Author's Accepted Manuscript

Recent trends of Human wellbeing in the Bangladesh delta

Md Sarwar Hossain, Fiifi Amoako Johnson, John A Dearing, Felix Eigenbrod

PII: S2211-4645(15)30019-1
DOI: <http://dx.doi.org/10.1016/j.envdev.2015.09.008>
Reference: ENVDEV265

To appear in: *Environmental Development*

Received date: 22 June 2015
Revised date: 4 September 2015
Accepted date: 21 September 2015

Cite this article as: Md Sarwar Hossain, Fiifi Amoako Johnson, John A Dearing and Felix Eigenbrod, Recent trends of Human wellbeing in the Bangladesh delta, *Environmental Development*, <http://dx.doi.org/10.1016/j.envdev.2015.09.008>

This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting galley proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Recent trends of human wellbeing in the Bangladesh delta

Md Sarwar Hossain^{1*} Fiifi Amoako Johnson² John A Dearing¹ Felix Eigenbrod³

1. Geography and Environment, University of Southampton, Southampton, UK
2. Social Sciences: Social Statistics & Demography, University of Southampton, Southampton, UK
3. Centre for Biological Sciences, University of Southampton, Southampton, UK

*Corresponding author: koushikadd@yahoo.com and Sarwar.Sohel@soton.ac.uk

Abstract

Although recent studies show that human wellbeing on global and national scales is improving, it is important to monitor the regional progress of human wellbeing and Millennium Development Goals (MDGs). Here we provide an assessment of human wellbeing in the south-west coastal part of Bangladesh by analysing Household Expenditure Survey (HIES) and Demographic Health Survey (DHS) data from 1995 to 2010. Indicators have been selected based on the five dimensions of human wellbeing, including health, material condition, personal security and freedom of choice and actions. This study shows that the south-west coastal region has made commendable progress in meeting the target MDGs goal for 'child and maternal health'. However, the areas of 'personal security' and 'freedom of choice and action' have not achieved the target MDGs despite showing substantial progress for 'poverty alleviation' (17%), 'sanitation coverage' (40%) and 'education' (23%). Incomes from fishery and 'non-ecosystem' based livelihood have increased 76% and 8% respectively, whereas income from shrimp and agriculture show declining trends. Production costs have increased substantially since 1995 in response to a rise in GDP. At a household level, proxy indicators of provisioning services, such as crop production, are positively correlated with poverty alleviation. Overall, greater attention on education and sustainable land use is required if Sustainable Development Goals (SDGs) are to be achieved by 2030.

Key words: Trends, Human wellbeing, Regional, MDGs, SDGs

Background

Human wellbeing is the subset of economic (e.g. GDP, income) and social wellbeing (e.g. education, health) factors (OECD, 2013) and has been classified into five dimensions: health (e.g. child mortality), material (e.g. income), security (e.g. sanitation), freedom and social relations (MA, 2005). Human wellbeing has been used to measure the progress of humanity such as the “health for all” goal set in 1990 and to design development strategies (McGillivray and Clarke, 2006). However, monitoring of the Millennium Development Goals (MDGs) is still very challenging mainly because of the spatial heterogeneity of human wellbeing with respect to social norms and access to ecosystem services (MA, 2005) and also data unavailability in low and middle income countries (UN, 2014). This difficulty in monitoring the MDGs is a major issue, as more than one billion people across the world are still living below the extreme poverty line set at \$1.00 per day (McGillivray, 2006). Despite many studies that show increasing trends of environmental degradation (e.g. Zhang et al. 2015; Dearing et al., 2014), the global average of human wellbeing is improving (Raudsepp-Hearne et al. 2010). Although ecosystem services make significant contributions (both direct and indirect) to security, basic materials and health for human wellbeing (Santos-Martin et al. 2013; MA, 2005), the relationships between ecosystem services and human wellbeing are complex (Vidal-Abarca et al. 2014; Raudsepp-Hearne et al. 2010). In particular, while the more efficient use of provisioning services (e.g. crops, fish) has supported poverty alleviation and human development (Scherr, 2000; Irz et al. 2001; CRA, 2006; Santos-Martin et al. 2013), the effects of declining regulating and supporting services on wellbeing may be nonlinear and long term (Balmford and Bond, 2005; Raudsepp-Hearne et al. 2010). Besides the contribution of provisioning services to human wellbeing, government initiatives for education and health, technological progress, development and investments are some of the prime factors explaining the positive global trends of human wellbeing (Cervellati and Sunde, 2005).

Risks of negative impact on human wellbeing due to environmental change are increasing at both the global (Rockström et al. 2009) and regional scale (Dearing et al. 2014). These studies show that humankind has already transgressed the safe operating space (point beyond which is dangerous to humanity) for some of the planetary boundaries such as climate change, biodiversity and water quality. However, there are no systematic analyses that consider the impact on social systems (i.e. human wellbeing) in terms of the capacity and resilience of societies in the face of changing environments (Raworth, 2012). For this purpose, it is

essential to develop an understanding of the dynamics of regional social and ecological systems, and their inter-relationship.

Bangladesh is one of the most densely populated countries of the world. It faces many challenges to meet the MGDs, specifically in alleviating poverty and providing education for all and access to health care. However, it has shown quite remarkable progress in achieving MGDs goals including a reduction of around 60% child and maternal mortality (Chowdhury et al. 2012) together with 2.5% poverty reduction per year (BBS, 2011; UNDP, 2014). Beside these development issues, Bangladesh possesses a highly complex and challenging environment, encountering yearly natural disasters including floods, droughts and cyclone surges. Urbanization, increased salinity and risks associated with climate change are all likely to increase in future (ADB, 2005). Due to this, quantification of the impacts on human wellbeing is important for regional sustainability in Bangladesh. Previous studies in Bangladesh have focused on analysing trends of environmental degradation (e.g. Hossain et al. 2015) and national progress of human wellbeing (e.g. Chowdhury et al. 2012). Despite research showing that provisioning services are most influential for improving human wellbeing (Raudsepp-Hearne et al. 2010), no studies have investigated the regional progress of MGDs and the income of people engaged in different occupations that are directly dependent on provisioning services as their income sources (e.g. farmers, fisherman, and shrimp farmers).

