J. Huting and B. Kempen (2016). Soil and terrain database of the Republic of Malawi, ISRIC-World Soil Information.

Dorélien, A. (2015). "Population's role in the current food crisis: focus on East Africa." World **6**(2.7): 8,000.

Dorward, A. and E. Chirwa (2011). "The Malawi agricultural input subsidy programme: 2005/06 to 2008/09." International journal of agricultural sustainability **9**(1): 232-247.

Duan, K., T. Yao and L. G. Thompson (2006). "Response of monsoon precipitation in the Himalayas to global warming." Journal of Geophysical Research: Atmospheres **111**(D19).

Duffy, K. J. and T. P. Masere (2015). "Effect of within-season daily rainfall distribution on maize crop yields." Outlook on AGRICULTURE **44**(4): 267-271.

Dünisch, O. and J. V. d. F. Latorraca (2016). "Impact of site conditions changes on the tree ring records suitability as climate proxies in the Brazilian Amazon." Floresta e Ambiente **23**(2): 258-269.

Dziak, J. J., D. L. Coffman, S. T. Lanza and R. Li (2017). "Sensitivity and specificity of information criteria." PeerJ PrePrints.

Eakin, C. M., J. Kleypas and O. Hoegh-Guldberg (2008). "Global climate change and coral reefs: rising temperatures, acidification and the need for resilient reefs." Status of coral reefs of the world: 29-34.

Ebi, K. L. and I. Loladze (2019). "Elevated atmospheric CO2 concentrations and climate change will affect our food's quality and quantity." The Lancet Planetary Health **3**(7): e283-e284.

Edame, G. E., A. Ekpenyong, W. M. Fonta and E. Duru (2011). "Climate change, food security and agricultural productivity in Africa: issues and policy directions." International journal of humanities and social science **1**(21): 205-223.

El-kholy, T. A., N. Hassanen and R. Hassan (2012). "Demographic, socio-economic factors and physical activity affecting the nutritional status of young children under five years." Life Science Journal **9**(4).

Elmadfa, I. and A. L. Meyer (2014). "Developing suitable methods of nutritional status assessment: a continuous challenge." Advances in Nutrition **5**(5): 590S-598S.

Environmental Protection Agency (2016). "Climate Change Indicators in the United States, 2016. Fourth Edition." (Fourth Edition).

Ericksen, P. J., J. S. Ingram and D. M. Liverman (2009). Food security and global environmental change: emerging challenges, Elsevier.

Eshete, H., Y. Abebe, E. Loha, T. Gebru and T. Tesheme (2017). "Nutritional status and effect of maternal employment among children aged 6–59 months in Wolayta Sodo town, southern Ethiopia: a cross-sectional study." Ethiopian journal of health sciences **27**(2): 155-162.
Estrada, F., R. S. Tol and W. J. Botzen (2017). "Global economic impacts of climate variability and change during the 20th century." PloS one **12**(2): e0172201.
Fadare, O., M. Amare, G. Mavrotas, D. Akerele and A. Ogunniyi (2019). "Mother's nutrition-related knowledge and child nutrition outcomes: Empirical evidence from Nigeria." PloS one **14**(2): e0212775.
FAO (2015). "Country Fact Sheet on Food and Agriculture Policy Trends."
FAO (2015). "'Summary of Food Security Intervention: Improving Food Security and Nutrition Policies and Program Outreach." Project Report.
FAO (2016). "The State of Food and Agriculture." international cooperation **10**: 0.
FAO (2018). "A resource guide to method selection and application in low resource settings." FAO: Rome, Italy.
FAO, A. (2008). "An introduction to the basic concepts of food security." FAO, Rome, Italy.
FAO, A. (2008). "Introduction to the Basic Concepts of Food Security." Food Security Information for Action, Rome.
FAO, I., W. IFAD and UNICEF (2017). "The State of Food Security and Nutrition in the World 2017. Building resilience for peace and food security." Rome: FAO. Accessed **10**(07): 2017.
FAO, I. and UNICEF (2018). "WFP and WHO (2017) The State of Food Security and Nutrition in the World 2017: Building Resilience for Peace and Food Security." Rome: Food and Agriculture Organization of the United Nations (FAO).
Farzana, F. D., A. S. Rahman, S. Sultana, M. J. Raihan, M. A. Haque, J. L. Waid, N. Choudhury and T. Ahmed (2017). "Coping strategies related to food insecurity at the household level in Bangladesh." PloS one **12**(4): e0171411.
Felix, B. and K. S. Romuald (2012). "Rainfall Shocks, Food Prices Vulnerability and Food Security: Evidence for Sub-Saharan African Countries." AEC , African Development Bank.
Fentaw, R., A. Bogale and D. Abebaw (2013). "Prevalence of child malnutrition in agro-pastoral households in Afar Regional State of Ethiopia." Nutrition Research and Practice **7**(2): 122-131.
Fernandez, J. M., A. Townsend-Small, A. Zastepa, S. B. Watson and J. A. Brandes (2019). "Large increases in emissions of methane and nitrous oxide from eutrophication in Lake Erie." bioRxiv: 648154.
Fiedler, J. L., K. Lividini, O. I. Bermudez and M.-F. Smitz (2012). "Household Consumption and Expenditures Surveys (HCES): a primer for food and nutrition analysts in low-and middle-income countries." Food and Nutrition Bulletin **33**(3_suppl2): S170-S184.
Fields, S. (2005). "Continental Divide: Why Africa's climate change burden is greater." Environmental Health Perspectives **113**(8): A534.
Filipović, B. F., M. Gajić, N. Milinić, B. Milovanović, B. R. Filipović, M. Cvetković and N. Šibalić (2010). "Comparison of two nutritional assessment methods in gastroenterology patients." World Journal of Gastroenterology: WJG **16**(16): 1999.
Fischer, G., M. M. Shah and H. Van Velthuizen (2002). "Climate change and agricultural vulnerability."
Fisher, M. and P. A. Lewin (2013). "Household, community, and policy determinants of food insecurity in rural Malawi." Development Southern Africa **30**(4-5): 451-467.
Fiwa, L., E. Vanuytrecht, K. A. Wiyo and D. Raes (2014). "Effect of rainfall variability on the length of the crop growing period over the past three decades in central Malawi." Climate Research **62**(1): 45-58.
Fleury, J. and S. M. Lee (2006). "The social ecological model and physical activity in African American women." American journal of community psychology **37**(1-2): 141-154.
Fontes, D., S. de Vasconcelos Generoso and M. I. T. D. Correia (2014). "Subjective global assessment: a reliable nutritional assessment tool to predict outcomes in critically ill patients." Clinical nutrition **33**(2): 291-295.
Fotso, J.-C. (2007). "Urban–rural differentials in child malnutrition: trends and socioeconomic correlates in sub-Saharan Africa." Health & Place **13**(1): 205-223.

French, S. A., M. Wall and N. R. Mitchell (2010). "Household income differences in food sources and food items purchased." International Journal of Behavioral Nutrition and Physical Activity **7**(1): 77.

Frenken, K. (2005). Irrigation in Africa in figures: AQUASTAT Survey, 2005, Food & Agriculture Org.

Frich, P., L. V. Alexander, P. Della-Marta, B. Gleason, M. Haylock, A. K. Tank and T. Peterson (2002). "Observed coherent changes in climatic extremes during the second half of the twentieth century." Climate research **19**(3): 193-212.

Fritts, H. C., E. A. Vaganov, I. V. Sviderskaya and A. V. Shashkin (1991). "Climatic variation and tree-ring structure in conifers: empirical and mechanistic models of tree-ring width, number of cells, cell size, cell-wall thickness and wood density." Climate Research: 97-116.

Frongillo, E. A., M. de Onis and K. M. Hanson (1997). "Socioeconomic and demographic factors are associated with worldwide patterns of stunting and wasting of children." The Journal of nutrition **127**(12): 2302-2309.

Frongillo Jr, E. A., M. de Onis and K. M. Hanson (1997). "Socioeconomic and demographic factors are associated with worldwide patterns of stunting and wasting of children." The Journal of nutrition **127**(12): 2302-2309.

Frost, M. B., R. Forste and D. W. Haas (2005). "Maternal education and child nutritional status in Bolivia: finding the links." Social science & medicine **60**(2): 395-407.

Gama, A. C., L. D. Mapemba, P. Masikat, S. H.-K. Tui, O. Crespo and E. Bandason (2015). "Modeling potential impacts of future climate change in Mzimba District Malawi, 2040-2070."

Gamula, G. E., L. Hui and W. Peng (2013). "An overview of the energy sector in Malawi."

Garrett, J. L. and M. T. Ruel (1999). "Are determinants of rural and urban food security and nutritional status different? Some insights from Mozambique." World Development **27**(11): 1955-1975.

Garson, G. (2013). Fundamentals of Hierarchical Linear and Multilevel Modeling. 3–25 in: GD Garson (Hrsg.): Hierarchical linear modeling, Thousand Oaks, Calif.: Sage.

Gasparrini, A., Y. Guo, F. Sera, A. M. Vicedo-Cabrera, V. Huber, S. Tong, M. d. S. Z. S. Coelho, P. H. N. Saldiva, E. Lavigne and P. M. Correa (2017). "Projections of temperature-related excess mortality under climate change scenarios." The Lancet Planetary Health **1**(9): e360-e367.

Gemeda, D. O. and A. D. Sima (2015). "The impacts of climate change on African continent and the way forward." Journal of Ecology and the Natural environment **7**(10): 256-262.

Gervais, M., L. B. Tremblay, J. R. Gyakum and E. Atallah (2014). "Representing extremes in a daily gridded precipitation analysis over the United States: Impacts of station density, resolution, and gridding methods." Journal of Climate **27**(14): 5201-5218.

Ghalhari, G., J. Dastjerdi and M. Nokhandan (2012). "Using Mann Kendal and t-test methods in identifying trends of climatic elements: A case study of northern parts of Iran." Management Science Letters **2**(3): 911-920.

Ghani, I., M. Zubair and R. Nissa (2017). "Climate Change and Its Impact on Nutritional Status and Health of Children."

Ghasemi, A. and S. Zahediasl (2012). "Normality tests for statistical analysis: a guide for non-statisticians." International journal of endocrinology and metabolism **10**(2): 486-489.

Gibson, M. (2012). "Food Security—A Commentary: What Is It and Why Is It So Complicated?" Foods **1**(1): 18-27.

Githeko, A., E. Ototo and Y. Guiyun (2012). "Progress towards understanding the ecology and epidemiology of malaria in the western Kenya highlands: opportunities and challenges for control under climate change risk." Acta tropica **121**(1): 19-25.

Gizaw, M. S. and T. Y. Gan (2017). "Impact of climate change and El Niño episodes on droughts in sub-Saharan Africa." Climate dynamics **49**(1-2): 665-682.

Goddard, L. and M. Dilley (2005). "El Nino: catastrophe or opportunity." Journal of Climate **18**(5): 651-665.

Godfray, H. C. J., J. R. Beddington, I. R. Crute, L. Haddad, D. Lawrence, J. F. Muir, J. Pretty, S. Robinson, S. M. Thomas and C. Toulmin (2010). "Food security: the challenge of feeding 9 billion people." science **327**(5967): 812-818.

Goletti, F. and S. Babu (1994). "Market liberalization and integration of maize markets in Malawi." Agricultural Economics **11**(2-3): 311-324.
Gómez, M. I., C. B. Barrett, T. Raney, P. Pinstrup-Andersen, J. Meerman, A. Croppenstedt, B. Carisma and B. Thompson (2013). "Post-green revolution food systems and the triple burden of malnutrition." Food Policy **42**: 129-138.
Goossens, S., Y. Bekele, O. Yun, G. Harczi, M. Ouannes and S. Shepherd (2012). "Mid-upper arm circumference based nutrition programming: evidence for a new approach in regions with high burden of acute malnutrition." PloS one **7**(11): e49320.
Gorstein, J., K. Sullivan, R. Yip, M. De Onis, F. Trowbridge, P. Fajans and G. Clugston (1994). "Issues in the assessment of nutritional status using anthropometry." Bulletin of the World Health Organization **72**(2): 273.
Grace, K., F. Davenport, C. Funk and A. M. Lerner (2012). "Child malnutrition and climate in Sub-Saharan Africa: An analysis of recent trends in Kenya." Applied Geography **35**(1-2): 405-413.
Graham, M. H. (2003). "Confronting multicollinearity in ecological multiple regression." Ecology **84**(11): 2809-2815.
Gray, J., H. Dautel, A. Estrada-Peña, O. Kahl and E. Lindgren (2009). "Effects of climate change on ticks and tick-borne diseases in Europe." Interdisciplinary perspectives on infectious diseases **2009**.
Gregory, P. J., J. S. Ingram and M. Brklacich (2005). "Climate change and food security." Philosophical Transactions of the Royal Society of London B: Biological Sciences **360**(1463): 2139-2148.
Gregory, P. J., J. S. Ingram and M. Brklacich (2005). "Climate change and food security." Philosophical Transactions of the Royal Society B: Biological Sciences **360**(1463): 2139-2148.
Grimm, N. B., F. S. Chapin III, B. Bierwagen, P. Gonzalez, P. M. Groffman, Y. Luo, F. Melton, K. Nadelhoffer, A. Pairis and P. A. Raymond (2013). "The impacts of climate change on ecosystem structure and function." Frontiers in Ecology and the Environment **11**(9): 474-482.
Grobler, W. C. (2016). "Perceptions of Poverty: A Study of Food Secure and Food Insecure Households in an Urban Area in South Africa." Procedia Economics and Finance **35**: 224-231.
Guan, K., B. Sultan, M. Biasutti, C. Baron and D. B. Lobell (2015). "What aspects of future rainfall changes matter for crop yields in West Africa?" Geophysical Research Letters **42**(19): 8001-8010.
Gubler, S., S. Hunziker, M. Begert, M. Croci ‐ Maspoli, T. Konzelmann, S. Brönnimann, C. Schwierz, C. Oria and G. Rosas (2017). "The influence of station density on climate data homogenization." International journal of climatology **37**(13): 4670-4683.
Guenang, G. and F. Mkankam Kamga (2012). "Onset, retreat and length of the rainy season over Cameroon." Atmospheric Science Letters **13**(2): 120-127.
Gurinović, M., M. Zeković, J. Milešević, M. Nikolić and M. Glibetić (2017). "Nutritional Assessment."
Gutro, R. (2005). "What's the difference between weather and climate." National Aeronautics and Space Administration (NASA). Last accessed in January **5**.
Haack, B., R. Mahabir and J. Kerkering (2015). "Remote sensing-derived national land cover land use maps: a comparison for Malawi." Geocarto International **30**(3): 270-292.
Hadadin, N. A. (2005). "Rainfall Intensity-Duration-Frequency Relationship in the Mujib Basin in Jordan." Journal of Applied Sciences **5**(10): 1777-1784.
Haddad, L., E. Kennedy and J. Sullivan (1994). "Choice of indicators for food security and nutrition monitoring." Food Policy **19**(3): 329-343.
Hagos, S., T. Lunde, D. H. Mariam, T. Woldehanna and B. Lindtjorn (2014). "Climate change, crop production and child under nutrition in Ethiopia; a longitudinal panel study." Bmc Public Health **14**.
Hagos, S., T. Lunde, D. H. Mariam, T. Woldehanna and B. Lindtjørn (2014). "Climate change, crop production and child under nutrition in Ethiopia; a longitudinal panel study." BMC public health **14**(1): 884.
Haigh, J. (2011). "Solar influences on climate." Grantham Institute for Climate Change.
Haines, A., R. S. Kovats, D. Campbell-Lendrum and C. Corvalán (2006). "Climate change and human health: impacts, vulnerability and public health." Public health **120**(7): 585-596.

Hajdu, F., F. Hadju, N. Ansell, E. Robson, L. van Blerk and L. Chipeta (2009). "Socio-economic causes of food insecurity in Malawi." The Society of Malawi Journal **62**(2): 6-18.
Hall, C., T. Dawson, J. Macdiarmid, R. Matthews and P. Smith (2017). "The impact of population growth and climate change on food security in Africa: looking ahead to 2050." International Journal of Agricultural Sustainability **15**(2): 124-135.
Hamlet, A., K. Jean, W. Perea, S. Yactayo, J. Biey, M. Van Kerkhove, N. Ferguson and T. Garske (2018). "The seasonal influence of climate and environment on yellow fever transmission across Africa." PLoS neglected tropical diseases **12**(3): e0006284.
Hänsel, S., D. M. Medeiros, J. Matschullat, R. A. Petta and I. de Mendonça Silva (2016). "Assessing Homogeneity and Climate Variability of Temperature and Precipitation Series in the Capitals of North-Eastern Brazil." Frontiers in Earth Science **4**: 29.
Hanson, K. L., J. Sobal and E. A. Frongillo (2007). "Gender and marital status clarify associations between food insecurity and body weight." The Journal of nutrition **137**(6): 1460-1465.
Hardwick, N. (2002). "Weather and plant diseases." Weather **57**(5): 184-190.
Harpold, A. A. and P. D. Brooks (2018). "Humidity determines snowpack ablation under a warming climate." Proceedings of the National Academy of Sciences **115**(6): 1215-1220.
Harrigan, J. (2008). "Food insecurity, poverty and the Malawian Starter Pack: Fresh start or false start?" Food Policy **33**(3): 237-249.
Harris-Fry, H., N. Shrestha, A. Costello and N. M. Saville (2017). "Determinants of intra-household food allocation between adults in South Asia–a systematic review." International journal for equity in health **16**(1): 107.
Harrison, L., J. Michaelsen, C. Funk and G. Husak (2011). "Effects of temperature changes on maize production in Mozambique." Climate Research **46**(3): 211-222.
Hart, S. and A. Classen (2003). "Potential for assessing long-term dynamics in soil nitrogen availability from variations in δ 15N of tree rings." Isotopes in Environmental and Health Studies **39**(1): 15-28.
Hart, T. (2009). "Exploring definitions of food insecurity and vulnerability: time to refocus assessments." Agrekon **48**(4): 362-383.
Hatfield, J. L. and J. H. Prueger (2015). "Temperature extremes: Effect on plant growth and development." Weather and climate extremes **10**: 4-10.
Haug, R. and B. KG Wold (2017). "Social Protection or Humanitarian Assistance: Contested Input Subsidies and Climate Adaptation in Malawi."
Hawkes, C. and J. Fanzo (2017). "Nourishing the SDGs: Global nutrition report 2017."
Heavens, N. G., D. S. Ward and M. Natalie (2013). "Studying and projecting climate change with earth system models." Nature Education Knowledge **4**(5): 4.
Henderson, S., N. Moore, E. Lee and M. D. Witham (2008). "Do the malnutrition universal screening tool (MUST) and Birmingham nutrition risk (BNR) score predict mortality in older hospitalised patients?" BMC geriatrics **8**(1): 26.
Hersey, J., J. Anliker, C. Miller, R. M. Mullis, S. Daugherty, S. Das, C. R. Bray, P. Dennee, M. Sigman-Grant and H. O. Thomas (2001). "Food shopping practices are associated with dietary quality in low-income households." Journal of Nutrition Education **33**: S16-S26.
Hipel, K. W. and A. I. McLeod (1994). Time series modelling of water resources and environmental systems, Elsevier.
Hirsch, R. M. and J. R. Slack (1984). "A nonparametric trend test for seasonal data with serial dependence." Water Resources Research **20**(6): 727-732.
Ho, E. (2013). "Planetary Survival in the 21st Century: Confronting Land Degradation, Biodiversity Loss, and Climate Change." Student Pulse **5**(01).
Hoerling, M., J. Hurrell, J. Eischeid and A. Phillips (2006). "Detection and attribution of twentieth-century northern and southern African rainfall change." Journal of climate **19**(16): 3989-4008.
Hofmeister, E., G. M. Rogall, K. Wesenberg, R. Abbott, T. Work, K. Schuler, J. Sleeman and J. Winton (2010). Climate change and wildlife health: direct and indirect effects, US Geological Survey.

Holben, D. H. and M. B. Marshall (2017). "Position of the Academy of Nutrition and Dietetics: Food Insecurity in the United States." Journal of the Academy of Nutrition and Dietetics **117**(12): 1991-2002.

Holden, J. E., K. Kelley and R. Agarwal (2008). "Analyzing change: a primer on multilevel models with applications to nephrology." American journal of nephrology **28**(5): 792-801.

Holden, S. and R. Lunduka (2010). "Impacts of the fertilizer subsidy program in Malawi: Targeting, household perceptions and preferences. Department of Economics and Resource Management. Norwegian University of Life Sciences. April 2010."

Hosmer, D. W. and S. Lemesbow (1980). "Goodness of fit tests for the multiple logistic regression model." Communications in statistics-Theory and Methods **9**(10): 1043-1069.

House, W. and G. Zimalirana (1992). "Rapid population growth and its implication for Malawi." Malawi Medical Journal **8**(2): 46-54.

Huang, S., Y. Wang, Y. Xie, P. Zhao and J. Lüers (2016). "OutlierFlag: A Tool for Scientific Data Quality Control by Outlier Data Flagging." Journal of Open Research Software **4**(1).

Huho, J. M., J. K. Ngaira, H. O. Ogindo and N. Masayi (2012). "The changing rainfall pattern and the associated impacts on subsistence agriculture in Laikipia East District, Kenya." Journal of Geography and Regional Planning **5**(7): 198.

Hulme, M. (1992). "Rainfall changes in Africa: 1931–1960 to 1961–1990." International Journal of Climatology **12**(7): 685-699.

Humphries, D. L., K. A. Dearden, B. T. Crookston, T. Woldehanna, M. E. Penny and J. R. Behrman (2017). "Household food group expenditure patterns are associated with child anthropometry at ages 5, 8 and 12 years in Ethiopia, India, Peru and Vietnam." Economics & Human Biology **26**: 30-41.

Idso, C., D. Legates and S. Singer (2019). "Climate Science." Climate Change Reconsidered II: Fossil Fuels.

IFPRI (2018). "Poverty, Health, and Nutrition Division (PHND)." International Food Policy Research Institute (IFPRI). .

Iizumi, T. and N. Ramankutty (2015). "How do weather and climate influence cropping area and intensity?" Global Food Security **4**: 46-50.

Ikejiaku, B.-V. (2009). "The relationship between poverty, conflict and development." Journal of Sustainable Development **2**(1): 15.

Íñigo, V.-G., O. Ecker and K. Pauw (2014). Changes in food and nutrition security in Malawi: Analysis of recent survey evidence, International Food Policy Research Institute (IFPRI).

International Bank for Reconstruction and Development (2017). "State of electricity access report."

International Monetory Fund (2017). "Malawi Economic Document " **IMF Country Report No, 17/184**.

IPCC, A. (2007). Intergovernmental panel on climate change, IPCC Secretariat Geneva.

Isioma, I. N., I. I. Rudolph and A. L. Omena (2018). "Non-parametric Mann-Kendall Test Statistics for Rainfall Trend Analysis in Some Selected States within the Coastal Region of Nigeria." Journal of Civil, Construction and Environmental Engineering **3**(1): 17.

Islam, M. and A. Wong (2017). "Climate change and food in/security: A critical nexus." Environments **4**(2): 38.

Jacob, D., L. Kotova, C. Teichmann, S. P. Sobolowski, R. Vautard, C. Donnelly, A. G. Koutroulis, M. G. Grillakis, I. K. Tsanis and A. Damm (2018). "Climate impacts in Europe under+ 1.5 C global warming." Earth's Future **6**(2): 264-285.

Jakuschné Kocsis, T. and A. Anda (2018). "Parametric or non-parametric: analysis of rainfall time series at a Hungarian meteorological station." IDŐJÁRÁS/QUARTERLY JOURNAL OF THE HUNGARIAN METEOROLOGICAL SERVICE **122**(2): 203-216.

Jalota, S., S. Singh, G. Chahal, S. Ray, S. Panigraghy and K. Singh (2010). "Soil texture, climate and management effects on plant growth, grain yield and water use by rainfed maize–wheat cropping system: Field and simulation study." Agricultural water management **97**(1): 83-90.

James, R. and R. Washington (2013). "Changes in African temperature and precipitation associated with degrees of global warming." Climatic change **117**(4): 859-872.

Janardhan, V., P. Soundararajan, N. V. Rani, G. Kannan, P. Thennarasu, R. A. Chacko and C. U. M. Reddy (2011). "Prediction of malnutrition using modified subjective global assessment-dialysis malnutrition score in patients on hemodialysis." Indian journal of pharmaceutical sciences **73**(1): 38.

Janecka, K. and R. Kaczka (2015). "Tree rings of Pinus cembra L. in the Tatra Mts as a proxy of significant volcanic eruptions in the last 280 years." TRACE—Tree rings in archaeology, climatology and ecology **13**: 49-55.

Jankowska, M. M., D. Lopez-Carr, C. Funk, G. J. Husak and Z. A. Chafe (2012). "Climate change and human health: Spatial modeling of water availability, malnutrition, and livelihoods in Mali, Africa." Applied Geography **33**: 4-15.

Javari, M. (2016). "Trend and homogeneity analysis of precipitation in Iran." Climate **4**(3): 44.

Jawaregowda, S. K. and M. M. Angadi (2017). "Gender differences in nutritional status among under five children in rural areas of Bijapur district, Karnataka, India." International Journal of Community Medicine and Public Health **2**(4): 506-509.

Jayanthi, H., G. J. Husak, C. Funk, T. Magadzire, A. Chavula and J. P. Verdin (2013). "Modeling rain-fed maize vulnerability to droughts using the standardized precipitation index from satellite estimated rainfall—Southern Malawi case study." International Journal of Disaster Risk Reduction **4**: 71-81.

Jensen, S. K., A. E. Berens and C. A. Nelson 3rd (2017). "Effects of poverty on interacting biological systems underlying child development." The Lancet Child & Adolescent Health **1**(3): 225-239.

Jeon, J. (2015). "The strengths and limitations of the statistical modeling of complex social phenomenon: Focusing on SEM, path analysis, or multiple regression models." Int J Soc Behav Educ Econ Bus Ind Eng **9**(5): 1594-1602.

Johnson, R. B., A. J. Onwuegbuzie and L. A. Turner (2007). "Toward a definition of mixed methods research." Journal of mixed methods research **1**(2): 112-133.

Jones, A. D., F. M. Ngure, G. Pelto and S. L. Young (2013). "What are we assessing when we measure food security? A compendium and review of current metrics." Advances in Nutrition **4**(5): 481-505.

Jørstad, H. and C. Webersik (2016). "Vulnerability to climate change and adaptation strategies of local communities in Malawi: Experiences of women fish-processing groups in the Lake Chilwa Basin." Earth System Dynamics **7**(4): 977-989.

Joshua, M. K., C. Ngongondo, M. Monjerezi, F. Chipungu, E. Liwenga, A. E. Majule, T. Stathers and R. Lamboll (2016). "Climate change in semi-arid Malawi: Perceptions, adaptation strategies and water governance." Jàmbá: Journal of Disaster Risk Studies **8**(3): 1-10.

Jury, M. R. and N. D. Mwafulirwa (2002). "Climate variability in Malawi, part 1: dry summers, statistical associations and predictability." International Journal of Climatology **22**(11): 1289-1302.

Kachaje, O., V. Kasulo and G. Chavula (2016). "Detection of Precipitation and Temperature Trend Patterns for Mulanje District, Southern Part of Malawi." J Climatol Weather Forecasting **4**(187): 2.

Kakota, T., D. Nyariki, D. Mkwambisi and W. Kogi‐Makau (2015). "Determinants of Household Vulnerability to Food Insecurity: A Case Study of Semi‐Arid Districts in Malawi." Journal of international development **27**(1): 73-84.

Kamndaya, M., L. N. Kazembe, J. Vearey, C. W. Kabiru and L. Thomas (2015). "Material deprivation and unemployment affect coercive sex among young people in the urban slums of Blantyre, Malawi: A multi-level approach." Health & place **33**: 90-100.

Kandala, N.-B., T. P. Madungu, J. B. Emina, K. P. Nzita and F. P. Cappuccio (2011). "Malnutrition among children under the age of five in the Democratic Republic of Congo (DRC): does geographic location matter?" BMC public health **11**(1): 261.

Kandoole, P., R. Record, K. Deininger, S. Kalemba, E. Stylianou, E. Chilima and L. Kufeyani (2017). Malawi Economic Monitor, November 2017: Land for Inclusive Development, World Bank.

Kane, R. (2009). "Periodicities, ENSO effects and trends of some South African rainfall series: an update." South African Journal of Science **105**(5-6): 199-207.

Kang, H. M. and F. Yusof (2012). "Homogeneity tests on daily rainfall series." Int. J. Contemp. Math. Sciences **7**(1): 9-22.

