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Potential answers to the adaptation to and mitigation of climate change through the adoption of underutilised crops

Colm Bowe

Introduction

Evidence increasingly indicates that most of the observed warming over the last 50 years is likely to have been due to the increase in greenhouse gas concentrations, released by the burning of fossil fuels. Global temperatures are expected to rise between 1.4 and 5.8 °C during this century depending on the level of greenhouses gases we emit (IPCC, 2001). Impact can be expected on many atmospheric systems leading to fundamental changes in weather patterns and extreme events resulting in a greater incidence and magnitude of hurricanes, floods, and droughts (IPCC, 2001; Jarvis *et al.*, 2006). These changes will in turn impact the productivity and structure of natural ecosystems, agriculture, rangelands and forestry with consequential effects on component plant and animal species and on many aspects of human welfare (IPCC, 2001).

The effects of climate change may have a greater impact on some nations than others and will vary in distribution across people, places and times. The impact on people's livelihoods will be greatest in the tropics and subtropics, mainly because these countries depend on agriculture for export earnings, national income, and employment. Their populations include many smallholder farmers, who are dependent on agriculture or who are directly dependent on goods and services from ecosystems, either as a primary or supplementary source of food, fodder, building materials and fuel, and they have few alternatives (IPCC, 2001; Nyong and Isabelle, 2006). Poverty, limited resources and poor infrastructure constrain these countries' abilities to invest in and develop technologies to enable adaptation to climate change.

Impacts of climate change on crops

Impacts of climate change will be felt at the level of the individual crop species, at the farming system level, and at the level of the natural resource base upon which rural communities depend (Verchot *et al.*, 2005). In the tropics and subtropics, where some crops are near their maximum temperature tolerance, and where dryland, non-irrigated agriculture dominates, yields are likely to decrease with even small increases in atmospheric temperature (IPCC, 2001). Studies have shown that although some reduction in yield in the major crops may be offset by direct CO_2 fertilisation effect, mainly at high altitude, the general trend in the tropics will be for a negative impact on the yield of annual crops due to increased temperature and decreased soil moisture (IPCC, 2001; Challinor *et al.*, 2006). It is estimated that climate change will place an additional 80-125 million people (±10 million) at risk of hunger by the 2080s, 70-80 percent of whom will be in Africa (Parry *et al.*, 2004)

The solution to problems caused by climate change in these countries is likely to include the adoption of 'minor', 'traditional' 'neglected' or 'underutilised' crops. Only a very small number of plant species available are used for food production and making greater use of the genetic resources available would enable the potential of 'new' landraces and wild relatives of the major crops or of underutilised crops to be realised.

The role of underutilised crops

Underutilised crops are often highly adapted to local niches and marginal areas, where they can provide sustainable production and food security of poor rural communities particularity under poor conditions. Although often ignored by scientists and poorly represented in seed banks, they may be well known to locals, who have detailed indigenous knowledge. Underutilised crops contribute significantly to maintain diversity-rich and hence more stable agro-ecosystems, and represent strategic crops for fragile ecosystems (IPGRI, 2006).

Tree crops

The diversification of the farming system with many crops is a risk avoidance strategy of many traditional farmers, which may place them in a better position to cope with climate change (Jarvis *et al.*, 2006). Such systems enhance resilience against the effects of adverse weather conditions, poor soils and pests *sensu lato* (Verchot *et al.*, 2005). Many underutilised fruit tree species are used in traditional farming systems and provide a diverse range of products (timber, fodder, resins and fruits) often being of high value in comparison to annual crops. They also provide environmental services such as the reducing land degradation associated with rainfall variability and poor agricultural practices. In regions where climate variability is common place and adverse impacts of climate change are expected, the role of trees in buffering against production risk can be of great importance (Ong and Leakey, 1999).

In Western Kenya fallow species such as fast-growing tree or shrub legume species like *Sesbania sesban*, *Crotalaria grahamiana* and *Tephrosia vogelii* have a high potential to restore soil fertility and reduce soil erosion as well as providing wood products. They also provide improved infiltration of water, while reducing runoff and transportation of sediments, improving water storage in the soil, and buffering agricultural crops against water deficiencies (Verchot *et al.*, 2005).

Other successful agro-forestry systems include the parkland system in the dryland of Africa and the Sahelian Eco-Farm (SEF) (Verchot *et al.*, 2005). In the parkland system trees such as the ana tree (*Faidherbia albida*) contributes significantly to maintaining crop yield through biological nitrogen fixation and shade-induced reduction of soil temperatures, particularly at the time of crop establishment (Vandenbeldt and Williams, 1992). The trees sheds their leaves during the rainy season thereby providing favourable micro-climate while minimizing tree–crop competition. Other parkland multipurpose tree species such as shea butter tree (*Vitellaria paradoxa*) and néré (*Parkia biglobosa*) have shown similar benefits Jonsson *et al.*(1999). The strength of the Sahel Eco-Farm lies in the fact that it promotes crop diversification and system resilience by combining various species of trees or shrubs (*Acacia colei*, *Zizyphus mauritiana*), grass (*Andropogon gayanus*) and annual crops such as roselle (*Hibiscus sabdariffa*), with food crops (millet and cowpea) (Verchot *et al.*, 2005).