In this new study, we extend our previous work (Hossain et al. 2015) on trends in ecosystem services in south-west Bangladesh by reconstructing decadal changes in human development based on 13 human wellbeing indicators in households engaged in agriculture, fishery, forest resource collection and shrimp farming. Moreover, we have analysed new datasets such as Household Income and Expenditure Survey (HIES) and Demographic Health Survey (DHS) for observing and understanding the causes of recent trends of human wellbeing and policy implications for SDGs 2030 at regional scale. By quantifying the parallel changes in ecosystem services and human development, the study can serve as the basis for monitoring the process of rising wellbeing. Such analyses are a prerequisite for drawing together sufficient information and understanding of the socio-ecological system dynamics to enable the definition of a safe operating space for the region in the progress towards meeting the Sustainable Development Goals (SDGs) by 2030.

Methods

Study area

We have selected the south-west coastal part of Bangladesh as our study area (Figure 1). This area represents 16% of the total land ($\sim 25,000 \text{ km}^2$) of Bangladesh, with a population of 14 million (BBS, 2010). This south-west coastal ecosystem produces more than 1300 million USD of Gross Domestic Product (GDP) (BBS, 2010), contributing 277 USD GDP per person (Sarwar, 2010). However, around 38% people of this region live below the poverty line (BBS, 2010). HIES data indicate that livelihoods in this region are heavily dependent on agriculture ($\sim 40\%$), fisheries ($\sim 20\%$) and forestry ($\sim 25\%$). The world's largest mangrove ecosystem 'Sundarban' located in this region supports the livelihoods of around 1.5 million people directly, and 10 million people indirectly. In addition, the mangrove forest also protects around 10 million coastal people from storm surges (Islam, 2004).

Selection of indicators

Human wellbeing is a subset of economic and social wellbeing factors (OECD, 2013) and has been classified into five dimensions: health, material, security, freedom and social relations (MA, 2005). The list of human wellbeing indicators (Table 1) are selected according to the MDG goals (2015) for Bangladesh based on data availability, measurability and length of time series. We have used Household Income and Expenditure Survey (HIES) datasets collected by the Bangladesh Bureau of Statistics (BBS) and World Bank in 1995/96, 2000, 2005 and 2010 to compile data for the indicators such as income, sanitation, electricity, safe drinking water, crop production and production cost at household level. We have used Demographic and Health Surveys (DHS) to compile data for child and infant mortality, maternal health, education and access to media, as the HIES datasets do not cover data for these indicators. Although, the DHS data is at divisional level, we have used two divisions (Khulna and Barisal) data for analysing the indicators as, our study area covers all districts of Barisal division and $\sim 65\%$ total area of Khulna division. This study has mainly used the results from the published reports on DHS dataset collected in 1993, 1996, 2000, 2004, 2007 and 2010.

Material condition

Income: Household income level enables families to meet the norms for a decent level of living standard and consumption. We have analysed HIES datasets for 1995, 2000, 2005 and 2010 to calculate the mean income of the households who are engaged in agriculture, fisheries and non-ecosystem based activities such as labour, services holder, teacher, and construction workers. The HIES dataset does not capture income data for households engaged in shrimp farming and collecting non-timber forest products, so we have used other sources to show the trends of income from shrimp firms. We have adjusted all sector incomes to a current price using the consumer price index (CPI). In addition, we also have normalized income (income per hectare) in order to compare the income over the time period after controlling for farm size.

Gross Domestic Product (GDP): GDP measures welfare through the aggregated indices of human and natural production (Boyd, 2004; Boyd and Banzhaf, 2007; Daw et al. 2011). We have analysed the trends of GDP (at a current price) for each of the four provisioning services (rice, fish, forestry and shrimp). Total GDP data is available from 1978 to 2005, whereas sector-wise GDP is available only for the period 1993-2000. We have used the average share of each sector's GDP to calculate the sector-wise GDP between the period 1978 to 1992 and 2005.

Poverty (% of population below poverty line): Ecosystem services directly contribute to the poverty alleviation by enabling people to meet basic needs (food, cloth, education) and security (safe drinking water, sanitation etc.) of individuals (UNEP/IISD, 2004; MA, 2005). In addition, 'poverty' describes the deprivation of well-being and is a good indicator for measuring the material condition, as the income and GDP often ignore the deprivation of well-being level in the society (OECD, 2013). We have used both upper and lower poverty thresholds which consider the cost of food items and the costs of both food and non-food items respectively in the cost of basic needs (CBN) method used by BBS (2010) and Wood (2007).

Security and freedom of choice

We have used the percentage of households with access to sanitation and safe drinking water to analyse the trends in 'personal security'. Data for the three indicators are derived from the HIES. We have classified both sanitation facilities and drinking water sources into improved and unimproved types as per the DHS (2007). Sanitary latrines and pacca latrines (water seal and pit) are categorized within the improved sanitation category, whereas kacha, open and other types of sanitation facilities are labelled as unimproved sanitation. Similar approaches have been followed to classify improved (supply, tubewell) and unimproved (pond/river, well and others) sources of drinking water.