Kang, Y., S. Khan and X. Ma (2009). "Climate change impacts on crop yield, crop water productivity and food security–A review." Progress in Natural Science **19**(12): 1665-1674.
Kanianska, R. (2016). "Agriculture and its impact on land ‑ use, environment, and ecosystem services." Landscape ecology-The influences of land use and anthropogenic impacts of landscape creation: 1-26.
Kanjilal, B., P. G. Mazumdar, M. Mukherjee and M. H. Rahman (2010). "Nutritional status of children in India: household socio-economic condition as the contextual determinant." International Journal for equity in Health **9**(1): 19.
Kaonga, C. C., I. B. M. Kosamu and C. Tenthani (2015). "Climate variation based on temperature and solar radiation data over a 29 year period in Lilongwe City, Malawi." African Journal of Environmental Science and Technology **9**(4): 346-353.
Kari Pauw, J. T. D. V. S. (2010). "Droughts and Floods in Malawi." IFPRI Discussion Paper 00962.
Kates, R. W., T. M. Parris and A. A. Leiserowitz (2005). "What is sustainable development? Goals, indicators, values, and practice." Environment(Washington DC) **47**(3): 8-21.
Katona, P. and J. Katona-Apte (2008). "The interaction between nutrition and infection." Clinical Infectious Diseases **46**(10): 1582-1588.
Kennedy, G., T. Ballard and M. C. Dop (2011). Guidelines for measuring household and individual dietary diversity, Food and Agriculture Organization of the United Nations.
Kennedy, G., A. Berardo, C. Papavero, P. Horjus, T. Ballard, M. Dop, J. Delbaere and I. D. Brouwer (2010). "Proxy measures of household food consumption for food security assessment and surveillance: comparison of the household dietary diversity and food consumption scores." Public health nutrition **13**(12).
Kennedy, G., G. Nantel and P. Shetty (2004). "Globalization of food systems in developing countries: impact on food security and nutrition."
Khaleghi, M. R. (2018). "Application of dendroclimatology in evaluation of climatic changes." Journal of Forest Science **64**(3): 139-147.
Khaliq, M. and T. Ouarda (2007). "On the critical values of the standard normal homogeneity test (SNHT)." International Journal of Climatology **27**(5): 681-687.
Khan, H. and E. Shaw (2011). "Multilevel logistic regression analysis applied to binary contraceptive prevalence data."
Kim, C.-G. (2008). "The Impact of Climate Change on the Agricultural Sector: Implications of the Agro-Industry for Low Carbon, Green Growth Strategy and Roadmap for the East Asian Region." Korea Rural Economic Institute.
Kimaro, T. and H. Sibande "Trends of rainfall and Maize productivity in Malawi." College of Engineering and Technology University of Dar es Salaam: 72.
Kimaro, T. and H. Sibande (2007). "Trends of rainfall and Maize productivity in Malawi." College of Engineering and Technology University of Dar es Salaam: 72.
Kimaro, T. and H. Sibande (2018). "Trends of rainfall and Maize productivity in Malawi." Tanzania Journal of Engineering and Technology **31**(1).
Kirui, O. K. (2016). Economics of land degradation and improvement in Tanzania and Malawi. Economics of Land Degradation and Improvement–A Global Assessment for Sustainable Development, Springer, Cham**:** 609-649.
Kjellstrom, T. (2009). "Climate change, direct heat exposure, health and well-being in low and middle-income countries." Global Health Action **2**.
Knox, T. A., M. Zafonte-Sanders, C. Fields-Gardner, K. Moen, D. Johansen and N. Paton (2003). "Assessment of Nutritional Status, Body Composition, and Human Immunodeficiency Virus—Associated Morphologic Changes." Clinical Infectious Diseases **36**(Supplement_2): S63-S68.
Koo, J. and C. M. Cox (2014). "Effects of rainfall variability on maize yields."
Koppmair, S., M. Kassie and M. Qaim (2017). "Farm production, market access and dietary diversity in Malawi." Public health nutrition **20**(2): 325-335.
Körner, C. and D. Basler (2010). "Phenology under global warming." Science **327**(5972): 1461-1462.

Kotir, J. H. (2011). "Climate change and variability in Sub-Saharan Africa: a review of current and future trends and impacts on agriculture and food security." Environment, Development and Sustainability **13**(3): 587-605.

Kowaleski-Jones, L. (2011). The Multiple Contexts of Food Insecurity: Evaluating the Impact on Child Energy Balance, Food Assistance and Nutrition Research Program.

Kraemer, K., J. Cordaro, J. Fanzo, M. Gibney, E. Kennedy, A. Labrique, J. Steffen and M. Eggersdorfer (2016). .2 Nutrition and Climate: Requirements for mitigating the influence of climate change. Good Nutrition: Perspectives for the 21st Century, Karger Publishers**:** 145-159.

Kruger, L. (2016). "The timing of agricultural production in hazard-prone areas to prevent losses at peak-risk periods: A case of Malawi, Madagascar and Mozambique." Jàmbá: Journal of Disaster Risk Studies **8**(2).

Kukal, M. S. and S. Irmak (2018). "Climate-Driven Crop Yield and Yield Variability and Climate Change Impacts on the US Great Plains Agricultural Production." Scientific reports **8**(1): 3450.

Kula, N., A. Haines and R. Fryatt (2013). "Reducing vulnerability to climate change in Sub-Saharan Africa: the need for better evidence." PLoS Med **10**(1): e1001374.

Kumar, A., M. M. Ahmad and P. Sharma (2017). "Influence of climatic and non-climatic factors on sustainable food security in India: A statistical investigation." International Journal of Sustainable Agricultural Management and Informatics **3**(1): 1-30.

Kumar, S., B. Raju, C. Rama Rao, K. Kareemulla and B. Venkateswarlu (2011). "Sensitivity of yields of major rainfed crops to climate in India." Indian Journal of Agricultural Economics **66**(3): 340.

Kumar, S., S. K. Singh and P. Mishra (2013). "Multivariate Analysis: An Overview." Journal of Dentofacial Science **2**(3): 19-26.

Kumbuyo, C. P., H. Yasuda, Y. Kitamura and K. Shimizu (2014). "Fluctuation of rainfall time series in Malawi: an analysis of selected areas." Geofizika **31**(1): 13-28.

Kundzewicz, Z. W., S. Kanae, S. I. Seneviratne, J. Handmer, N. Nicholls, P. Peduzzi, R. Mechler, L. M. Bouwer, N. Arnell and K. Mach (2014). "Flood risk and climate change: global and regional perspectives." Hydrological Sciences Journal **59**(1): 1-28.

Kundzewicz, Z. W. and A. J. Robson (2004). "Change detection in hydrological records—a review of the methodology/revue méthodologique de la détection de changements dans les chroniques hydrologiques." Hydrological Sciences Journal **49**(1): 7-19.

Künnemann, R. and S. Epal-Ratjen (2004). The right to food: A resource manual for NGOs, American Association for the Advancement of Science, Science and Human ….

Kuri, F., A. Murwira, K. S. Murwira and M. Masocha (2014). "Predicting maize yield in Zimbabwe using dry dekads derived from remotely sensed Vegetation Condition Index." International Journal of Applied Earth Observation and Geoinformation **33**: 39-46.

Kusumayati, A. and R. Gross (1998). "Ecological and geographic characteristics predict nutritional status of communities: rapid assessment for poor villages." Health policy and planning **13**(4): 408-416.

Kwak, S. K. and J. H. Kim (2017). "Statistical data preparation: management of missing values and outliers." Korean journal of anesthesiology **70**(4): 407.

LaHuis, D. M., M. J. Hartman, S. Hakoyama and P. C. Clark (2014). "Explained variance measures for multilevel models." Organizational Research Methods **17**(4): 433-451.

Lake, I. R., L. Hooper, A. Abdelhamid, G. Bentham, A. B. Boxall, A. Draper, S. Fairweather-Tait, M. Hulme, P. R. Hunter and G. Nichols (2012). "Climate change and food security: health impacts in developed countries." Environmental Health Perspectives **120**(11): 1520.

Lamidi, E. O. (2017). "Multilevel Analysis of Household Food Insecurity and Child Malnutrition in Nigeria."

Lavy, V., J. Strauss, D. Thomas and P. De Vreyer (1995). The impact of the quality of health care on children's nutrition and survival in Ghana, The World Bank.

le Roux, A., S. Khuluse-Makhanya, K. Arnold, F. Engelbrecht, P. Paige-Green and B. Verhaeghe (2019). "A framework for assessing the risks and impacts of rural access roads to a changing climate." International Journal of Disaster Risk Reduction: 101175.

Lee, B. C., C. Bendixsen, A. K. Liebman and S. S. Gallagher (2017). "Using the socio-ecological model to frame agricultural safety and health interventions." Journal of agromedicine **22**(4): 298-303.

Lele, U., W. A. Masters, J. Kinabo, J. Meenakshi, B. Ramaswami, J. Tagwireyi and S. Goswami (2016). "Measuring food and nutrition security: An independent technical assessment and user's guide for existing indicators." Food Security Information Network.

Lelijveld, N., A. Seal, J. C. Wells, J. Kirkby, C. Opondo, E. Chimwezi, J. Bunn, R. Bandsma, R. S. Heyderman and M. J. Nyirenda (2016). "Chronic disease outcomes after severe acute malnutrition in Malawian children (ChroSAM): a cohort study." The Lancet Global Health **4**(9): e654-e662.

Li, Y., K. Guan, G. D. Schnitkey, E. DeLucia and B. Peng (2019). "Excessive rainfall leads to maize yield loss of a comparable magnitude to extreme drought in the United States." Global change biology **25**(7): 2325-2337.

Linneman, Z., D. Matilsky, M. Ndekha, M. J. Manary, K. Maleta and M. J. Manary (2007). "A large‐scale operational study of home‐based therapy with ready‐to‐use therapeutic food in childhood malnutrition in Malawi." Maternal & child nutrition **3**(3): 206-215.

Lipiec, J., C. Doussan, A. Nosalewicz and K. Kondracka (2013). "Effect of drought and heat stresses on plant growth and yield: a review." International Agrophysics **27**(4): 463-477.

Lipper, L., P. Thornton, B. M. Campbell, T. Baedeker, A. Braimoh, M. Bwalya, P. Caron, A. Cattaneo, D. Garrity and K. Henry (2014). "Climate-smart agriculture for food security." Nature climate change **4**(12): 1068.

Lividini, K., J. L. Fiedler and O. I. Bermudez (2013). "Policy implications of using a Household Consumption and Expenditures Survey versus an Observed-Weighed Food Record Survey to design a food fortification program." Food and nutrition bulletin **34**(4): 520-532.

Lloyd, P. (2009). "On the determination of trends in rainfall." Water SA **35**(3).

Longhurst, D. and R. Sabates-Wheeler (2019). "Malawi Shock-Responsive Social Protection (SRSP) Case Study."

Longo, P. (2016). "Food justice and sustainability: a new revolution." Agriculture and agricultural science procedia **8**: 31-36.

Loo, Y. Y., L. Billa and A. Singh (2015). "Effect of climate change on seasonal monsoon in Asia and its impact on the variability of monsoon rainfall in Southeast Asia." Geoscience Frontiers **6**(6): 817-823.

Lu, J., G. J. Carbone and P. Gao (2017). "Detrending crop yield data for spatial visualization of drought impacts in the United States, 1895–2014." Agricultural and Forest Meteorology **237**: 196-208.

Lucht, W., S. Schaphoff, T. Erbrecht, U. Heyder and W. Cramer (2006). "Terrestrial vegetation redistribution and carbon balance under climate change." Carbon Balance and Management **1**(1): 6.

Lupo, A. and W. Kininmonth (2013). "Global climate models and their limitations." Climate change reconsidered II: Physical science: 9-148.

Lutgens, F. K., E. J. Tarbuck and D. Tusa (1995). The atmosphere, Prentice-Hall Englewood Cliffs, NJ.

Mabaso, M. and N. Ndlovu (2012). "Critical review of research literature on climate-driven malaria epidemics in sub-Saharan Africa." public health **126**(11): 909-919.

MacColl, D. (1989). "Studies on maize (Zea mays) at Bunda, Malawi. II. Yield in short rotations with legumes." Experimental Agriculture **25**(3): 367-374.

Machiwal, D. and M. K. Jha (2012). Hydrologic time series analysis: theory and practice, Springer Science & Business Media.

Machiwal, D. and M. K. Jha (2012). Methods for time series analysis. Hydrologic Time Series Analysis: Theory and Practice, Springer**:** 51-84.

Madise, N. J. and M. Mpoma (1997). "Child malnutrition and feeding practices in Malawi." FOOD AND NUTRITION BULLETIN-UNITED NATIONS UNIVERSITY- **18**: 190-201.

Makombe, T., P. Lewin and M. Fisher (2010). The determinants of food insecurity in rural Malawi: Implications for agricultural policy, International Food Policy Research Institute (IFPRI).

Malawi Government (2013). "Malawi Labour Force Survey."

Malawi Government (2015). "Malawi Demographic and Health Survey."
Malawi Government (2016). "Annual Economic Report."
Malawi Government (2016). "Malawi Growth and Development Strategy."
Malawi Government (2016). "National Trade Policy."
Malawi Government (2017). "Statistical Year Book."
Malawi Government (2018). "Population and Housing Census." National Statistical Office.
MalawiGovernment (2015). "Malawi Millenium Development Goals Endline Survey report.".
MalawiGovernment (2015). "Malawi Vulnerability Assessment report' Ministry of Finance, Economic Planning and Development." Report.
MalawiGovernment (2016). "Review of Malawi National Social Support Program." Report.
MalawiGovernment (2017). "Fourth Integrated Household Survey, National Statistical Office, Ministry of Finance, Economic Planning and Development." Survey report.
MalawiGovernment (2017). "Malawi Vulnerability Assessment report, Ministry of Finance, Economic Planning and Development." Study report.
Mallakpour, I. and G. Villarini (2016). "A simulation study to examine the sensitivity of the Pettitt test to detect abrupt changes in mean." Hydrological Sciences Journal **61**(2): 245-254.
Manatsa, D., Y. Morioka, S. K. Behera, T. D. Mushore and R. Mugandani (2015). "Linking the southern annular mode to the diurnal temperature range shifts over southern Africa." International Journal of Climatology **35**(14): 4220-4236.
Manda, M. and E. Wanda (2017). "Understanding the nature and scale of risks in Karonga, Malawi." Environment and urbanization **29**(1): 15-32.
Mango, N., C. Makate, L. Mapemba and M. Sopo (2018). "The role of crop diversification in improving household food security in central Malawi." Agriculture & Food Security **7**(1): 7.
Manoj, K. and K. Senthamarai Kannan (2013). "Comparison of methods for detecting outliers." International Journal of Scientific & Engineering Research **4**(9): 709-714.
Manyeruke, C., S. Hamauswa and L. Mhandara (2013). "The effects of climate change and variability on food security in Zimbabwe: a socio-economic and political analysis."
Maraseni, T. N. and J. Maroulis (2008). "Piggery: from environmental pollution to a climate change solution." Journal of Environmental Science and Health Part B **43**(4): 358-363.
Margulis, M. E. (2013). "The regime complex for food security: Implications for the global hunger challenge." Global Governance **19**: 53.
Martínez Pérez, G. and A. Pascual García (2013). "Nutritional taboos among the Fullas in Upper River region, the Gambia." Journal of Anthropology **2013**.
Martins, V. J., T. M. Toledo Florêncio, L. P. Grillo, M. Do Carmo P Franco, P. A. Martins, A. P. G. Clemente, C. D. Santos, M. d. F. A. Vieira and A. L. Sawaya (2011). "Long-lasting effects of undernutrition." International journal of environmental research and public health **8**(6): 1817-1846.
Martinsen, O. G. and S. Grimnes (2011). Bioimpedance and bioelectricity basics, Academic press.
Martorell, R. and J.-P. Habicht (1986). "Growth in early childhood in developing countries."
Masih, I., S. Maskey, F. Mussá and P. Trambauer (2014). "A review of droughts on the African continent: a geospatial and long-term perspective." Hydrology and Earth System Sciences **18**(9): 3635.
Matchaya, G., S. Nhlengethwa and P. Chilonda (2014). "Agricultural sector performance in Malawi." Regional and Sectoral Economic Studies **14**(2): 141-156.
Matiu, M., D. P. Ankerst and A. Menzel (2017). "Interactions between temperature and drought in global and regional crop yield variability during 1961-2014." PloS one **12**(5): e0178339.
Matsui, N. (2016). "11-Year Rainfall and Maize Yield Variation (2003-2013) in Four Northern Districts of Malawi." Journal of Agricultural Science **8**(5): 95.
Mazunda, J. and K. Droppelmann (2012). Maize consumption estimation and dietary diversity assessment methods in Malawi, International Food Policy Research Institute (IFPRI).
McCarthy, J. J., O. F. Canziani, N. A. Leary, D. J. Dokken and K. S. White (2001). Climate change 2001.
McElroy, M. (2002). Resistance to exercise: A social analysis of inactivity, Human Kinetics.

McIntosh, W. A. (1996). The Sociology of Food and Nutrition A Sociological Assessment. Sociologies of Food and Nutrition, Springer**:** 235-253.

McMichael, A. J. (2013). "Globalization, climate change, and human health." New England Journal of Medicine **368**(14): 1335-1343.

McMichael, A. J., R. E. Woodruff and S. Hales (2006). "Climate change and human health: present and future risks." The Lancet **367**(9513): 859-869.

Mechoso, C. and A. Arakawa (2015). "NUMERICAL MODELS| General Circulation Models."

Melek, W. W., Z. Lu, A. Kapps and W. D. Fraser (2005). "Comparison of trend detection algorithms in the analysis of physiological time-series data." IEEE transactions on biomedical engineering **52**(4): 639-651.

Méndez-Lázaro, P., A. Nieves-Santiango and J. Miranda-Bermúdez (2014). "Trends in total rainfall, heavy rain events, and number of dry days in San Juan, Puerto Rico, 1955-2009." Ecology and Society **19**(2).

Mgbemene, C. A., C. C. Nnaji and C. Nwozor (2016). "Industrialization and its backlash: focus on climate change and its consequences." Journal of Environmental Science and Technology **9**(4): 301-316.

Miles, J. and P. Gilbert (2005). A handbook of research methods for clinical and health psychology, Oxford University Press on Demand.

Miller, C., M. Tsoka and K. Reichert (2010). "Impacts on children of cash transfers in Malawi." Social protection for Africa's children **86**: 96.

Milton, A. H., M. A. F. Lusha, W. Smith, M. B. Rahman and M. I. Kabir (2015). Child Centred Approach to Climate Change and Health Adaptation through Schools in Bangladesh: A Cluster Randomised Intervention Trial.

Mirzaei, J., Majid Raoof 2,Ali Ghasemi3,AbazarEsmali4,Hasan Etaati 5,Maryam Moradnezhadi 6,Yadollah Mirzaei7 (2014). "Determination of A Some Simple Methods for Outlier Detection in Maximum Daily Rainfall (Case Study: Baliglichay Watershed

Basin – Ardebil Province – Iran)." Bulletin of Environment, Pharmacology and Life Sciences **3**(3).

Mkandawire, M. (2014). Investigating dry spells in Malawi during the rainfall season, Masters, Uiversity of Nairobi, Nairobi.

Moeletsi, M. E., S. Walker and W. A. Landman (2011). "ENSO and implications on rainfall characteristics with reference to maize production in the Free State Province of South Africa." Physics and Chemistry of the Earth, Parts A/B/C **36**(14): 715-726.

Moffitt, R. A. and D. C. Ribar (2016). "Rasch analyses of very low food security among households and children in the Three City Study." Southern economic journal **82**(4): 1123-1146.

Moore, N., G. Alagarswamy, B. Pijanowski, P. Thornton, B. Lofgren, J. Olson, J. Andresen, P. Yanda and J. Qi (2012). "East African food security as influenced by future climate change and land use change at local to regional scales." Climatic change **110**(3-4): 823-844.

Moore, S. M., A. S. Azman, B. F. Zaitchik, E. D. Mintz, J. Brunkard, D. Legros, A. Hill, H. McKay, F. J. Luquero and D. Olson (2017). "El Niño and the shifting geography of cholera in Africa." Proceedings of the National Academy of Sciences **114**(17): 4436-4441.

Morris, R. W. (1991). "Limitations of quantitative methods for research on values in sexuality education." Canadian Journal of Education/Revue canadienne de l'education: 82-92.

Msongaleli, B. M., S. Tumbo, N. Kihupi and F. B. Rwehumbiza (2017). "Performance of Sorghum Varieties under Variable Rainfall in Central Tanzania." International scholarly research notices **2017**.

Msowoya, K., K. Madani, R. Davtalab, A. Mirchi and J. R. Lund (2016). "Climate change impacts on maize production in the warm heart of Africa." Water Resources Management **30**(14): 5299-5312.

Mueller, W. H. and R. Martorell (1988). "Reliability and accuracy of measurement." Anthropometric standardization reference manual: 83-86.

Mukatay, A., P. Kalenga, M. Dramaix, P. Hennart, C. Schirvel, L. M. Kabamba, B. I. Kabyla and P. Donnen (2010). "Factors associated with malnutrition in children aged under five years in Lubumbashi (DRC)." Sante publique (Vandoeuvre-les-Nancy, France) **22**(5): 541-550.

Müller, C., K. Waha, A. Bondeau and J. Heinke (2014). "Hotspots of climate change impacts in sub ‐ Saharan Africa and implications for adaptation and development." Global change biology **20**(8): 2505-2517.

Munodawafa, A. (2012). "The effect of rainfall characteristics and tillage on sheet erosion and maize grain yield in semiarid conditions and granitic sandy soils of Zimbabwe." Applied and environmental soil science **2012**.

Munthali, M. G., N. Davis, A. M. Adeola, J. O. Botai, J. M. Kamwi, H. L. Chisale and O. O. Orimoogunje (2019). "Local Perception of Drivers of Land-Use and Land-Cover Change Dynamics across Dedza District, Central Malawi Region." Sustainability **11**(3): 832.

Murphy, C. and M. Tembo (2014). "Observed and projected climate change in the Philippines, Honduras, Kenya, Malawi and Ethiopia." Report prepared for Trócaire.

Musaiger, A. O. (1993). "Socio-cultural and economic factors affecting food consumption patterns in the Arab countries." Journal of the Royal Society of Health **113**(2): 68-74.

Muthoni, F. K., V. O. Odongo, J. Ochieng, E. M. Mugalavai, S. K. Mourice, I. Hoesche-Zeledon, M. Mwila and M. Bekunda (2018). "Long-term spatial-temporal trends and variability of rainfall over Eastern and Southern Africa." Theoretical and Applied Climatology: 1-14.

Mutisya, M., M. W. Ngware, C. W. Kabiru and N.-b. Kandala (2016). "The effect of education on household food security in two informal urban settlements in Kenya: a longitudinal analysis." Food Security **8**(4): 743-756.

Myers, J., T. Young, M. Galloway, P. Manyike and T. Tucker (2011). "A public health approach to the impact of climate change on health in southern Africa: identifying priority modifiable risks." SAMJ: South African Medical Journal **101**(11): 817-819.

Myers, S. S., M. R. Smith, S. Guth, C. D. Golden, B. Vaitla, N. D. Mueller, A. D. Dangour and P. Huybers (2017). "Climate change and global food systems: potential impacts on food security and undernutrition." Annual review of public health **38**: 259-277.

Mzembe, A. N. and J. Meaton (2014). "Driving corporate social responsibility in the Malawian mining industry: a stakeholder perspective." Corporate Social Responsibility and Environmental Management **21**(4): 189-201.

Nangoma, E. (2007). "National adaptation strategy to climate change impacts: A case study of Malawi." Human Development Report **2008**(8).

Nash, D. (2017). "Changes in precipitation over southern Africa during recent centuries."

Nash, D. J., K. Pribyl, G. H. Endfield, J. Klein and G. C. Adamson (2018). "Rainfall variability over Malawi during the late 19th century." International Journal of Climatology **38**: e629-e642.

National Research Council (2005). Measuring food insecurity and hunger: Phase 1 report, National Academies Press.

National Research Council (2006). Food insecurity and hunger in the United States: an assessment of the measure, National Academies Press.

Naveau, P., M. Nogaj, C. Ammann, P. Yiou, D. Cooley and V. Jomelli (2005). "Statistical methods for the analysis of climate extremes." Comptes Rendus Geoscience **337**(10-11): 1013-1022.

Ndamani, F. and T. Watanabe (2015). "Influences of rainfall on crop production and suggestions for adaptation." Int. J. Agric. Sci **5**(1): 367-374.

Nel, E. (2010). "Diarrhoea and malnutrition." South African Journal of Clinical Nutrition **23**(sup1): 15-18.

New, M., B. Hewitson, D. B. Stephenson, A. Tsiga, A. Kruger, A. Manhique, B. Gomez, C. A. Coelho, D. N. Masisi and E. Kululanga (2006). "Evidence of trends in daily climate extremes over southern and west Africa." Journal of Geophysical Research: Atmospheres **111**(D14).

Ngongondo, C., L. Tallakanse and C.-Y. Xu (2014). "Growing season length and rainfall extremes analysis in Malawi." Hydrology in a changing world: Environmental and human dimensions. Oxfordshire: International Association of Hydrological Sciences (IHAS) Publications **363**: 361-366.

NGONGONDO, C., L. M. TALLAKSEN and C.-Y. XU (2014). "Growing season length and rainfall extremes analysis in Malawi." Hydrology in a changing world: Environmental and human dimensions. Oxfordshire: International Association of Hydrological Sciences (IHAS) Publications **363**: 361-366.

Ngongondo, C., C.-Y. Xu, L. Gottschalk and B. Alemaw (2011). "Evaluation of spatial and temporal characteristics of rainfall in Malawi: a case of data scarce region." Theoretical and applied climatology **106**(1-2): 79-93.

Ngongondo, C., C.-Y. Xu, L. M. Tallaksen and B. Alemaw (2015). "Observed and simulated changes in the water balance components over Malawi, during 1971–2000." Quaternary International **369**: 7-16.

Ngwira, S. and T. Watanabe (2019). "An Analysis of the Causes of Deforestation in Malawi: A Case of Mwazisi." Land **8**(3): 48.

Nicholson, S., D. Klotter and G. Chavula (2014). "A detailed rainfall climatology for Malawi, Southern Africa." International Journal of Climatology **34**(2): 315-325.

Nicholson, S. E. and H. Flohn (1980). "African environmental and climatic changes and the general atmospheric circulation in late Pleistocene and Holocene." Climatic change **2**(4): 313-348.

Nicholson, S. E., D. J. Nash, B. M. Chase, S. W. Grab, T. M. Shanahan, D. Verschuren, A. Asrat, A.-M. Lézine and M. Umer (2013). "Temperature variability over Africa during the last 2000 years." The Holocene **23**(8): 1085-1094.

Niles, M. T. and M. E. Brown (2017). "A multi-country assessment of factors related to smallholder food security in varying rainfall conditions." Scientific reports **7**(1): 16277.

Nkomwa, E. C., M. K. Joshua, C. Ngongondo, M. Monjerezi and F. Chipungu (2014). "Assessing indigenous knowledge systems and climate change adaptation strategies in agriculture: A case study of Chagaka Village, Chikhwawa, Southern Malawi." Physics and Chemistry of the Earth, Parts A/B/C **67**: 164-172.

Nord, M. (2010). Household food security in the United States (2008), DIANE publishing.

Norton, K. and T. Olds (2001). "Morphological evolution of athletes over the 20th century." Sports Medicine **31**(11): 763-783.

Novella, R. (2013). Parental education, gender preferences and child nutritional status: evidence from four developing countries, ISER working paper series.

Nurliyana, A. R., Z. M. Shariff, M. N. M. Taib, W. Y. Gan and K.-A. Tan (2016). "Early nutrition, growth and cognitive development of infants from birth to 2 years in Malaysia: a study protocol." BMC pediatrics **16**(1): 160.

Nyangasa, M. A., C. Buck, S. Kelm, M. Sheikh and A. Hebestreit (2019). "Exploring Food Access and Sociodemographic Correlates of Food Consumption and Food Insecurity in Zanzibari Households." International journal of environmental research and public health **16**(9): 1557.

Nyaradi, A., J. Li, S. Hickling, J. Foster and W. H. Oddy (2013). "The role of nutrition in children's neurocognitive development, from pregnancy through childhood." Frontiers in human neuroscience **7**: 97.

O'Gorman, P. A. (2014). "Contrasting responses of mean and extreme snowfall to climate change." Nature **512**(7515): 416.

Obayelu, A. E. (2012). "Households' food security status and its determinants in the North-Central Nigeria." Food Economics **9**(4): 241-256.

Ochieng, J., L. Kirimi and M. Mathenge (2016). "Effects of climate variability and change on agricultural production: The case of small scale farmers in Kenya." NJAS-Wageningen Journal of Life Sciences **77**: 71-78.

Ogbo, F. A., K. Agho, P. Ogeleka, S. Woolfenden, A. Page and J. Eastwood (2017). "Infant feeding practices and diarrhoea in sub-Saharan African countries with high diarrhoea mortality." PloS one **12**(2): e0171792.

Ogden, L. E. (2018). "Climate change, pathogens, and people: The challenges of monitoring a moving target." BioScience **68**(10): 733-739.

Ogwang, B. A., H. Chen, X. Li and C. Gao (2014). "The influence of topography on East African October to December climate: sensitivity experiments with RegCM4." Advances in Meteorology **2014**.

Okaka, F. O. and B. Odhiambo (2018). "Relationship between Flooding and Out Break of Infectious Diseasesin Kenya: A Review of the Literature." Journal of environmental and public health **2018**.

Olson, C. M. (1999). "Nutrition and health outcomes associated with food insecurity and hunger." The Journal of nutrition **129**(2): 521S-524S.

Omotesho, O., M. O. Adewumi and K. Fadimula (2010). "Food security and poverty of the rural households in Kwara State, Nigeria." Libyan Agriculture Research Center Journal International **1**(1): 56-59.

Omoyo, N. N., J. Wakhungu and S. Oteng'i (2015). "Effects of climate variability on maize yield in the arid and semi arid lands of lower eastern Kenya." Agriculture & Food Security **4**(1): 8.

Onis, M. (2006). "WHO Child Growth Standards based on length/height, weight and age." Acta paediatrica **95**(S450): 76-85.

Organization, W. M. (2017). WMO Statement on the State of the Global Climate in 2016, World Meteorological Organization (WMO).

Ornes, S. (2018). "Core Concept: How does climate change influence extreme weather? Impact attribution research seeks answers." Proceedings of the National Academy of Sciences **115**(33): 8232-8235.

Osborne, J. (2005). "Notes on the use of data transformations." Practical assessment, research and evaluation **9**(1): 42-50.

Osborne, J. W. and A. Overbay (2004). "The power of outliers (and why researchers should always check for them)." Practical assessment, research & evaluation **9**(6): 1-12.

Pachauri, R. K., M. R. Allen, V. R. Barros, J. Broome, W. Cramer, R. Christ, J. A. Church, L. Clarke, Q. Dahe and P. Dasgupta (2014). Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change, Ipcc.

Palamuleni, L. G., P. M. Ndomba and H. J. Annegarn (2011). "Evaluating land cover change and its impact on hydrological regime in Upper Shire river catchment, Malawi." Regional Environmental Change **11**(4): 845-855.

Pande, R. P. (2003). "Selective gender differences in childhood nutrition and immunization in rural India: the role of siblings." Demography **40**(3): 395-418.

