Impacts of and Adaptation to Climate Variability and Climate Change in the East African Community

A Focus on the Agricultural Sector

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1. Introduction

1.1. Rationale

This paper is the third in a series of reports that are aimed at discussing the vulnerability of African countries to climatic hazards, the meaning of climate change for these countries and the existing efforts in terms of policy and research to tackle the climate problem. The first two reports focused on the west-African Sahel and southern Africa, respectively. This one deals with East Africa, and more specifically the East African Community (EAC) that regroups Kenya, Tanzania and Uganda.

The focus is on agriculture simply because this sector is the mainstay of the majority of African economies. Agriculture is the base for food security, the biggest employment provider, a major contributor to the GDP, and an important source of foreign exchange earnings. At the same time, agriculture is one the most vulnerable sectors to climate variability and climate change, especially under rainfed conditions.

It is a widely held belief that climate change is unavoidable and any effort undertaken to curb anthropogenic greenhouse gas (GHG) emissions today will be useful only to avoid the further warming of the globe in the future. The atmosphere, it is now understood, is characterised by a certain inertia, which means that the GHG load that has accumulated in it for centuries as a result of human activities will take a long time to subside. Until that happens (this can take several decades), these heat-trapping gases will continue to warm the earth and disturb the global climate.

The United Nations Convention on Climate Change (UNFCCC) recognises this fact. Indeed, the Convention recommends that, while the global community is looking for an effective framework to stabilise and reduce GHG emissions, it should also find ways and means to adapt to the unavoidable changes that are already occurring and those that will occur in the near future. There are many signs that climatic changes are already happening as suggested by the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) and many other reliable sources.

The Kyoto Protocol, places great emphasis on mitigation efforts whether through the reduction of GHG emissions or the creation of GHG sinks in the terrestrial biosphere. However, even if the most effective reductive measures are implemented, the impacts will not be seen immediately. Therefore, developing or reinforcing adaptive mechanisms to deal with the negative effects of climate change must be a high priority.

Adapting to the perverse effects of climate change is more pressing for low-income countries. Although African countries can claim to be least responsible for man-made climate change, given their negligible share in the global GHGs emissions, they stand to bear the greatest impact nonetheless. This is due to such factors as: (1) heavy dependence of most African economies on agriculture, livestock, fisheries and other forms of natural resource use, all of which are strongly influenced by the climate; (2) most African countries lack the financial, human and institutional resources to adequately deal with extreme climatic events. The more frequent and intense climatic extremes such as the El Niño/La Niña-related floods and droughts that have been afflicting the eastern and southern parts of the continent in recent years are believed to be some of the manifestations of long-term climate change.

1.2. The East African Community

The (new) East African Community or EAC (www.eac.int) was created in the year 2000 and is composed of three countries: Kenya, Tanzania and Uganda. This was an effort to revive the defunct East African Community that existed between 1967 and 1977. The EAC region covers a total land area of more than 1.7 million km^2 (Table 1). From a climatic viewpoint, East Africa is characterised by a great spatial variability, ranging from arid/semi-arid to sub-humid and humid conditions. In Kenya, for instance, rainfall ranges from about 200 mm in the north-western and eastern parts to 1200-2000 mm in the areas bordering Lake Victoria and the central highlands east of the Rift Valley. Over two-thirds of the country receive less than 500 mm annually. Rainfall in Kenya follows a strong bimodal seasonal pattern, with a long rainy season occurring in March–June and a short rainy season occurring in October–December. In Uganda, rainfall is also bimodal and varies between 750 and 2000 mm. There is one rainy season from March to June and another one from August to October. In Tanzania, there are both unimodal (December–April) and bimodal (March–May and October–December) rainfall regimes, depending on the area. In general, annual rainfall ranges between 500 and 2500 mm.

Table 1. Population and GDP estimates of the East African Community (EAC) countries (source: CIA World Fact book: www.cia.gov/cia/publications/factbook).

	Area (km^2)	Population (million)§	Purchasing Power Parity GDP*	
			National (US$ billion)	Per capita (US$)
Kenya	582,650	33.8	34.68	1,100
Tanzania	945,087	36.8	23.71	700
Uganda	236,040	27.3	39.39	1,500
EAC	1,763,777	97.9	97.78	1,100

§ July 2005 estimate

* 2004 estimate

The EAC has a combined population of nearly 98 million people. The aggregated purchasing power parity GPD of the region was estimated at US$ 98 billion in 2004. Population distribution is extremely uneven in East Africa. For example, in Kenya nearly 80 percent of the population lives on the 16 percent of the land area that has high to medium agricultural potential. The remaining 20 percent of the population live in arid and semi-arid areas, which make the remaining 84 percent of the total land area. Despite the differences in their per capita GDP, all three countries are classified as low income countries (Table 1).

1.3. Importance of agriculture in East Africa

The EAC countries rely heavily on agriculture for food security, economic growth, employment and foreign exchange earnings (Table 2). About 80% of the people in the region live in rural areas and depend directly or indirectly on agriculture for their livelihoods. Although its share in the national GDPs varies between countries, agriculture remains an important economic sector in the EAC. It accounts for 75 percent of the foreign exchange earnings of the region and provides raw materials for most industries. Coffee and tea are the major export crops for the region. Agricultural production systems are more concentrated and more intensive in the high potential areas such as the highlands. Livestock also plays an important role in the economies of the EAC countries and falls under two systems: the diary system, predominant in high potential areas, and the pastoral system in the semi-arid areas.