Moreover, we have selected the percentage of people who completed primary school and the ratio of men and women achieving this level of education as the indicator for 'freedom of choice', together with the indicator 'access to mass media'. In this case, we have focused on women due to the data availability and an attempt to prioritize the women as per the MDGs. We did not select any indicators for 'good social relations' due to data unavailability.

We have also analysed mean crop output (all types) and production (per unit) cost for agriculture and shrimp farming at the household level. We have also calculated crop yield (kg/ha) by dividing total produced by cultivated area at the household level. These indicators are not only part of the sustainable agriculture under the dimension of 'material condition', but also can be used as the proxy of provisioning services (e.g. food, fish) production at a household level. These data allow us to analyse the relationship between human well-being and provisioning services. It is also worth investigating whether the rising trend of food provisioning services is also increasing the cost of production. Hence, we have calculated normalized production cost per hectare to compare the production cost over the time period and also to compare with the mean income per hectare and crop yield.

Data analyses

The HIES uses a two stage randomly selected sampling, through the integrated multipurpose sampling (IMS) scheme in which, firstly, primary sampling units (PSU) were selected across the country and secondly, households were selected randomly per PSU. The number of PSU and household samples selected for the surveys in the HIES was 371 in the year 1995, 1000 in the year 2000, 7400 in the year 2005 and 12,240 in the year 2010. Moreover, surveys were conducted across the year to account for the seasonality (BBS, 1997; BBS 2011). The survey datasets are representative at the national and divisional level for urban and rural sampling (Azam and Imai, 2009). However, this study considers samples of all households located in

all nine districts using the similar approach of Mottaleb et al. (2013) and (Szabo et al. submitted). In this approach, samples from the same nine districts are used to investigate the impacts of the natural disaster on household income and expenditure. Moreover, all these nine districts cover the whole Barisal division and 65% of the total Khulna division area. Because the HIES and DHS datasets are only representative at national and divisional levels, we are only able to investigate the trends aggregated over the all nine districts in our study region from 1995 to 2010, not at individual district level.

In the case of the HIES, data are combined into one dataset by merging (e.g. one to one) using the unique household identification. The householders' information (e.g. sex, area) also linked with the newly created datasets and the merged datasets for the nine districts are used for analyses.

Household level crop production and the production cost were calculated from the individual level data. Descriptive statistics (e.g. mean, median, standard deviation) for the variables were then calculated using the statistical package STATA 13.

Results

Health

In 1993, the infant mortality (Figure 2a) rate was 95.5 per 1000 live births which declined to 42.5 per 1000 live births in 2011. Child mortality (Figure 2a) shows a decline from 1993 to 2011, although the decreases were small between 1996 and 2004. Child mortality declined from 38 per 1000 live births in 1993 to 24.45 per 1000 live births in 1996 but rose to 25.7 per 1000 live births in 2000. Since 2000, it has declined by 16.7 per 1000 live births within 10 years. Similarly, maternal health (Figure 2b) has improved, as the proportion of births attended by skilled personnel has increased from ~10% in 1993 to ~38% in 2011 with a step change increase since 2011, when the proportion of births attended by skilled personnel has risen from 20% to 38% within the last four years (2007-2011).

Material condition

The total GDP (Figure 3a) has increased from 74 million USD to 1,025 million USD in the period 1978-2005 (at current prices), showing a sharply increasing trend (36 million USD/ yr) since the 1980s. Sector-wise curves of GDP linked to crops, fisheries, shrimp and forestry show (Figure 3b) show that GDP from crops has seen the highest growth (>100 million

USD), exceeding forestry and fisheries (~ 40-60 million USD) and shrimp production (~20-40 million USD).

Table 2 shows the changes in household income for all three sectors (agriculture, fishing and non-ecosystem). Household mean yearly income from agriculture has decreased from ~64,000BDT in 1995 to ~54,000 BDT in 2010. The median income also declined from 45,000 BDT in 1995 to ~29,000 BDT in 2010. The median income per hectare (Table 3) declined 53,700 BDT in 2000 to 41,400 BDT in 2005, before rising to 52,400 BDT in 2010. However, mean income per hectare shows increasing trend since 2000. It has shown a stepwise increase from ~31,000 BDT in 2005 to 142,000 BDT in 2010. Household mean income from non-ecosystem sources (Table 2) is higher (>6,000 BDT) for the period 2000 to 2010, compared to the mean income from agriculture and fishery. In addition, the median income and standard deviation of non-ecosystem based income are observed as quite stable (median 5,000-6,000 BDT; Stdv ~6,400 BDT) since 2000. Mean yearly income from fisheries shows a sharp increasing trend (425 BDT/yr) with a stepwise increase in median (~5,600 BDT in 2000 and ~18,000 in 2010) income in 2010. Although, the mean income of households engaged in shrimp farming shows (Figure 3d) a declining trend (2, 500 BDT ha⁻¹/yr) since 1985, the income is higher compared to the income from agriculture, fishery and non-ecosystem sectors. Household mean yearly income from shrimp was ~270,000 BDT/ha in 1975 and 1985, then falls back to ~230,000 BDT/ha and ~180,000 BDT/ha respectively in 1995 and 2007.

Table 3 shows the changes in income per hectare for crop production, crop yield and production costs from 1995 to 2010 at the household level. Mean crop yield (kg/ha) has increased 3 fold from ~3,600 (kg/ha) in 2000 and 2005 to 10,600 (kg/ha) in 2010. Similarly, the mean crop production at household level has also increased from 3,200 kg in 1995 to 3,800 kg in 2010. However, the mean cultivated area has decreased from 1.3 ha in 2000 to 0.92 ha in 2010. Production costs and production costs ha⁻¹ have increased, mirroring the rising level of crop yield and mean crop production. Both production costs and production costs ha⁻¹ have increased respectively from 6,000 BDT and ~20,000 BDT ha⁻¹ in 2000 to 48,000 BDT and 123,000 BDT ha⁻¹ in 2010. The mean fish catch of households shows a steep increase from ~ 186 kg in 2000 to ~ 465 kg in 2010, a 2.5-fold increase within only 10 years (Figure 10).