Papadimitriou, S., H. Kitagawa, P. B. Gibbons and C. Faloutsos (2003). Loci: Fast outlier detection using the local correlation integral. Data Engineering, 2003. Proceedings. 19th International Conference on, IEEE.

Parmesan, C. and M. E. Hanley (2015). "Plants and climate change: complexities and surprises." Annals of botany **116**(6): 849-864.

Parry, M., C. Rosenzweig, A. Iglesias, G. Fischer and M. Livermore (1999). "Climate change and world food security: a new assessment." Global environmental change **9**: S51-S67.

Parry, M. L., C. Rosenzweig, A. Iglesias, M. Livermore and G. Fischer (2004). "Effects of climate change on global food production under SRES emissions and socio-economic scenarios." Global Environmental Change **14**(1): 53-67.

Parsons, E. (2011). "Nutritional care and the Malnutrition Universal Screening Tool (MUST)." British Journal of Community Nursing **16**(Sup5): S16-S21.

Pauw, K., J. Thurlow and D. van Seventer (2010). Droughts and floods in Malawi, International Food Policy Research Institute (IFPRI).

Peña-Ortiz, C., D. Barriopedro and R. García-Herrera (2015). "Multidecadal variability of the summer length in Europe." Journal of Climate **28**(13): 5375-5388.

Pendergrass, A. G., R. Knutti, F. Lehner, C. Deser and B. M. Sanderson (2017). "Precipitation variability increases in a warmer climate." Scientific reports **7**(1): 17966.

Pérez-Escamilla, R. and A. M. Segall-Corrêa (2008). "Food insecurity measurement and indicators." Revista de Nutrição **21**: 15s-26s.

Peugh, J. L. (2010). "A practical guide to multilevel modeling." Journal of school psychology **48**(1): 85-112.

Phalkey, R. K., C. Aranda-Jan, S. Marx, B. Höfle and R. Sauerborn (2015). "Systematic review of current efforts to quantify the impacts of climate change on undernutrition." Proceedings of the National Academy of Sciences **112**(33): E4522-E4529.

Pham, N., P. Cox-Reijven, J. Greve and P. Soeters (2006). "Application of subjective global assessment as a screening tool for malnutrition in surgical patients in Vietnam." Clinical nutrition **25**(1): 102-108.

Pohlert, T. (2016). "Non-parametric trend tests and change-point detection." CC BY-ND **4**.

Polade, S. D., D. W. Pierce, D. R. Cayan, A. Gershunov and M. D. Dettinger (2014). "The key role of dry days in changing regional climate and precipitation regimes." Scientific reports **4**: 4364.

Poon, T., M.-È. Labonté, C. Mulligan, M. Ahmed, K. M. Dickinson and M. R. L'Abbé (2018). "Comparison of nutrient profiling models for assessing the nutritional quality of foods: A validation study." British Journal of Nutrition **120**(5): 567-582.

Poppy, G., P. Jepson, J. Pickett and M. Birkett (2014). Achieving food and environmental security: new approaches to close the gap, The Royal Society.

Porter, A. J., T. R. Kuhn and B. Nerlich (2018). "Organizing authority in the climate change debate: IPCC controversies and the management of dialectical tensions." Organization Studies **39**(7): 873-898.

Porter, J., R. Raja, R. Cant and R. Aroni (2009). "Exploring issues influencing the use of the Malnutrition Universal Screening Tool by nurses in two Australian hospitals." Journal of human nutrition and dietetics **22**(3): 203-209.

Púčik, T., P. Groenemeijer, A. T. Rädler, L. Tijssen, G. Nikulin, A. F. Prein, E. van Meijgaard, R. Fealy, D. Jacob and C. Teichmann (2017). "Future Changes in European Severe Convection Environments in a Regional Climate Model Ensemble." Journal of Climate **30**(17): 6771-6794.

Quisumbing, A. R., L. R. Brown, H. S. Feldstein, L. Haddad and C. Peña (1995). "Women: The key to food security." Food policy statement **21**.

Randall, D., R. Wood, S. Bony, R. Colman, T. Fichefet, J. Fyfe, V. Kattsov, A. Pitman, J. Shukla and J. Srinivasan (2007). "Climate Models and Their Evaluation, Chapter 8." Climate Change 2007. The Fourth Scientific Assessment.

Rasheed, S. and R. T. Woods (2013). "Predictive validity of 'Malnutrition Universal Screening Tool'('MUST') and Short Form Mini Nutritional Assessment (MNA-SF) in terms of survival and length of hospital stay." e-SPEN Journal **8**(2): e44-e50.

Rasmussen, H. H., M. Holst and J. Kondrup (2010). "Measuring nutritional risk in hospitals." Clinical epidemiology **2**: 209.

Ray, D. K., J. S. Gerber, G. K. MacDonald and P. C. West (2015). "Climate variation explains a third of global crop yield variability." Nature communications **6**: 5989.

Reeves, J., J. Chen, X. L. Wang, R. Lund and Q. Q. Lu (2007). "A review and comparison of changepoint detection techniques for climate data." Journal of Applied Meteorology and Climatology **46**(6): 900-915.

Rezaei, E. E., S. Siebert, H. Hüging and F. Ewert (2018). "Climate change effect on wheat phenology depends on cultivar change." Scientific reports **8**(1): 4891.

Rice, A. L., L. Sacco, A. Hyder and R. E. Black (2000). "Malnutrition as an underlying cause of childhood deaths associated with infectious diseases in developing countries." Bulletin of the World Health organization **78**: 1207-1221.

Ricker-Gilbert, J., C. Jumbe and J. Chamberlin (2014). "How does population density influence agricultural intensification and productivity? Evidence from Malawi." Food Policy **48**: 114-128.

Riebeek, H. (2005). "Paleoclimatology: The Ice Core Record: Feature Articles."

Rojas, R., L. Feyen and P. Watkiss (2013). "Climate change and river floods in the European Union: Socio-economic consequences and the costs and benefits of adaptation." Global Environmental Change **23**(6): 1737-1751.

Rose, D. (2010). "Access to healthy food: a key focus for research on domestic food insecurity." The Journal of nutrition **140**(6): 1167-1169.

Rose, D. and K. E. Charlton (2002). "Quantitative indicators from a food expenditure survey can be used to target the food insecure in South Africa." The Journal of nutrition **132**(11): 3235-3242.

Rosegrant, M. W. and S. A. Cline (2003). "Global food security: challenges and policies." Science **302**(5652): 1917-1919.

Rosenzweig, C., A. Iglesias, X. Yang, P. R. Epstein and E. Chivian (2001). "Climate change and extreme weather events; implications for food production, plant diseases, and pests." Global change & human health **2**(2): 90-104.

Rowhani, P., O. Degomme, D. Guha-Sapir and E. F. Lambin (2012). Malnutrition and Conflict in Eastern Africa: Impacts of Resource Variability on Human Security. Climate Change, Human Security and Violent Conflict, Springer**:** 559-571.

Ruel, M. T. and P. Menon (2002). "Child feeding practices are associated with child nutritional status in Latin America: innovative uses of the demographic and health surveys." The Journal of nutrition **132**(6): 1180-1187.
Rukuni, M. (2002). "Africa: addressing growing threats to food security." The Journal of nutrition **132**(11): 3443S-3448S.
Rurinda, J., M. T. Wijk, P. Mapfumo, K. Descheemaeker, I. Supit and K. E. Giller (2015). "Climate change and maize yield in southern Africa: what can farm management do?" Global change biology **21**(12): 4588-4601.
Sachs, J. D. (2012). "From millennium development goals to sustainable development goals." The Lancet **379**(9832): 2206-2211.
Sahley, C., B. Groelsema, T. Marchione and D. Nelson (2005). The governance dimensions of food security in Malawi, USAID Washington, DC.
Sarkar, D. (2016). "Socioeconomic Determinants of Child Under-nutrition in India: Evidence from National Family Health Survey-III."
Sasson, A. (2012). "Food security for Africa: an urgent global challenge." Agriculture & Food Security **1**(1): 2.
Sauberlich, H. E. (2018). Laboratory tests for the assessment of nutritional status, Routledge.
Savage, G. (1973). "Malawi." IDRC country profile.
Scaramozzino, P. (2006). "Measuring vulnerability to food insecurity." ESAWorking Paper(6-12).
Schewe, J. and A. Levermann (2012). "A statistically predictive model for future monsoon failure in India." Environmental Research Letters **7**(4): 044023.
Schlenker, W. and D. B. Lobell (2010). "Robust negative impacts of climate change on African agriculture." Environmental Research Letters **5**(1): 014010.
Schlenker, W. and M. J. Roberts (2009). "Nonlinear temperature effects indicate severe damages to US crop yields under climate change." Proceedings of the National Academy of sciences **106**(37): 15594-15598.
Schmidhuber, J. and F. N. Tubiello (2007). "Global food security under climate change." Proceedings of the National Academy of Sciences **104**(50): 19703-19708.
Scrimshaw, N. S. (2003). "Historical concepts of interactions, synergism and antagonism between nutrition and infection." The Journal of nutrition **133**(1): 316S-321S.
Seaman, J. A., G. E. Sawdon, J. Acidri and C. Petty (2014). "The Household Economy Approach. Managing the impact of climate change on poverty and food security in developing countries." Climate risk management **4**: 59-68.
Sen, A. (1976). "Famines as failures of exchange entitlements." Economic and Political Weekly: 1273-1280.
Serdeczny, O., S. Adams, F. Baarsch, D. Coumou, A. Robinson, W. Hare, M. Schaeffer, M. Perrette and J. Reinhardt (2017). "Climate change impacts in Sub-Saharan Africa: from physical changes to their social repercussions." Regional Environmental Change **17**(6): 1585-1600.
Shahin, M., H. Van Oorschot and S. De Lange (1993). Statistical analysis in water resources engineering, AA Balkema.
Sheffield, P. E. and P. J. Landrigan (2011). "Global climate change and children’s health: threats and strategies for prevention." Environmental health perspectives **119**(3): 291.
Sheil, D. and D. Murdiyarso (2009). "How forests attract rain: an examination of a new hypothesis." Bioscience **59**(4): 341-347.
Sheppard, P. R. (2010). "Dendroclimatology: extracting climate from trees." Wiley Interdisciplinary Reviews: Climate Change **1**(3): 343-352.
Shongwe, M. E., G. Van Oldenborgh, B. Van Den Hurk, B. De Boer, C. Coelho and M. Van Aalst (2009). "Projected changes in mean and extreme precipitation in Africa under global warming. Part I: Southern Africa." Journal of climate **22**(13): 3819-3837.
Siebert, J., M. Suennemann, H. Auge, S. Berger, S. Cesarz, M. Ciobanu, N. R. Guerrero-Ramirez and N. Eisenhauer (2019). "The effects of drought and nutrient addition on soil organisms vary across taxonomic groups, but are constant across seasons." Scientific reports **9**(1): 639.

Sigl, M., T. M. Jenk, T. Kellerhals, S. Szidat, H. W. Gäggeler, L. Wacker, H.-A. Synal, C. Boutron, C. Barbante and J. Gabrieli (2009). "Towards radiocarbon dating of ice cores." Journal of Glaciology **55**(194): 985-996.
Silvestri, S., D. Sabine, K. Patti, F. Wiebke, R. Maren, M. Ianetta, Q. F. Carlos, H. Mario, N. Anthony and N. Nicolas (2015). "Households and food security: lessons from food secure households in East Africa." Agriculture & Food Security **4**(1): 23.
Simon, A. K., G. A. Hollander and A. McMichael (2015). "Evolution of the immune system in humans from infancy to old age." Proceedings of the Royal Society B: Biological Sciences **282**(1821): 20143085.
Singh, K. and S. Upadhyaya (2012). "Outlier detection: applications and techniques." International Journal of Computer Science Issues **9**(1): 307-323.
Skerrett, P. J. and W. C. Willett (2010). "Essentials of healthy eating: a guide." Journal of midwifery & women's health **55**(6): 492-501.
Smale, M. (1995). "“Maize is life”: Malawi's delayed Green Revolution." World Development **23**(5): 819-831.
Solak, M. K. (2009). "Detection of multiple outliers in univariate data sets." Paper SP06-2009, Schering.
Solar, O. and A. Irwin (2010). "A conceptual framework for action on the social determinants of health."
Spalding-Fecher, R., B. Joyce and H. Winkler (2017). "Climate change and hydropower in the Southern African Power Pool and Zambezi River Basin: System-wide impacts and policy implications." Energy Policy **103**: 84-97.
Srinivasan, C. S., G. Zanello and B. Shankar (2013). "Rural-urban disparities in child nutrition in Bangladesh and Nepal." BMC public health **13**(1): 581.
Stainforth, D. A., S. C. Chapman and N. W. Watkins (2013). "Mapping climate change in European temperature distributions." Environmental Research Letters **8**(3): 034031.
Stamenkovic, Z., B. Djikanovic, U. Laaser and V. Bjegovic-Mikanovic (2016). "The role of mother's education in the nutritional status of children in Serbia." Public health nutrition **19**(15): 2734-2742.
Stephenson, J., K. Newman and S. Mayhew (2010). "Population dynamics and climate change: what are the links?" Journal of Public Health **32**(2): 150-156.
Stevens, T. and K. Madani (2016). "Future climate impacts on maize farming and food security in Malawi." Scientific reports **6**: 36241.
Stocker, T. (2014). Climate change 2013: the physical science basis: Working Group I contribution to the Fifth assessment report of the Intergovernmental Panel on Climate Change, Cambridge University Press.
Stocker, T., D. Qin, G. Plattner, M. Tignor, S. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P. Midgley (2013). IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 1535 pp, Cambridge Univ. Press, Cambridge, UK, and New York.
Stokols, D. (1996). "Translating social ecological theory into guidelines for community health promotion." American journal of health promotion **10**(4): 282-298.
Stoller-Conrad (2017). "Core Questions: An introduction to ice cores." Feature.
Subramanyam, M. A., I. Kawachi, L. F. Berkman and S. Subramanian (2010). "Socioeconomic inequalities in childhood undernutrition in India: analyzing trends between 1992 and 2005." PLoS One **5**(6): e11392.
Suckall, N., E. Fraser and P. Forster (2017). "Reduced migration under climate change: evidence from Malawi using an aspirations and capabilities framework." Climate and Development **9**(4): 298-312.
Suen, S. (2013). "The education of women as a tool in development: challenging the African maxim." Interdiscip J Soc Sci Hydrea **1**: 60-71.
Sulaiman, M., M. Sulaiman, M. Parveen and N. C. Das (2009). Impact of the food price hike on nutritional status of women and children, Citeseer.

Sutcliffe, C., A. J. Dougill and C. H. Quinn (2016). "Evidence and perceptions of rainfall change in Malawi: Do maize cultivar choices enhance climate change adaptation in sub-Saharan Africa?" Regional Environmental Change **16**(4): 1215-1224.

Sweeney, a. G. (2012). "Regression Analysis of Anthropometry Data." Department of Geography, University of North Carolina, Santa Barbara, CA, 93106-4060.

Szumilas, M. (2010). "Explaining odds ratios." Journal of the Canadian academy of child and adolescent psychiatry **19**(3): 227.

Tadross, M., P. Suarez, A. Lotsch, S. Hachigonta, M. Mdoka, L. Unganai, F. Lucio, D. Kamdonyo and M. Muchinda (2007). Changes in growing-season rainfall characteristics and downscaled scenarios of change over southern Africa: implications for growing maize. IPCC regional Expert Meeting on Regional Impacts, Adaptation, Vulnerability, and Mitigation, Nadi, Fiji.

Tadross, M., P. Suarez, A. Lotsch, S. Hachigonta, M. Mdoka, L. Unganai, F. Lucio, D. Kamdonyo and M. Muchinda (2009). "Growing-season rainfall and scenarios of future change in southeast Africa: implications for cultivating maize." Climate Research **40**(2/3): 147-161.

Tantu, A. T., T. D. Gamebo, B. K. Sheno and M. Y. Kabalo (2017). "Household food insecurity and associated factors among households in Wolaita Sodo town, 2015." Agriculture & Food Security **6**(1): 19.

Tao, F., M. Yokozawa, Y. Xu, Y. Hayashi and Z. Zhang (2006). "Climate changes and trends in phenology and yields of field crops in China, 1981–2000." Agricultural and Forest Meteorology **138**(1-4): 82-92.

Taulo, J. L., K. J. Gondwe and A. B. Sebitosi (2015). "Energy supply in Malawi: Options and issues." Journal of energy in Southern Africa **26**(2): 19-32.

Team, C. W., R. K. Pachauri and L. Meyer (2014). "IPCC, 2014: climate change 2014: synthesis report. Contribution of Working Groups I." II and III to the Fifth Assessment Report of the intergovernmental panel on Climate Change. IPCC, Geneva, Switzerland **151**.

Teshager, A. D., P. W. Gassman, J. T. Schoof and S. Secchi (2016). "Assessment of impacts of agricultural and climate change scenarios on watershed water quantity and quality, and crop production." Hydrology and Earth System Sciences **20**(8): 3325-3342.

Thapa G, K. A., Joshi P.K. (2017). "Household Food Expenditure, Dietary Diversity and Child Nutrition in Nepal." International Food Policy and Research Institute, South Asia Office **IFPRI Discussion Paper 01674**.

The Economist (2018). "Global Food Security Index : Building resilience in the face of rising food security risks."

Thompson, L. G. (2010). "Climate change: The evidence and our options." The Behavior Analyst **33**(2): 153-170.

Thomson, M., K. Abayomi, A. G. Barnston, M. Levy and M. Dilley (2003). "El Niño and drought in southern Africa." The Lancet **361**(9355): 437-438.

Thornton, P. K., P. J. Ericksen, M. Herrero and A. J. Challinor (2014). "Climate variability and vulnerability to climate change: a review." Global change biology **20**(11): 3313-3328.

Timmer, C. P. (2014). "Food security in Asia and the Pacific: the rapidly changing role of rice." Asia & the Pacific Policy Studies **1**(1): 73-90.

Tirado, M. C., P. Crahay, L. Mahy, C. Zanev, M. Neira, S. Msangi, R. Brown, C. Scaramella, D. C. Coitinho and A. Müller (2013). "Climate change and nutrition: creating a climate for nutrition security." Food and Nutrition bulletin **34**(4): 533-547.

Tjaden, N. B., C. Caminade, C. Beierkuhnlein and S. M. Thomas (2018). "Mosquito-borne diseases: advances in modelling climate-change impacts." Trends in parasitology **34**(3): 227-245.

Tol, R. S. (2009). "The economic effects of climate change." Journal of economic perspectives **23**(2): 29-51.

Tolossa, D. (2002). Household seasonal food insecurity in Oromiya Zone, Ethiopia: causes, Organization for Social Science Research in Eastern and Southern Africa.

Toreti, A., F.-G. Kuglitsch, E. Xoplaki, P. M. Della ‐ Marta, E. Aguilar, M. Prohom and J. Luterbacher (2011). "A note on the use of the standard normal homogeneity test to detect inhomogeneities in climatic time series." International Journal of Climatology **31**(4): 630-632.

Traore, B., M. Corbeels, M. T. Van Wijk, M. C. Rufino and K. E. Giller (2013). "Effects of climate variability and climate change on crop production in southern Mali." European Journal of Agronomy **49**: 115-125.

Trapp, E. M. and J. Menken (2005). "Assessing child nutrition: problems with anthropometric measures as a proxy for child health in malnourished populations." Population Program Working Paper POP2005-0006/Population Aging Center Working Paper PAC2005-0006.

Tshediso, J. (2013). "Determinants of the Food Security Status of Households Receiving Government Grants in Kwakwatsi, South Africa." Mediterranean Journal of Social Sciences **4**(1): 147-153.

Tucker, J., M. Daoud, N. Oates, R. Few, D. Conway, S. Mtisi and S. Matheson (2015). "Social vulnerability in three high-poverty climate change hot spots: What does the climate change literature tell us?" Regional Environmental Change **15**(5): 783-800.

Türkkahraman, M. (2012). "The role of education in the societal development." J. Educ. and Instructional Studies **2**(4): 38-42.

Turner, J. (2004). "The El Niño–Southern Oscillation and Antarctica." International Journal of Climatology: A Journal of the Royal Meteorological Society **24**(1): 1-31.

Twerefou, D. K., K. Adjei-Mantey and N. L. Strzepek (2014). The economic impact of climate change on road infrastructure in sub-Saharan Africa countries: evidence from Ghana, WIDER Working Paper.

UNFCCC (2006). "Climate Change : Impacts, Vulnerabilities and Adaptation." <http://unfccc.int/resource/docs/ publications/handbook.pdf>.

Unicef (1994). The state of the world's children. 1998, Unicef.

United Nations (2015). "World Population Ageing 2015." Department of Economic and Social Affairs, Population Division

United Nations Framework Convention on Climate Change (UNFCCC) (1992). "The full text of the convention, Climate Change Secretariat, Bonn." http://unfccc.int/resource/docs/convkp/conveng.pdf.

Urke, H. B., T. Bull and M. B. Mittelmark (2011). "Socioeconomic status and chronic child malnutrition: wealth and maternal education matter more in the Peruvian Andes than nationally." Nutrition research **31**(10): 741-747.

USAID (2016). "Green gas emissions by sector in Malawi."

Uthman, O. A. (2008). "A multilevel analysis of individual and community effect on chronic childhood malnutrition in rural Nigeria." Journal of tropical pediatrics **55**(2): 109-115.

Van de Poel, E., O. O'Donnell and E. Van Doorslaer (2007). "Are urban children really healthier? Evidence from 47 developing countries." Social science & medicine **65**(10): 1986-2003.

van der Maaten-Theunissen, M., E. van der Maaten and O. Bouriaud (2015). "pointRes: An R package to analyze pointer years and components of resilience." Dendrochronologia **35**: 34-38.

Vatcheva, K. P., M. Lee, J. B. McCormick and M. H. Rahbar (2016). "Multicollinearity in regression analyses conducted in epidemiologic studies." Epidemiology (Sunnyvale, Calif.) **6**(2).

Venema, J. (1990). "Methods of description, classification and mapping of the physiography and soils of Malawi."

Verburg, R., E. Arets, J. Verhagen, C. T. Van Scheltinga, F. Ludwig, R. Schils and J. van Geene (2010). Climate change in East Africa: towards a methodological framework on adaptation and mitigation strategies of natural resources, Alterra.

Vermeulen, S. J., B. M. Campbell and J. S. Ingram (2012). "Climate change and food systems." Annual Review of Environment and Resources **37**.

Vincent, K., A. J. Dougill, D. D. Mkwambisi, T. Cull, L. C. Stringer and D. Chanika (2014). "Analysis of existing weather and climate information for Malawi." Pietermaritzburg: Kulima Integrated Development Solutions.

Von Grebmer, K., H. Fritschel, B. Nestorova, T. Olofinbiyi, R. Pandya-Lorch and Y. Yohannes (2008). Global hunger index: The challenge of hunger 2008.

Vozoris, N. T. and V. S. Tarasuk (2003). "Household food insufficiency is associated with poorer health." The Journal of nutrition **133**(1): 120-126.

Vrieling, A., J. De Leeuw and M. Y. Said (2013). "Length of growing period over Africa: Variability and trends from 30 years of NDVI time series." Remote Sensing **5**(2): 982-1000.

Waha, K., C. Müller and S. Rolinski (2013). "Separate and combined effects of temperature and precipitation change on maize yields in sub-Saharan Africa for mid-to late-21st century." Global and Planetary Change **106**: 1-12.

Wamani, H., A. N. Åstrøm, S. Peterson, J. K. Tumwine and T. Tylleskär (2007). "Boys are more stunted than girls in sub-Saharan Africa: a meta-analysis of 16 demographic and health surveys." BMC pediatrics **7**(1): 17.

Wamani, H., T. Tylleskär, A. N. Åstrøm, J. K. Tumwine and S. Peterson (2004). "Mothers' education but not fathers' education, household assets or land ownership is the best predictor of child health inequalities in rural Uganda." International Journal for Equity in Health **3**(1): 9.

Wang, G. (2005). "Agricultural drought in a future climate: results from 15 global climate models participating in the IPCC 4th assessment." Climate dynamics **25**(7-8): 739-753.

Wang, T., A. Hamann, D. Spittlehouse and C. Carroll (2016). "Locally downscaled and spatially customizable climate data for historical and future periods for North America." PloS one **11**(6): e0156720.

Wang, W., P. Van Gelder and J. Vrijling (2005). Trend and stationarity analysis for streamflow processes of rivers in western Europe in the 20th century. Proceedings: IWA International Conference on Water Economics, Statistics, and Finance Rethymno, Greece.

Wang, Y., L. R. Leung, J. L. McGREGOR, D.-K. Lee, W.-C. Wang, Y. Ding and F. Kimura (2004). "Regional climate modeling: progress, challenges, and prospects." Journal of the Meteorological Society of Japan. Ser. II **82**(6): 1599-1628.

Ward, D. and N. Mahowald (2014). "Contributions of developed and developing countries to global climate forcing and surface temperature change." Environmental Research Letters **9**(7): 074008.

Warnatzsch, E. A. and D. S. Reay (2019). "Temperature and precipitation change in Malawi: Evaluation of CORDEX-Africa climate simulations for climate change impact assessments and adaptation planning." Science of the Total Environment **654**: 378-392.

Watts, N., W. N. Adger, P. Agnolucci, J. Blackstock, P. Byass, W. Cai, S. Chaytor, T. Colbourn, M. Collins and A. Cooper (2015). "Health and climate change: policy responses to protect public health." The Lancet **386**(10006): 1861-1914.

Watts, N., M. Amann, S. Ayeb-Karlsson, K. Belesova, T. Bouley, M. Boykoff, P. Byass, W. Cai, D. Campbell-Lendrum and J. Chambers (2018). "The Lancet Countdown on health and climate change: from 25 years of inaction to a global transformation for public health." The Lancet **391**(10120): 581-630.

Weber, T., A. Haensler, D. Rechid, S. Pfeifer, B. Eggert and D. Jacob (2018). "Analyzing regional climate change in africa in a 1.5, 2, and 3 C global warming world." Earth's Future **6**(4): 643-655.

Weisent, J., W. Seaver, A. Odoi and B. Rohrbach (2014). "The importance of climatic factors and outliers in predicting regional monthly campylobacteriosis risk in Georgia, USA." International journal of biometeorology **58**(9): 1865-1878.

Weyl, O. L., A. J. Ribbink and D. Tweddle (2010). "Lake Malawi: fishes, fisheries, biodiversity, health and habitat." Aquatic Ecosystem Health & Management **13**(3): 241-254.

Wheeler, T. and J. Von Braun (2013). "Climate change impacts on global food security." Science **341**(6145): 508-513.

Whitmore, A. P. and W. R. Whalley (2009). "Physical effects of soil drying on roots and crop growth." Journal of Experimental Botany **60**(10): 2845-2857.

WHO (2001). "Macroeconomics and Health : Investigating in Health for Economic Developing, Report the C ommission on Macroeconomic and Health."

WHO (2016). "World Health Organisation Health Statistical Profile for Malawi."

Wiesmann, D. (2006). A global hunger index: Measurement concept, ranking of countries, and trends, Intl Food Policy Res Inst.

Wiesmann, D., L. Bassett, T. Benson and J. Hoddinott (2009). Validation of the World Food Programme s Food Consumption Score and Alternative Indicators of Household Food Security, Intl Food Policy Res Inst.

Wight, V., N. Kaushal, J. Waldfogel and I. Garfinkel (2014). "Understanding the link between poverty and food insecurity among children: Does the definition of poverty matter?" Journal of Children and Poverty **20**(1): 1-20.

Wilson, A. L., J. Bradley, B. Kandeh, K. Salami, U. D'Alessandro, M. Pinder and S. W. Lindsay (2018). "Is chronic malnutrition associated with an increase in malaria incidence? A cohort study in children aged under 5 years in rural Gambia." Parasites & vectors **11**(1): 451.

WMO (2017). WMO Statement on the State of the Global Climate in 2016, World Meteorological Organization (WMO).

Woodward, A., K. R. Smith, D. Campbell-Lendrum, D. D. Chadee, Y. Honda, Q. Liu, J. Olwoch, B. Revich, R. Sauerborn and Z. Chafe (2014). "Climate change and health: on the latest IPCC report." The Lancet **383**(9924): 1185-1189.

World Bank (2017). "World Bank Annual Report, 2017."

Wright, C., R. M. Garland, M. Norval and C. Vogel (2014). "Human health impacts in a changing South African climate." South African Medical Journal **104**(8): 579-582.

Wu, E., W. Liu and S. Chawla (2010). Spatio-temporal outlier detection in precipitation data. Knowledge discovery from sensor data, Springer**:** 115-133.

Wu, X., Y. Lu, S. Zhou, L. Chen and B. Xu (2016). "Impact of climate change on human infectious diseases: Empirical evidence and human adaptation." Environment international **86**: 14-23.

Xu, Z., P. E. Sheffield, W. Hu, H. Su, W. Yu, X. Qi and S. Tong (2012). "Climate change and children's health—A call for research on what works to protect children." International journal of environmental research and public health **9**(9): 3298-3316.

Xu, Z., Y. Tang, T. Connor, D. Li, Y. Li and J. Liu (2017). "Climate variability and trends at a national scale." Scientific Reports **7**.

Yu, K., X. Liu, R. Alhamzawi, F. Becker and J. Lord (2018). "Statistical methods for body mass index: a selective review." Statistical methods in medical research **27**(3): 798-811.

Zakari, S., L. Ying and B. Song (2014). "Factors influencing household food security in West Africa: The case of Southern Niger." Sustainability **6**(3): 1191-1202.

Zeller, M., A. Diagne and C. Mataya (1998). "Market access by smallholder farmers in Malawi: Implications for technology adoption, agricultural productivity and crop income." Agricultural Economics **19**(1-2): 219-229.

Zere, E. and D. McIntyre (2003). "Inequities in under-five child malnutrition in South Africa." International journal for equity in health **2**(1): 7.

Zewdie, A. (2014). "Impacts of Climate Change on Food Security: A Literature Review in Sub Saharan Africa." Journal of Earth Science & Climatic Change **5**(8): 1.