Table 2. Role of agriculture in the economies of the EAC countries

	Employment (%)	Contribution to GDP (%)	Contribution to forex earning (%)	Source
Kenya	80	24.5	60	GoK, 2002
Tanzania	80	49.6	75	GoT, 2003
Uganda	81	42.0	90	GoU, 2002
EAC	80	38.7	75	

1.4. State of food security in the EAC

Cereal production in the region has steadily increased from 1961, driven both by an improvement in yield per unit area and an expansion of the harvested area (Figure 2). Yet because of its rapidly growing population, East Africa is still food insecure. From around 29.5 million in 1965, the combined population of the three EAC countries increased rapidly; reaching 89 million in 2000, i.e. tripling in 35 years. As a result, the land to population ratio has undergone a free fall over the last four decades. Low cereal yields (less than 2 tonnes per hectare) has kept food production from keeping pace with population growth, prompting per capita food production to nose-dive from the middle of the 1970’s (Figure 3).

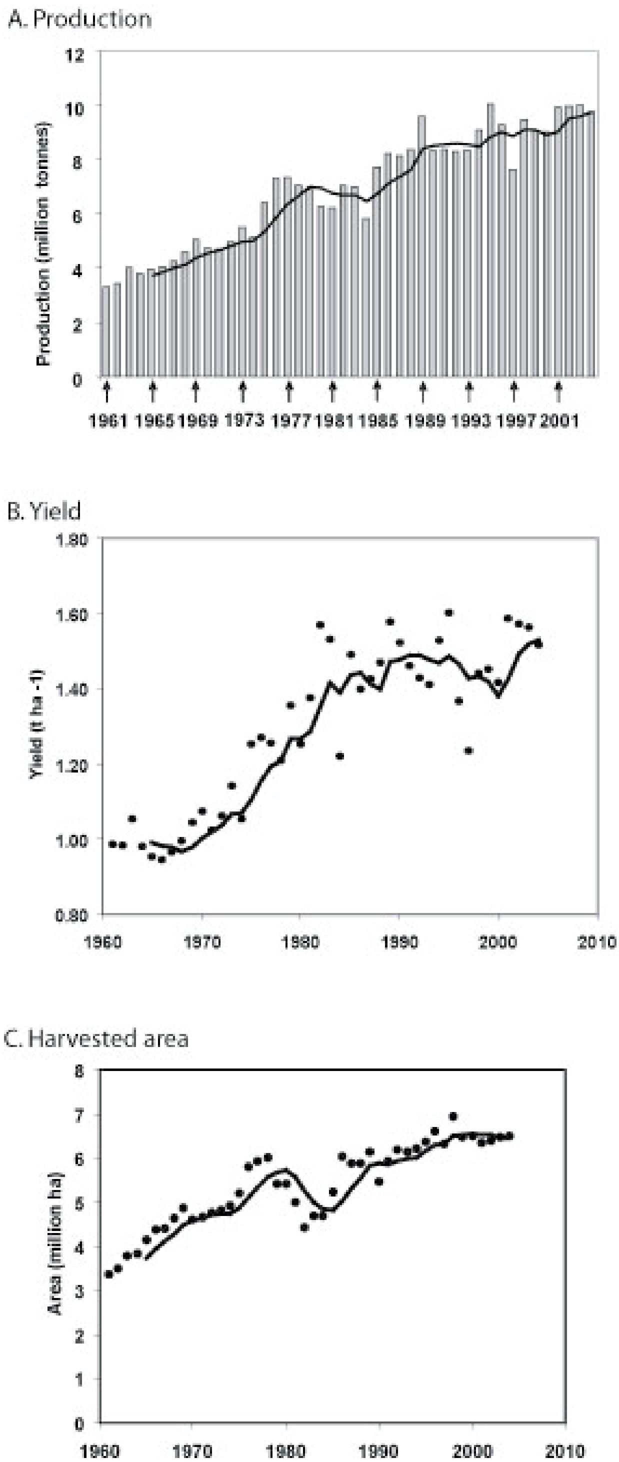

Figure 2. Cereal production, average yield and harvested area in the EAC ensemble between 1961 and 2004. The curves represent the 5-year running averages of the various parameters.

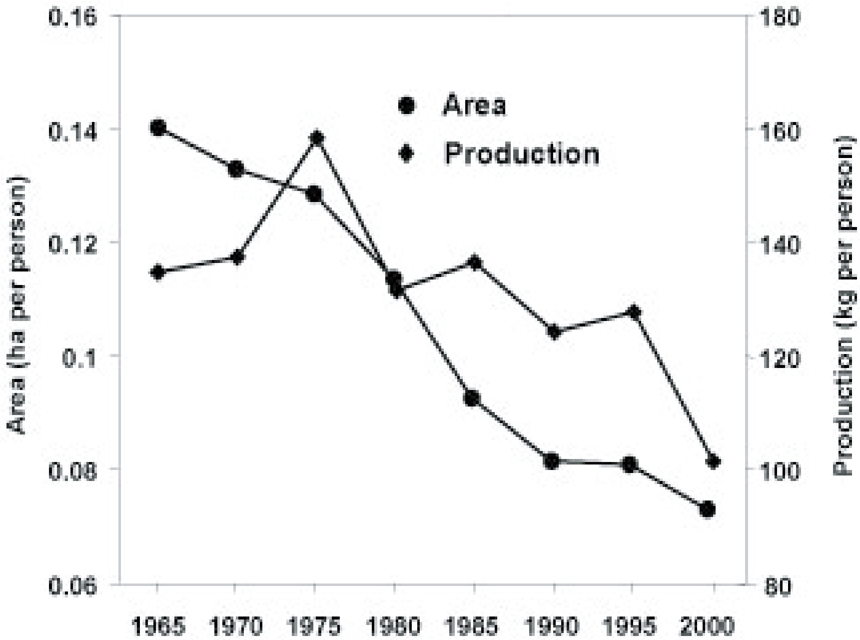

Figure 3. Changes in per capita harvested area and food production in the EAC ensemble between 1965 and 2000 (data from FAOSTAT).