Poverty

Current (2010) levels of lower and upper poverty in the south-west coastal region are 36% and 20% of the total population down from 53% and 37% respectively in 1983 (Figure 3c). Even though both lower and upper poverty have declined from 1983 to 2010, poverty trends show fluctuating figures in which, upper-level poverty rose from 51% to a peak at ~61% in 1991 before falling back to 43% in 2000 and 2005. Improvement of upper-level poverty becomes stagnant between the period 2000 and 2005, and even the lower level poverty rose from ~28% in 2000 to ~33% in 2005. Moreover, lower level poverty rose at ~46% in 1985 before falling back to ~28% in 2005.

Quality of life

The quality of life appears to have improved because of the improvement of access to electricity and sanitation, and high levels of access to improved drinking water (Figure 2c-3h). Access to improved sanitation shows a rising trend since 2000, when improved sanitation shows stepwise change from 49% in 2000 to 72% in 2005. Currently (2010), ~78% have access to improved sanitation across the study area and ~75% households are using pucca and sanitary latrines, whereas in 1995 ~43% of households were using the inferior kacha latrines and ~10% no latrines at all (open space). Access to improved drinking water is high (>90% households), but the data show slightly worsening trends since 1995, while reliance on unimproved drinking water source rose from 1995 to 2010. The percentage of the households having access to electricity has increased from 30% in 1995 to 50% in 2010. However, currently (2010) half (49.7%) of households have no electricity in their house.

Freedom of choice and action

Overall access to primary education has improved from 23% to 47% in the period 1993-2010 (Figure 2f and 3h). Moreover, significant progress has been made in increasing equitable education by reducing the difference between the percentages of people with access to education for male and female. In 2010, the gap between the percentage of male and female access to education is ~2.5%, whereas in 1993 the gap was ~12%. Even though the gap between male and female education has decreased substantially, the proportion of females having access to media (% of females reading newspaper weekly) has declined in the period 1993-2011 (Figure 3g).

Discussion

Data unavailability was a major limitation of this study. For example, we could not construct yearly time series data for all the indicators as the datasets are collected every five years (e.g. HIES). HIES and DHS datasets are only representative at national and divisional level, thus, we are only able to investigate the trends aggregated over the all nine districts in our study region from 1995 to 2010, and not carry out analyses at the district level. In addition, HIES datasets do not cover the income of forest-dependent people and shrimp farmers. Thus, we had to depend on the GDP from the forest sector and literature sources for shrimp farm incomes. Despite these limitations, the findings serve as the basis for measuring the progress in achieving human wellbeing goals (e.g. MDGs, SDGs) and drawing out policy implications for the region.

Human wellbeing trends

The study provides evidence that human wellbeing could be improving in the south west coastal region of Bangladesh. However, this may not reflect the subjective wellbeing (e.g. happiness, life satisfaction) because we could not analyse the subjective wellbeing indicators due to data unavailability. The quality of life in terms of access to improved sanitation facilities and electricity connection has improved, although access to improved drinking water sources has remained not changed significantly since 1995. About 75% of tube wells were tested for the presence of arsenic, in which 5% of tube wells are contaminated by arsenic. However, this restricted analysis of drinking water quality in terms of metal toxicity needs to be extended to other properties of water relevant to health (e.g. salinity) which may be worsening (Hossain et al. 2015) but are not covered in the HIES datasets. Nevertheless, general health has improved since the 1990s, in particular, with respect to infant and child mortality that have declined 50% and 75% respectively in less than two decades. Freedom of choice and action have improved mainly because of the improvement (23%) in both male and female education, whereas access to media (percentage of women who read newspapers weekly) has declined 2% over the period 1993 to 2010.

Incomes (median) from fishery and non-ecosystem based livelihoods have increased 76% and 8% respectively. The mean income from fisheries is higher than national and other regional average incomes (Kabir et al. 2012). Non-ecosystem-based average income is similar to the national average income for sectors (BBS, 2011). However, both income (median) and income (median) per hectare from agriculture have decreased -18% and -2% respectively. The rising trends of income and GDP seem to support the progress in eradicating poverty and

improving human wellbeing because, overall, poverty has declined by 17% over 17 years. The rising trend of material wellbeing (income and GDP) in the agriculture and fisheries sector are mainly because of the adoption of technology (e.g. high yielding rice varieties, irrigation and fertilizer inputs) and fish cultivation in ponds (Ali, 1995; Husain 2001). Our previous findings (Hossain et al. 2013; Hossain et al. 2015) showed how wild fish catches in rivers have declined substantially in contrast to the rising trend of fish cultivation in ponds (FAO, 2014).

All these improvements in human wellbeing are primarily the result of the poverty alleviation efforts of government and NGOs that have provided access to sanitation, safe drinking water, better health facilities, raised educational attainment and free primary education. The Bangladesh government received more than 8,500 million USD from 1981 to 2012 as foreign aid to develop health, education and family planning sectors and now allocates ~20% of the annual national budget each year to these sectors. Other government investment in commercial sectors such as agriculture, industry, energy and rural development have also supported the eradication of poverty (UNDP, 2014; MoF 2014).