Zhang, X., C. Wenhong, G. Qingchao and W. Sihong (2010). "Effects of landuse change on surface runoff and sediment yield at different watershed scales on the Loess Plateau." International Journal of Sediment Research **25**(3): 283-293.

Zhang, Z. (2016). "Univariate description and bivariate statistical inference: the first step delving into data." Annals of translational medicine **4**(5).

Zhao, C., B. Liu, S. Piao, X. Wang, D. B. Lobell, Y. Huang, M. Huang, Y. Yao, S. Bassu and P. Ciais (2017). "Temperature increase reduces global yields of major crops in four independent estimates." Proceedings of the National Academy of Sciences **114**(35): 9326-9331.

Zhou, D., T. Shah, S. Ali, W. Ahmad, I. U. Din and A. Ilyas (2017). "Factors affecting household food security in rural northern hinterland of Pakistan." Journal of the Saudi Society of Agricultural Sciences.

Zhuang, J., S. Suphachalasai and J. N. Samson (2010). "The economics of climate change in Southeast Asia."

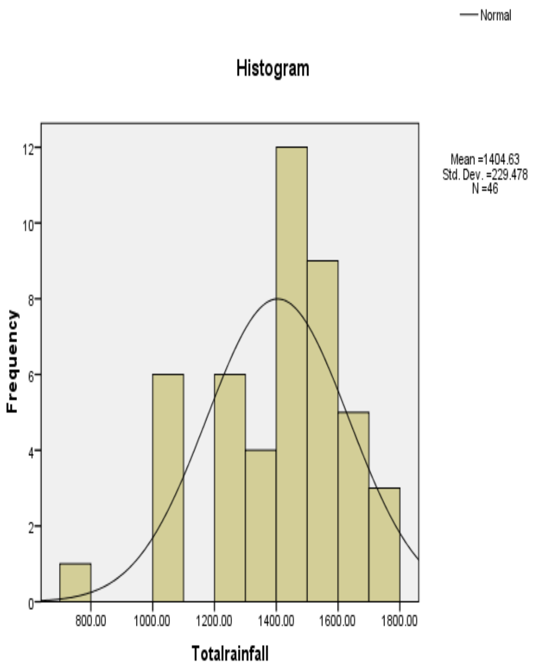
Ziervogel, G., M. New, E. Archer van Garderen, G. Midgley, A. Taylor, R. Hamann, S. Stuart ‐ Hill, J. Myers and M. Warburton (2014). "Climate change impacts and adaptation in South Africa." Wiley Interdisciplinary Reviews: Climate Change **5**(5): 605-620.

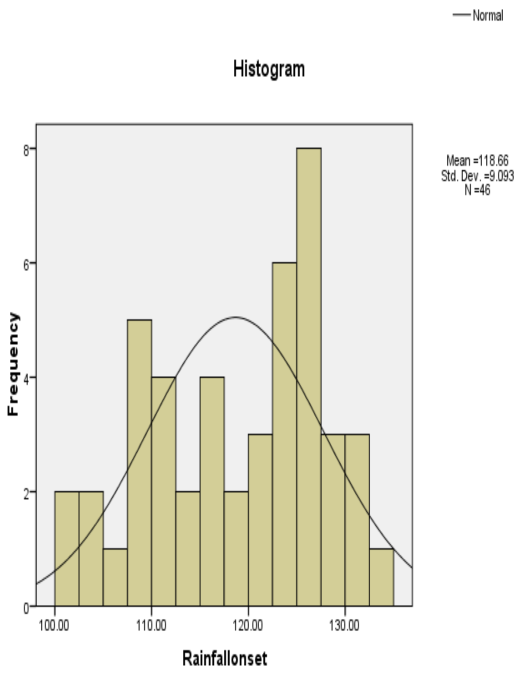
Zuberi, T. and K. J. Thomas (2012). Demographic Change, the IMPACT Model, and Food Security in Sub-Saharan Africa, United Nations Development Programme, Regional Bureau for Africa.

Zulu, L. (2017). Existing Research and Knowledge on Impacts of Climate Variability and Change on Agriculture and Communities in Malawi, Malawi Report.

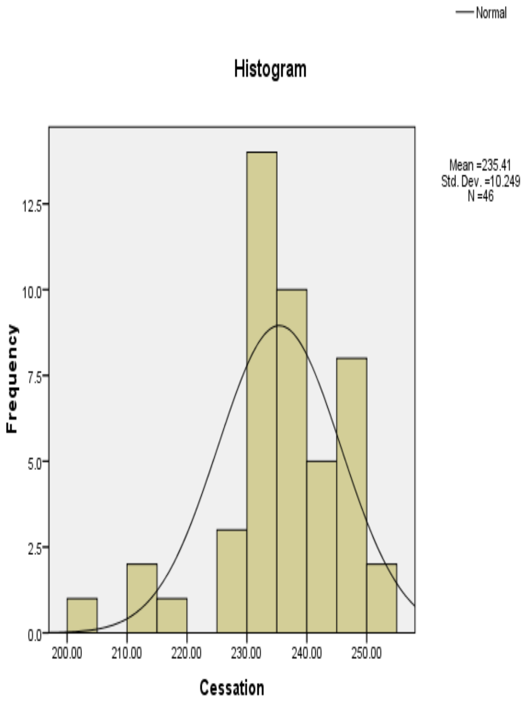
APPENDICES

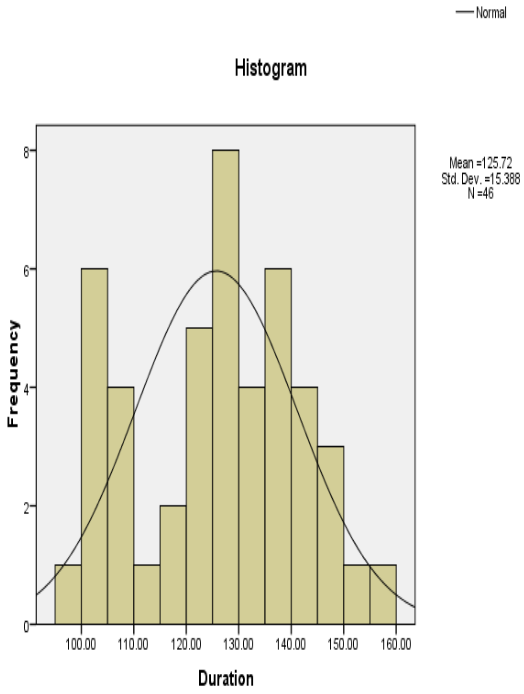
Appendix A. Questionnaire for the 2010/11 Integrated Household Survey
Appendix B. Histogram showing normality test results for time distribution of rainfall and temperature variables used in the study.





AppendixB1 Mean rainfall distribution, 1970-2015 AppendixB2 Mean rainfall onset days, 1970-2015





Appendix B3 Mean rainfall cessation days 1970-2015 AppendixB4 Mean rainfall duration days1970-2015

Appendix C1. Linear regression analysis results for selected temperature and rainfall variables and de-trended maize yield per hectare

R^2	Model Sig (p-value)	Regression Variables	Standardized coefficients		Sig (p-value)	Collinearity statistics	
			B	Std.Error		Tolerance	VIF
0.401	0.072	Constant	-11.498	7.376	0.133		
		Total Rainfall	0.000	0.001	0.834	0.299	3.345
		Rain Onset	0.020	0.028	0.956	0.062	16.090
		Cessation	0.240	0.028	0.380	0.130	7.717
		Duration	0.040	0.028	0.882	0.043	23.432
		Dry-days	0.240	0.014	0.100	0.270	3.701
		Min-temp	0.362	0.260	0.178	0.743	1.346
		Max-temp	-0.490	0.249	0.061	0.000	2.559

Dependent Variable: De-trended Maize

NB: Note the high VIF values for rainfall onset and rainfall duration, all above the cut point of 5. This shows presence of multi-collinearity between the variables, which could affect model parameters i.e. significance of independent variables in the model and coefficients of the regression model. Rainfall onset was pulled out as independent variable in the follow up model as a way of improving the model as shown in Appendix C2 below.

Appendix C2. Linear regression analysis results for selected temperature and rainfall variables and de-trended maize yield per hectare

R^2	Model Sig (p-value)	Regression Variables	Standardized coefficients		Sig (p-value)	Collinearity statistics	
			B	Std.Error		Tolerance	VIF
0.401	0.039	Constant	-11.503	7.220	0.124		
		Total Rainfall	0.000	0.001	0.813	0.320	3.130
		Cessation	0.240	0.015	0.123	0.422	2.370
		Duration	-0.050	0.015	0.710	0.147	6.862
		Dry-days	0.240	0.013	0.073	0.296	3.381
		Min-temp	0.361	0.255	0.169	0.712	1.405
		Max-temp	-0.488	0.240	0.053	0.244	4.103

Dependent Variable: De-trended Maize

Having removed rainfall onset as one of the variables with higher VIF in the model, there were changes in the model parameters i.e. regression coefficients, significance in the model and also their standard errors as can be observed in Appendix C2. The Coefficient of variation remained R-square; 0.401 but model significance improved from p-value 0.072 to p-value 0.039. This procedure was repeated in model the follow-up model below; Appendix C3, where rainfall duration as an independent variable in the model was removed since its VIF was also above the cut-off point of 5.

Appendix C3. Linear regression analysis results for selected temperature and rainfall variables and de-trended maize yield per hectare

R^2	Model Sig (p-value)	Regression Variables	Standardized coefficients		Sig (p-value)	Collinearity statistics	
			B	Std.Error		Tolerance	VIF
0.398	0.020	Constant	-11.478	7.095	0.118		
		Total Rainfall	0.000	0.001	0.758	0.329	3.043
		Cessation	-0.270	0.012	0.028	0.663	1.508
		Dry-days	0.200	0.008	0.020	0.700	1.429
		Min-temp	0.353	0.249	0.169	0.717	1.394
		Max-temp	-0.465	0.288	0.053	0.261	3.838

Dependent Variable: De-trended Maize

As can be observed in appendix C3, removing 'rainfall duration' from the model (due to the high VIF) does improve the significance of the model from p-value 0.039 to p-value 0.020. The VIFs for the other independent variables improved. However, rainfall still remain non-significant in the model, and its coefficient is very 0, as such it was removed in the subsequent model as shown in appendix C4. This was the final model.

Appendix C4. Linear regression analysis results for selected temperature and rainfall variables and de-trended maize yield per hectare

R^2	Model Sig (p-value)	Regression Variables	Standardized coefficients		Sig (p-value)	Collinearity statistics	
			B	Std. Error		Tolerance	VIF
0.395	0.009	Constant	10.104	5.458	0.1076		
		Cessation	-0.270	0.011	0.023	0.669	1.494
		Dry-days	0.210	0.008	0.016	0.705	1.418
		Min-temp	0.334	0.238	0.172	0.761	1.314
		Max-temp	-0.410	0.141	0.007	0.661	1.513

Dependent Variable: De-trended Maize

Results in appendix C4 show that removing variables with possible higher VIFs improved the model parameters as i.e. resulted in the remaining independent variables in the model becoming statistically significant

Appendix C5. Linear regression analysis results for selected lagged (1 month) temperature and rainfall variables and de-trended maize yield per hectare

R^2	Model Sig (p-value)	Regression Variables	Standardized coefficients		Sig (p-value)	Collinearity statistics	
			B	Std. Error		Tolerance	VIF
0.391	0.012	Constant	-14.490	5.1432	0.009		
		Cessation	-0.010	0.014	0.509	0.669	1.494
		Dry-days	-0.037	0.012	0.006	0.705	1.418
		Max-temp	0.520	0152	0.002	0.761	1.314
		Duration	0.030	0.140	0.010	0.661	1.513

Dependent Variable: De-trended Maize

APPENDIX 4 NATIONAL DISASTER PROFILE

YEAR	NATURE OF DISASTER	PLACE	EXTENT OF DAMAGE	ACTION TAKEN (Assistance Provided)
1946	Napolo	Zomba, Mtiya Village	People died	Not known
1949	Drought	Country wide	People died	
1966	Earthquake	Karonga	Magnitude 6.2 but did not cause damage;	
1970	Floods due to heavy rains	Nsanje-Tengani	86 families affected,	Christian Services Committee
		Ndamela and T.A. Chimombo areas.	27 villages and 9000 people were affected	Red Cross, Save the Children Fund
		Chikwawa-East and West Banks of Shire.	99 people and 41 families affected.	and Malawi Government gave some relief food. Government sent poles to Likoma Island.
		Likoma Island	Cassava gardens were washed away at Likoma	
1971	Displaced persons from Mozambique	Chikwawa-Penda, Kakoma and Chigwata areas. Mwanza-Chifunga area.	6000 people occupied these areas	Christian Services Committee, Red Cross, Save the Children Fund and Malawi, Government provided some relief assistance.
1973, December	Poor harvest Floods due to Lalanje stream overflooding	Nsanje-Dande village, T.A. Chikwawa-Mwananjobvu village, T.A. Ngabu	1000 people were affected. 122 people were affected	Government provided beans
	Displaced persons from Mozambique Poor harvest	Ntcheu	64 people were registered, 39 adults and 45 children were affected	Transferred to Mwanza to Chifunga Refugee Camp.
	Strong winds (February)	Chikwawa-Chipsyanda village, Likoma	4 families were affected, 32 houses	Government provided maize

	and heavy rains	Island in Nkhata bay Affecting Nkhwemba and Vesusa Village	and 4 fishing nets were damaged	
January, 1974 to April,	Cholera	Ntcheu	Severe cases died in hospital and at home	- Health talks on Preventive measures throughout the district,
1975, June February	Floods	Karonga-Songwe river	107 families were affected	Relief assistance was provided. It comprised of maize and beans.
1975	Floods	Mangochi-Namiasi; Machinga-Mpheta; Mulanje-	61 families affected; 600 families affected;	Save the Children Fund provided cash for relief
		Chigumukire; Nsanje-Chiromo, Makhanga.	5 villages affected;	purposes
1979	Floods	Chitimba to Mlowe; (Chiweta North	Crops swept away. Houses damaged and Cassava gardens flooded	Health personnel helped in the distribution of food. Public Health staff put on alert
1979	Cholera	Rumphi river).	Four confirmed cholera cases died.	in case of disease outbreaks Health Education on pit Latrines.
1980/81 December	Floods	Salima (the Boma and Maganga areas)	334 families affected (about 1326 people) and 112 house were damaged.	Relief assistance was provided by the government. More drainage channels were dug
1980	Floods	Rumphi-Mlowe	Health Centre premises were in water	Health Centre was moved further ashore
1980	Floods	Nkhata-Bay (Usisya)	Health Centre premises were in water	Health Centre has been moved

Questionnaire Number

UNITY AND FREEDOM

Malawi Government
National Statistical Office

THIRD INTEGRATED HOUSEHOLD SURVEY, 2010/11

THIS SURVEY IS BEING CONDUCTED BY THE NATIONAL STATISTICAL OFFICE UNDER THE AUTHORITY OF THE 1967 STATISTICS ACT.
THIS INFORMATION IS STRICTLY CONFIDENTIAL AND IS TO BE USED FOR STATISTICAL PURPOSES ONLY.

HOUSEHOLD QUESTIONNAIRE

MODULE A-1: HOUSEHOLD IDENTIFICATION

WRITE CODES FOR TA, STA, OR TOWN; EA; AND HH ID. WRITE NAME OF DISTRICT; TA; VILLAGE; AND HOUSEHOLD HEAD.

		CODE	NAME
A01. DISTRICT:		☐☐☐	....
A02. TA, STA, or TOWN:		☐☐	....
A03. ENUMERATION AREA:		☐☐☐	
A04. IS THIS A PANEL EA?	YES..1; NO..2	☐	
A05. PLACE / VILLAGE NAME:			....
A06. HOUSEHOLD ID (FROM LIST):		☐☐☐	
A07. NAME OF HOUSEHOLD HEAD:			....
A08. DWELLING STRUCTURE NO. (FROM LIST):	CODE	☐☐☐	

MARK BOX WITH AN 'X' AND NUMBER FORMS BELOW IF YOU USE MORE THAN THIS SINGLE FORM TO COLLECT INFORMATION FROM THIS HOUSEHOLD. IF SO, BE SURE TO MARK IN THE SAME WAY THE OTHER FORMS USED FOR THIS HOUSEHOLD.

☐

FORM ____ OF ___ FORMS IN TOTAL

A09. DESCRIPTION OF LOCATION OF HOUSEHOLD - INCLUDE ANY IDENTIFYING CHARACTERISTICS OF DWELLING AND NAME OF NEIGHBOURING HOUSEHOLDS. (PROVIDE A SKETCH MAP OF DWELLING LOCATION ON PAGE 4)

....

....

....

A10. WHAT ARE THE GPS COORDINATES OF THE DWELLING?

LATITUDE (S)								
__	__	o	__	__	.	__	__	__

LONGITUDE (E)									
__	__	__	o	__	__	.	__	__	__

A11. DOES THIS HOUSEHOLD REPLACE ANOTHER SAMPLE HOUSEHOLD CHOSEN FOR THE SURVEY? YES..1; NO..2 **(»A14)** ☐

A12. WHICH HOUSEHOLD IN THIS EA DOES IT REPLACE? HOUSEHOLD ID OF ORIGINALLY SELECTED HOUSEHOLD ☐☐☐

A13. WHY WAS ORIGINALLY SELECTED HOUSEHOLD REPLACED? ☐

1 - DWELLING FOUND, BUT NO HH MEMBER COULD BE FOUND.
2 - DWELLING FOUND, BUT RESPONDENT REFUSED.
3 - DWELLING FOUND, BUT APPEARS UNOCCUPIED.
4 - DWELLING FOUND, BUT NOT A RESIDENTIAL BUILDING.
5 - DWELLING DESTROYED.
6 - DWELLING NOT FOUND.

PHONE NUMBER FOR HOUSEHOLD HEAD:

A14.A NAME : ____________________ A14.B PHONE : ____________________

PHONE NUMBERS FOR OTHER HOUSEHOLD MEMBERS:

A15.A NAME : ____________________ A15.B PHONE : ____________________ A15.C HH ROSTER ID CODE: _________ [TO BE FILLED AFTER MODULE B]

A16.A NAME : ____________________ A16.B PHONE : ____________________ A16.C HH ROSTER ID CODE: _________ [TO BE FILLED AFTER MODULE B]

A17.A NAME : ____________________ A17.B PHONE : ____________________ A17.C HH ROSTER ID CODE: _________ [TO BE FILLED AFTER MODULE B]

CONTACT INFORMATION FOR **REFERENCE PERSON 1**

A18.A NAME : ____________________
A18.B RELATION TO HEAD : ____________________
A18.C PHONE : ____________________
A18.D DISTRICT : ____________________
A18.E TA, STA, or TOWN : ____________________
A18.F PLACE/VILLAGE : ____________________

CONTACT INFORMATION FOR **REFERENCE PERSON 2**

A19.A NAME : __________________
A19.B RELATION TO HEAD : __________________
A19.C PHONE : __________________
A19.D DISTRICT : __________________
A19.E TA, STA, or TOWN : __________________
A19.F PLACE/VILLAGE : __________________

CONTACT INFORMATION FOR **REFERENCE PERSON 3**

A20.A NAME : __________________
A20.B RELATION TO HEAD : __________________
A20.C PHONE : __________________
A20.D DISTRICT : __________________
A20.E TA, STA, or TOWN : __________________
A20.F PLACE/VILLAGE : __________________

MODULE A-2: SURVEY STAFF DETAILS

A21. NAME OF ENUMERATOR: ……………………………………

A22. ENUMERATOR CODE: | | |

A23. DATE OF INTERVIEW: / /

(ENUMERATOR
»NEXT PAGE)

A24. NAME OF FIELD SUPERVISOR: ……………………………………

A25. FIELD SUPERVISOR CODE: | | |

A26. DATE OF QUESTIONNAIRE INSPECTION: / /

A27. NAME OF ZONE SUPERVISOR: ……………………………………

A28. ZONE SUPERVISOR CODE: | | |

A29. DATE OF QUESTIONNAIRE INSPECTION: / /

A30. NAME OF DATA ENTRY CLERK: ……………………………………

A31. DATA ENTRY CLERK CODE: | | |

A32. DATE OF DATA ENTRY: / /

A33. NAME OF DATA VALIDATION CLERK: ……………………………………

A34. DATA VALIDATION CLERK CODE: | | |

A35. DATE OF DATA VALIDATION: / /

RECORD GENERAL NOTES ABOUT THE INTERVIEW AND ANY SPECIAL INFORMATION THAT WILL BE HELPFUL FOR SUPERVISORS AND DATA ANALYSIS.

COPY A01-A08 FROM THE COVER PAGE.

A01. DISTRICT:	☐☐☐
A02. TA, STA, or TOWN:	☐☐
A03. ENUMERATION AREA:	☐☐☐
A04. IS THIS A PANEL EA? YES..1; NO..2	☐
A06. HOUSEHOLD ID (FROM LIST):	☐☐☐
A08. DWELLING STRUCTURE NO. (FROM LIST):	☐☐☐

SKETCH MAP OF DWELLING LOCATION

INTRODUCTION TO THE HOUSEHOLD TO BE INTERVIEWED

CONVEY THE FOLLOWING INFORMATION TO THE RESPONDENT:

Every five years the National Statistical Office in Zomba selects at random several hundred households in each district of the country to ask them questions about how they are living. The responses which are provided by the households to these questions are intended to help the government of Malawi do a better job in meeting the needs of all Malawians.

Your household was selected as one of those to which the IHS questions will be asked this time. You were not selected for any specific reason. Simply your name was on a list of all of the households in this area, and your name was chosen randomly.

I would like to ask the questions in this form to you as head of household or spouse of the head. I will also need to ask questions to other members of your household, as well as weigh and measure the height of any children under age 5 years who live in your household. These questions will take several hours to complete. All of your answers will be held in confidence. The answers which you and the members of your household might give me will only be used by the NSO or under its supervision.

Before I start, do you have any questions or is there anything which I have said on which you would like any further clarification? May I proceed with interviewing you and members of your household?

TABLE OF CONTENTS

MODULE B: HOUSEHOLD ROSTER

IN ORDER TO MAKE A COMPREHENSIVE LIST OF INDIVIDUALS CONNECTED TO THE HOUSEHOLD, USE THE FOLLOWING PROBE QUESTIONS:

First, give me the names of all the members of your immediate family who normally live and eat their meals together here.

WRITE DOWN NAMES, SEX, AND RELATIONSHIP TO HH HEAD (B02 to B04). LIST HOUSEHOLD HEAD ON LINE 1.

Then, give me the names of any other persons related to you or other household members who normally live and eat their meals together here.
FILL IN B02 to B04.

Are there any other persons not here now who normally live and eat their meals here? For example, household members studying elsewhere or traveling.
FILL IN B02 to B04.

Then, give me the names of any other persons not related to you or other household members, but who normally live and eat their meals together here, such as servants, lodgers, or other who are not relatives.
FILL IN B02 to B04.

DO NOT LIST SERVANTS WHO HAVE A HOUSEHOLD ELSEWHERE, AND GUESTS WHO ARE VISITING TEMPORARILY AND HAVE A HOUSEHOLD ELSEWHERE.

IF MORE THAN 12 INDIVIDUALS, USE SECOND QUESTIONNAIRE. MAKE SURE TO MARK BOX ON FIRST PAGE OF BOTH QUESTIONNAIRES.

B01	B02	B03	B04	B05		B06		B07
ID CODE	NAME MAKE A COMPLETE LIST OF ALL INDIVIDUALS WHO NORMALLY LIVE AND EAT THEIR MEALS TOGETHER IN THIS HOUSEHOLD, STARTING WITH THE HEAD OF HOUSEHOLD. (CONFIRM THAT HOUSEHOLD HEAD HERE IS SAME AS HOUSEHOLD HEAD LISTED ON COVER.) FILL IN B02 TO B04 BEFORE COMPLETING QUESTIONS B05 AND FOLLOWING.	SEX MALE....1 FEMALE..2	RELATIONSHIP TO HEAD: HEAD. . . . . .1 WIFE/HUSBAND. . . . . .2 CHILD/ADOPTED CHILD . .3 GRANDCHILD. . . . . . .4 NIECE/NEPHEW. . . . . .5 FATHER/MOTHER . . . . .6 SISTER/BROTHER. . . . .7 SON/DAUGHTER-IN-LAW . .8 BROTHER/SISTER-IN-LAW .9 GRANDFATHER/MOTHER. . 10 FATHER/MOTHER-IN-LAW. 11 OTHER RELATIVE. . . . 12 SERVANT OR SERVANT'S RELATIVE . . . . . . 13 LODGER/LODGER'S RELATIVE . . . . . . 14 OTHER NON-RELATIVE. . 15 OTHER (SPECIFY) . . . 16	How old is [NAME]? IF 6 YEARS AND OVER, GIVE YEARS ONLY. IF LESS THAN 6 YEARS IN AGE, GIVE YEARS AND MONTHS.		When was [NAME] born?		For how many months during the past 12 months (since MONTH/ YEAR) has [NAME] been **away** from this household?
				YEARS	MONTHS	MONTH	YEAR (4-DIGIT)	CUMULATED MONTHS
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								

MODULE B: HOUSEHOLD ROSTER (CONTINUED)

B01	B08	B09	B10		B11	B12	B13	B14	B15		B16
ID CODE	How many days did [NAME] eat in this household in the past 7 days?	Where was [NAME] born? THIS VILLAGE......1**>>B11** OTHER VILLAGE IN THIS DISTRICT.....2**>>B11** VILLAGE IN OTHER DISTRICT..........3 THIS TOWN OR URBAN CENTRE......4**>>B11** OTHER TOWN OR URBAN CENTER IN THIS DISTRICT..........5**>>B11** TOWN OR URBAN CENTRE IN OTHER DISTRICT..........6 OUTSIDE MALAWI....7	In which district/country was [NAME] born? IF BORN IN ANOTHER DISTRICT IN MALAWI, LIST THE DISTRICT NAME & CODE; IF BORN ABROAD, LIST THE COUNTRY NAME & CODE. REFER TO THE MANUAL FOR DISTRICT AND COUNTRY CODES. (**THEN >> B12**)		Has [NAME] always lived in this village or urban location? YES..1**>>B16** NO...2	How long is it since [NAME] came to stay here, in this village or urban location?	What was the main reason that [NAME] moved here? PARENTS MOVED. .1 TO LIVE WITH RELATIVES . . .2 SCHOOLING. . . .3 MARRIAGE . . . .4 FAMILY QUARREL .5 DIVORCE. . . . .6 RETURN FROM WORK ELSEWHERE.7 JOB TRANSFER . .8 LOOK FOR WORK. .9 START NEW JOB OR BUSINESS . 10 LOOKING FOR LAND TO FARM. 11 TO RECOVER FROM ILLNESS. 12 OTHER (SPEC.). 13	Where did [NAME] move from? OTHER VILLAGE IN THIS DISTRICT...2**>>B16** VILLAGE IN OTHER DISTRICT........3 OTHER TOWN OR URBAN CENTER IN THIS DISTRICT ..5**>>B16** TOWN OR URBAN CENTRE IN OTHER DISTRICT........6 OUTSIDE MALAWI..7	From which district/country did [NAME] move from? IF MOVED FROM ANOTHER DISTRICT IN MALAWI, LIST THE DISTRICT NAME & CODE; IF MOVED FROM ABROAD, LIST THE COUNTRY NAME & CODE. REFER TO THE MANUAL FOR DISTRICT AND COUNTRY CODES.		Where is [NAME]'s father? IF MEMBER OF HH, COPY ID AND **>>B19** LIVING OUTSIDE OF HH...97**>>B18** DEAD.98 DOES NOT KNOW.99**>>B18**
			DISTRICT/COUNTRY						**DISTRICT/COUNTRY**		
	NUMBER OF DAYS		**NAME**	**CODE**		**YEARS**			**NAME**	**CODE**	
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
11											
12											

MODULE B: HOUSEHOLD ROSTER (CONTINUED)

B01	B17	B18	B19	B20	B21	B22	B23	B24	B25	B26				B27	B28
ID CODE	What was [NAME]'s age when his/her father died?	What was the highest educational qualification acquired by [NAME]'s father? NONE. . . 1 PSLC. . . 2 JCE . . . 3 MSCE. . . 4 NON-UNIV. DIPLOMA. 5 UNIVER. DIPLOMA, DEGREE . 6 POST-GRAD. DEGREE . 7	Where is [NAME]'s mother? IF MEMBER OF HH, COPY ID AND **>>B22** LIVING OUTSIDE OF HH...97**>>B21** DEAD.98 DOES NOT KNOW.99>>B21	What was [NAME]'s age when his/her mother died?	What was the highest educational qualification acquired by [NAME]'s mother? NONE. . . 1 PSLC. . . 2 JCE . . . 3 MSCE. . . 4 NON-UNIV. DIPLOMA. 5 UNIVER. DIPLOMA, DEGREE . 6 POST-GRAD. DEGREE . 7	ASK OF ONLY HH HEAD: What language do you speak at home? CHEWA. . 1 NYANJA . 2 YAO. . . 3 TUMBUKA. 4 LOMWE. . 5 NKHONDE. 6 NGONI. . 7 SENA . . 8 NYAKYUSA 9 TONGA . 10 LAMBYA. 11 SENGA. 12 SUKWA . 13 ENGLISH.14 OTHER . 15	ASK OF ALL HH MEMBERS AGED 12 YEARS AND OLDER. (UNDER AGE 12 »NEXT ROW) What religion, if any, does [NAME] practice? NONE.........1 TRADITIONAL..2 CHRISTIANITY.3 ISLAM........4 OTHER RELIGION.....5	What is [NAME]'s present marital status? MONOGAMOUS MARRIED OR NON-FORMAL UNION.....1 POLYGAMOUS MARRIED OR NON-FORMAL UNION.....2 SEPARATED.3**>>NEXT ROW** DIVORCED..4**>>NEXT ROW** WIDOW OR WIDOWER...5**>>NEXT ROW** NEVER MARRIED...6**>>NEXT ROW**	Does [NAME]'s spouse live in this household now? YES..1 NO...2**>>B27**	COPY THE ID CODE OF THE WIFE/ HUSBAND. IF MORE THAN ONE WIFE, COPY ID CODES OF ALL WIVES RESIDENT IN HOUSEHOLD.				Does [NAME] have a spouse living outside of this household now? YES..1 NO...2**>>NEXT ROW**	How many spouses does [NAME] have who are residing elsewhere?
										ID CODE					
	YEARS			**YEARS**						**SPOUSE**	**2ND WIFE**	**3RD WIFE**	**4TH WIFE**		**NUMBER**
1															
2															
3															
4															
5															
6															
7															
8															
9															
10															
11															
12															

MODULE C: EDUCATION

[ASK OF ALL PERSONS AGED 5 YEARS AND OLDER.]