Biodiversity

Enhancing plant biodiversity in agricultural landscapes can produce positive interactions that could contribute to controlling pest and disease outbreak and spread, as well as combating weed species, the effects of both will be modified by changes in climate. Bio-diverse push-pull systems may provide a solution to pests (Khan and Hassanali, 2003). Effective methods to combat weed by diverse systems include shading (Verchot *et al.*, 2005), allelopathy (Gallagher *et al.*, 1999) and trap effects triggering the germination of the weed seeds without being suitable hosts (Rao and Gacheru, 1998).

Biodiverse agro-forestry systems may also provide some mitigation to climate change. Even if not primarily designed for carbon sequestration, they present a unique opportunity to increase carbon stocks in the terrestrial biosphere. As small-scale farmers are enrolled in carbon-offset projects, we will need to develop a better understanding of the implications for carbon sequestration by agro-forestry and what it means to livelihoods (Verchot *et al.*, 2005).

Environmental effects

Underutilised crops that are adapted to extreme environments may provide one solution to mitigate the detrimental effects of floods and droughts. Approximately 1.7 billion people, one third of the world's population, live in countries that are water stressed and this may increase to about 5 billion by 2025. Projected climate change could further decrease stream flow and ground water recharge in many of these water stressed countries (IPCC 2001).

Many underutilised species show drought tolerant properties. Deep-rooted small millets, such as finger millet (*Eleusine coracana*), foxtail millet (*Setaria italica*) and little millet (*Panicum sumatrense*) are extremely drought tolerant, very nutritious and have higher vitamin levels than rice. Drought tolerant legume species such as bambara groundnut also show great potential (Azam-Ali *et al.*, 2001). Other drought resistant underutilised crops include colocynth (*Citrullus colocynthus*, a multiple uses cucurbit species indigenous to India) and safflower (*Carthamus tinctorius*) which hold both drought and salt tolerance traits (IPGRI, 2006). Drought tolerant underutilised fruit tree species include tamarind (*Tamarindus indica*) (El-Siddig *et al.*, 2006) and ber (*Ziziphus mauritiana*) (Azam-Ali *et al.*, 2006)

Many coastal areas are already experiencing increased levels of sea flooding, accelerated coastal erosion, and salinization of freshwater and agricultural land. The large deltas and low-lying coastal areas of Asia are particularly at risk from sea level rise. Increase precipitation intensity, could increase flooding of low lying areas with flash floods becoming more frequent particularly in parts of India, Nepal and Bangladesh. Human land-use change (i.e. conversion of forestland to cropland and pasture) is already a prime force in the cause frequent floods, and climate change will exacerbate these problems leading to soil erosion, loss of soil fertility, depletion of water resources and loss of crops.

Bangladesh

The tidal floodplain at the southern end of the Ganges delta in Bangladesh is one such region that is highly vulnerable to global climate change. The region includes the world's largest single block of mangrove ecosystem the Sunderbans; more than 70 per cent of the land is low-lying, barely one meter above mean sea-level and below high-tide level. The region is already experiencing the effects of rising sea levels and increased flooding; farming systems have been seriously disrupted with few coping mechanisms available to local people to adjust to the new situation. The CDP-CARE RVCC Project (Hossen and Roy, 2005) was developed as the first initiative of its kind in Bangladesh to work directly at the grassroots level to address vulnerabilities caused by or enhanced by climate change. A number of adaptation strategies to reduce vulnerability to climate change incorporated the use of underutilised species.

Floating vegetable gardens were used to grow traditional crops. The floating beds were made using water hyacinth and straw of aman paddy along with duckweed and other aquatic plants. Crops grown on these floating beds include saline tolerant underutilised vegetables such as bitter gourd (*Momordica charantia*), lal sak (Red Amaranth) (*Amaranthus gangeticus*), kohlrabi (*Brassica oleracea* L. var. *gangyloides*), palang sak (*Spinacea oleracea*) and Panikachu (*Colsacea esculenta*).

Saline tolerant varieties of reeds such as mele (*Cyperus tagetiformis*) and saline-tolerant and drought-resistant fruit and timber trees have been planted for longer-term income generation. This involved the establishment of community tree nurseries and distribution of indigenous varieties of coconut and mango and including some underutilised species such as sapodilla (*Manilkara achras*), guava (*Psidium guajava*), neem (*Azadirachta indica*) and kewra (*Pandanus fascicularis*) (a mangrove species). Cultivation of such species reduces pressure on the mangrove forests and may provide a viable crop on land which is regularly flooded with saline water, as well as providing a buffer to flooding. Other mangrove or mangrove associated species which may have potential include mangrove apple (*Sonneratia caseolaris*), bakau putih (*Bruguiera cylindrical*), sea almond tree (*Terminalia catappa*) and portia tree (*Thespesia populnea*).