Provisioning services and material wellbeing

The proxy indicators of food provision services at a household level such as the mean crop have increased 16% between 1995 and 2010. Moreover, the evidence of increase (200%) in crop yield, despite a decrease (-29%) in mean cultivated area at household level suggests that people have intensified cultivation to cope with the growing need for food security. Farmers have adopted high yield varieties of crops (rice) which demand more fertilizer, pesticides and others input compared to the traditional local rice varieties (Hossain et al. 2015; Hossain et al. 2013; Ali 1995). That is why, in response to the intensive cultivation, the production cost has also increased ~7 fold as crop yields have risen. Increase in production cost and the lack of fair pricing (Hossain et al. 2013; IFPRI, 2013) may be the reason for decreasing income of households engaged in agriculture. Moreover, the stable level of crop yield and income per hectare both in 2000 and 2005, coincides with a rising lower poverty level and a stable trend in upper poverty level in 2005. Moreover, the bivariate plots (Figure 3f) suggest that crop production at household level is positively related to poverty alleviation, which is also linked with total rice production in the region (Hossain et al. 2015). The contribution of provisioning services in improving human wellbeing at region scale is also evident from national (Hossain

et al. 2007) and global studies (Raudsepp-Hearne et al. 2010). Despite showing the links between crop production and poverty alleviation there are several reasons to be cautious.

First, the recent HIES survey reports (2010) estimated that ~22% of the total poor households are engaged in agriculture, forestry and fisheries. Indeed, the data for average income from agriculture and for the poverty lower threshold line (monthly ~5,600 BDT per household) suggests that farmers are more likely to belong to the poor income level of the society, whereas fishermen and non-ecosystem-based people are more likely to be above the lower poverty line. Therefore, it would be useful to document the changing percentage of households living below the poverty line within different occupations, especially in the south west coastal part of the study area which is the second poorest region (just above the Rangpur division).

Second, the apparent link between poverty and crop production suggests that poverty could increase because of the increasing trends of environmental threats, like salinity and flooding (Ali, 1995; ADB, 2005; Hossain et al. 2015) that are more likely to affect disproportionately the crop production in south west coastal Bangladesh. In addition, increased fertilizer usage is also raising the nutrient loads to rivers through runoff (Hossain et al. 2015) that may affect the sustainability of fish production in future. This will not only increase the poverty in agricultural sectors but will also raise the threat of food security problems across the whole densely populated delta area. As Raudsepp-Hearne et al. (2010) have argued, despite the generally observed rise in provisioning services and poverty alleviation, the growing losses of regulating and supporting may be eventually be expected to feedback negatively on essential provisioning services, and in turn human wellbeing.

Third, besides the environmental threats, there is a risk of an increase in income poverty because of the increase in production costs, which are rising faster than crop production. Rising trends of fertilizer input to improve production in agriculture was evident in previous studies (Ali, 1995; Husain, 2001; Hossain et al. 2015) but costs may make fertilizer applications prohibitively expensive.

Fourth, in the case of shrimp farming, despite an increasing trend of total GDP from shrimp production the sector can produce other consequences, such as an increase in poverty and environmental pollution. The salinity increase due to shrimp farming reduces crop production and creates unemployment for farmers because of the low labour demand in shrimp farming compared to crop production (Swapan and Gavin 2010). All these indicate the potential of

human capital investment to improve the wellbeing of the population in response to environmental changes in the study area.

Achievements of MDG goals

Table 4 provides an assessment of the progress in achieving MDG goals at national and regional scales. The south-west coastal area has shown (Table 4) progress (similar to national achievements of MGD targets 4 and 5) by reducing child and infant mortality and improving maternal health. Although the maternal mortality was not covered in this study due to the lack of data, national trends on maternal mortality have also achieved the target of MDG 2015 (Chowdhury et al. 2011). However, the poverty eradication target (to halve figures between 1990 and 2015) has not been achieved for MDG 2015, despite showing significant poverty eradication (17%) within 15 years. Similarly, personal security and freedom of choice indicators have not achieved the MDG target in regional and national scale and it seems unreachable by 2015, with the exception of the provision of sanitation facilities which has progressed well (78%) compared to the national (51%) scale. In contrast, half of the households are still without coverage of electricity and achievable education attainment (primary education).

Moving beyond MDGs

This study suggests that achieving some of the SDG goals by 2030 is achievable while others will remain challenging. Our results suggest that reaching the goals for a healthy life for all (Goal 3: child and infant mortality) and sustainable use of water and sanitation for all (Goal 6: sanitation and safe drinking water source) appear to be achievable in this region by 2030. Great emphasis has been placed on reducing discrepancies within countries (Goal 10). In this study, with respect to reducing child and infant mortality generally and, specifically, to ensuring improved sanitation and births attended by skilled personnel, south west coastal Bangladesh is developing well compared to the nation as a whole.

On the more challenging side, quality education (Goal 4) needs to receive higher attention as half of the households are still without primary education attainment. The proposed SDGs also recommends the promotion of sustainable agriculture (Goal 2) by increasing productivity and farm incomes (Goal 2.3). These goals will be quite challenging to achieve by 2030 as the analysis shows that despite an increasing trend of mean crop production (16%) and crop yield (kg/ha) (192%) at household level, median income per hectare from agriculture production

has already decreased -2% between 2000 and 2010. Evidence of production cost increases from this study (also from Ali, 1995; Husain, 2001), as well as claims that farmers suffer from the lack of fair pricing (Hossain et al. 2013; IFPRI, 2013) suggest that poor regulation of commodity markets and weak agricultural investment needs to be reversed. Without these reforms, farmers may become demotivated with serious consequences for production, such as a reduction in jute production (Hossain et al. 2015) and for personal health (e.g. rising suicides among Indian farmers) (BBC, 2013; BBC 2015).