C01	C02	C03	C04	C05		C06	C07		C08	C09	C10	C11
ID CODE	PUT AN 'X' FOR ALL INDIVIDUALS WHO ARE AGED BELOW 5 YEARS. DO NOT ADMINISTER THIS MODULE TO THESE INDIVIDUALS.	IS THE INFORMATION SELF-REPORTED OR IS IT BEING PROVIDED BY ANOTHER HOUSEHOLD MEMBER? SELF-REPORTED..1>>**C05** ANOTHER HH MEMBER....2	WHO IS REPORTING THE INFORMATION FOR THE INDIVIDUAL? LIST FROM HOUSEHOLD ROSTER	Are you able to read and write in the following languages? YES..1 NO...2		Have you ever attended school? YES..1>>**C08** NO...2	What was the reason you never attended school? LIST UP TO 2 REASONS. STILL TOO YOUNG TO ATTEND SCHOOL. . . . . .1 NO MONEY FOR FEES, UNIFORM .2 POOR QUALITY OF SCHOOLS. . .3 ILLNESS OR DISABILITY. . . .4 NOT INTERESTED, LAZY . . . .5 PARENTS DID NOT LET ME . . .6 HAD TO WORK OR HELP AT HOME.7 SCHOOL TOO FAR FROM HOME . .8 SCHOOL CONFLICT WITH BELIEFS . . . . .9 OTHER (SPECIFY). . . . . . 10 **(THEN »NEXT MODULE**)		What class are you in or what was the highest class level you ever attended? NURSERY/PRE-SCHOOL-0 PRIMARY STND. 1 - 1 STND. 2 - 2 STND. 3 - 3 STND. 4 - 4 STND. 5 - 5 STND. 6 - 6 STND. 7 - 7 STND. 8 - 8 SECONDARY FORM 1 - 9 FORM 2 - 10 FORM 3 - 11 FORM 4 - 12 FORM 5 - 13 FORM 6 - 14 UNIVERSITY UNIV. 1 - 15 UNIV. 2 - 16 UNIV. 3 - 17 UNIV. 4 - 18 UNIV. 5 & ABOVE - 19 TRAINING COLLEGE TC YR. 1 - 20 TC YR. 2 - 21 TC YR. 3 - 22 TC YR. 4 - 23	What is the highest educational qualification you have acquired? NONE. . . 1 PSLC. . . 2 JCE . . . 3 MSCE. . . 4 NON-UNIV. DIPLOMA. 5 UNIVER. DIPLOMA, DEGREE . 6 POST-GRAD. DEGREE . 7	How old were you when you started school?	Did you attend school in the last completed academic year? YES..1 NO...2>>**C13**
			HH ROSTER ID CODE	**Chichewa**	**English**		1st reason	2nd reason			YEARS	
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												

MODULE C: EDUCATION (CONTINUED)

C01	C12	C13	C14	C15	C16	C17	C18	C19	
I D CODE	What class were you in during the last completed academic year?	Are you currently attending school or, if school is not now in session, did you attend school in the session just completed and plan to attend next session?	Why did you not continue your education?	In which calendar year did you last attend school?	What type of school do you attend?	Are you a day scholar or a boarder at the school?	How do you get to school each day?	How long does it usually take you to get to school by this means of transport?	
	NURSERY/ PRE-SCHOOL-0 PRIMARY STND. 1 - 1 STND. 2 - 2 STND. 3 - 3 STND. 4 - 4 STND. 5 - 5 STND. 6 - 6 STND. 7 - 7 STND. 8 - 8 SECONDARY FORM 1 - 9 FORM 2 - 10 FORM 3 - 11 FORM 4 - 12 FORM 5 - 13 FORM 6 - 14 UNIVERSITY UNIV. 1 - 15 UNIV. 2 - 16 UNIV. 3 - 17 UNIV. 4 - 18 UNIV. 5 & ABOVE - 19 TRAINING COLLEGE TC YR. 1 - 20 TC YR. 2 - 21 TC YR. 3 - 22 TC YR. 4 - 23	YES..1>>**C16** NO...2	ACQUIRED ALL EDUCATION WANTED . 1 NO MONEY FOR FEES OR UNIFORM. . 2 TOO OLD TO CONTINUE . . 3 MARRIED / BECAME PREGNANT . . . 4 ILLNESS OR DISABILITY . . . . . 5 FOUND WORK. . . . . 6 NOT INTERESTED, LAZY. . . . . . 7 PARENTS TOLD ME TO STOP . . . . 8 HAD TO WORK OR HELP AT HOME . . 9 POOR/CROWDED SCHOOL FACILITIES.10 POOR QUALITY INSTRUCTION. . . .11 TEACHERS OFTEN ABSENT . . . . .12 SCHOOL TOO DANGEROUS FOR GIRLS.13 SCHOOL TOO FAR FROM HOME. . . .14 SCHOOL CONFLICT W/ BELIEFS. . .15 FAILED PROMOTION EXAM . . . . .16 DISMISSED / EXPELLED. . . . . .17 OTHER (SPECIFY) 18	RECORD CALENDAR YEAR IF WITHIN PAST 12 MONTHS>>**C22** OTHERWISE>>**NEXT MODULE**	PRIMARY LEA/GOVERNMENT. . . . .11 PRIVATE NON-RELIGIOUS .12 CHURCH/MISSION SCHOOL .13 ISLAMIC SCHOOL. . . . .14 OTHER PRIMARY . . . . .15 SECONDARY GOVERNMENT (CONVENTIONAL). . . . 21 COMMUNITY DAY (CDSS) . 22 CHURCH/MISSION SCHOOL .23 ISLAMIC SCHOOL. . . . .24 NIGHT SCHOOL. . . . . .25 OTHER SECONDARY . . . .26 TERTIARY UNIVERSITY. . . . . . .31 TRAINING COLLEGE. . . .32 OTHER TERTIARY. 33	DAY SCHOLAR..1 BOARDER..2>>**C20**	FOOT......1 BICYCLE...2 BUS/MINI-BUS......3 PRIVATE VEHICLE..4 OTHER (SPECIFY).5		MINUTE. 1 HOUR. . 2
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MODULE C: EDUCATION (CONTINUED)

C01	C20	C21	C22									
ID CODE	At any time in the past 12 months, did you ever <u>temporarily withdraw from school</u>, so that you missed more than two consecutive weeks of instruction? YES..1 NO...2>>**C22**	What was the main reason you temporarily withdrew from school? NO MONEY FOR NECESSARY EXPENSES....1 OWN-ILLNESS.2 HELP NEEDED AT HOME.....3 SUSPENSION..4 TEACHERS ON STRIKE......5 TEACHERS ABSENT......6 FUNERAL.....7 OTHER (SPECIFY)...8	How much was spent on you education in the last 12 months by the household, family, and friends for: IF NOTHING WAS SPENT, RECORD ZERO. IF THE RESPONDENT CAN ONLY GIVE A TOTAL AMOUNT, RECORD "999999" IN THE RELEVANT COLUMNS, AND THE TOTAL AMOUNT IN THE LAST COLUMN.									
			A Tuition, including extra tuition fees MK	B Expenditures on after school programs & tutoring MK	C School books & stationery MK	D School uniform clothing MK	E Boarding Fees MK	F Contribution for school building or maintenance MK	G Transport MK	H Parent/ Teacher Association & other related fees MK	I Other MK	J TOTAL **THEN>> NEXT MODULE** MK
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MODULE D: HEALTH

[ASK OF ALL PERSONS IN THE HOUSEHOLD. MOTHERS OR GUARDIANS TO ANSWER FOR CHILDREN UNDER 10 YEARS OF AGE.]

D01 ID CODE	D02 IS THE INFORMATION SELF-REPORTED OR IS IT BEING PROVIDED BY ANOTHER HOUSEHOLD MEMBER? SELF-REPORTED..1>>**D04** ANOTHER HH MEMBER....2	D03 WHO IS REPORTING THE INFORMATION FOR THE INDIVIDUAL? LIST FROM HOUSEHOLD ROSTER HH ROSTER	D04 During the past 2 weeks have you suffered from an illness or injury? YES..1 NO...2>>**D10**	D05 What was the illness or injury? FEVER, MALARIA . 1 DIARRHEA . . . . 2 STOMACH ACHE . . 3 VOMITING . . . . 4 SORE THROAT. . . 5 UPPER RESPIRATORY (SINUSES) . . . 6 LOWER RESPIRATORY (CHEST, LUNGS). 7 FLU. . . . . . . 8 ASTHMA . . . . . 9 HEADACHE . . . .10 FAINTING . . . .11 SKIN PROBLEM . .12 DENTAL PROBLEM .13 EYE PROBLEM. . .14 EAR/NOSE/THROAT.15 BACKACHE . . . .16 HEART PROBLEM. .17 BLOOD PRESSURE .18 PAIN WHEN PASSING URINE . . .19 DIABETES . . . .20 MENTAL DISORDER.21 TB . . . . .22 SEXUALLY TRANSMITTED DISEASE . . . .23 BURN . . . . . . .24 FRACTURE . . . .25 WOUND . . . . . . 26 POISONING . . . 27 PREGNANCY . . . 28 UNSPECIFIED LONG-TERM ILLNESS . . . .29 OTHER (SPECIFY).30		D06 Who diagnosed the illness? MEDICAL WORKER (DOCTOR, CLINICAL OFFICER, NURSE) AT HOSPITAL . . . 1 MEDICAL WORKER AT OTHER HEALTH FACILITY. . . . . 2 HEALTH SURVEILLANCE ASSISTANT . . . . .3 TRADITIONAL HEALER 4 NON-HH MEMBER (NOT MEDICAL). . 5 SELF . . . . 6 OTHER HH MEMBER. . 7 OTHER (SPECIFY). . 8		D07 What action did you take to find relief for your illness? DID NOTHING, NOT SERIOUS . 1 DID NOTHING, NO MONEY. . . 2 USED MEDICINE HAD IN STOCK 3 PERSONALLY KNOWN REMEDIES. 4 SOUGHT TREATMENT AT GOVT. HEALTH FACILITY . . . . . . 5 SOUGHT TREATMENT AT CHURCH/MISSION FACILITY . 6 SOUGHT TREATMENT AT PRIVATE HEALTH FACILITY . 7 SOUGHT TREATMENT AT VILLAGE HEALTH CLINIC/WITH HEALTH SURVEILLANCE ASSISTANT . . 8 WENT TO LOCAL PHARMACY . . 9 WENT TO LOCAL GROCERY FOR MEDICINE. . . . . .10 SOUGHT TREATMENT WITH TRADITIONAL HEALER. . . .11 SOUGHT TREATMENT WITH FAITH HEALER. . . . . . . .12 OTHER (SPECIFY). 13		D08 During the past 2 weeks, for how many days did you have to stop your normal activities because of this (these) illness(es)? IF NONE, RECORD ZERO AND >> **D10**.	D09 During the past 2 weeks, for how many days, did anyone else in the household have to stop their normal activities to care for you? IF NONE, RECORD ZERO.
		ID CODE		Problem 1	Problem 2	Problem 1	Problem 2	Problem 1	Problem 2	DAYS	DAYS
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MODULE D: HEALTH (CONTINUED)

D01 ID CODE	D10 How much in total did you spend in the past 4 weeks for all illnesses and injuries, including for medicine, tests, con-sultation, & in-patient fees, if any? INCLUDE ESTIMATED VALUE OF ANY IN-KIND PAYMENTS.	D11 How much in total did you spend in the past 4 weeks for medical care not related to an illness - preventative health care, pre-natal visits, check-ups, etc., if any? INCLUDE ESTIMATED VALUE OF ANY IN-KIND PAYMENTS.	D12 How much in total did you spend in the past 4 weeks for non-prescription medicines - Panadol, Fansidar, cough syrup, etc.? INCLUDE ESTIMATED VALUE OF ANY IN-KIND PAYMENTS.	D13 During the last 12 months, were you hospital-ized or had an overnight stay(s) in a medical facility?	D14 What was the total cost of your hospitalization(s) or overnight stay(s) in a medical facility during the last 12 months? INCLUDE ESTIMATED VALUE OF ANY IN-KIND PAYMENTS.	D15 How much in total did you spend to travel to the medical facility for overnight stay(s) during the last 12 months? INCLUDE ESTIMATED VALUE OF ANY IN-KIND PAYMENTS.	D16 How much did you spend on food during overnight stay(s) at the medical facility during the last 12 months? INCLUDE ESTIMATED VALUE OF ANY IN-KIND PAYMENTS.	D17 Did you or other members of your household have to borrow money or sell assets in order to pay for these costs during the last 12 months?	D18 During the last 12 months, did you stay over-night(s) at a traditional healer's or faith healer's dwelling?	D19 What was the total cost of your stay(s) at the traditional healer's or faith healer's dwelling during the last 12 months? INCLUDE ESTIMATED VALUE OF ANY IN-KIND PAYMENTS.
	MK	MK	MK	YES..1 NO...2>>D18	MK	MK	MK	YES..1 NO...2	YES..1 NO...2>>D23	MK
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MODULE D: HEALTH (CONTINUED)

D01	D20	D21	D22	D23	D24	D25	D26	D27	D28	D29
ID CODE	How much in to tal did you spend to travel to the traditional healer's or faith healer's dwelling for overnight stay(s) during the last <u>12 months</u>? INCLUDE ESTIMATED VALUE OF ANY IN-KIND PAYMENTS.	How much did you spend on food during overnight stay(s) at the traditional healer's or faith healer's dwelling during the last <u>12 months</u>? INCLUDE ESTIMATED VALUE OF ANY IN-KIND PAYMENTS.	Did you or other members of your household have to borrow money or sell assets in order to pay for these costs during the last <u>12 months</u>? YES..1 NO...2	**ENUMERATOR:** IS THIS PERSON [NAME] LESS THAN 5 YEARS OF AGE? YES..1>>**D33** NO...2	Do you have difficulty seeing, even if he/she is wearing glasses? READ RESPONSES No difficulty..1 Yes - Some difficulty.....2 Yes - A lot of difficulty.....3 Cannot Perform Activity At All............4	Do you have difficulty hearing, even if he/she is wearing a hearing aid? READ RESPONSES No difficulty..1 Yes - Some difficulty.....2 Yes - A lot of difficulty.....3 Cannot Perform Activity At All............4	Do you have difficulty walking or climbing steps? READ RESPONSES No difficulty..1 Yes - Some difficulty.....2 Yes - A lot of difficulty.....3 Cannot Perform Activity At All............4	Do you have difficulty remembering or concentrating? READ RESPONSES No difficulty..1 Yes - Some difficulty.....2 Yes - A lot of difficulty.....3 Cannot Perform Activity At All............4	Do you [NAME] have difficulty (with self care such as) washing all over or dressing, feeding, toileting etc? READ RESPONSES No difficulty..1 Yes - Some difficulty.....2 Yes - A lot of difficulty.....3 Cannot Perform Activity At All............4	Using your usual language, do you have difficulty communicating; for example understanding or being understood? READ RESPONSES No difficulty..1 Yes - Some difficulty.....2 Yes - A lot of difficulty.....3 Cannot Perform Activity At All............4
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MODULE D: HEALTH (CONTINUED)

D01 ID CODE	D30 **ENUMERATOR:** CHECK QUESTIONS D24 THROUGH D29. DID THE RESPONDENT HAVE ANY DIFFICULTY? YES...1 NO....2>>D33	D31 Does this difficulty reduce the amount of work you can do at home, at work or at school? Yes, all the time..1 Yes, sometimes.....2 No.................3 NA (If not working or attending school)............4			D32 During the past 12 months, what measures are taken to improve your performance in activities? NONE....................1 SURGICAL OPERATION......2 MEDICATION.............3 ASSISTIVE DEVICES (GLASSES, WHEELCHAIR, BRACES, HEARING AID, ARTIFICIAL LIMBS).......4 SPECIAL EDUCATION.......5 SKILLS TRAINING (VOCATIONAL)...........6 ACTIVITY OF DAILY LIVING (ADL) TRAINING...............7 COUNSELING.............8 SPIRITUAL/TRADITIONAL HEALER.................9 OTHER (SPECIFY)........10	D33 Do you suffer from a chronic illness? YES...1 NO....2>>D37	D34 What chronic illness do you suffer from? LIST UP TO 2. CHRONIC MALARIA/FEVER 1 TUBERCULOSIS . . . . . .2 HIV/AIDS . . . . .3 DIABETES . . . . .4 ASTHMA . . . . .5 BILHARZIA/ SCHISTOSOMIASIS . . .6 ARTHRITIS/ RHEUMATISM. . . . . .7 NERVE DISORDER . . . .8 STOMACH DISORDER. . . 9 SORES THAT DO NOT HEAL . . . . . .10 CANCER. . . . . . . .11 PNEUMONIA . . . . . .12 EPILEPSY . . . . . . 13 MENTAL ILLNESS . . . 14 OTHER (SPEC.) 15		D35 How long have you suffered from this illness (these illnesses)?		D36 Who diagnosed the illness? MEDICAL WORKER (DOCTOR, CLINICAL OFFICER, NURSE) AT HOSPITAL . . . 1 MEDICAL WORKER AT OTHER HEALTH FACILITY. . . . . 2 HSA . . . . .3 TRADITIONAL HEALER 4 NON-HH MEMBER (NOT MEDICAL). . 5 SELF . . . . 6 OTHER HH MEMBER. . 7 OTHER (SPECIFY). . 8	
		AT HOME	AT SCHOOL	AT WORK			ILLNESS 1	ILLNESS 2	YEARS	MONTHS	ILLNESS 1	ILLNESS 2
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MODULE D: HEALTH (CONTINUED)

D01 ID CODE	D37 IS THIS PERSON, [NAME], LESS THAN 15 YEARS OLD? YES...1 NO....2**>>D39**	D38 What did you have for breakfast yesterday? TEA/DRINK WITH SUGAR.......1 MILK/MILK TEA WITH SUGAR.......2 SOLID FOOD ONLY..3 TEA/DRINK WITH SOLID FOOD..4 PORRIDGE WITH G/NUT FLOUR.5 PORRIDGE WITH SOLID FOOD..6 PORRIDGE WITH SUGAR.......7 PORRIDGE WITH MILK........8 PORRIDGE WITHOUT SUGAR....9 NOTHING.........10 OTHER (SPECIFY).11	D39 IS THIS PERSON, [NAME], A WOMAN AGED 12 TO 49 YEARS? YES..1 NO...2**>>NEXT MODULE**	D40 In the past 24 months, did you <u>give birth</u> to a child, even if born dead? YES..1 NO...2**>>NEXT MODULE**	D41 Did you regularly go to a health clinic when you were pregnant with your last child born in the last 24 months? YES..1 NO...2	D42 Where did you deliver your last child born in the last 24 months? HOSPITAL/ MATERNITY CLINIC....1 AT HOME...2 OTHER (SPECIFY).3	D43 Who assisted in delivering this child? DOCTOR/ CLINICAL OFFICER . 1 NURSE/MIDWIFE. . .2 PATIENT ATTENDANT .3 TRADITIONAL BIRTH ATTENDANT . . . . .4 RELATIVE/FRIEND . .5 NO ONE . . . . . . 6 OTHER (SPECIFY). . 7 (**THEN >> NEXT MODULE**)
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MODULE E: TIME USE & LABOUR

[ASK ALL HOUSEHOLD MEMBERS AGED 5 YEARS AND OLDER.] IF DID NOT DO TASK, WRITE ZERO; IF LESS THAN 1/2 HOUR, WRITE '0.5'; OTHERWISE, ROUND TO NEAREST HOUR.

E01	E02	E03	E04	E05	E06	E07	E08	E09	E10	E11	E12	E13
ID CODE	PUT AN 'X' FOR ALL INDIVIDUALS WHO ARE AGED BELOW 5 YEARS. <u>DO NOT</u> ADMINISTER THIS MODULE TO THESE INDIVIDUALS.	IS THE RESPONDENT REPORTING FOR HIM/HERSELF? YES.1>>**E05** NO..2	WHO IS RESPONDING ON BEHALF OF [NAME]? LIST FROM HOUSEHOLD ROSTER HH ROSTER ID CODE	How many hours did you spend <u>yesterday collecting water</u>? HOURS	How many hours did you spend <u>yesterday collecting firewood</u> (or other fuel materials)? HOURS	How many hours <u>in the last seven days</u> did you <u>spend</u> on <u>household agricultural activities</u> (including livestock and fishing-related activities) whether for sale or for household food? HOURS	How many hours <u>in the last seven days</u> did you <u>run</u> or do any kind of non-agricultural or non-fishing <u>household business</u>, big or small, for yourself? HOURS	How many hours <u>in the last seven days</u> did you <u>help</u> in any of the household's non-agricultural or non-fishing <u>household businesses</u>, if any? HOURS	How many hours <u>in the last seven days</u> did you <u>engage in</u> casual, part-time or <u>*ganyu*</u> <u>labour</u>? HOURS	How many hours <u>in the last seven days</u> did you <u>do any work for a wage, salary, commission</u>, or any payment in kind, <u>excluding *ganyu*</u>? HOURS	How many hours <u>in the last seven days</u> did you <u>engage in an unpaid apprenticeship</u>? HOURS	REVIEW QUESTIONS E07 TO E11. DID THIS PERSON, [NAME], WORK FOR ANY HOURS AT THESE TASKS OVER THE LAST SEVEN DAYS? YES.1>>**E18** NO..2
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MODULE E: TIME USE & LABOUR (CONTINUED)

						MAIN JOB OVER THE LAST 12 MONTHS			
E01 ID CODE	E14 Even though you did not do any activities in the last seven days, do you have a job, business, or other economic or farming activity that you will return to? NOT *GANYU.* YES.1 NO..2**>>E16**	E15 What is the main reason you did not work at this activity during the last seven days? ON LEAVE . .1 ILL. . . . .2 BUSINESS CLOSED TEMPORARILY .3 NOT FARMING SEASON. . .4 OTHER (specify) .5 **(THEN »E18)**	E16 In the past four weeks have you taken any action to look for any kind of work or start any kind of business / income generating activity? YES.1 NO..2	E17 If you were offered a job, would you be willing to accept the job? YES.1 NO..2	E18 At any time over the last 12 months, were you employed for a wage, salary, commission or any payment in kind, **excluding *ganyu*** ,for anyone who is not a member of your household? YES.1 NO..2**>>E46**	E19 Describe your main job over the last 12 months. WRITTEN DESCRIPTION	(Supervisor to put in occupation code after interview) OCCUP. CODE	E20 Describe what kind of trade or business your main job over the last 12 months is connected with. WRITTEN DESCRIPTION	(Supervisor to put in industry code after interview) IND. CODE
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MODULE E: TIME USE & LABOUR (CONTINUED)

E01 ID CODE	E21 Is your employer for your main occupation over the last 12 months… READ RESPONSES Private Company........1 Private Individual.....2 Government............3 State-Owned Enterprise (Parastatal)...........4 MASAF/Public Works Program................5 Church/Religious Organization...........6 Political Party........7 Other (Specify)........8	E22 In how many months over the last 12 months, did you work at this job? NUMBER OF MONTHS	E23 During these months, approximately how many weeks per month did you work at this job? NUMBER OF WEEKS / MONTH	E24 During these weeks, approximately how many hours per week did you work at this job? NUMBER OF HOURS / WEEK	E25 How much was your last payment for wages/salary? MK	E26 What period of time do each of your salary payments cover? NUMBER OF TIME UNITS	E26 TIME UNIT DAY. .3 WEEK .4 MONTH.5	E27 How much do you usually receive in allowances or gratuities, including in-kind payments such as uniform, housing, food, and transport, that were not included in the salary you just reported? ESTIMATE CASH VALUE OF ANY IN-KIND PAYMENTS RECEIVED. **IF NOTHING, RECORD ZERO, >> E29.** MK	E28 Over what period of time are you reporting your allowances and gratuity payments? NUMBER OF TIME UNITS	E28 TIME UNIT DAY. .3 WEEK .4 MONTH.5
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MODULE E: TIME USE & LABOUR (CONTINUED)

SECONDARY JOB OVER THE LAST 12 MONTHS

E01	E29	E30	E31	E32	E33		E34	
ID CODE	Is this job considered an apprenticeship?	Have you made any payments to your employer for your apprenticeship?	How much in total have you paid over the last 12 months for your apprenticeship?	At any time over the last 12 months, were you employed for a second job, including casual/part-time labour, for a wage, salary, commission or any payment in kind, **excluding *ganyu*,** for anyone who is not a member of your household?	Describe your secondary job over the last 12 months.	(Supervisor to put in occupation code after interview)	Describe what kind of trade or business your secondary job over the last 12 months is connected with.	(Supervisor to put in industry code after interview)
	YES.1 NO..2**>>E32**	YES.1 NO..2**>>E32**		YES.1 NO..2**>>E46**	WRITTEN DESCRIPTION	OCCUP. CODE	WRITTEN DESCRIPTION	IND. CODE
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MODULE E: TIME USE & LABOUR (CONTINUED)

E01 ID CODE	E35 Is your employer for your secondary job over the last 12 months… READ RESPONSES Private Company........1 Private Individual.....2 Government............3 State-Owned Enterprise (Parastatal)...........4 MASAF/Public Works Program................5 Church/Religious Organization...........6 Political Party........7 Other (Specify)........8	E36 In how many months over the last 12 months, did you work at this job?	E37 During these months, approximately how many weeks per month did you work at this job?	E38 During these weeks, approximately how many hours per week did you work at this job?	E39 How much was your last payment for wages/salary?	E40 What period of time do each of your salary payments cover?		E41 How much do you usually receive in allowances or gratuities, including in-kind payments such as uniform, housing, food, and transport, that were not included in the salary you just reported? ESTIMATE CASH VALUE OF ANY IN-KIND PAYMENTS RECEIVED. **IF NOTHING, RECORD ZERO, >> E43.**	E42 Over what period of time are you reporting your allowances and gratuity payments?	
		NUMBER OF MONTHS	NUMBER OF WEEKS / MONTH	NUMBER OF HOURS / WEEK	MK	NUMBER OF TIME UNITS	TIME UNIT DAY. .3 WEEK .4 MONTH.5	MK	NUMBER OF TIME UNITS	TIME UNIT DAY. .3 WEEK .4 MONTH.5
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MODULE E: TIME USE & LABOUR (CONTINUED)

				UNPAID APPRENTICESHIP				
E01 ID CODE	E43 Is this job considered an apprenticeship? YES.1 NO..2>>**E46**	E44 Have you made any payments to your employer to for your apprenticeship? YES.1 NO..2>>**E46**	E45 How much in total have you paid over the last 12 months for your apprenticeship? ESTIMATE CASH VALUE OF ANY IN-KIND PAYMENTS.	E46 At any time over the <u>last 12 months</u>, were you <u>employed as an unpaid apprentice</u> for anyone who is not a member of your household? YES.1 NO..2>>**E55**	E47 Describe your unpaid apprenticeship over the last 12 months? REFER TO MAIN UNPAID APPRENTICESHIP, IF MORE THAN ONE		E48 Describe what kind of trade or business your unpaid apprenticeship over the last 12 months is connected with? REFER TO MAIN UNPAID APPRENTICESHIP, IF MORE THAN ONE	
						(Supervisor to put in occupation code <u>after</u> interview)		(Supervisor to put in industry code <u>after</u> interview)
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MODULE E: TIME USE & LABOUR (CONTINUED)

							GANYU LABOUR OVER THE LAST 12 MONTHS		
E01	E49	E50	E51	E52	E53	E54	E55	E56	E57
ID CODE	Is your employer for your unpaid apprenticeship over the last 12 months… (READ ALL RESPONSES) Private Company........1 Private Individual.....2 Government.............3 State-Owned Enterprise (Parastatal)...........4 MASAF/Public Works Program................5 Church/Religious Organization...........6 Political Party........7 Other (Specify)........8	In how many months over the last 12 months, did you work at this unpaid apprenticeship?	During these months, approximately how many weeks per month did you work at this unpaid apprenticeship?	During these weeks, approximately how many hours per week did you work at this unpaid apprenticeship?	Have you made any payments to your employer for your unpaid apprenticeship? YES.1 NO..2>>**E55**	How much in total have you paid over the last 12 months for your unpaid apprenticeship? ESTIMATE CASH VALUE OF ANY IN-KIND PAYMENTS.	At any time over the <u>last 12 months</u>, did you <u>do any ganyu labour</u> for anyone who is not a member of your household? YES.1 NO..2>>**E60**	In how many months over the last 12 months, did you do ganyu labour?	During these months, approximately how many weeks per month did you do ganyu labour?
		NUMBER OF MONTHS	NUMBER OF WEEKS / MONTH	NUMBER OF HOURS / WEEK		MK		NUMBER OF MONTHS	NUMBER OF WEEKS / MONTH
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MODULE E: TIME USE & LABOUR (CONTINUED)

OTHER UNPAID LABOUR OVER THE LAST 12 MONTHS

E01 ID CODE	E58 During these weeks, approximately how many days per week did you do ganyu labour?	E59 What was the average daily wage, in cash or in kind, that you received for the days worked at ganyu over the last 12 months?	E60 At any time over the last 12 months, did you work for other households, free of charge, as exchange labourer or to assist for nothing in return? YES.1 NO..2**>>NEXT PERSON**	E61 Over the last 12 months, for how many households in total did you work as exchange labourer or to assist for nothing in return?	E62 Among the households for whom you worked as exchange laborer or to assist for nothing in return, how many were households of relatives? RECORD ZERO IF NONE.	E63 Among the households for whom you worked as exchange laborer or to assist for nothing in return, how many were households of friends/ neighbors? RECORD ZERO IF NONE.	E64 Was the household of the village headman among the households for whom you worked as exchange laborer or to assist for nothing in return? YES.1 NO..2	E65 Over the last 12 months, for how many days in total did you work for other households as exchange labourer or to assist for nothing in return?
	NUMBER OF DAYS / WEEK	MK		NUMBER OF HHs IN TOTAL	NUMBER OF HHs OF RELATIVES	NUMBER OF HHs OF FRIENDS/ NEIGHBORS		NUMBER OF DAYS
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MODULE F: HOUSING