Biofuels

The increasing need for energy and the drive for sustainable fuels have meant the bio-energy market has been growing massively in the last 5-10 year. Promoting production and use of biofuels in the developing world may have the potential to provide greater energy security and socio-economic development, especially in rural areas (UNCTAD Biofuels Initiative team, 2006). Some caution has been stressed in relation to biofuel crops in the light of the negative environmental and social impacts caused by the large-scale export-oriented production (Biopact, 2006; Energy Bulletin, 2006) and for this reason there has been increased focus on the use of non-edible crops (BP, 2005).

Underutilised crops which have been found to have high potential for biofuels include the oilseed crop jatropha (*Jatropha curcas*) (Pramanik, 2003) and jojoba (*Simmondsia chinensis*) (Selim *et al.*, 2002), which is resistance to drought and salinity. Other tropical crops which show potential for bioenergy in the tropics include tropical grasses such as miscanthus and bamboo, cassava (*Manihot esculenta*) and tropical tree species such as eucalyptus, acacia and rubberwood for solid fuel markets (Biopact, 2006).

Models

A number of underutilised crops show potential for both the mitigation and adoption to climate change but it is important to identify where these species can be grown today and how this may change under future climate scenarios. Lack of data on the physiological response of these species to the environment and information on yield crop modelling has been very limited. Exceptions include global modelling of the potential yield of bambara groundnut (Azam-Ali *et al.*, 2001) These models can be applied to future climate scenarios in order to identify distribution and yield under future climates. However, development of such process-based crop models requires extensive time and financial investment in greenhouse and field experiments in order to measure physiological responses.

The increasing availability of plant species location data in the form of passport information from herbarium records and germplasm collections may enable modelling of the potential distribution of a large number of underutilised crops quickly. Once geo-referenced, such data when combined with environmental data (e.g. climatic, soil) will allow the quantitative modelling of the potential distribution and therefore potential production areas for plants species for which limited or no empirical growth and yield data exists. Figure 1 shows the potential global distribution of tamarind (*Tamarindus indica*) based on geo- referenced herbarium records.

However farmers do not grow species, they cultivate landraces, cultivars or varieties that have morphological characteristics which meet their needs. While such models provide information on the effects of climate change on the crops at the species level, and may provide information on the niche requirement of subpopulations, they provide little information on the ecological requirement of high value landraces, cultivars or varieties. It is clear that the focus should now be on identifying (through farmer participation and research) and modelling land races, varieties or cultivars of underutilised species that adapted to future environments and meet nutritional and market requirements under both current and future climate scenarios.

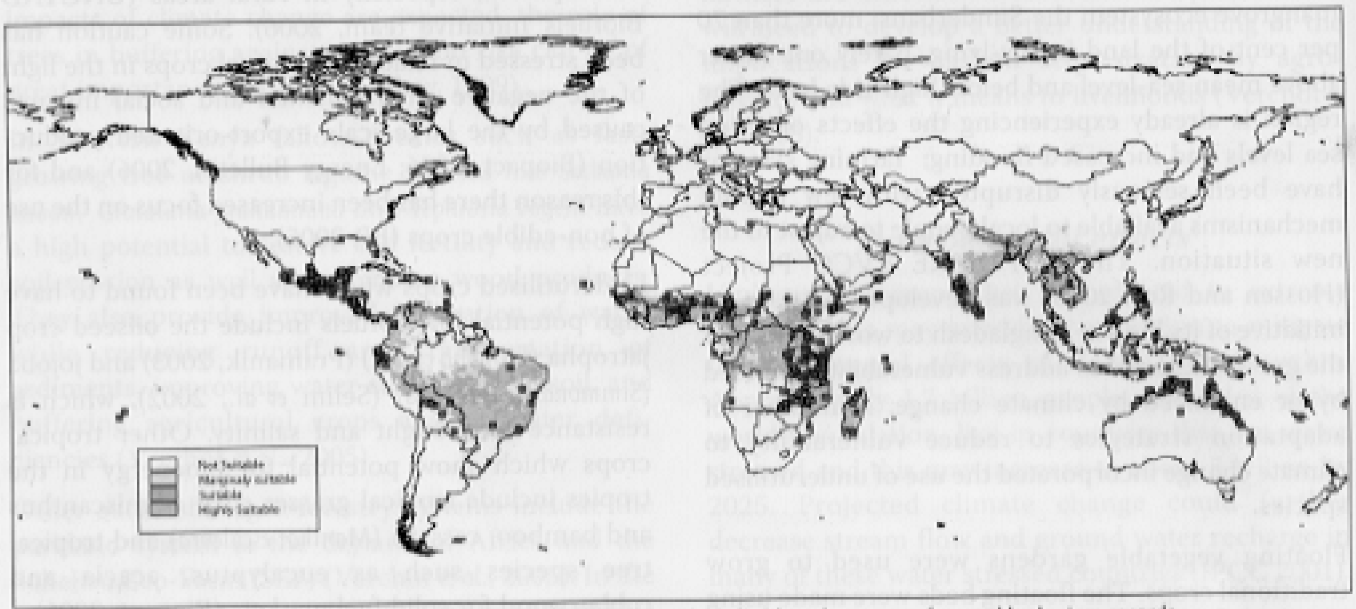

Fig. 1. potential global distribution of tamarind (*Tamarindus indica*) based on geo- referenced herbarium records.

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