Although there has been significant poverty alleviation in this region, it is unlikely that it will achieve the SDG Goal 1 of poverty elimination in MDGs by 2015. Moreover, going beyond MDGs, towards achieving SDGs by 2030, may be even more challenging. Declining or stationary crop production coupled with ongoing environmental degradation (e.g. salinity rise, water scarcity) and projected climate change may impact negatively on incomes. This underlines the need to establish sustainable agriculture as the basis for poverty alleviation.

Conclusions

- Since the 1990s, child mortality and infant mortality have declined 50% and 75% respectively in the south-west coastal area of Bangladesh. Moreover, the number of births attended by trained personnel also increased (28%) from 1993 to 2011.
- Data for the material condition, such as incomes from agriculture, fishing and Non-ES based livelihoods, have increased from 1995 to 2010. Income from fishing has shown a sharply increasing trend since 2000. Even though GDP from shrimp farms is sharply increasing, as in other sectors such as agriculture, fishery and forestry, income from shrimp farms declined after 1995.
- Over this period, poverty has been reduced by an impressive 17%, a figure that is closely linked with crop production at the household level and total rice production over the region. However, associated production costs have increased 7-fold in response to the changing nature of farming aimed at raising crop yields to meet the growing demand for regional food security.
- Despite showing improving trends in all these human wellbeing indicators, including education for men and women, the region has only achieved the MDGs target for 2015 for child and maternal health. It has failed to meet several important targets (e.g. poverty alleviation, education, and sanitation) by 2015.

- Achieving the SDGs by 2030 will be highly challenging because of a) the increasing likelihood of environment threats and ecological feedbacks affecting agricultural and fishing incomes, and water availability; and b) the need to raise production levels through financial investment in poor households already constrained by high production costs.
- The study demonstrates the importance of detailed monitoring of human wellbeing trends at regional scales to support policy-making. Achieving the SDG targets by 2030 will require new policies and their implementation with continued monitoring of livelihoods as an essential element in monitoring progress. The study also provides the basis for ongoing attempts to define and model safe operating spaces (Dearing et al 2014) as the basis of determining sustainable land use within the region.

Acknowledgement

Md. Sarwar Hossain acknowledges financial support provided by a joint NERC/ESRC interdisciplinary PhD studentship award and the University of Southampton. John Dearing acknowledges the project 'Assessing health, livelihoods, ecosystem services and poverty alleviation in populous deltas' (NE/J002755/1) funded by the Ecosystem Services for Poverty Alleviation Programme (ESPA). The UK ESPA programme is funded by the Department for International Development (DFID), the Economic and Social Research Council (ESRC) and the Natural Environment Research Council (NERC). This is a Sustainability Science at Southampton publication.

References

- Azam, M.S., Imai, K.S., 2009. Vulnerability and poverty in Bangladesh. Working Paper No 141. Economics, School of Social Sciences University of Manchester, UK.
- ADB, 2005. Summery environmental impact assessment: South West Area Integrated Water Resources Planning and Management Project in Bangladesh. Asian Development Bank (ADB), Manila, Philippine.
- Ali, A.M.S., 1995. Population pressure, environmental constraints and agricultural change in Bangladesh: examples from three agro ecosystems. *Agriculture, Ecosystems and Environment* 55, 95-109.
- BBC, 2015. Delhi farmer death highlights countryside crisis. British Broadcasting Corporation (BBC). Accessed at <http://www.bbc.co.uk/news/world-asia-india-32408549>
- BBC, 2013. Indian farmers and suicide: How big is the problem? British Broadcasting Corporation (BBC). Accessed at <http://www.bbc.co.uk/news/magazine-21077458>
- BBS, 2011. Report of the household income and expenditure Survey 2010. Dhaka: Bangladesh Bureau of Statistics (BBS).
- BBS, 2010. Report of the household income and expenditure survey 2010. Bangladesh Bureau of Statistics (BBS) Dhaka Bangladesh.
- Boyd, J., Banzhaf, S., 2007. What are ecosystem services? The need for standardized environmental accounting units. *Ecological Economics* 63, 616-626. doi:10.1016/j.ecolecon.2007.01.002