F01	F02	F03		F04		F05	F06	F07	F08	F09
Do you own or are purchasing this house, is it provided to you by an employer, do you use it for free, or do you rent this house?	If you sold this dwelling today, how much would you receive for it?	Estimate the rent you could receive if you rented this dwelling? (THEN >>F05)		How much do you pay to rent this dwelling?		How many years ago was this house built? How old is it? IF DO NOT KNOW, RECORD 999.	WHAT GENERAL TYPE OF CONSTRUCTION MATERIALS ARE USED FOR THE DWELLING?	THE OUTER WALLS OF THE MAIN DWELLING OF THE HOUSEHOLD ARE PREDOMINANTLY MADE OF WHAT MATERIAL?	THE ROOF OF THE MAIN DWELLING IS PREDOMINANTLY MADE OF WHAT MATERIAL?	THE FLOOR OF THE MAIN DWELLING IS PREDOMINANTLY MADE OF WHAT MATERIAL?
OWNED. . . . 1 BEING PURCHASED . 2 EMPLOYER PROVIDES. . . .3**>>F03** FREE, AUTHORIZED . .4**>>F03** FREE, NOT AUTHORIZED. . .5**>>F03** RENTED. . . . .6**>>F04**			DAY....3 WEEK...4 MONTH..5 YEAR...6		DAY....3 WEEK...4 MONTH..5 YEAR...6		PERMANENT. . . 1 SEMI-PERMANENT 2 TRADITIONAL. . 3 (SEMI-PERMANENT IS MIX OF TRADITIONAL (GRASS, MUD)& MODERN MATERIALS (IRON SHEET, CEMENT)	GRASS . . . . . 1 MUD (YOMATA). . 2 COMPACTED EARTH (YAMDINDO). . 3 MUD BRICK (UNFIRED) . . 4 BURNT BRICKS. . 5 CONCRETE. . . . 6 WOOD. . . . . . 7 IRON SHEETS . . 8 OTHER (SPECIFY) 9	GRASS......1 IRON SHEETS.....2 CLAY TILES......3 CONCRETE...4 PLASTIC SHEETING...5 OTHER (SPECIFY)..6	SAND. . . . . . .1 SMOOTHED MUD. .2 SMOOTH CEMENT .3 WOOD. . . . .4 TILE. . . . . .. 5 OTHER (SPECIFY) . . 6
	MK	MK	TIME UNIT	MK	TIME UNIT	YEARS				

F10	F11	F12	F13	F14	F15	F16		F17	F18	F19
How many separate rooms do the members of your household occupy? (DO NOT COUNT BATHROOMS, TOILETS, STOREROOMS, OR GARAGE)	What is your main source of lighting fuel?	What is your main source of cooking fuel?	Do you ever use firewood for fuel?	Do you ever collect firewood?	Where do you go to collect firewood?	How long does it take you to walk from your dwelling to where you usually go to collect firewood?		Of the firewood you used in the past week, how much of it did you purchase?	What is the total value of the firewood you used in the past week, whether gathered or purchased? (Estimate purchase cost of gathered firewood.)	Do you have electricity working in your dwelling?
	COLLECTED FIREWOOD. . .1 PURCHASED FIREWOOD. . .2 GRASS. . . . .3 PARAFFIN . . .4 ELECTRICITY. .5 GAS. . . . . .6 BATTERY/DRY CELL (TORCH). . . .7 CANDLES. . . .8 OTHER (SPECIFY). . .9	COLLECTED FIREWOOD. . 1 **(»F15)** PURCHASED FIREWOOD. . 2 **(»F14)** PARAFFIN . . 3 ELECTRICITY. 4 GAS. . . . . 5 CHARCOAL . . 6 CROP RESIDUE 7 SAW DUST . . 8 ANIMAL WASTE 9 OTHER (SPECIFY). .10	YES..1 NO...2**>>F19**	YES..1 NO...2>>**F18**	OWN WOODLOT .1 COMMUNITY WOODLOT .2 FOREST RESERVE .3 UNFARMED AREAS OF COMMUN-ITY . . .4 OTHER (SPECIFY).5		MINUTE..1 HOUR....2	ALL . . . 1 ALMOST ALL. . . 2 MORE THAN HALF . . 3 HALF. . . 4 LESS THAN HALF . . 5 A LITTLE. 6 NONE. . . 7		YES..1 NO...2**>>F27**
NUMBER OF ROOMS						TIME AMOUNT	UNIT		MK	

MODULE F: HOUSING (CONTINUED)

F20		F21	F22	F23	F24	F25	F26		F27	F28
In the event of a black out, what source of energy do you use for ...?		Do you get your electricity via ESCOM?	Following your application to get electricity, how many weeks did you have to wait for your connection to be in working order? IF DID NOT APPLY, RECORD 9999.	Did you have to pay an unofficial fee to get a connection?	In the last 12 months, how frequently did you experience blackouts in your area? READ RESPONSES	How much did you last pay for electricity? IF NEVER PAYS FOR ELECTRICITY, RECORD 9999 AND **>> F31**	To what length of time does this cost for electricity refer? **(THEN »F31)**		Although you do not have electricity in your dwelling, does your village / neighborhood have access to electricity provided by ESCOM?	**ENUMERATOR:** IS THE DWELLING **OWNED** BY THE HOUSEHOLD ACCORDING TO F01?
LIGHTING	COOKING									
FIREWOOD....1 PARAFFIN....2 CANDLES.....3 OTHER (SPECIFY)...4	CHARCOAL..1 FIREWOOD..2 GAS.......3 PARAFFIN..4 OTHER (SPECIFY).5	YES..1 NO...2**>>F25**		YES..1 NO...2	Never....1 Every day......2 Several times a week.....3 Several times a month....4			DAY....3 WEEK...4 MONTH..5 YEAR...6	YES..1 NO...2**>>F31**	YES..1 NO...2**>>F31**
			WEEKS			MK	TIME AMOUNT	TIME UNIT		

F29	F30	F31	F32	F33		F34	F35	F36	F37
What is the main reason for your household not to have access to electricity?	How many weeks have you been waiting for?	Is there a MTL telephone in working condition in the dwelling unit?	What was the total cost for MTL telephone service in the household over the last period? LAST BILL AMOUNT	To what length of time does this MTL telephone cost refer?		How many working cell phones in total does your household own? IF NONE, RECORD 0 AND **>> F36.**	Estimate the total cost for all cell phone service for all household members last month?	What is your main source of drinking water?	What was the total cost of drinking water for your house-hold last month? IF NONE, ENTER 0 AND CONTINUE TO F38.
CONNECTION/ WIRING FEE UNAFFORDABLE..1**>>F31** NO NEED FOR ELECTRICITY...2**>>F31** DWELLING UNAPPROPRIATE FOR CONNECTION....3**>>F31** APPLICATION PENDING.......4 LINE WAS DISCONNECTED..5**>>F31** OTHER (SPECIFY).....6**>>F31**		YES..1 NO...2**>>F34**			DAY....3 WEEK...4 MONTH..5 YEAR...6			PIPED INTO DWELLING. . 1 PIPED INTO YARD/PLOT. . 2 COMMUNAL STANDPIPE . . .3 OPEN WELL IN YARD/PLOT. 4 OPEN PUBLIC WELL. . . . 5 PROTECTED WELL IN YARD/PLOT. . . . . . . .6 PROTECTED PUBLIC WELL. .7 BOREHOLE . . . . .8 SPRING . . . . .9 RIVER/STREAM. . . . . .10 POND/LAKE. . . . . . . 11 DAM. . . . . 12 RAINWATER. . . . . . . .13 TANKER TRUCK/BOWSER. . 14 BOTTLED WATER. . . . . 15 OTHER (SPECIFY). . . . 16	
	WEEKS		MK	TIME AMOUNT	TIME UNIT	NUMBER	MK		MK

MODULE F: HOUSING (CONTINUED)

F38		F39	F40	F41	F42	F43	F44	F45
How long does it take you to walk (ONE WAY) to the main water source from your dwelling? IF THE WATER SOURCE IS ON PREMISES, RECORD 99 FOR TIME AMOUNT AND CONTINUE TO F39.		Do you use the main water source…	What is your main source of drinking water in the other season?	What kind of toilet facility does your household use?	Is this toilet facility for the use of: READ RESPONSES	What kind of rubbish disposal facilities does your household use?	Do any members of your household sleep under a bed net to protect against mosquitoes at some time during the year?	Has/have the bed net(s) ever been dipped in insecticide against mosqui-toes in the past six months?
TIME AMOUNT	MINUTE..1 HOUR....2 TIME UNIT	ALL YEAR AROUND..1>>**F41** ONLY RAINY SEASON...2 ONLY DRY SEASON...3	PIPED INTO DWELLING. . 1 PIPED INTO YARD/PLOT. . 2 COMMUNAL STANDPIPE . . .3 OPEN WELL IN YARD/PLOT. 4 OPEN PUBLIC WELL. . . . 5 PROTECTED WELL IN YARD/PLOT. . . . . . . .6 PROTECTED PUBLIC WELL. .7 BOREHOLE. . . . . 8 SPRING . . . . .9 RIVER/STREAM. . . . . .10 POND/LAKE. . . . . . . 11 DAM. . . . . 12 RAINWATER. . . . .13 TANKER TRUCK/BOWSER. . 14 BOTTLED WATER. 15	FLUSH TOILET. . 1 VIP LATRINE. .2 TRADIT. LATRINE W/ROOF. . 3 TRADIT. LATRINE W/O ROOF. 4 NONE. . . .5>>**F43** OTHER (SPECIFY) 6	Household members only.. . . 1 Other households also.. . ..2	COLLECTED FROM RUBBISH BIN. . .1 RUBBISH PIT . .2 BURNING . . . . 3 PUBLIC RUBBISH HEAP . . . . . .4 OTHER (SPECIFY) . . . 5 NONE. 6	YES..1 NO...2>>**NEXT MODULE**	YES. . . . . .1 NO . . . . 2 ALL NETS TREATED & LESS THAN 6 MONTHS OLD. . .3

F46	F47
ENUMERATOR: DOES THIS HOUSEHOLD HAVE ANY CHILDREN BELOW 5 YEARS OF AGE?	Do the children under 5 in the household sleep under a bed net at those times of the year when there are mosquitoes present?
YES..1 NO...2>>**NEXT MODULE**	YES, FOR ALL CHILDREN UNDER FIVE . . . . 1 YES, FOR SOME CHILDREN UNDER FIVE . . . . 2 NO, NONE OF THE CHILDREN UNDER FIVE 3

MODULE G: FOOD CONSUMPTION OVER PAST ONE WEEK

DATA ENTRY LINE NUMBER	Over the past one week (7 days), did you or others in your household consume any [. . .]? INCLUDE FOOD BOTH EATEN COMMUNALLY IN THE HOUSEHOLD AND THAT EATEN SEPARATELY BY INDIVIDUAL HOUSEHOLD MEMBERS.	G01 YES..1 NO...2>> **NEXT ITEM**	G02	G03 How much in total did your household consume in the past week?		G04 How much came from purchases?		G05 How much did you spend?	G06 How much came from own-production?		G07 How much came from gifts and other sources?	
			ITEM CODE	QUANTITY	UNIT	QUANTITY	UNIT	MK	QUANTITY	UNIT	QUANTITY	UNIT
1	**Cereals, Grains and Cereal Products**											
2	Maize *ufa mgaiwa* (normal flour)		101									
3	Maize *ufa* refined (fine flour)		102									
4	Maize *ufa madeya* (bran flour)		103									
5	Maize grain (not as *ufa*)		104									
6	Green maize		105									
7	Rice		106									
8	Finger millet (*mawere*)		107									
9	Sorghum (*mapira*)		108									
10	Pearl millet (*mchewere*)		109									
11	Wheat flour		110									
12	Bread		111									
13	Buns, scones		112									
14	Biscuits		113									
15	Spaghetti, macaroni, pasta		114									
16	Breakfast cereal		115									
17	Infant feeding cereals		116									
18	Other (specify)		117									
19	**Roots, Tubers, and Plantains**											
20	Cassava tubers		201									
21	Cassava flour		202									
22	White sweet potato		203									
23	Orange sweet potato		204									
24	Irish potato		205									
25	Potato crisps		206									
26	Plantain, cooking banana		207									
27	Cocoyam (*masimbi*)		208									
28	Other (specify)		209									

CODES FOR UNIT:

KILOGRAMME	1
50 KG. BAG	2
90 KG. BAG	3
PAIL (SMALL)	4
PAIL (LARGE)	5
No. 10 PLATE	6
No. 12 PLATE	7
BUNCH	8
PIECE	9
HEAP	10
BALE	11
BASKET (*DENGU*) (SHELLED)	12
BASKET (*DENGU*) (UNSHELLED)	13
OX-CART (UNSHELLED)	14
LITRE	15
CUP	16
TIN	17
GRAM	18
MILLILITRE	19
TEASPOON	20
BASIN	21
SATCHET/TUBE	22
OTHER (SPECIFY)	23

MODULE G: FOOD CONSUMPTION OVER PAST ONE WEEK (CONTINUED)

DATA ENTRY LINE NUMBER	Over the past one week (7 days), did you or others in your household consume any [. . .]? INCLUDE FOOD BOTH EATEN COMMUNALLY IN THE HOUSEHOLD AND THAT EATEN SEPARATELY BY INDIVIDUAL HOUSEHOLD MEMBERS.	G01 YES..1 NO...2>> **NEXT ITEM**	G02 ITEM CODE	G03 How much in total did your household consume in the past week?		G04 How much came from purchases?		G05 How much did you spend?	G06 How much came from own-production?		G07 How much came from gifts and other sources?	
				QUANTITY	UNIT	QUANTITY	UNIT	MK	QUANTITY	UNIT	QUANTITY	UNIT
29	**Nuts and Pulses**											
30	Bean, white		301									
31	Bean, brown		302									
32	Pigeonpea (*nandolo*)		303									
33	Groundnut		304									
34	Groundnut flour		305									
35	Soyabean flour		306									
36	Ground bean (*nzama)*		307									
37	Cowpea (*khobwe*)		308									
38	Macademia nuts		309									
39	Other (specify)		310									
40	**Vegetables**											
41	Onion		401									
42	Cabbage		402									
43	*Tanaposi* /Rape		403									
44	*Nkhwani*		404									
45	Chinese cabbage		405									
46	Other cultivated green leafy vegetables		406									
47	Gathered wild green leaves		407									
48	Tomato		408									
49	Cucumber		409									
50	Pumpkin		410									
51	Okra / *Therere*		411									
52	Tinned vegetables (specify:)		412									
53	Mushroom		413									
54	Other vegetables (specify:)		414									

CODES FOR UNIT:

KILOGRAMME	1
50 KG. BAG	2
90 KG. BAG	3
PAIL (SMALL)	4
PAIL (LARGE)	5
No. 10 PLATE	6
No. 12 PLATE	7
BUNCH	8
PIECE	9
HEAP	10
BALE	11
BASKET (*DENGU*) (SHELLED)	12
BASKET (*DENGU*) (UNSHELLED)	13
OX-CART (UNSHELLED)	14
LITRE	15
CUP	16
TIN	17
GRAM	18
MILLILITRE	19
TEASPOON	20
BASIN	21
SATCHET/TUBE	22
OTHER (SPECIFY)	23

MODULE G: FOOD CONSUMPTION OVER PAST ONE WEEK (CONTINUED)

DATA ENTRY LINE NUMBER	Over the past one week (7 days), did you or others in your household consume any [. . .]? INCLUDE FOOD BOTH EATEN COMMUNALLY IN THE HOUSEHOLD AND THAT EATEN SEPARATELY BY INDIVIDUAL HOUSEHOLD MEMBERS.	G01 YES..1 NO...2>> **NEXT ITEM**	G02	G03 How much in total did your household consume in the past week?		G04 How much came from purchases?		G05 How much did you spend?	G06 How much came from own-production?		G07 How much came from gifts and other sources?	
			ITEM CODE	QUANTITY	UNIT	QUANTITY	UNIT	MK	QUANTITY	UNIT	QUANTITY	UNIT
55	**Meat, Fish and Animal products**											
56	Eggs		501									
57	Dried fish		502									
58	Fresh fish		503									
59	Beef		504									
60	Goat		505									
61	Pork		506									
62	Mutton		507									
63	Chicken		508									
64	Other poultry - guinea fowl, doves, etc.		509									
65	Small animal – rabbit, mice, etc.		510									
66	Termites, other insects (eg Ngumbi, caterpillar)		511									
67	Tinned meat or fish		512									
68	Smoked fish		513									
69	Fish Soup/Sauce		514									
70	Other (specify)		515									
71	**Fruits**											
72	Mango		601									
73	Banana		602									
74	Citrus – naartje, orange, etc.		603									
75	Pineapple		604									
76	Papaya		605									
77	Guava		606									
78	Avocado		607									
79	Wild fruit (*masau, malambe, etc.*)		608									
80	Apple		609									
81	Other fruits (specify)		610									

CODES FOR UNIT:

KILOGRAMME	1
50 KG. BAG	2
90 KG. BAG	3
PAIL (SMALL)	4
PAIL (LARGE)	5
No. 10 PLATE	6
No. 12 PLATE	7
BUNCH	8
PIECE	9
HEAP	10
BALE	11
BASKET (*DENGU*) (SHELLED)	12
BASKET (*DENGU*) (UNSHELLED)	13
OX-CART (UNSHELLED)	14
LITRE	15
CUP	16
TIN	17
GRAM	18
MILLILITRE	19
TEASPOON	20
BASIN	21
SATCHET/TUBE	22
OTHER (SPECIFY)	23

MODULE G: FOOD CONSUMPTION OVER PAST ONE WEEK (CONTINUED)

DATA ENTRY LINE NUMBER	Over the past one week (7 days), did you or others in your household consume any [. . .]? INCLUDE FOOD BOTH EATEN COMMUNALLY IN THE HOUSEHOLD AND THAT EATEN SEPARATELY BY INDIVIDUAL HOUSEHOLD MEMBERS.	G01 YES..1 NO...2>> **NEXT ITEM**	G02 ITEM CODE	G03 How much in total did your household consume in the past week?		G04 How much came from purchases?		G05 How much did you spend?	G06 How much came from own-production?		G07 How much came from gifts and other sources?	
				QUANTITY	UNIT	QUANTITY	UNIT	MK	QUANTITY	UNIT	QUANTITY	UNIT
82	**Cooked Foods from Vendors**											
83	Maize - boiled or roasted (vendor)		820									
84	Chips (vendor)		821									
85	Cassava - boiled (vendor)		822									
86	Eggs - boiled (vendor)		823									
87	Chicken (vendor)		824									
88	Meat (vendor)		825									
89	Fish (vendor)		826									
90	*Mandazi* , doughnut (vendor)		827									
91	Samosa (vendor)		828									
92	Meal eaten at restaurant		829									
93	Other (specify)		830									
94	**Milk and Milk Products**											
95	Fresh milk		701									
96	Powdered milk		702									
97	Margarine - Blue band		703									
98	Butter		704									
99	*Chambiko* - soured milk		705									
100	Yoghurt		706									
101	Cheese		707									
102	Infant feeding formula (for bottle)		708									
103	Other (specify)		709									
104	**Sugar, Fats, and Oil**											
105	Sugar		801									
106	Sugar Cane		802									
107	Cooking oil		803									
108	Other (specify)		804									

CODES FOR UNIT:

KILOGRAMME	1
50 KG. BAG	2
90 KG. BAG	3
PAIL (SMALL)	4
PAIL (LARGE)	5
No. 10 PLATE	6
No. 12 PLATE	7
BUNCH	8
PIECE	9
HEAP	10
BALE	11
BASKET (*DENGU*) (SHELLED)	12
BASKET (*DENGU*) (UNSHELLED)	13
OX-CART (UNSHELLED)	14
LITRE	15
CUP	16
TIN	17
GRAM	18
MILLILITRE	19
TEASPOON	20
BASIN	21
SATCHET/TUBE	22
OTHER (SPECIFY)	23

MODULE G: FOOD CONSUMPTION OVER PAST ONE WEEK (CONTINUED)

DATA ENTRY LINE NUMBER	Over the past one week (7 days), did you or others in your household consume any [. . .]? INCLUDE FOOD BOTH EATEN COMMUNALLY IN THE HOUSEHOLD AND THAT EATEN SEPARATELY BY INDIVIDUAL HOUSEHOLD MEMBERS.	G01 YES..1 NO...2>> **NEXT ITEM**	G02 ITEM CODE	G03 How much in total did your household consume in the past week?		G04 How much came from purchases?		G05 How much did you spend?	G06 How much came from own-production?		G07 How much came from gifts and other sources?	
				QUANTITY	UNIT	QUANTITY	UNIT	MK	QUANTITY	UNIT	QUANTITY	UNIT
109	**Beverages**											
110	Tea		901									
111	Coffee		902									
112	Cocoa, millo		903									
113	Squash (Sobo drink concentrate)		904									
114	Fruit juice		905									
115	Freezes (flavoured ice)		906									
116	Soft drinks (Coca-cola, Fanta, Sprite, etc.)		907									
117	Chibuku(commercial traditional-style beer)		908									
118	Bottled water		909									
119	Maheu		910									
120	Bottled / canned beer (Carlsberg, etc.)		911									
121	Thobwa		912									
122	Traditional beer (*masese*)		913									
123	Wine or commercial liquor		914									
124	Locally brewed liquor (*kachasu*)		915									
125	Other (specify)		916									
126	**Spices & Miscellaneous**											
127	Salt		810									
128	Spices		811									
129	Yeast, baking powder, bicarbonate of soda		812									
130	Tomato sauce (bottle)		813									
131	Hot sauce (Nali, etc.)		814									
132	Jam, jelly		815									
133	Sweets, candy, chocolates		816									
134	Honey		817									
135	Other (specify)		818									

CODES FOR UNIT:

KILOGRAMME 1
50 KG. BAG 2
90 KG. BAG 3
PAIL (SMALL) 4
PAIL (LARGE) 5
No. 10 PLATE 6
No. 12 PLATE 7
BUNCH. 8
PIECE. 9
HEAP 10
BALE 11
BASKET (*DENGU*) (SHELLED). . . 12
BASKET (*DENGU*) (UNSHELLED) . . 13
OX-CART (UNSHELLED) . . 14
LITRE. 15
CUP. 16
TIN. 17
GRAM 18
MILLILITRE 19
TEASPOON. 20
BASIN. 21
SATCHET/TUBE. . . .22
OTHER (SPECIFY). 23

MODULE G: FOOD CONSUMPTION OVER PAST ONE WEEK (CONTINUED)

		G08. Over the past one week (7 days), how many days did you or others in your household consume any [...]? IF NOT CONSUMED, RECORD ZERO. **NUMBER OF DAYS**
A	**Cereals, Grains and Cereal Products** (Previous Page: 100s) (Maize Grain/Flour; Green Maize; Rice; Finger Millet ; Pearl Millet; Sorghum; Wheat Flour; Bread; Pasta; Other Cereal)	
B	**Roots, Tubers, and Plantains** *[Previous Page: 200]* (Cassava Tuber/Flour; Sweet Potato; Irish Potato; Other Tuber/Plantain)	
C	**Nuts and Pulses** *[Previous Page: 300s]* (Bean; Pigeon Pea; Macademia Nut; Groundnut; Ground Bean; Cow Pea; Other Nut/Pulse)	
D	**Vegetables** *[Previous Page: 400s]* (Onion; Cabbage; Tanaposi; Nkhwani; Wild Green Leaves; Tomato; Cucumber; Other Vegetables/Leaves)	
E	**Meat, Fish and Animal Products** *[Previous Page: 500s]* Egg;Dried/Fresh/Smoked Fish (Excluding Fish Sauce/Powder); Beef; Goat Meat; Pork; Poultry; Other Meat)	
F	**Fruits** *[Previous Page: 600s]* (Mango; Banana; Citrus; Pineapple; Papaya; Guava; Avocado; Apple; Other Fruit)	
G	**Milk/Milk Products** *[Previous Page: 700s]* (Fresh/Powdered/Soured Milk; Yogurt; Cheese; Other Milk Product - Excluding Margarine/Butter or Small Amounts of Milk for Tea/Coffee)	
H	**Fats/Oil** *[Previous Page: 703, 704, 803, 804 (if app.)]* (Cooking Oil; Butter; Margarine; Other Fat/Oil)	
I	**Sugar/Sugar Products/Honey** *[Previous Page: 801, 802, 804 (if app.), 815, 816, 817, 817 (if app.)]* (Sugar; Sugar Cane; Honey; Jam; Jelly; Sweets/Candy/Chocolate; Other Sugar Product)	
J	**Spices/Condiments** *[Previous Page: 900s, 810-814, 817 (if app.)]* (Tea; Coffee/Cocoa/Millop; Salt; Spices; Yeast/Baking Powder; Tomato/Hot Sauce;Fish Powder/Sauce; Other Condiment - Including Small Amounts of Milk for Tea/Coffee)	

G09. Over the past one week (7 days), did any people that you did not list as household members [READ LIST FROM HH ROSTER] eat any meals in your household?

YES..1
NO...2>> **NEXT MODULE** ☐

	For G10-G11: IF NOT SHARED, RECORD ZERO.	G10 What was the total number of days in which any meal was shared with people […]? **NUMBER OF DAYS**	G11 What was the total number of meals that were shared over past 7 days with […]? **NUMBER OF MEALS**
A	Children 0-5 years		
B	Children 6-15 years		
C	Adults 16-65 years		
D	People over 65 years old		

MODULE H: FOOD SECURITY

H01	H02					H03		H04
In the past 7 days, did you worry that your household would not have enough food?	In the past 7 days, how many days have you or someone in your household had to: IF NO DAYS, RECORD ZERO.					How many meals, including breakfast are taken per day in your household?		In the last 12 months, have you been faced with a situation when you did not have enough food to feed the household?
YES..1 NO...2	**a. Rely on less preferred and/or less expensive foods?**	**b. Limit portion size at meal-times?**	**c. Reduce number of meals eaten in a day?**	**d. Restrict con-sumption by adults in order for small children to eat?**	**e. Borrow food, or rely on help from a friend or relative?**	**a. Adults**	**b. Children (6-59 months)** **LEAVE BLANK IF NO CHILDREN**	YES.1 NO..2 **>>NEXT MODULE**
	DAYS	**DAYS**	**DAYS**	**DAYS**	**DAYS**	**NUMBER**	**NUMBER**	

H05
When did you experience this incident in the last 12 months?

MARK X IN EACH MONTHOF 2009 AND 2010 THE HOUSEHOLD DID NOT HAVE ENOUGH FOOD

LEAVE CELL BLANK FOR FUTURE MONTHS FROM INTERVIEW DATE OR MOTNHS MORE THAN 12 MONTHS AGO FROM INTERVIEW DATE.

2009										**2010**	
Mar	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**

2010										**2011**		
Mar	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**

H06
What was the cause of this situation?