2. Climate variability in the EAC

2. 1. Recent climatic trends

It is now widely accepted that the climate is changing all over the world. The global mean temperature increased by 0.6° C in the last century, and the 1990s were particularly hot years (IPCC, 2001). Moreover, there is growing scientific evidence that this warming of the world's climate is due to the greenhouse gases (GHGs) that have built up in the atmosphere, especially in the last century. East Africa is also showing signs of climate change. For example, in Uganda an analysis of the temperature records shows a sustained warming particularly over the southern parts of the country with the minimum temperature rising faster than the maximum temperature. With a rate of 0.3° C, the southwest is the fastest warming region of Uganda (GoU, 2002). The disappearance of the snow caps on Mount Kilimanjaro and the Ruwenzori peaks provides strong evidence of the warming trend in East Africa.

Evidence of increasing climatic instability in East Africa manifests itself in more frequent and intense weather extremes. For instance, Kenya has suffered a series droughts and floods which have had devastating socio-economic and environmental consequences. Here is a chronology of the most recent events:

- ❖ January 1997: the Kenyan Government declared a state of national disaster after a severe drought threatened the livelihoods of 2 million people.
- ❖ 1997/98. Heavy El Niño-induced rains caused destructive floods in many areas of the country.
- ❖ 2000: Kenya was again hit by drought, the worst in 37 years. In June, an estimated 1.7 million people were in need of food assistance. By December, this grew to 4 million people and the Kenyan government appealed to the international community for food aid.
- ❖ 2002: devastating floods hit many areas of the country leading to human death by drowning and landslides, loss of properties and displacement of people.
- ❖ 2004: the long rains failed and the subsequent crop failure left more than 2.3 million people in need of assistance, pushing Kenyan President Mwai Kibaki to issue an urgent appeal to international donors for relief assistance for drought-affected households in mid-2004.
- ❖ April 2005: the UN World Food Programme (WFP) estimated that up to 2 million Kenyans, most of them residents of arid or semi-arid regions of the country, needed food assistance due to failed rains.

In Tanzania, recent extreme weather events have caused severe damage to the economy. Over the last four decades, the country has been hit by a string of severe droughts, the most recent occurring in 1971, 1975-76, 1983, 1985, 1987, 1992, 1996-97, 1999-2000. An observation of the rainfall data in the 20th century has also revealed an increased variability in the monthly rainfall (Paavola, 2004). The La-Niña event of 1996/97 was responsible for the severe drought that occurred in most parts of the country leading to insufficient rainfall for hydroelectric power generation and urban water supplies. Crop failure was widespread and rangelands could not support livestock resulting in massive production shortfalls. Tanzania is also prone to flooding and some the most severe episodes in recent years occurred in 1993, 1997/98 and 2000/01.

Droughts and floods have also occurred in Uganda in the past, but the last few decades have seen an increase in the frequency of these extreme weather events. Records of dry and wet years for Uganda between 1943 and 1999 show a marked increase in the frequency of very dry years over the past 30 years, especially in the northern and western parts of the country. There was a particularly severe drought in 2001, causingfood insecurity and social conflicts as people squabbled over dwindling water and pasture resources (Orindi and Eriksen, 2005).

The persistent deficits in rainfall are threatening the food and livelihood securities of millions of people in East Africa. The number of people in Kenya, Uganda and Tanzania depending on relief food has been on the rise over the last few years. In addition to its direct effect on the agricultural sector, the lowering of the water level in rivers reduces the potential for hydropower generation, leading to interruptions of economic activities and declines in manufacturing output. This was the case in Kenya, where poor rainfall between 1998 and 2000 led to drastic power rationing schedules. The Kenya Power and Lighting Company lost an estimated US$20 million as a result of the drought. Many industries were forced to reduce or stop their operations, causing Kenya's GDP to shrink by 0.3% in 2000 (GoK, 2005).

2.2. The 1997/98 El Niño

According to many observers, the 1997/98 El Niño was the most severe in the last century and East Africa was one of the world's worst hit areas. The sub-region underwent heavy human and economic losses. Thousands of people died directly due to flood related accidents and indirectly due to water- or vector-borne diseases (cholera, malaria, etc). The region's infrastructure was badly affected, roads and bridges were washed away, isolating rural areas from the mainstream activities, bringing road transit between the port of Mombasa and Nairobi to a standstill for several weeks.

The agricultural sector was badly hit. In Kenya there was heavy damage to the food crops and coffee industries. The livestock sector also underwent severe losses due to increased disease infection (especially Rift Valley Fever), drowning, damaged water facilities (dams, boreholes, water troughs), and disruptions in market infrastructure and road systems. The total losses in the agricultural sector were estimated at more than US$230 million (GoK, 2002). In Uganda, although the direct and indirect losses in the agricultural sector were not estimated in monetary value, they were also likely to be in hundreds of millions of US dollars. Hundreds of hectares of wheat were destroyed and several tea estates flooded, making tea picking a difficult exercise. Coffee exports dropped by 60 percent between October and November [1997] due to disruptions in the transport system (GoU, 2002).

Despite these massive losses, the abundant rainfall was beneficial in some areas. In Kenya, for instance, the tea sector outputs went up by about 20 percent in 1997/98. Also, in some agriculturally marginal areas of Eastern Province, production of cereals, tubers and root crops were above average. In general, there were improved fodder and water stocks in the arid and semi-arid areas, leading to an improvement in livestock performance in those areas.

2.3. Coping with and adapting to climate variability: what do communities do?

Local communities, especially dryland dwellers, have used a wide range of strategies to deal with climatic hazards such as drought. Whereas coping refers to the short-term responses that are utilised to face a sudden, unanticipated climatic risk, adaptation is a more long-term process that often entails some socio-economic and institutional changes to sustain livelihood security (Orindi and Eriksen, 2005). Farmers have minimised or spread risks by managing a mix of crops, crop varieties and sites; staggering the sowing/planting of crops; and adjusting land and crop management to suit the prevailing conditions (Eyzaguirre and Iwanaga; 1996; van Oosterhout, 1996; Tengberg et al., 1998; O'brien et al., 2000; Blench, 2003). Pastoralists have also developed useful strategies including: transhumance (strategic movement of livestock to manage pasture and water resources); distributing stock among relatives and friends in various places to minimise the risk of losing all animals if a drought strikes one particular area; and the opportunistic cultivation of food and cash crops to meet some of their needs (Paavola, 2004; Orindi and Eriksen, 2005).