- Balmford, A., Bond, W., 2005. Trends in the state of nature and their implications for human well-being. *Ecology Letters*, 8, 1218–1234. DOI: 10.1111/j.1461-0248.2005.00814.x
- Boyd, J., 2004. What's nature worth? Using indicators to open the black box of ecological valuation. *Resource*, 154, 18–22.
- BBS, 1997. Summary report of the household expenditure survey 1995-86. Dhaka: Bangladesh Bureau of Statistics (BBS). Dhaka, Bangladesh.
- Chowdhury, S., Banu, L.A., Chowdhury, T.A., Rubayet, S., Khatoon, S., 2012. Achieving Millennium Development Goals 4 and 5 in Bangladesh. *BJOG*, 118 (2) 36–46.
- CRA, 2006. Assessing the linkage between ecosystems, ecosystem Services & poverty reduction. Centre for Resource Analysis Limited (CRA), Final Report Uganda.
- Cervellati, M., Sunde, U., 2005. Human capital formation, life expectancy, and the process of Development. *The American Economic Review* 95, 1653-1672.
- Dearing, J.A., Wang, R., Zhang, Ke., Dyke, J.G., Haberl, H., Hossain, M.S., Langdon, P.G., Lenton T., Raworth, K., Brown, S., Carstensen, J., Cole, M., Cornell, S., Dawson, T., Doncaster, C.P., Eigenbrod, F., Flörke, M., Jeffers, E., Mackay, A., Nykvist, B., Poppy, G.M., 2014. Safe and just operating spaces for regional social-ecological systems. *Global Environmental Change*, 28, 227-238. doi:10.1016/j.gloenvcha.2014.06.012
- Daw, T., Brown, K., Rosendo, S., Pomeroy, R., 2011. Applying the ecosystem services concept to poverty alleviation: the need to disaggregate human well-being. *Environmental Conservation*, 38 (4), 370–379. DOI: <http://dx.doi.org/10.1017/S0376892911000506>.
- DHS, 2007. Bangladesh Demographic and Health Survey 2007. National Institute of Population Research and Training, Mitra and Associates, and Macro International.
- FAO, 2014. State of world fisheries and aquaculture. Food and Agricultural Organization of the United Nations (FAO) Rome.
- Hossain, M.S., Dearing, J.A., Rahman, M. M., Salehin, M., 2015. Recent changes in ecosystem services and human wellbeing in the coastal zone. *Regional Environmental change*. DOI 10.1007/s10113-014-0748-z
- Hossain, M.S., Hein, L., Rip, F., Dearing, J.A., 2013. Integrating ecosystem services and climate change responses in the coastal wetland development plans of Bangladesh. *Mitigation and Adaptation Strategies for Global Change* 20(2), 241-261. DOI 10.1007/s11027-013-9489-4
- Hossain, M., Lewis, D., Bose, M.L., Chowdhury, A., 2007. Rice research, technological progress and poverty: the Bangladesh case. In Adato M, Meinzen-Dick R (Editors). *Agricultural research, livelihoods, and poverty: Studies of economic and social impacts in six countries*. John Hopkins University Press and International Food Policy Research Institute 56-102.
- Husain, A.M.M., Hossain, M., Janaiah, A., 2001. Hybrid rice adoption in Bangladesh: A socioeconomic assessment of farmers' experiences. *Research Monograph Series No. 18*, BRAC and International Rice Research Institute, Dhaka, Bangladesh.
- IFPRI, 2014. The status of food security in the feed the future zone and other regions of Bangladesh. Results from the 2011-2012 Bangladesh integrated household survey. International Food Policy Research Institute.
- Islam, N., 2007. Exploring the drivers for conversion of agricultural land to shrimp farms in south west region of Bangladesh. MSc Thesis, Environmental Science Discipline, Khulna University, Bangladesh.
- Islam, M.S., Haque, M., 2004. The mangrove-based coastal and nearshore fisheries of Bangladesh: ecology, exploitation and management. *Reviews in Fish Biology and Fisheries* 14, 153-180.
- Irz, X., Lin, L., Thirtle, C., Wiggins, S., 2001. Agricultural productivity growth and poverty alleviation. *Development Policy Review*. 19(4), 449-466. DOI: 10.1111/1467-7679.00144

Kabir, K.M.R., Adhikari, R.K., Hossain, M.B., Minar, M.H., 2012. Livelihood status of fishermen of the old Brahmaputra River, Bangladesh. *World Applied Sciences Journal*, 16(6) 869-873.

MoF, 2014. Ministry of Finance (MoF). Accessed at: <http://www.mof.gov.bd/en/>.

Mottaleb, K.A., Mohanty, S., Hoang, H.T.K., Rejesus, R.M., 2013. The effects of natural disasters on farm household income and expenditures: A study on rice farmers in Bangladesh, *Agricultural Systems* 121,43-52. doi:10.1016/j.agsy.2013.06.003

McGillivray, M., 2006. Human Well-being: Issues, Concepts, and Measures. In McGillivray M (Ed.), *Human Well-Being Concept and Measurement*. Palgrave Macmillan.

McGillivray, M., Clarke, M., 2006. Human well-being: Concepts and measures. In McGillivray M (Ed.), *Human Well-Being: Concept and Measurement (Studies in Development Economics and Policy)*. United Nations University Japan.

MA, 2005. Ecosystems and human well-being: a framework for assessment. *Millennium Ecosystem Assessment (MA)*, Island Press.

OECD, 2013. OECD Guidelines on measuring subjective well-being. OECD publishing.

Raworth, K., 2012 A Safe and just space for humanity: Can We Live within the doughnut? Oxfam Discussion Paper Oxfam, Oxford, UK..

Raudsepp-Hearne, C., Peterson, G.D., Tengö, M., Bennett, E.M.; Holland, T., Benessaiah, K., MacDonald, G.K., Pfeifer, L., 2010. Untangling the environmentalist's paradox: Why is human well-being increasing as ecosystem services degrade?. *BioScience*, 60, 576-589. doi: <http://dx.doi.org/10.1525/bio.2010.60.8.4>

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F.S., Lambin, E.F., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., Nykvist, B., De Wit, C.A., Hughes, T., Van Der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P., Foley, J.A., 2009. A safe operating space for humanity. *Nature*, 461, 7263, 472-475. doi:10.1038/461472a

Szabo, S., Hossain, M.S., Adger, W.N., Mathews, Z., Sayem, A., Lazar, A.N., Ahmed, S. Soil salinity, household wealth and food insecurity in tropical deltas: evidence from South-west coast of Bangladesh. *Sustainability Science* (Submitted).

Santos-Martin, F., Martí'n-Lo'pez1, B., Garcí'a-Llorente, M., Aguado, M., Benayas, J., Montes, C., 2013. Unravelling the Relationships between Ecosystems and Human Wellbeing in Spain. *PLoS ONE* 8 (9), 1-12. DOI: 10.1371/journal.pone.0073249.

StataCorp., 2013. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP.