LIST UP TO 3 IN ORDER OF IMPORTANCE; USE CODES ON THE RIGHT.

a.	b.	c.
1ST	**2ND**	**3RD**

CODES FOR H06:

Inadequate household stocks due to drought/ poor rains..............1

Inadequate household food stocks due to crop pest damage...2

Inadequate household food stocks due to small land size.....3

Inadequate household food stocks due to lack of farm inputs.4

Food in the market was very expensive......5

Unable to reach the market due to high transportation costs...............6

No food in the market.............7

Floods/water logging............8

Other (Specify).....9

MODULE I: NON-FOOD EXPENDITURES – OVER PAST ONE WEEK & ONE MONTH

ONE WEEK RECALL

DATA ENTRY LINE NUMBER	Over the past one week (7 days), did your household purchase or pay for any [...]?	I01 YES.1 NO..2>>NEXT ITEM	I02 ITEM CODE	I03 How much did you pay in total? MK
1	Charcoal		101	
2	Paraffin or kerosene		102	
3	Cigarettes or other tobacco		103	
4	Candles		104	
5	Matches		105	
6	Newspapers or magazines		106	
7	Public transport - Bicycle Taxi		107	
8	Public transport - Bus/Minibus		108	
9	Public transport - Other (Truck, Oxcart, Etc..)		109	

ONE MONTH RECALL

DATA ENTRY LINE NUMBER	Over the past one month, did your household purchase or pay for any [...]?	I01 YES.1 NO..2>>NEXT ITEM	I02 ITEM CODE	I03 How much did you pay in total? MK
1	Milling fees, grain		201	
2	Bar soap (body soap or clothes soap)		202	
3	Clothes soap (powder, paste)		203	
4	Toothpaste, toothbrush		204	
5	Toilet paper		205	
6	Glycerine, Vaseline, skin creams		206	
7	Other personal products (shampoo, razor blades, cosmetics, hair products, etc.)		207	
8	Light bulbs		209	
9	Postage stamps or other postal fees		210	
10	Donation - to church, charity, beggar, etc.		211	
11	Petrol or diesel		212	
12	Motor vehicle service, repair, or parts		213	
13	Bicycle service, repair, or parts		214	
14	Wages paid to servants		215	
15	Mortgage - regular payment to purchase house		216	
16	Repairs & maintenance to dwelling		217	
17	Repairs to household and personal items (radios, watches, etc., excluding battery purchases)		218	
18	Expenditures on pets		219	
19	Batteries		220	
20	Recharging batteries, cell phones		221	

MODULE J: NON-FOOD EXPENDITURES OVER PAST THREE MONTHS

Over the past three months, did your household purchase or pay for any [...]?	J01 YES.1 NO..2**>>NEXT ITEM**	J02 ITEM CODE	J03 How much did you pay in total? MK
Infant clothing		301	
Baby nappies/diapers		302	
Boy's trousers		303	
Boy's shirts		304	
Boy's jackets		305	
Boy's undergarments		306	
Boy's other clothing		307	
Men's trousers		308	
Men's shirts		309	
Men's jackets		310	
Men's undergarments		311	
Men's other clothing		312	
Girl's blouse/shirt		313	
Girl's dress/skirt		314	
Girl's undergarments		315	
Girl's other clothing		316	
Lady's blouse/shirt		317	
Chitenje cloth		318	
Lady's dress/skirt		319	
Lady's undergarments		320	

Over the past three months, did your household purchase or pay for any [...]?	J01 YES.1 NO..2**>>NEXT ITEM**	J02 ITEM CODE	J03 How much did you pay in total? MK
Lady's other clothing		321	
Boy's shoes		322	
Men's shoes		323	
Girl's shoes		324	
Lady's shoes		325	
Cloth, thread, other sewing material		326	
Laundry, dry cleaning, tailoring fees		327	
Bowls, glassware, plates, silverware, etc.		328	
Cooking utensils (cookpots, stirring spoons and whisks, etc.)		329	
Cleaning utensils (brooms, brushes, etc.)		330	
Torch / flashlight		331	
Umbrella		332	
Paraffin lamp (hurricane or pressure)		333	
Stationery items (not for school)		334	
Books (not for school)		335	
Music or video cassette or CD/DVD		336	
Tickets for sports / entertainment events		337	
House decorations		338	
Night's lodging in rest house or hotel		339	

MODULE K: NON-FOOD EXPENDITURES OVER PAST 12 MONTHS

Over the past one year (twelve months), did your household purchase or pay for any [...]?	K01 YES.1 NO..2>>**NEXT ITEM**	K02 ITEM CODE	K03 How much did you pay in total? MK
Carpet, rugs, drapes, curtains		401	
Linen - towels, sheets, blankets		402	
Mat - sleeping or for drying maize flour		403	
Mosquito net		404	
Mattress		405	
Sports & hobby equipment, musical instruments, toys		406	
Film, film processing, camera		407	
Cement		408	
Bricks		409	
Construction timber		410	
Council rates		411	
Insurance - health (MASM, etc.), auto, home, life		412	
Losses to theft (value of items or cash lost)		413	
Fines or legal fees		414	
Lobola (bridewealth) costs		415	
Marriage ceremony costs		416	
Funeral costs, household members		417	
Funeral costs, nonhousehold members (relatives, neighbors/friends)		418	

NON-FOOD ITEMS THAT MAY NOT HAVE BEEN PURCHASED

Over the past one year (twelve months) did your household gather, purchase, or pay for any [...]?	K01 YES.1 NO..2>>**NEXT ITEM**	K02 ITEM CODE	K03 What was the estimated total value of [...] consumed? MK	K04 What was the cost of that which you purchased? MK
Woodpoles, bamboo		419		
Grass for thatching roof or other use		420		

MODULE L: DURABLE GOODS

ITEM	L01 Does your household own a [ITEM]? YES..1 NO...2 >> **NEXT ITEM**	L02 DURABLE GOOD ITEM CODE	L03 How many [ITEM]s do you own? NUMBER	L04 What is the age of this [ITEM]? IF MORE THAN ONE ITEM, AVERAGE AGE. YEARS	L05 If you wanted to sell one of this [ITEM] today, how much would you receive? IF MORE THAN ONE, AVERAGE VALUE. MK	L06 Did you purchase or pay for any [ITEM] in the last 12 months? YES..1 NO...2 >> **NEXT ITEM**	L07 How much in total did pay for [ITEM] in the last 12 months? MK
Mortar/pestle (*mtondo*)		501					
Bed		502					
Table		503					
Chair		504					
Fan		505					
Air conditioner		506					
Radio ('wireless')		507					
Tape or CD/DVD player; HiFi		508					
Television		509					
VCR		510					
Sewing machine		511					
Kerosene/paraffin stove		512					
Electric or gas stove; hot plate		513					
Refrigerator		514					
Washing machine		515					
Bicycle		516					

MODULE L: DURABLE GOODS (CONTINUED)

ITEM	L01 Does your household own a [ITEM]? YES..1 NO...2>> **NEXT ITEM**	L02 DURABLE GOOD ITEM CODE	L03 How many [ITEM]s do you own? NUMBER	L04 What is the age of this [ITEM]? IF MORE THAN ONE ITEM, AVERAGE AGE. YEARS	L05 If you wanted to sell one of this [ITEM] today, how much would you receive? IF MORE THAN ONE, AVERAGE VALUE. MK	L06 Did you purchase any [ITEM] in the last 12 months? YES..1 NO...2 >> **NEXT ITEM**	L07 How much in total did you pay for [ITEM] in the last 12 months? MK
Motorcycle/scooter		517					
Car		518					
Mini-bus		519					
Lorry		520					
Beer-brewing drum		521					
Upholstered chair, sofa set		522					
Coffee table (for sitting room)		523					
Cupboard, drawers, bureau		524					
Lantern (paraffin)		525					
Desk		526					
Clock		527					
Iron (for pressing clothes)		528					
Computer equipment & accessories		529					
Sattelite dish		530					
Solar panel		531					
Generator		532					

MODULE M: FARM IMPLEMENTS, MACHINERY, AND STRUCTURES

A. Did your household own or rent any farm implements, machinery and/or structures, such as hand hoe, panga knife, treadle pump, ox cart, tractor, plough, generator, chicken house, storage house, barn, etc… in the last 12 months?

YES..1 NO....2>> **NEXT MODULE** ☐

DATA ENTRY LINE NUMBER	ITEM		M00 Does your household currently own [ITEM] ? YES..1 NO...2>> **M04**	M01 How many [ITEM] does your household currently own?	M02 What is the age of the [ITEM]? IF MORE THAN ONE [ITEM], ASK FOR THECOMBINED AGE OF ALL [ITEM]S.	M03 If you wanted to sell one of this [ITEM] today, how much would you receive? IF MORE THAN ONE [ITEM], ASK FOR THE AVERAGE VALUE.	M04 Did your household buy any [ITEM] during the last 12 months? YES..1 NO...2>> **M07**	M05 How many [ITEM] did your household buy?	M06 What was the value of these	M07 **ENUMERATOR:** IS THE [ITEM] A FARM STRUCTURE/ BUILDING? YES..1 NO...2>> **M10**	M08 How many [ITEM] did your household build during the last 12 months? IF NONE, RECORD ZERO AND **>> M10.**
				NUMBER	YEARS	MK		NUMBER	MK		NUMBER
1	**IMPLEMENTS**										
2	601	HAND HOE									
3	602	SLASHER									
4	603	AXE									
5	604	SPRAYER									
6	605	PANGA KNIFE									
7	606	SICKLE									
8	607	TREADLE PUMP									
9	608	WATERING CAN									
10	**MACHINERY**										
11	609	OX CART									
12	610	OX PLOUGH									
13	611	TRACTOR									
14	612	TRACTOR PLOUGH									
15	613	RIDGER									
16	614	CULTIVATOR									
17	615	GENERATOR									
18	616	MOTORISED PUMP									
19	617	GRAIN MILL									
20	618	OTHER (SPECIFY)									
21	**STRUCTURES/BUILDINGS**										
22	619	CHICKEN HOUSE									
23	620	LIVESTOCK KRAAL									
24	621	POULTRY KRAAL									
25	622	STORAGE HOUSE									
26	623	GRANARY									
27	624	BARN									
28	625	PIG STY									

MODULE M: FARM/FISHERY IMPLEMENTS, STRUCTURES AND MACHINERY (CONTINUED)

DATA ENTRY LINE NUMBER	ITEM		M09 How much did it cost to build [ITEM]? MK	M10 Did your household use the [ITEM] during the last 12 months? YES..1>> **M12** NO...2	M11 What was the main reason for not using the [ITEM]? NO NEED FOR ONE........1 NEEDS REPAIRS....2 LENT TO OTHERS.....3 RENTED TO OTHERS.....4 OTHER (SPECIFY)..5	M12 Did your household rent or borrow any [ITEM] during the last 12 months? YES..1 NO...2 **>>NEXT ITEM**	M13 How many [ITEM] did your household rent or borrow during the last 12 months? NUMBER	M14 How much did your household pay to rent or borrow [ITEM] during the last 12 months? ESTIMATE THE VALUE OF IN-KIND PAYMENTS MK
1	**IMPLEMENTS**							
2	601	HAND HOE						
3	602	SLASHER						
4	603	AXE						
5	604	SPRAYER						
6	605	PANGA KNIFE						
7	606	SICKLE						
8	607	TREADLE PUMP						
9	608	WATERING CAN						
10	**MACHINERY**							
11	609	OX CART						
12	610	OX PLOUGH						
13	611	TRACTOR						
14	612	TRACTOR PLOUGH						
15	613	RIDGER						
16	614	CULTIVATOR						
17	615	GENERATOR						
18	616	MOTORISED PUMP						
19	617	GRAIN MILL						
20	618	OTHER (SPECIFY)						
21	**STRUCTURES/BUILDINGS**							
22	619	CHICKEN HOUSE						
23	620	LIVESTOCK KRAAL						
24	621	POULTRY KRAAL						
25	622	STORAGE HOUSE						
26	623	GRANARY						
27	624	BARN						
28	625	PIG STY						

MODULE N: HOUSEHOLD ENTERPRISES

[ASK OF HOUSEHOLD HEAD]

A. Over the past 12 months, has anyone in your household operated any non-agricultural income-generating enterprise which produces goods or services or has anyone in your household owned a shop or operated a trading business?

YES. 1
NO . 2

☐

ENUMERATOR: REFER TO THE ANSWER TO **A**. IF THE RESPONDENT STATED "**YES**," ASK THE FOLLOWING: TO UNDERSTAND THE TYPE OF NON-AGRICULTURAL INCOME GENERATING ENTERPRISES OPERATED BY YOUR HOUSEHOLD OVER THE PAST 12 MONTHS, COULD YOU PLEASE ANSWER THE FOLLOWING SET OF QUESTIONS.

ENUMERATOR: REFER TO THE ANSWER TO **A**. IF THE RESPONDENT STATED "**NO**," STATE THE FOLLOWING: EVEN THOUGH YOU STATED THAT NO ONE IN YOUR HOUSEHOLD OPERATED ANY NON-AGRICULTURAL INCOME-GENERATING ENTERPRISE OVER THE PAST 12 MONTHS, LET ME BE CLEAR ON WHAT I MEAN BY "NON-AGRICULTURAL INCOME-GENERATING ENTERPRISE."

Over the past 12 months has anyone in your household…

FOR QUESTIONS N01 THROUGH N08

YES..1 NO...2

N01 … owned a non-agricultural business or provided a non-agricultural service from home or a household-owned shop, as a carwash owner, metal worker, mechanic, carpenter, tailor, barber, etc.? ☐

N02 … processed and sold any agricultural by-products, including flour, starch, juice, beer, jam, oil, seed, bran, etc., but excluding livestock by-products, fresh/processed fish? ☐

N03 … owned a trading business on a street or in a market? ☐

N04 … offered any service or sold anything on a street or in a market, including firewood, home-made charcoal, curios, construction timber, woodpoles, traditional medicine, mats, bricks, cane furniture, weave baskets, thatch grass etc.? ☐

N05 … owned a professional office or offered professional services from home as a doctor, accountant, lawyer, translator, private tutor, midwife, mason, etc? ☐

N06 … driven a household-owned taxi or pick-up truck to provide transportation or moving services? ☐

N07 … owned a bar or restaurant? ☐

N08 …owned any other non-agricultural business, even if it is a small business run from home or on a street? ☐

B. **ENUMERATOR:** IS THERE A "1" FOR ANY OF THE QUESTIONS N01 THROUGH N08?

YES..1
NO...2**>> MODULE O**

☐

PLEASE INCLUDE HOUSEHOLD BUSINESS VENTURES THAT HAVE BEEN SHUT DOWN PERMANENTLY OR TEMPORARILY DURING THE PAST 12 MONTHS.

MODULE N: HOUSEHOLD ENTERPRISES (CONTINUED)

ENTERPRISE ID	N09 Please provide details on the main product or service of each [ENTERPRISE] that your household operated during the past 12 months. PROVIDE A WRITTEN DESCRIPTION CONCERNING THE MAIN PRODUCT/SERVICE OF EACH ENTERPRISE THAT THE HOUSEHOLD OPERATED DURING THE PAST 12 MONTHS, BEFORE GOING ON TO N10. PLEASE INCLUDE BUSINESS VENTURES THAT HAVE BEEN SHUT DOWN PERMANENTLY OR TEMPORARILY DURING THE PAST 12 MONTHS.		N10 Who in the household manages this enterprise or is most familiar with it? LIST UP TO 2 FROM HOUSEHOLD ROSTER		N11 RECORD THE ID OF THE RESPONDENT, FOR THIS [ENTERPRISE]. LIST FROM HOUSEHOLD ROSTER	N12 Who in the household owns this [ENTERPRISE]? LIST UP TO 2 JOINT OWNERS		N13 How many individuals outside of the household are co-owners of this [ENTERPRISE]? IF NONE, RECORD ZERO IN BOTH COLUMNS, AND **>> N15.**		N14 What share of the profits from this [ENTERPRISE] is kept by your household, rather than the other owners? READ RESPONSES Almost none..1 About 25%....2 About half...3 About 75%....4 Almost all...5 Other (Specify)....6	N15 When was this [ENTERPRISE] first started?	
		(Supervisor to put in code after interview)	**MANAGER 1**	**MANAGER 2**		**OWNER 1**	**OWNER 2**	**MALE**	**FEMALE**			
	WRITTEN DESCRIPTION	**INDUSTRY CODE**	**HH ROSTER ID CODE**	**HH ROSTER ID CODE**	**ROSTER ID CODE**	**HH ROSTER ID CODE**	**HH ROSTER ID CODE**	**NUMBER**	**NUMBER**		**MONTH**	**YEAR (4-DIGIT)**
1												
2												
3												
4												
5												

MODULE N: HOUSEHOLD ENTERPRISES (CONTINUED)

ENTERPRISE ID	N16 What weres the sources of start-up capital for this enterprise? READ ANSWERS. LIST UP TO 2. IF ONLY ONE SOURCE, RECORD "99" IN THE SECOND COLUMN. IF NO SOURCES OF START-UP CAPITAL, RECORD "99" IN BOTH COLUMNS. Own-savings from agriculture...............1 Own-savings from n on-agriculture............2 Sale of assets owned......3 Proceeds from another business..................4 Agricultural input credit.5 Non-agricultural credit from bank or other institution......6 Loan from money lender....7 Loan from family/friends..8 Savings club..............9 Gift from family/friends.10 Inherited................11 Other (specify)..........12		N17 Where do you operate this [ENTERPRISE]? READ RESPONSES Home (inside residence).....1 >> N20 Home (outside residence).....2 >> N20 Industrial site...........3 Traditional market place...4 >> N20 Commercial area shop......5 Roadside.......6 >> N20 Other fixed place..........7 Mobile.........8 >> N20	N18 Does this [ENTERPRISE] have access to working electricity? Yes..1 No...2 >> N20	N19 What is the main source of electricity for this [ENTERPRISE]? ESCOM/GRID...1 SOLAR PANEL..2 GENERATOR....3 OTHER (SPECIFY)....4	N20 To whom do you mostly sell your products or services? READ RESPONSES LIST UP TO 2 BUYERS. Final consumers..........1 Traders..................2 Other small businesses...3 Large established businesses/institutions..4 Export...................5 Manufacturer.............6 Marketing board..........7 Other (specify)..........8		N21 Is this [ENTERPRISE] officially registered with the… YES..1 NO...2			N22 Does this [ENTER-PRISE] or any of its owners or managers belong to any registered business association? YES..1 NO...2
	1ST	**2ND**				**1ST**	**2ND**	**a.** **Registrar of Companies?**	**b.** **Malawi Revenue Authority?**	**c.** **Local Assembly?**	
1											
2											
3											
4											
5											

MODULE N: HOUSEHOLD ENTERPRISES (CONTINUED)

ENTERPRISE ID	N23 **ENUMERATOR:** DOES THIS BUSINESS SELL FOREST-BASED PRODUCTS? YES..1 NO...2>>**N25**	N24 What is the source of the forest-based product sold by this [ENTERPRISE]? READ RESPONSES Own land........1 Forest/wild park reserve....2 Communal land...3 Purchased from someone else....4 Other (Specify).5	N25 During the past 12 months, was this [ENTERPRISE] operational in the month of [MONTH], and if so, were your sales high, average, or low? MARK FOR EACH MONTH IN TURN. START FROM THE MOST RECENT MONTH THAT WAS COMPLETED, GOING BACK MONTH BY MONTH. MAKE SURE ALL APPLICABLE MONTHS IN THE PAST 12 MONTH PERIOD ARE MARKED WITH ONE OF THE CODES BELOW. IF THERE IS NO MONTH MARKED WITH "0" IN THE PAST 12 MONTHS, SKIP TO QUESTION N27. NONE:NOT IN OPERATION..0 LOW....................1 AVERAGE................2 HIGH...................3																									N26 Why was this [ENTERPRISE] not in operation for [PERIOD INDICATED IN N25]? READ RESPONSES LIST UP TO 2 Lack of non-labour inputs..1 Lack of credit............2 Lack of cash.......3 Seasonal work......4 Bad weather........5 Not profitable.....6 Own-Illness/Need to care for household members..7 Other (Specify)....8	
			2009										**2010**												**2011**				
			MAR	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**	**JAN**	**FEB**	**MAR**	**1ST**	**2ND**
1																													
2																													
3																													
4																													
5																													

MODULE N: HOUSEHOLD ENTERPRISES (CONTINUED)

ENTERPRISE ID	N27 **ENUMERATOR:** REFER TO N25. WAS THIS [ENTERPRISE] IN OPERATON IN THE LAST MONTH?	N28 Are you planning to resume the operations of this [ENTERPRISE] within the next 12 months?	N29 Why not? READ RESPONSES LIST UP TO 2 Lack of non-labour inputs..1 Lack of credit.............2 Lack of cash...............3 Not profitable.....4 Own-Illness/Need to care for household members..5 Other (Specify)....6		N30 A. During the last month of operation, which household members worked for this [ENTERPRISE]? MAKE SURE THE RESPONDENT IS REFERRING TO THE LAST MONTH OF OPERATION AS STATED IN QUESTION N25. LIST UP TO 4 ID CODES FROM HOUSEHOLD ROSTER. IF MORE THAN 4 HOUSEHOLD MEMBERS WERE EMPLOYED, USE ANOTHER QUESTIONNAIRE. B. During the last month of operation in the past 12 months, how many days did each household member work for this [ENTERPRISE]? C. During those days, approximately, how many hours did each member work for this [ENTERPRISE]? D. During the last 12 months, how many months did each member work for this [ENTERPRISE]?															
					OWNER # 1				**OWNER # 2**											
					HH MEMBER # 1				**HH MEMBER # 2**				**HH MEMBER # 3**				**HH MEMBER # 4**			
	YES..1 >> **N30** NO...2	YES..1 >> **N30** NO...2	**1ST**	**2ND**	**ID**	**DAYS**	**HOURS**	**MONTHS**	**ID**	**DAYS**	**HOURS**	**MONTHS**	**ID**	**DAYS**	**HOURS**	**MONTHS**	**ID**	**DAYS**	**HOURS**	**MONTHS**
1																				
2																				
3																				
4																				
5																				

MODULE N: HOUSEHOLD ENTERPRISES (CONTINUED)

N31

A. During the last month of operation, how many non-household member men/women/children (under-15) worked for this [ENTERPRISE] ?

MAKE SURE THE RESPONDENT IS REFERRING TO THE LAST MONTH OF OPERATION AS STATED IN QUESTION N25. IF THERE WAS NO HIRED LABOR, RECORD ZERO IN THE "NUMBER" COLUMNS AND CONTINUE TO QUESTION N32.

B. During the last month of operation in the past 12 months, how many days did a **typical** man/woman/child employee work?

C. During the days of employment in the last month of operation in the past 12 months, how many hours did a **typical** man/woman/child employee work?

D. During the last month of operation in the past 12 months, what was the total expenditure of this [ENTERPRISE] on salaries or wages of **ALL** men/women/children employees?

INCLUDE: ESTIMATED VALUE OF IN-KIND PAYMENTS. IF THERE WERE NO WAGE/SALARY (CASH OR IN-KIND) PAYMENTS, RECORD ZERO.

N32

During the last month of operation, what was the value of **total sales** (***zogulitsa***) of products, goods or services of this [ENTERPRISE]?

MAKE SURE THE RESPONDENT IS REFERRING TO THE LAST MONTH OF OPERATION AS STATED IN QUESTION N25, AND THAT HE/SHE IS NOT NETTING OUT ANY COSTS INCURRED.

ENTERPRISE ID	MEN				WOMEN				CHILDREN (U-15)				SALES (MK)
	NUMBER	**DAYS PER MONTH**	**HOURS PER DAY**	**TOTAL WAGES / SALARIES LAST MONTH**	**NUMBER**	**DAYS PER MONTH**	**HOURS PER DAY**	**TOTAL WAGES / SALARIES LAST MONTH**	**NUMBER**	**DAYS PER MONTH**	**HOURS PER DAY**	**TOTAL WAGES / SALARIES LAST MONTH**	**LAST MONTH OF OPERATION**
1													
2													
3													
4													
5													

MODULE N: HOUSEHOLD ENTERPRISES (CONTINUED)

ENTERPRISE ID	N33 **ENUMERATOR:** REFER TO QUESTION 25. WAS THE LAST MONTH OF OPERATION A MONTH OF... LOW SALES.......1 AVERAGE SALES...2 >> **N36** HIGH SALES......3 >> **N38**	N34 During the **last month of average sales**, what was the value of **total sales** (***zogulitsa***) of products, goods or services of this [ENTERPRISE]?	N35 During the **last month of high sales**, what was the value of **total sales** (***zogulitsa***) of products, goods or services of this [ENTERPRISE]? **>> N40**	N36 During the **last month of low sales**, what was the value of **total sales** (***zogulitsa***) of products, goods or services of this [ENTERPRISE]?	N37 During the **last month of high sales**, what was the value of **total sales** (***zogulitsa***) of products, goods or services of this [ENTERPRISE]? **>> N40**	N38 During the **last month of low sales**, what was the value of **total sales** (***zogulitsa***) of products, goods or services of this [ENTERPRISE]?	N39 During the **last month of average sales**, what was the value of **total sales** (***zogulitsa***) of products, goods or services of this [ENTERPRISE]?	N40 During the last month of operation, what was the **profit** (***phindu***)of this [ENTERPRISE]?
		AVG SALES	**HIGH SALES**	**LOW SALES**	**HIGH SALES**	**LOW SALES**	**AVG SALES**	**PROFIT (MK)**
		MK	**MK**	**MK**	**MK**	**MK**	**MK**	**LAST MONTH OF OPERATION**
1								
2								
3								
4								
5								

MODULE N: HOUSEHOLD ENTERPRISES (CONTINUED)

N41

During the last month of operation, what was the total expenditure of this [ENTERPRISE] on…

MAKE SURE THE RESPONDENT IS REFERRING TO THE LAST MONTH OF OPERATION AS STATED IN QUESTION N25.

INCLUDE: ESTIMATED VALUE OF IN-KIND PAYMENTS.

IF NOTHING WAS SPENT, RECORD ZERO.

ENTERPRISE ID	a.	b.	c.	d.	e.	f.	g.	h.
	Raw Materials	**Purchase of Goods for Sale (Inventory)**	**Freight / Transport**	**Fuel / Oil**	**Electricity**	**Water**	**Insurance**	**Other (Specify)**
	MK	**MK**	**MK**	**MK**	**MK**	**MK**	**MK**	**MK**
1								
2								
3								
4								
5								

MODULE O: CHILDREN LIVING ELSEWHERE

A. Does the household head or spouse have any biological sons and/or daughters who are 15 years old and over and do not live in this household?

YES..1
NO...2 **>> NEXT MODULE** ☐

LINE NUMBER	RESPONDENT ID	O01 Please list all biological sons and/or daughters of head and/or spouse 15 years old and over who do not live in this household.	O02 Age	O03 Sex MALE....1 FEMALE..2	O04 What is the highest grade [NAME] has completed in school? NEVER ATTENDED SCHOOL- 0 PRIMARY STND. 1 - 1 STND. 2 - 2 STND. 3 - 3 STND. 4 - 4 STND. 5 - 5 STND. 6 - 6 STND. 7 - 7 STND. 8 - 8 SECONDARY FORM 1 - 9 FORM 2 - 10 FORM 3 - 11 FORM 4 - 12 FORM 5 - 13 FORM 6 - 14 UNIVERSITY UNIV. 1 - 15 UNIV. 2 - 16 UNIV. 3 - 17 UNIV. 4 - 18 UNIV. 5 & ABOVE - 19 TRAINING COLLEGE TC YR. 1 - 20 TC YR. 2 - 21 TC YR. 3 - 22 TC YR. 4 - 23	O05 Has [NAME] ever lived in this household? YES..1 NO...2**>>O07**	O06 In which year did [NAME] leave the household?	O07 Where does [NAME] currently live? IF IN MALAWI, ASK FOR THE NAME OF DISTRICT OF CURRENT RESIDENCE. IF ABROAD, ASK FOR THE NAME OF COUNTRY OF CURRENT RESIDENCE. REFER TO THE MANUAL FOR DISTRICT AND COUNTRY CODES.		O08 For how long has [NAME] lived in this [DISTRICT/ COUNTRY REPORTED IN O07]? CODES FOR UNIT: MONTH..1 YEAR...2		O09 What is [NAME]'s current activity status? WORKING.....1 UNEMPLOYED..2**>>O11** STUDENT.....3**>>O11** HOUSE WORK..4**>>O11** HANDI-CAPPED......5**>>O11** OTHER (SPECIFY)...6**>>O11**
			YEARS				**YEAR (4-DIGIT)**	**DISTRICT or COUNTRY**	**CODE**	**LENGTH**	**UNIT**	
01												
02												
03												
04												
05												
06												
07												
08												
09												
10												
11												
12												

MODULE O: CHILDREN LIVING ELSEWHERE (CONTINUED)

LINE NUMBER	O10 What is the current main occupation of [NAME]?	(Supervisor to put in occupation code after interview)	O11 Did [NAME] send any cash to this household at any point during the last 12 months? EXCLUDE FOOD AND NON-FOOD IN-KIND ASSISTANCE. YES..1 NO...2>>O15	O12 At what frequency did [NAME] send cash to this household during the last 12 months? READ RESPONSES Twice or More Per Month..1 Monthly....2 Quarterly..3>>O14 Semi-Annually...4>>O14 Annually...5>>O14 SporadicallY As Needed..6>>O14 Other (Specify)..7>>O14	O13 How much cash did [NAME] send to this household **each month** during the last 12 months? IF IN FOREIGN CURRENCY, ESTIMATE THE VALUE IN MALAWI KWACHA. >>O15	O14 How much cash did [NAME] send to this household **in total** during the last 12 months? IF IN FOREIGN CURRENCY, ESTIMATE THE VALUE IN MALAWI KWACHA.	O15 Did [NAME] send any in-kind assistance to this household at any point during the last 12 months? INCLUDE ONLY FOOD AND NON-FOOD IN-KIND ASSISTANCE. Yes..1 No...2>>NEXT PERSON	O16 At what frequency did [NAME] send in-kind assistance to this household during the last 12 months? READ RESPONSES Twice or More Per Month..1 Monthly....2 Quarterly..3 Semi-Annually...4 Annually...5 Sporadically As Needed..6 Other (Specify)..7	O17 What was the total estimated cash value of all food and other in-kind assistance that [NAME] sent to this household during the last 12 months? (THEN >>NEXT PERSON)
	DESCRIPTION	OCCUP. CODE			AMOUNT/ MONTH	AMOUNT IN TOTAL			MK
01									
02									
03									
04									
05									
06									
07									
08									
09									
10									
11									
12									

MODULE P: OTHER INCOME

DATA ENTRY LINE NUMBER	CODE	SOURCE	P01 During the last 12 months, did you or any members of your household receive any [SOURCE]? YES.1 NO..2>> **NEXT SOURCE**	P02 How much [SOURCE] did your household receive in total during the last 12 months? ESTIMATE THE CASH VALUE OF IN-KIND TRANSFERS RECEIVED	P03 How much of [SOURCE] came from rural/urban/international locations?			P04 Who in your household kept/decided what to do with these earnings? LIST UP TO 2 FROM HOUSEHOLD ROSTER.	
				MK	**FROM RURAL AREAS** **MK**	**FROM URBAN AREAS** **MK**	**FROM OTHER COUNTRIES** **MK**	**HH ROSTER ID CODE # 1**	**HH ROSTER ID CODE # 2**
1		**Incoming Transfers/Gifts**							
2	101	Cash Transfers/Gifts from Individuals (Friends/Relatives) [DO NOT INCLUDE REMITTANCES FROM HH HEAD'S AND SPOUSE'S OWN CHILDREN. THESE ARE RECORDED IN THE PREVIOUS MODULE.]							
3	102	Food Transfers/Gifts from Individuals (Friends/Relatives) [DO NOT INCLUDE REMITTANCES FROM HH HEAD'S AND SPOUSE'S OWN CHILDREN. THESE ARE RECORDED IN THE PREVIOUS MODULE.]							
4	103	Non-Food In-Kind Transfers/Gifts from Individuals (Friends/Relatives) [DO NOT INCLUDE REMITTANCES FROM HH HEAD'S AND SPOUSE'S OWN CHILDREN. THESE ARE RECORDED IN THE PREVIOUS MODULE.]							
5		**Pension & Investment Income**							
6	104	Savings, Interest or Other Investment Income							
7	105	Pension Income							
8		**Rental Income**							
9	106	Income from Non-Agricultural Land Rental							
10	107	Income from Apartment, House Rental							

MODULE P: OTHER INCOME (CONTINUED)

DATA ENTRY LINE NUMBER	CODE	SOURCE	P01 During the last 12 months, did you or any members of your household receive any [SOURCE]? `YES.1` `NO..2` **>> NEXT SOURCE**	P02 How much [SOURCE] did your household receive in total during the last 12 months? ESTIMATE THE CASH VALUE OF IN-KIND TRANSFERS RECEIVED	P03 How much of the total [SOURCE] came from rural/urban/international locations?			P04 Who in your household kept/decided what to do with these earnings? LIST UP TO 2 FROM HOUSEHOLD ROSTER.	
				MK	**FROM RURAL AREAS** **MK**	**FROM URBAN AREAS** **MK**	**FROM OTHER COUNTRIES** **MK**	**HH ROSTER ID CODE # 1**	**HH ROSTER ID CODE # 2**
11		**Rental Income (Continued)**							
12	108	Income from Shop, Store Rental							
13	109	Income from Car, Truck, Other Vehicle Rental (DO NOT INCLUDE ANY NON-FARM ENTERPRISE INCOME)							
14		**Revenue from Sales of Assets**							
15	110	Income from Real Estate Sales							
16	111	Income from Household Non-Agricultural Asset Sales							
17	112	Income from Household Agricultural/Fishing Asset Sales							
18		**Other Income**							
19	113	Inheritance							
20	114	Lottery/Gambling Winnings							
21	115	Other Income (Specify)________________							

MODULE Q: GIFTS GIVEN OUT

			Q01	Q02			Q03	
			During the last 12 months, did you or any members of your household give away any [ITEM] to individuals (friends/family) outside your household?	How much of the [ITEM] given away was destined to rural/urban/international locations?			Who in the household decided on the allocation of [ITEM] given away to individuals outside your household (friends/family) during the last 12 months? LIST UP TO 2 FROM HOUSEHOLD ROSTER.	
DATA ENTRY LINE NUMBER	**CODE**	**ITEM**	`YES.1` `NO..2` **>> NEXT ITEM**	**TO RURAL AREAS** **MK**	**TO URBAN AREAS** **MK**	**TO OTHER COUNTRIES** **MK**	**HH ROSTER ID CODE # 1**	**HH ROSTER ID CODE # 2**
1		**Outgoing Transfers/Gifts**						
2	201	Cash Transfers/Gifts [DO NOT INCLUDE GIFTS GIVEN FOR WEDDINGS, CEREMONIES OR FUNERALS. THESE EXPENDITURES ARE RECORDED IN MODULE K]						
3	202	Food Transfers/Gifts [DO NOT INCLUDE GIFTS GIVEN FOR WEDDINGS, CEREMONIES OR FUNERALS. THESE EXPENDITURES ARE RECORDED IN MODULE K.]						
4	203	Non-Food In-Kind Transfers/Gifts [DO NOT INCLUDE GIFTS GIVEN FOR WEDDINGS, CEREMONIES OR FUNERALS.THESE EXPENDITURES ARE RECORDED IN MODULE K.]						