In many cases, however, these adjustments in cropping and animal husbandry practices alone may not be enough to respond to climatic hazards. Increasingly, rural communities are embracing non-agricultural activities to broaden their livelihood options. Natural resources have provided a useful fallback where farming has become riskier due to increased climate variability. Gathering of forest products such as fruits, timber, medicine, firewood and honey for home consumption and for sale is becoming more important in East Africa. Eriksen (2000) identified sixteen strategies used by the local communities in Mbitini (Kenya) and Saweni (Tanzania) locations to deal with droughts, and six out of these sixteen strategies were based on the use of indigenous plant species. Other activities include making bricks for sale in urban areas and migration to more favourable areas and to urban settlements to seek paid employment (Paavola, 2004).

Two important questions that need to be asked, however, are: (1) to what extent are these coping/adaptive strategies working? and; (2) will these strategies be relevant in the advent of climate change in the future? To vulnerable people, coping with disasters is often synonymous with search for survival. As a result, some of these survival responses may undermine an individual or family's capability to cope with disasters in the future. For instance, overstocking (keeping a high number of animals), expansion of agricultural land to compensate for low yields, and cutting of trees for firewood or to make charcoal are common coping strategies. While these offer short-term relief to local communities, they also lead to land degradation that has a multiplier effect on the impacts of natural disasters. Other factors such as demographic pressure, conflicts, inadequate agricultural/environmental policies, and trade are also negatively impacting some of these coping mechanisms.

The most worrisome aspect of climate change is not the shift in long-term average climate, but rather the increased frequency and magnitude of climatic extremes. Isolated cases of drought have been dealt with quite successfully either at the individual/household level or through well established social networks. Climate change erodes these coping mechanisms by causing climatic extremes with a frequency and intensity that do not give the affected people enough time to recover. The recurrent droughts in Africa have led to the degradation of the resource base and forced millions of farmers to sell their assets, forcing them into absolute destitution.

In conclusion, climate change may bring about a new set of weather patterns and extremes that are well beyond what the local communities in East Africa are capable of dealing with. This, coupled with the many non-climate constraints that undermine the adaptive capacity of these communities, warrants that external help is necessary to rebuild or enhance the social and ecological resilience among rural communities. Indigenous coping and adaptive mechanisms on their own will certainly not be enough to respond to climate change. However, they can serve as a useful entry point for interventions by governments, relief organisations and development agencies in the fight against climate change.

2.4. Coping with and adapting to climate variability: what do the governments do?

There are ongoing efforts at the regional and national levels to mitigate the negative impacts of extreme climatic events. For instance, a regional drought monitoring centre was established in Nairobi in 1989 with the help of WMO and UNDP. The centre is currently known as the Drought Monitoring Centre, Nairobi (ICPAC: www.icpac.net) .The main objective of this centre is to contribute to monitoring adverse impacts of extreme climatic events on agricultural production and food security, water resources, energy, and health. The centre has played a key role in providing the sub-region with weather and climate advisories and more importantly, timely advance warnings on droughts, floods and other extreme climate related events. The DMCN covered the Greater Horn of Africa that comprises: Burundi, Djibouti, Ethiopia, Eritrea, Kenya, Rwanda, Somalia, Sudan, Tanzania, and Uganda.

Despite these efforts, there has been an inherent problem in the way climate variability is tackled in the region. Instead of promoting long-term structural development that would reduce the vulnerability of the local communities, African governments, together with their development partners, tend to provide relief after disasters have struck. This approach has two major shortcomings: (1) relief only offers short-term solutions to crises; and (2) it keeps the local community in a chronic state of dependency. Obviously, this is an ineffective and costly way of addressing climate related disasters. For example, during the 2000/2001 fiscal year, Kenya spent Kshs 10.5 billion on relief food (excluding contributions from WFP and other sources). It is argued that with a quarter of this amount, the country could have put in place a more effective and sustainable system to addresses long term food insecurity in arid and semi-arid areas (GoK, 2004).

3. East Africa and climate change

3.1. How responsible are the EAC countries?

One principle that has perhaps kept the climate change negotiations going since the climate convention was agreed is that of *common but differentiated responsibilities*. The question therefore is not who is responsible for climate change but rather to what extent one is responsible. It is accepted that the rich nations have the largest GHG emissions on a per capita basis although a few developing countries do have large per capita emissions. Apart from South Africa which makes it in the top 20 of the world's big GHG emitters, sub-Saharan Africa has the lowest per capita emissions in the world. Yet, the per capita emissions of the EAC region are even lower than the average for sub-Saharan Africa. In fact, the inventories of GHG sources and sinks in the initial national communications to the UNFCCC have shown that the EAC countries are net sinks rather than net sources of GHGs.

One irony of climate change is that countries that have little responsibility for climate change, such as the EAC countries, are the most vulnerable to the adverse effects of climate change. The sad fact is that in the majority of cases, the reason why a given country has low GHG emissions is the same reason for its vulnerability: underdevelopment. Being a low GHG emitter or sink should not, however, absolve a country from participating in the global effort to curb GHG emissions. Due to the immense potential it has for economic growth, the developing world including Africa can become a great GHG emitter in the future if clean sources of energy are not developed and promoted now.

3.2. How vulnerable are the EAC African countries?

Vulnerability is a product of two factors: the exposure of an entity to a stress factor, such as climatic shocks, and the capability of that entity to respond to that stress factor. The following paragraphs discusses some of the reasons why the EAC countries are so vulnerable to climate change.