Swapan, M.S.H., Gavin, M. A., 2007. Desert in the delta: Participatory assessment of changing livelihoods induced by commercial shrimp farming in Southwest Bangladesh. *Ocean & Coastal Management* 54, 45-54. doi:10.1016/j.ocecoaman.2010.10.011

Sarwar, M.G.M., 2005. Impacts of Sea Level Rise on the Coastal Zone of Bangladesh. MSc Dissertation. Programme in Environmental Science, Lund University, Sweden.

Scherr, S.J.A., 2000. Downward spiral? Research evidence on the relationship between poverty and natural resource degradation. *Food Policy* 25, 479-498. doi:10.1016/S0306-9192(00)00022-1

UNDP, 2014. Millennium Development Goals (MDGs). United Nations Development Program in Bangladesh. Accessed at <http://www.bd.undp.org/content/bangladesh/en/home/mdgoverview/>. Accessed : 29th Oct, 2014

UNEP/IISD, 2004. Human well-being, poverty and ecosystem services. Exploring the links. United Nations Environmental Programme (UNEP) and International Institute for Sustainable Development (IISD).

Wood, 2007. Food energy intake and cost of basic needs: Measuring poverty in Bangladesh. The Journal of Development Studies, 34, 2, 66-101. DOI: 10.1080/00220389708422512

Zhang, K., Dearing, J.A., Dawson, T.P., Dong, X., Yang, X., Zhang, W., 2015. Poverty alleviation strategies in eastern China lead to critical ecological dynamics, Science of the Total Environment 506–507, 164–181. doi:10.1016/j.scitotenv.2014.10.096

List of Tables and Figures

Table1. Human welling indicators based on MA (2005) and OECD (2013) classification

Dimension		Indicators	Temporal Scale	Data source
MA	OECD			
Health	Quality of life	Child mortality (probability of dying before the first birth day)	1993-2011	DHS
		Infant mortality (probability of dying between the first and fifth birth day)		
		Proportion of births attended by skilled health personnel (%)		
Material	Material condition	Sector wise Household income Production cost	1995-2010	authors own calculation (AOC) from HIES Income from shrimp farms and production cost (Islam, 2007)
		Gross Domestic Product (GDP)	1974-2005	BBS
		Poverty–Percentage of people living below the upper and lower poverty thresholds	1983-2010	BBS and Wood 2007
Security	Quality of life (Personal security)	Access to electricity, sanitation, drinking water source	1995-2010	AOC HIES data
Freedom of choice and action	Quality of life	Education (% of people completed primary education)- Man and women Access to mass media (television and newspaper)	1993-2011	DHS

Table 2. Income (Adjusted) (Bangladeshi Taka-BDT) and sample size for agriculture, fishing and Non-ES. Household samples (household size) selected from the HIES surveys (1995, 2000, 2005 and 2010) ranged from 211 to 437 for ‘agriculture’, from 280 to 347 for ‘fishery’, from 686 to 1,063 for ‘Non-ES’ based households.

	Mean	Median	Standard deviation	Household size
Agriculture				
1995	64,262	45,549	68,267	211
2000	71,231	40,665	91,785	333
2005	56,656	21,967	77,477	428
2010	54,661	37,117	47,528	437
Fishery				
2000	54,592	5,630	216,458	280
2005	60,614	24,140	37,292	504
2010	96,297	18,211	253,558	347
Non ES				
2000	80,761	67,559	77,946	681
2005	76,019	65,836	52,208	927
2010	87,654	72,843	77,198	1063

Table 3 Agriculture investment and production (crops and fish) at the household level.

Indicators	Mean	Median	Standard deviation
Income per hectare (BDT)			
2000	73,677	53,783	90,398
2005	58,170	41,424	81,784
2010	179,812	52,421	1,214,920
Crop production (Kg)			
1995	3,278	2,251	3,505
2000	3,531	2,100	4,246
2005	3,649	2,059	4,807
2010	3,817	2,700	3,683
Crop yield (Kg/ha)			
2000	3,636	2,520	2,964
2005	3,631	2,471	2,957
2010	10,648	3,867	5,4548
Production cost (BDT)			
1995	5,212	3,568	5,483
2000	15,065	6,709	21,286
2005	31,695	8,787	83,620
2010	48,786	26,633	76,467
Production cost per hectare (BDT)			
2000	19,951	10,441	47,951

2005	44,950	15,879	154,115
2010	123,738	69,760	550,557
Fish catch (kg)			
2000	186	45	914
2005	233	90	646
2010	465	160	1,252

Table 4. Target and progress of MDGs in regional and national scale of Bangladesh

Indicators	Regional Target by 2015	2010	2005	2000	1995	National Target by 2015	National -2010
Child mortality	16.3	9	22.5	25.7	24.45	48	53
Infant mortality	53.83	42.5	63.5	70	80.75	31	43
Proportion of births attended by skilled health personnel (%)	50	20	16.45	14.85	11.4	50	31.7
Poverty	26.63	36.475	43.425	43	53.275	27.05	31.5
Improved Sanitation	100	78.04	72.94	49.75	45.85	100	51.05
Improved drinking water source	100	90.32	92.31	94.16	95	100	95.99
Electricity	100	50.32	41.05		30.42	100	55.26
Education	100	42.825	41.7	39.7	34.475	100	48.42

Figure 1 Bangladesh delta zone study area showing location in Bangladesh (inset), the three greater districts (three different gray color) and the Sundarbans (in green)

Accepted manuscript

Figure 2 Trends of quality of life indicators in the study area from 1993 to 2011.

Figure 3 Trends of material wellbeing indicators : a-b) Total and sector-wise gross domestic product (GDP), trends of poverty (c) income (d) and production cost from shrimp farms (e) and linkage between poverty and crop production at household level (f)