MODULE R: SOCIAL SAFETY NETS

[ASK OF HOUSEHOLD HEAD]

CODE	**PROGRAM** ***DO NOT INCLUDE PENSIONS AND VOUCHERS FOR FERTILIZER AND SEED.***	R01 In the last 12 months, has any member of your household received cash, food, or other aid from [PROGRAMME]? YES...1 NO....2 **>>NEXT PROGRAMME**	R02 In the last 12 months, what was the total assistance received from [PROGRAMME]?			R03 Was the assistance given to… READ RESPONSES Entire HH.......1**>> R5** Specific HH Members..2
			CASH	**IN-KIND**	**MAIZE**	
			MK	**CASH VALUE - MK**	**KG**	
101	Free Maize					
102	Free Food (other than Maize)					
103	Food/Cash-for-Work Programme (e.g., MASAF - Public Works Programme [PWP])					
104	Inputs-For-Work Programme					
105	School Feeding Programme					
106	Free Distribution of Likuni Phala to Children and Mothers (Targeted Nutrition Programme [TNP])					
107	Supplementary Feeding for Malnourished Children at a Nutritional Rehabilitation Unit					
108	Scholarships/Bursaries for Secondary Education. (e.g., CRECCOM)					
109	Scholarships for Tertiary Education (e.g.University Scholarship, Upgrading Teachers)					
110	Tertiary Loan Scheme (Government Loan for University and Other Tertiary Education)					
111	Direct Cash Transfers from Government					
112	Direct Cash Transfers from others (Development Partners; NGOs). SPECIFY________________					
113	Other, Specify: ___________________________________					

MODULE R: SOCIAL SAFETY NETS (CONTINUED)

[ASK OF HOUSEHOLD HEAD]

		R04 Which household members received this assistance in the last 12 months? RECORD HOUSEHOLD ROSTER ID OF EACH MEMBER MENTIONED					R5 Who in your household controls/decides on the use of assistance from [PROGRAMME]? LIST UP TO 2 FROM HOUSEHOLD ROSTER		R6 In the last 12 months, for how many months did your household receive assistance from [PROGRAMME]?	R7 When was the last time your household received this assistance (THEN >> NEXT PROGRAMME)	
CODE	**PROGRAM** ***DO NOT INCLUDE PENSIONS AND VOUCHERS FOR FERTILIZER AND SEED.***	**ID CODE # 1**	**ID CODE # 2**	**ID CODE # 3**	**ID CODE # 4**	**ID CODE # 5**	**HH ROSTER ID CODE #1**	**HH ROSTER ID CODE #2**	**NUMBER**	**MONTH**	**YEAR (4-DIGIT)**
101	Free Maize										
102	Free Food (other than Maize)										
103	Food/Cash-for-Work Programme (e.g., MASAF - Public Works Programme [PWP])										
104	Inputs-For-Work Programme										
105	School Feeding Programme										
106	Free Distribution of Likuni Phala to Children and Mothers (Targeted Nutrition Programme [TNP])										
107	Supplementary Feeding for Malnourished Children at a Nutritional Rehabilitation Unit										
108	Scholarships/Bursaries for Secondary Education. (e.g., CRECCOM)										
109	Scholarships for Tertiary Education (e.g.University Scholarship, Upgrading Teachers)										
110	Tertiary Loan Scheme (Government Loan for University and Other Tertiary Education)										
111	Direct Cash Transfers from Government										
112	Direct Cash Transfers from others (Development Partners, NGOs). SPECIFY________________										
113	Other, Specify: ___________________________________										

MODULE S: CREDIT

[ASK OF HOUSEHOLD HEAD]

S01 Over the past 12 months, did you or anyone else in this household borrow on credit from someone outside the household or from an institution for business or farming purposes, receiving either cash or inputs?

YES...1
NO....2>>**S12** ☐

S02 L O A N N O	S03 What are the names of the persons or institutions from whom you or anyone else in your household borrowed on credit money for business or farming over the past 12 months? LIST ALL NAMES BEFORE GOING TO THE NEXT QUESTION.	S04 CODE SOURCE OF LOAN USE CODES ON THE NEXT PAGE.	S05 Which household member was responsible for the loan? LIST UP TO 2 FROM HOUSEHOLD ROSTER		S06 What was main reason for obtaining loan? Was it: [READ] PURCHASE LAND. .1 PURCHASE AGRI-CULTURAL INPUTS FOR FOOD CROP .2 PURCHASE INPUTS FOR TOBACCO . .3 PURCHASE INPUTS FOR OTHER CASH CROPS . . . . .4 BUSINESS START-UP CAPITAL. . .5 PURCHASE NON-FARM INPUTS . .6 CONSUMPTION. . .7 OTHER (SPECIFY).8	S07 How much was borrowed?	S08 When did you get the loan within the past 12 months? JAN. .1 FEB. .2 MAR. .3 APR. .4 MAY. .5 JUN. .6 JUL. .7 AUG. .8 SEP. .9 OCT. 10 NOV. 11 DEC. 12		S09 Is the loan re-paid? YES..1>>**S11** NO...2	S10 Approximately when do you expect to pay back the money? JAN. .1 FEB. .2 MAR. .3 APR. .4 MAY. .5 JUN. .6 JUL. .7 AUG. .8 SEP. .9 OCT. 10 NOV. 11 DEC. 12		S11 How much did you pay (do you expect to have paid) in total when you (will have) paid off this loan (interest + principal)? **(THEN >> NEXT LOAN.** **WHEN ALL LOANS DONE, >> 12)**
			HH ROSTER ID CODE # 1	HH ROSTER ID CODE # 2		MK	CALENDAR MONTH	CALENDAR YEAR		CALENDAR MONTH	CALENDAR YEAR	MK
1												
2												
3												
4												
5												
6												
7												
8												

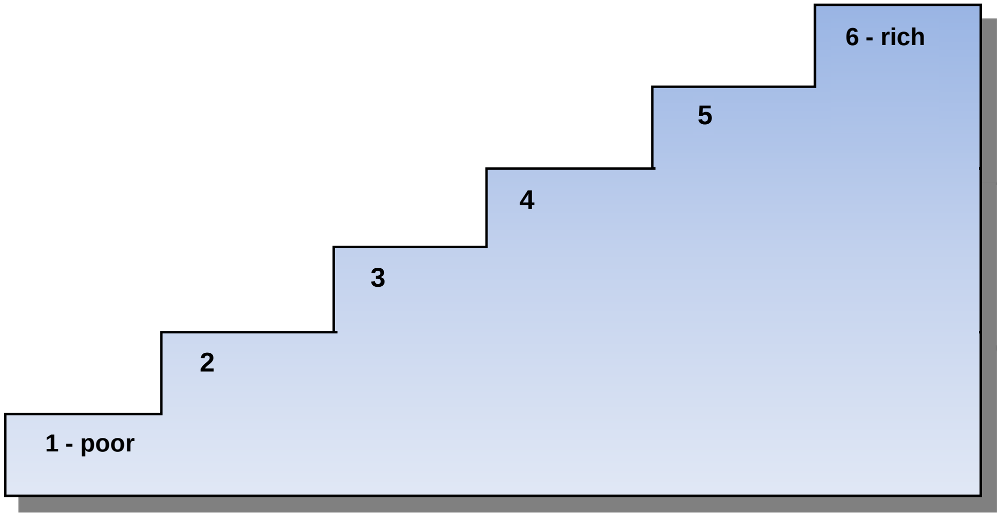
MODULE S: CREDIT (CONTINUED)

S12 During the last 12 months, did you try to borrow from someone outside the household or from an institution and <u>were turned down</u>? YES..1 NO...2 **>>S15**	S13 Who turned you down? LIST UP TO 2. USE CODES BELOW.		S14 What was main <u>reason</u> for trying to obtain the loan? Was it: [READ RESPONSES] PURCHASE LAND. .1 PURCHASE AGRICULTURAL INPUTS FOR FOOD CROP .2 PURCHASE INPUTS FOR TOBACCO . .3 PURCHASE INPUTS FOR OTHER CASH CROPS . . . . .4 BUSINESS START-UP CAPITAL. . .5 PURCHASE NON-FARM INPUTS . .6 CONSUMPTION. . .7 OTHER (SPECIFY).8	S15 Are you awaiting word on a loan that you applied for during the last 12 months? YES..1 NO...2 **>>S18**	S16 From whom or which institution are you awaiting word on a loan? LIST UP TO 2. USE CODES BELOW.		S17 What was main <u>reason</u> for trying to obtain the loan? Was it: [READ RESPONSES] PURCHASE LAND. .1 PURCHASE AGRICULTURAL INPUTS FOR FOOD CROP .2 PURCHASE INPUTS FOR TOBACCO . .3 PURCHASE INPUTS FOR OTHER CASH CROPS . . . . .4 BUSINESS START-UP CAPITAL. . .5 PURCHASE NON-FARM INPUTS . .6 CONSUMPTION. . .7 OTHER (SPECIFY).8	S18 **ENUMERATOR:** WAS THE ANSWER TO QUESTIONS **S01, S12 AND S15 ALWAYS "NO"?** ANSWER TO ALL THREE QUESTIONS WAS ALWAYS "NO"..1 ANSWER TO ALL THREE QUESTIONS WAS NOT ALWAYS "NO"..2**>>NEXT MODULE**	S19 Why did you <u>not attempt to borrow</u> in the last 12 months? [LIST UP TO TWO ANSWERS IN ORDER OF IMPORTANCE.] NO NEED . . . . .1 BELIEVED WOULD BE REFUSED. . . . . . . .2 TOO EXPENSIVE . . . . .3 TOO MUCH TROUBLE FOR WHAT IT IS WORTH .4 INADEQUATE COLLATERAL .5 DO NOT LIKE TO BE IN DEBT. . . . . . . .6 DO NOT KNOW ANY LENDER.7 OTHER (SPECIFY) . . . .8 **(THEN >> NEXT MODULE)**	
	1ST	2ND			1ST	2ND			1ST	2ND

<u>CODES FOR S4, S13 & S16:</u>
RELATIVE 1
NEIGHBOUR. 2
GROCERY/LOCAL MERCHANT 3
MONEY LENDER (KATAPILA). 4
EMPLOYER 5
RELIGIOUS INSTITUTION 6
MARDEF 7
MRFC 8
SACCO. 9
BANK (COMMERCIAL). 10
NGO. 11
OTHER (SPECIFY). . 12

MODULE T: SUBJECTIVE ASSESSMENT OF WELL-BEING

T01	T02	T03	T04	T05	T06	T07	T08	T09	T10	T11	T12
Concerning your household's food consumption over the past one month, which of the following is true?	Concerning your housing, which of the following is true?	Concerning your household's clothing, which of the following is true?	Concerning the standard of health care you receive for household members, which of the following is true?	Imagine six steps, where on the bottom, the first step, stand the poorest people, and on the highest step, the sixth, stand the rich. SHOW THE PICTURE OF THE STEPS BELOW.			Which of the following is true? Your current income . . . [READ]:	How many changes of clothes do you (HH HEAD) own?	What do you (HH HEAD) sleep on?	What do you (HH HEAD) sleep under in the cold season (July)?	What do you (HH HEAD) sleep under in the hot season (October)?
It was less than adequate for household needs. 1 It was just adequate for household needs.. . . 2 It was more than adequate for household needs. 3 *(NOTE THAT 'ADEQUATE' MEANS NO MORE OR NO LESS THAN WHAT THE RESPONDENT CONSIDERS TO BE THE MINIMUM CONSUMPTION NEEDS OF THE HOUSEHOLD.)*				On which step are you today?	On which step are most of your neighbors today?	On which step are most of your friends today?	ALLOWS YOU TO BUILD YOUR SAVINGS. . . .1 ALLOWS YOU TO SAVE JUST A LITTLE . . .2 ONLY JUST MEETS YOUR EXPENSES . . .3 IS NOT SUFFICIENT, SO YOU NEED TO USE YOUR SAVINGS TO MEET EXPENSES . . .4 IS REALLY NOT SUFFICIENT, SO YOU NEED TO BORROW TO MEET EXPENSES . . .5	(NUMBER OF TROUSERS FOR MEN; SKIRTS/ DRESSES FOR WOMEN) NUMBER	BED & MATTRESS . . 1 BED & MAT (GRASS). 2 BED ALONE. . . . . 3 MATTRESS ON FLOOR. 4 MAT (GRASS) ON FLOOR . . . . . . 5 CLOTH/SACK ON FLOOR . . . . . . 6 FLOOR (NOTHING ELSE) . . . . . . 7 OTHER (SPECIFY). . 8	BLANKET & SHEETS. . .1 BLANKET ONLY. . . . .2 SHEETS ONLY . . . . .3 CHITENJE CLOTH. . . .4 FERTILIZER or GRAIN SACK . . . . .5 CLOTHES . . . . . . .6 NOTHING . . . . . . .7 OTHER (SPECIFY) . . .8	



MODULE U: SHOCKS & COPING STRATEGIES

[ASK OF HOUSEHOLD HEAD]

CODE	SHOCK	U01 During the last 12 months, was your household affected negatively by any of the following [SHOCK]? YES..1 NO...2 >> **NEXT SHOCK**	U02 Rank the three most significant shocks you experienced - **Most Severe (1), Second Most Severe (2), Third (3).**	U03 As a result of this [SHOCK], did your […] … READ RESPONSES FOR EACH COLUMN Increase........1 Decrease........2 Did Not Change..3					U04 What did your household do in response to this [SHOCK] to try to regain your former welfare level? FOR EACH SHOCK, LIST UP TO 3 ANSWERS BY ORDER OF IMPORTANCE. IF HAPPENED MORE THAN ONCE DURING THE LAST 12 MONTHS, ASK ABOUT THE MOST RECENT INCIDENT. USE CODES ON THE RIGHT.		
				INCOME	ASSETS	FOOD PRODUCTION	FOOD STOCKS	FOOD PURCHASES	1ST	2ND	3RD
101	Drought/Irregular Rains										
102	Floods/Landslides										
103	Earthquakes										
104	Unusually High Level of Crop Pests or Disease										
105	Unusually High Level of Livestock Disease										
106	Unusually Low Prices for Agricultural Output										
107	Unusually High Costs of Agricultural Inputs										
108	Unusually High Prices for Food										
109	End of Regular Assistance/Aid/ Remittances From Outside Household										
110	Reduction in the Earnings from Household (Non-Agricultural) Business (Not due to Illness or Accident)										
111	Household (Non-Agricultural) Business Failure (Not due to Illness or Accident)										
112	Reduction In the Earnings of Currently Salaried Household Member(s) (Not due to Illness or Accident)										
113	Loss of Employment of Previously Salaried Household Member(s) (Not due to Illness or Accident)										
114	Serious Ilness or Accident of Household Member(s)										
115	Birth in the Household										
116	Death of Income Earner(s)										
117	Death of Other Household Member(s)										
118	Break-Up of Household										
119	Theft of Money/Valuables/Assets/Agricultural Output										
120	Conflict/Violence										
121	Other (Specify)										

THE QUESTIONS TO THE RIGHT SHOULD ONLY BE ASKED CONCERNING THE THREE MOST SEVERE SHOCKS, AS NOTED IN U02.

LEAVE ALL OTHER ROWS BLANK.

```
RELIED ON OWN-SAVINGS....1

RECEIVED UNCONDITIONAL HELP
FROM RELATIVES/FRIENDS....2

RECEIVED UNCONDITIONAL HELP
FROM GOVERNMENT...........3

RECEIVED UNCONDITIONAL HELP
FROM NGO/RELIGIOUS
INSTITUTION...............4

CHANGED EATING PATTERNS
(RELIED ON LESS PREFERRED
FOOD OPTIONS, REDUCED THE
PROPORTION OR NUMBER OF
MEALS PER DAY, OR
HOUSEHOLD MEMBERS SKIPPED
DAYS OF EATING, ETC.).....5

EMPLOYED HOUSEHOLD MEMBERS
TOOK ON MORE EMPLOYMENT...6

ADULT HOUSEHOLD MEMBERS WHO
WERE PREVIOUSLY NOT WORKING
HAD TO FIND WORK..........7

HOUSEHOLD MEMBERS
MIGRATED..................8

REDUCED EXPENDITURES ON
HEALTH AND/OR EDUCATION...9

OBTAINED CREDIT..........10

SOLD AGRICULTURAL ASSETS.11

SOLD DURABLE ASSETS......12

SOLD LAND/BUILDING.......13

SOLD CROP STOCK..........14

SOLD LIVESTOCK...........15

INTENSIFY FISHING........16

SENT CHILDREN TO LIVE
ELSEWHERE................17

ENGAGED IN SPIRITUAL EFFORTS
- PRAYER, SACRIFICES,
DIVINER
CONSULTATIONS............18

DID NOT DO ANYTHING......19
```

MODULE V: CHILD ANTHROPOMETRY

V01	V02	V03	V04		V05	V06	V07	V08	V09	V10	V11	V12	V13	V14
ID CODE	PUT AN 'X' FOR ALL INDIVIDUALS WHO ARE AGED UNDER SIX MONTHS <u>OR</u> OLDER THAN EXACTLY FIVE YEARS OLD (60 MONTHS). <u>DO NOT</u> ADMINISTER THIS MODULE TO THESE INDIVIDUALS. IF NONE AGED SIX TO 59 MONTHS, »**NEXT MODULE**.	RECORD THE ID OF THE MOTHER / GUARDIAN OF THE CHILD IN THE HOUSE-HOLD	How old is [NAME]? RECONFIRM EXACT AGE - MUST INCLUDE <u>BOTH</u> YEARS AND MONTHS.		WAS [NAME] MEAS-URED? YES, MEASURED FULLY.....1>>V07 YES, MEASURED PARTIALLY.2 NO........3	WHY NOT? NOT AT HOME DURING SURVEY PERIOD. .1 TOO ILL. .2 UNWILLING.3 OTHER. . .4	IS THE ANSWER TO V05 "NO"? YES..1>>V12 NO...2	WEIGHT OF CHILD IN KG TO ONE DECIMAL PLACE. (IF LESS THAN 10 KG, PUT ZERO IN FIRST BLANK.)	HEIGHT / LENGTH OF CHILD CHILDREN AGED UNDER 24 MONTHS SHOULD BE MEASURED LYING DOWN. ALL OTHERS, STANDING. IN CM, TO ONE DECIMAL PLACE. (IF LESS THAN 100 CM, PUT ZERO IN FIRST BLANK.)	HEIGHT / LENGTH MEASURED WITH CHILD STANDING OR LYING DOWN? STANDING...1 LYING DOWN.2 NOT APPLICABLE.3	WAS THE MEASURE-MENT OF THE CHILD DONE IN A NORMAL MANNER, OR WAS MEASURE-MENT DIFFICULT? NORMAL....1 DIFFICULT.2	ASK OF MOTHER / GUARDI-AN: Does the child partici-pate in a <u>nutrition programme</u>? YES. .1 NO . .2	ASK OF MOTHER/ GUARDIAN: Does the child participate in an <u>under-five clinic</u>? YES. .1 NO . .2 **(IF CHILD NOT MEASURED » NEXT CHILD)**	DID CHILD APPEAR TO HAVE OEDEMA (SWELLING THAT IS NOT NORMAL)? YES. .1 NO . .2
		HH ROSTER ID	YEARS	MONTHS										
1								___ ___ . ___	___ ___ ___ . ___					
2								___ ___ . ___	___ ___ ___ . ___					
3								___ ___ . ___	___ ___ ___ . ___					
4								___ ___ . ___	___ ___ ___ . ___					
5								___ ___ . ___	___ ___ ___ . ___					
6								___ ___ . ___	___ ___ ___ . ___					
7								___ ___ . ___	___ ___ ___ . ___					
8								___ ___ . ___	___ ___ ___ . ___					
9								___ ___ . ___	___ ___ ___ . ___					
10								___ ___ . ___	___ ___ ___ . ___					
11								___ ___ . ___	___ ___ ___ . ___					
12								___ ___ . ___	___ ___ ___ . ___					

MODULE W: DEATHS IN HOUSEHOLD

W01. Over the past two years, did any member of your household die, including any infants?

YES..1
NO...2>>NEXT MODULE

☐

W02	W03	W04	W05	W06		W07	W08	W09	W10	W11		W12		W13	W14	W15
SERIAL NO	NAME OF DECEASED	DECEASED'S RELATION-SHIP TO HEAD OF HOUSEHOLD	SEX MALE. .1 FEMALE.2	AGE AT DEATH IF UNDER 5 YEARS, INCLUDE MONTHS		ACCORDING TO W06, WAS THE DECEASED UNDER 12 YEARS OLD WHEN HE/SHE DIED? YES 1>>W09 NO...2	What kind of work did [NAME] do for most of his/her life? FARMING . . . . . 1 FISHING . . . . . 2 TRADER/MERCHANT . 3 TRANSPORT . . . . 4 TRADESMAN (MASON, CARPENTER, ETC). 5 CIVIL SERVANT . . 6 TEACHER . . . . . 7 DOCTOR/NURSE/ETC. 8 OTHER PROFESSION. 9 CLERK/SECRETARY .10 FACTORY WORKER. .11 RESTAURANT, BAR .12 GENERAL LABOURER.13 HOME WORKER . . .14 STUDENT . . . . .15 MILITARY. . . . .16 OTHER 17	Did [NAME] die of old age, an illness, or of some other cause? OLD AGE .1 **(>>W14)** ILLNESS .2 **(>>W11)** OTHER CAUSE. .3	What was the [NON-ILLNESS] cause of [NAME]'s death? TRAFFIC ACCIDENT . . . 1 OTHER ACCIDENT OR INJURY. . . 2 CHILDBIRTH OR COMPLICATIONS. 3 MURDER. . . . . 4 SUICIDE . . . . 5 WITCHCRAFT/ SORCERY. . . . 6 OTHER (SPEC.) . 7 (THEN >>W13)	What was the illness that caused [NAME]'s death? CAN NOTE UP TO TWO. CODES BELOW		For how long was [NAME] suffering from this illness before he/she died?	DAY . 3 WEEK. 4 MONTH 5 YEAR. 6	Was this cause of death diagnosed, or is this only your own percep-tion? MEDICAL DIAGNOSIS 1 NON-MEDICAL DIAGNOSIS .2 OWN PERCEPTION 3	After this person died, did you or members of your house-hold lose any land or other assets due to inheritance traditions? YES..1 NO...2 **(»NEXT DECEASED)**	What was the value of the land or assets lost?
		CODES BELOW		YEARS	MONTHS					1ST ILLNESS	2ND ILLNESS	TIME AMOUNT	UNIT			MK
31																
32																
33																
34																
35																
36																

RELATIONSHIP CODES

WIFE/HUSBAND. 2
CHILD/ADOPTED CHILD . .3
GRANDCHILD. 4
NIECE/NEPHEW. 5
FATHER/MOTHER 6
SISTER/BROTHER. 7
SON/DAUGHTER-IN-LAW . .8
BROTHER/SISTER-IN-LAW .9
GRANDFATHER/MOTHER. . 10
FATHER/MOTHER-IN-LAW. 11
OTHER RELATIVE. . . . 12
SERVANT OR SERVANT'S RELATIVE 13
TENANT OR TENANT'S RELATIVE 14

ILLNESS CODES

MALARIA 1
MEASLES 2
DIARRHEA. . . .3
PNEUMONIA . . .4
MENINGITIS. . .5
MALNUTRITION. .6
TUBERCULOSIS. .7
HIV/AIDS............... 8
HEART DISEASE 9
HIGH BLOOD PRESSURE OR CIRCULATORY PROBLEM.....10
STROKE..................11
CANCER..................12
KIDNEY DISEASE..........13
LIVER DISEASE...........14
SEXUALLY TRANSMITTED DISEASE.................15
DIABETES COMPLICATION...16

DOES NOT KNOW 17
REFUSED TO ANSWER ..18
OTHER (SPECIFY) 19

MODULE X: FILTER QUESTIONS FOR AGRICULTURE & FISHERY QUESTIONNAIRES

X01. ENUMERATOR: IS THIS A PANEL HOUSEHOLD?	YES..1**>>X10** NO . 2	☐

CROSS-SECTIONAL HOUSEHOLDS

X02. ENUMERATOR: WHAT WAS THE LAST COMPLETED RAINY SEASON?	2009/10..1 2008/09..2	☐
X03. Did you or anyone in your household own or cultivate a plot during the [LAST COMPLETED RAINY SEASON - IN X02]?	YES..1 NO . 2	☐
X04. ENUMERATOR: WHAT WAS THE LAST COMPLETED DRY (DIMBA) SEASON?	2009..1 2010..2	☐
X05. Did you or anyone in your household own or cultivate any plot during the [LAST COMPLETED DRY (DIMBA) SEASON - IN X04]?	YES..1 NO . 2	☐
X06. Did you or anyone in your household produce any cassava, tea, coffee or any other fruits in the last 12 months?	YES..1 NO . 2	☐
X07. Did you or anyone in your household own any livestock in the last 12 months?	YES..1 NO . 2	☐
X08. **ENUMERATOR:** SHOULD THE AGRICULTURE QUESTIONNAIRE BE ADMINISTERED? MARK 'YES' IF RESPONDENT SAID 'YES' TO ONE OF X03, X05, X06, OR X07.	YES..1 NO . 2	☐
X09. Did you or anyone in this household do any fishing or fish trading in the last 12 months?	YES..1 NO . 2	☐

IF YES, <u>FISHERY QUESTIONNAIRE</u> HAS TO BE ADMINISTERED.

END OF QUESTIONS

PANEL HOUSEHOLDS

X10. Did you or anyone in your household own or cultivate a plot during the 2009/2010 rainy season?	YES..1 NO . 2	☐
X11. Did you or anyone in your household own any livestock in the last 12 months?	YES..1 NO . 2	☐
X12. **ENUMERATOR:** SHOULD THE AGRICULTURE VISIT 1 QUESTIONNAIRE BE ADMINISTERED? MARK 'YES' IF RESPONDENT SAID 'YES' TO ONE OF X10 OR X11.	YES..1 NO . 2	☐
X13. Did you or anyone in your household harvest any cassava, tea, coffee or other fruits in the last 6 months?	YES..1 NO . 2	☐
X14. Do you or anyone in your household plan to harvest any cassava, tea, coffee or other fruits in the next 6 months?	YES..1 NO . 2	☐
X15. ENUMERATOR: MARK 'YES' IF RESPONDENT SAID 'YES' TO ONE OF X13 or X14.	YES..1 NO . 2	☐
X16. Did you or anyone in this household do any fishing or fish trading in the last 12 months?	YES..1 NO . 2	☐

IF X16 IS "YES" AND HOUSEHOLD IS IN <u>PANEL GROUP A</u>, <u>FISHERY QUESTIONNAIRE</u> HAS TO BE ADMINISTERED DURING <u>VISIT 1</u>.
IF X16 IS "YES" AND HOUSEHOLD IS IN <u>PANEL GROUP B</u>, <u>FISHERY QUESTIONNAIRE</u> HAS TO BE ADMINISTERED DURING <u>VISIT 2</u>.

END OF QUESTIONS

SURVEY HOUSEHOLD MEMBER LIST

ID CODE	B02 NAMES OF HOUSEHOLD MEMBERS ONLY LIST HOUSEHOLD MEMBERS, NO OTHERS.	B03 SEX MALE....1 FEMALE..2	B05 AGE YEARS	 MONTHS
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				