3.2.1. The climate

Geography is a key factor in defining who is more exposed to climate change and who is not. Many areas of East Africa are prone to climate variability. However, the arid and semi-arid areas, where annual rainfall below 500 mm is commonplace, are by far the most vulnerable. Both the amount and distribution of rains between and within seasons are unpredictable. These conditions make the sub-region particularly vulnerable to the negative impacts of climate change, especially in relation to food and livelihood security. Periodical droughts and floods are part of the climate system, and people livelihoods in arid and semi-arid areas often approach the brink of collapse when severe droughts occur.

Dryland dwellers in East Africa know a lot about climate variability. For instance, work by the relief organisation Oxfam (www.oxfam.org.uk) has captured local knowledge among the Turkana of north-western Kenya about the most severe drought events, the latest of which are:

- Namotor or "bones exposed" in 1960, due to the high number of dead animals;
- Kimududu or "the plague that killed humans and livestock" in 1970;
- Lopiar or "sweeping everything away" in 1979-80;
- Longuensil or "when the man with no legs came" occurred between 1992 and 1995. The name of the drought was in reference to an Oxfam member of staff with a disability;
- Kichutanak or "it has swept away everything, even animals" is the prolonged drought that started in 1999 and is still ongoing.

One peculiar aspect of climate change is that, in many instances, it will render desperately dry areas even drier and wet areas wetter. While any of these two outcomes will have serious implications for the communities and the environment, an increased frequency and intensity of climatic extremes such as droughts and floods will be an even bigger challenge in the future.

3.2.2. Fragile economies

Poverty is a major factor influencing the vulnerability of people to climate change. Despite the poverty reduction strategies implemented by the various countries, the latest national MDG reports do not show a very encouraging picture of the EAC region.

Uganda is by far the best MDG performer in the region and one of the best in Africa. Yet, the latest economic trends show that it may be off-track on the poverty and health targets. An average income growth rate of 5 percent between 1990 and 2000 helped the country reduce income poverty from 56 percent in 1992 to 35 percent in 2000 and improve its Human Development Index. However, economic growth has slowed down since 2000 and poverty is on the rise again. At the same time, the inequalities have been increasing since 1997 as translated by a rising Gini coefficient (from 34 in 1997 to 42 in 2002). Poverty is highly concentrated in rural areas, especially in the north and east and is higher with subsistence farming communities (UNDP, 2005).

The other two countries are in a much worse shape than Uganda. Kenya performed economically well in its first years of independence growing at a rate of more than 6% between 1964 and 1973. However, that growth rate has been declining since, culminating in a recession of 0.3 percent in 2000. Between 1992 and 2002, the Kenyan economy grew at an average rate of 1.5 percent against a population growth rate of 2.5 percent. As a result, the proportion of people living daily on less than one US dollar increased from 44.7 percent in 1992 to 56 percent in 2002 (GoK, 2005). In the meantime, child mortality has also been on the rise, and Kenya's HDI declined from 0.546 in 1990 to 0.474 in 2003. If the current trend continues unabated, the poverty rate is expected to reach 67 percent by 2015. Despite a timid recovery in recent years (the economy grew by 2.8 percent in 2003 and 4.3 percent in 2004), Kenya's chances of halving the number of poor by 2015 compared to the 1990 level are remote.

Tanzania's situation is not encouraging either. The country has also seen its HDI drop. Tanzania is one of the poorest countries in the world. The number of people currently living with less than a dollar per day stands at close to 50% of the population. One in six children die before the age of five, and almost one-third of the population will not live until the age of forty. These human welfare indicators are the culmination of almost two decades of slow growth and under-investment in basic social services. Economic reform programmes have succeeded in raising per capita growth rates during the 1990s, but this has largely bypassed the rural and urban poor who will be the most affected by climate change.

3.2.3. High dependence on agriculture and natural resources

Overdependence of people on agriculture for their livelihood is a major cause of vulnerability in Africa, and the East African countries are no exception. The fact that this sector (directly and indirectly) employs about 80 percent of the active people and provides 75 percent of the foreign exchange earnings in the EAC is problematic. More worrying is the fact that agriculture is almost exclusively pegged on rainfall with little use of modern technologies. This narrow livelihood base is one of the factors that make the East African countries highly vulnerable to global changes including climatic and non climatic factors. For example, it has been reported that the drop in world coffee prices is, to a great extent, responsible for Uganda's recent economic downturn (UNDP, 2005).

3.2.4. Environmental degradation

Although droughts and floods are intrinsically damaging, their effects are often magnified by other factors. In Africa, it is often a combination of degraded soils, a dwindling resource base and climate extremes that traps the smallholder farmers in a vicious circle of food insecurity and poverty. Land degradation is rampant in East Africa and the causes are now well understood. Although natural factors such as drought play an important role, a significant part of the problem is man made. In the highlands, many soils are degraded due to the intense population density and the over-exploitation of natural resources. Continuous cropping without replenishing soil fertility and inadequate tilling practices have been identified as some of the major causes of land degradation in the region (Jonsson et al., 2003). According to FAO, only 15 percent of the farming households in Tanzania were using mineral fertilisers. The average amounts of nutrients applied to cultivable land were as low as 3.26 kg per ha of nitrogen, 1.9 kg per ha phosphorus and 1.08 kg per ha, potassium.

3.2.5. Conflicts

There is a two-way relationship between climatic disasters and conflicts. On the one hand, droughts can force communities to compete for scarce natural resources such as water, agricultural land and pastures. For example, although the Turkana and other pastoralist groups in northern Kenya have always haggled for access to water and pastures, tensions have intensified in the last few decades because of the recurrent drought. The dry season grazing areas on which the Turkana traditionally relied in times of drought have seriously dwindled, thus reducing their adaptive options.

Studies on dryland livelihood systems have also shown that there are clear links between cattle raiding and drought. Since raiding is a strategy to restock herds during or after a drought, it is little surprise that prolonged droughts lead to more frequent and more violent raids. In Uganda, cattle rustling, inter-tribal fighting and overall environmental insecurity have been blamed on the increased frequency of drought. In the north, ongoing rebel attacks on civilians have prevented farmers from reaching their fields. Internally displaced people and refugees in the region rely on food aid from the WFP for more than 80 percent of their basic food needs.

On the other hand, conflicts (whatever the causes are) can prevent vulnerable communities from accessing the resources that would help them cope with disasters in normal times. Growing insecurity is seriously jeopardising the coping capacity of the dryland communities of East Africa, increasingly exposing them to destitution and food insecurity.

3.3. Anticipated impacts of climate change on the agricultural sector

The East African region is already among the most food insecure in the world, and climate change has the potential to aggravate the problem. Climate predictions for the region indicate that humid areas are likely to become wetter while dry regions are expected to become even drier (Orindi and Murray, 2005). Some likely outcomes are:

- semi-arid areas could expand intothe higher potential areas;
- crop yields could decrease as a result of drought and disease pressure;
- livestock could suffer from fodder and water shortages as well as diseases; and
- the potential for heavy floods may increase during the long rainy season and negatively affect agricultural production and the wellbeing of the rural communities.

A study by Jones and Thornton (2003) concluded that all the three EAC countries will experience a decline in maize production in the 2055 horizon if current trends are maintained. Keeping the cultivated area unchanged, decreasing yield per unit area will lead to production shortfalls in relation to the 2000 baseline. These shortfalls are estimated to be 90,000, 638,000 and 165,000 tonnes for Kenya, Tanzania and Uganda in 2055, respectively Another study carried out in Tanzania has predicted that maize yield will declineby 33 percent towards 2075 if atmospheric CO_2 doubles and temperature increases by 2-4° C. In the Tabora – Dodoma area, maize yield could decrease by as much as 80 percent (Mwandosya et al., 1998; Paavola, 2004).

Increased precipitation due to climate change can also interfere the livestock sector. For example, in the aftermath of the 1997-1998 El Niño, outbreaks of Rift Valley Fever (RVF) in Somalia and northern Kenya killed as much as 80 percent the livestock, threatening the livelihood of millions of people. Higher temperatures as a result of an increased concentration of atmospheric CO_2 will also affect the major export crops in the region (Figure 2).

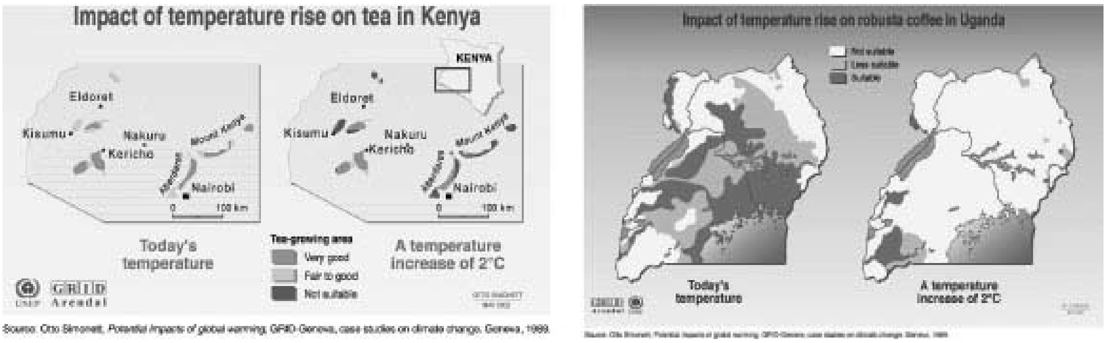

Figure 2. Potential impacts of global warming on the major export crops in East Africa (Simonett, 1989)

Given the high diversity of ecologies and socio-economic conditions in East Africa, it is not easy to make generalisations on the effects of future climate change over the region. For instance, while increased rainfall may cause flooding and increase disease pressure in some areas, it can also improve productivity in other areas. This was observed during the 1997/98 El Niño event. The big question is how the positive effects and the negative effects will influence each other.

3.4. Climate change and the MDGs

When, in 2000, the global community met in New York in the framework of the Millennium Summit, eight goals were defined. There was consensus that these goals will be used to monitor progress towards achieving sustainable development in the world. These Millennium Development Goals (MDGs), are:

Goal 1: eradicate extreme poverty and hunger
Goal 2: achieve universal primary education
Goal 3: promote gender equality and empower women
Goal 4: reduce child mortality
Goal 5: improve maternal health
Goal 6: combat HIV/AIDS, malaria and other diseases
Goal 7: ensure environmental sustainability
Goal 8: develop a global partnership for development

To achieve each of the MDGs, clear and measurable targets have been defined for 2015, using 1990 as baseline (UNDP, 2003). For instance, achieving Goal 1 requires that the proportion of the world's poor and hungry in 2015 should not be more than half of the 1990 figure.

In East Africa, an additional warming of the globe can adversely influence the MDGs in many ways:

1) A warmer climate, characterised by increased frequency and intensity of weather extremes, may reduce soil moisture and water runoff to rivers in the drylands, increase floods and disease outbreak in the wetter areas, thus hampering crop production, which has a major influence on food security and poverty reduction (Goal 1);
2) Increased aridity will exacerbate land degradation, desertification and loss of biological diversity in arid and semi-arid areas, a set of processes that undermines environmental sustainability (Goal 7);
3) A long-term rise in temperatures, and occasional flooding due to events, may increase water and vector-borne diseases. Poor nutrition due to crop failure can exacerbate disease impacts (Goal 6);
4) Increased frequency of climatic disasters can remove children from school (Goal 2) due to increased poverty, food shortage, isolation (for example when roads are damaged by floods), and child abandonment;
5) Women often get a disproportionate share of the burden when disasters strike because they have less opportunities than men; this can undermine their education and development, and affect their welfare and that of children (Goals 3, 4, 5);
6) The importance of agriculture (Box 1) and the heavy dependence of the EAC countries on natural resources mean that more intense and frequent droughts and floods will have a major bearing on development in general. A collapse in national income, combined with the heavy costs of disaster response operations, has the potential to reduce the ability of governments to invest in key socio-economic sectors (Goals 1-7).

3.5. Adaptation to climate change: an analysis of the national communications

All the three EAC countries have submitted their initial national communications (INCs) to the UNFCCC. One of the requirements in these INCs was to carry out climate change impacts and vulnerability studies in some key sectors. There is a strong focus on the agricultural sector given its socio-economic and cultural importance in Africa but also its high dependency on climate. Table 2 summarises what the EAC countries believe the impact of climate change on the agricultural sector will be as well as a few proposed measures to deal with the problem.

However, climate change is not about some changes in average climatic parameters that will abruptly happen in the future. It is also worth considering that climate change will not have only negative aspects, and therefore climate change adaptation strategies should seek both to reduce the negative impacts and to capitalise on the positive aspects. For instance, an El Niño event in East Africa can lead to destructive floods, but it can also boost productivity in some arid and semi-arid areas. Therefore, putting in place mechanisms to reap the benefits from surplus rainfall in the dry areas should constitute an important part of climate change adaptation strategies. This can only be achieved if climate information is used to influence decision making in the agricultural sector. Unfortunately, to date only Uganda has emphasised the importance of using climate information in climate change adaptation.

Additionally, adaptation to climate change will involve much more than issuing a 'wish list'. The strategies that the various governments will put in place and the steps required to translate these adaptation measures into concrete actions have not come clearly in the INCs. Therefore, the EAC countries should address these shortcomings in their second and subsequent national communication. As LDCs, Tanzania and Uganda have another unique opportunity to come up with clearly defined adaptation strategies through the National Adaptation Plan of Action (NAPA) process.

Box 1. Agricultural development and the MDGs

Agriculture is the foundation upon which food and nutrition security is to be built in developing countries. It is also the foundation upon which attainment of the Millennium Development Goals must be built. There are direct links between agricultural productivity, food security and poverty. In Africa, most of the poor live in rural areas, and both hunger and malnutrition are higher in these areas compared to urban areas.

Increased agricultural productivity translates into better diets, increased income and better food security. These effects, in turn, translate into impacts in all of the MDGs. For example, MDG 2 is to achieve universal primary education. In many rural areas smallholder farming families cannot afford to send their children to school. Education fees and the opportunity costs of sending children to school rather than having them work on the farm are often prohibitive.

MDG 3 is to promote gender equality and empower women. Most of the cultivation activities on African farms are the responsibility of women. Women depend mainly on farming to secure food and earn money for their families. Increasing agricultural productivity contributes directly to empowerment of women.

MDG 4 and 5 are to reduce child and maternal mortality, respectively. About half of all child deaths occur because of malnutrition (von Braun et al., 2004). Mildly underweight children are twice as likely to die as normal weight children. Micronutrient deficiencies are also linked with maternal mortality. Anaemia is particularly problematic, as it affects women during pregnancy, delivery and during the first few months post partum. More than 65,000 women die of anaemia each year (von Braun et al., 2004). Improved diets through diversified agricultural production can contribute significantly to child and maternal health.

MDG 6 is also focused on health, and at reducing infectious diseases like HIV/AIDS, tuberculosis, and malaria. Again, agriculture and food and nutrition security play an important, if underappreciated role in addressing these problems. Nutrition is a key factor in the transition from HIV to AIDS. Individuals with HIV require up to 50 percent more protein and 15 percent more calories than healthy individuals. Anti-retroviral therapy is less effective in people with nutritional deficiencies.

MDG 7 is to ensure environmental sustainability, including biodiversity, critical habitats, safe water, sanitation, atmospheric greenhouse gas accumulation. Traditionally, agriculture has been part of the problem, but it can also be part of the solution. Pressure to increase agricultural production has led to land degradation, erosion and soil depletion. Ecosystems have been destroyed and biodiversity threatened. For agricultural to be environmentally sustainable, long-term environmental costs need to be appreciated and taken into account in planning processes. Policies and regulations need to be in place to encourage efficient energy, water, fertiliser and pesticide use. Agricultural development needs to be closely linked with sound natural resource management. An ecosystem approach to land management is necessary to accomplish this.

MDG 8 focuses on global partnerships. Specific targets include job creation, and the creation of fair trading and financial systems. In order to be meaningful in Africa, the realisation of this goal must include diversification of rural economies through value addition to agricultural products and rationalisation of global trade in agricultural commodities.

Table 3. Future climate change, its expected effects on crops and the various adaptive strategies proposed by EAC countries in their initial national communications (INCs) to the UNFCCC

Country	Baseline period	Predictions	Effects on crops and livestock	Adaptive measures	Source
Kenya	1961-1990	0.5-3° C temperature increase by 2030 Mild rainfall increases in region from Lake Victoria to Central highlands east of the Rift Valley. Reduced rainfall for rest of country More droughts, floods, severe storms, hail-storms, frost and changes in soil struc-ture.	Increase in grain yields by 2030 Decrease in bean yield	Drought: introduction of drought tolerant or drought escaping crops, irrigation and fertilisers; high yielding, more resistant, early maturing and dis-ease- and pest-tolerant crops; disposal of stock before onset of drought. Floods: flood control measures in prone areas, soil liming and application of organic fertilisers to mitigate soil leaching Frost: promotion of agroforestry and application of mulching material Severe storms and hailstorms: plant trees for windbreaks Changes in soil structure: application of organic fertilisers, establishment of soil conservation structures and soil liming; discourage farmers from clear-ing vegetation on steep slopes and also in arid and semi-arid areas.	GoK (2002)

Tanzania	3-5° C temperature rise Increased rainfall of 5-45 percent in bimodal areas Decreased rainfall of 5-15 percent in the unimodal areas.	Maize yield decrease of 33 percent throughout the country	Change of crops; drought resistant crops; irrigation; cover crops; reduced tillage; mulching; food programmes and other social security programmes	GoT (2002)
Uganda	2-4° C increase in temperature by 2100. Overall decrease or slight increase in rainfall depending on model.	Effects on maize not clear Areas conducive to dairy cattle rearing may reduce due to increased heat.	Apply weather and climate information; irrigation; promote water harvesting and develop effective irrigation systems; crop diversification including the use of drought resistant crops; soil and water conservation; investment in processing and storage facilities; modernising the livestock sector through pasture improvement and the use of better performing breeds	GoU (2002)

4. Adapting to climate change: the role of agricultural research

There are many ways in which agricultural and natural resource management research and development (R&D) can contribute to climate change adaptation. For the sake of this paper, however, only four R&D areas will be considered: improved crop varieties, soil and water conservation, agroforestry, and the use of seasonal climate forecasting to strengthen agriculture.

4.1. Drought mitigation through plant breeding

Drought has always been a great limiting factor to agricultural development in sub-Saharan Africa, particularly in East Africa. However, many observers are now linking the increase in the frequency and intensity of drought events in recent years to climate change. The CGIAR centres and their national partners in the region strive to develop and disseminate new crop varieties that are better adapted to the changing environment. For instance, the International Centre for Maize and Wheat Improvement (CIMMYT) has initiated important projects to develop and distribute maize varieties that are able to yield more than the currently available cultivars under conditions of limiting moisture, low fertility and disease/pest pressure while bearing no yield penalty under optimal conditions (CIMMYT, 2004). New breeding methods were introduced to eastern and southern Africa in the late 1990's through collaborative projects with the national agricultural research services (NARS).

This has paid off since extra-early maize varieties have been released in East Africa (Figure 4), and the farmers that experimented with these varieties have stressed that they prefer them to Katumani, (the most popular drought tolerantmaize variety in the region) and other hybrids used in the area. In western Kenya, more than 100,000 farmers were exposed to the new stress tolerant varieties developed by CIMMYT in 2004, and 32,000 hectares were estimated to be planted with stress tolerant germplasm in Kenya.

Another important initiative by the CGIAR to cope with drought in East Africa is the pigeon pea research work spearheaded by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). With Financial support from the African Development Bank (ADB), the Danish International Development Agency (DANIDA) and the Rockefeller foundation, ICRISAT and its various partners have succeeded in expanding the cultivation of pigeon pea in East Africa since 1991. Pigeon pea is a hardy and drought-tolerant crop that can survive when crops like maize fail.

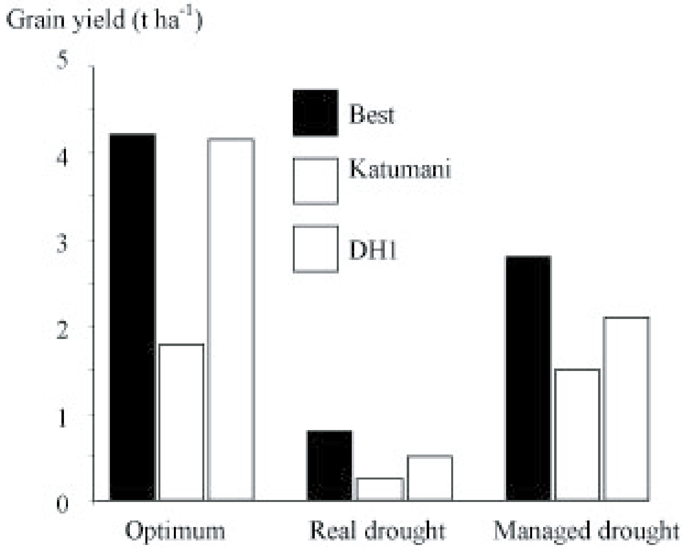

Figure 4. Yield of best stress tolerant population (Best), a commercial hybrid (DH1) and Katumani composite across 7 environments in East Africa in 1999 (adapted from CIMMYT, 2004).

With (maize) crop failures becoming more frequent in recent years and since the situation is likely to worsen due to climate change, especially in the semi-arid areas of Kenya, crops such as pigeon pea are likely to gain in importance. However, most of the pigeon pea varieties traditionally grown in East Africa take too long (6 to 10 months) to mature, making them vulnerable to a range of stresses such as mid-season dry spells, terminal drought, diseases and insect pests. As a result, yields are generally low (300-500 kg per hectare). Some of the new varieties developed by ICRISAT escape drought by maturing in just three months. Medium-duration varieties have also been developed that can be harvested twice or thrice during the year. These new varieties can provide a decent harvest even in drought years, when traditional landraces normally fail. In good years, they can double or triple landrace yields (ICRISAT, 1998, 2005).

Are the new varieties adopted?

A survey has shown that the maize varieties recently developed by CIMMYT are being adopted in the EAC region (Table 4). By 1997, about 46 percent of the 3.7 million hectares of maize were planted with these new varieties. However, this figure masks the big discrepancies that exist between countries. While in Kenya about 73 percent of the maize growers were using improved varieties, 45 percent and 90 percent of farmers in Uganda and Tanzania, respectively still rely on their farm-saved seed.

Table 4. Maize area planted to traditional and modern varieties in eastern Africa (source: CIMMYT global maize impacts survey)

	1997 maize area planted (000 ha)	Planted to farm-saved seed[a] (%)	Planted to modern varieties		
			OPVs[b] (%)	Hybrids (%)	Total
Kenya	1,505	27.5	7.5	65.0	72.5
Tanzania	1,564	90.0	4.0	6.0	10.0
Uganda	598	45.3	50.0	4.7	54.7
EAC	3,667	54.3	20.5	25.2	45.7

[a] Includes landraces and very old OPVs and hybrids grown from advanced-generation recycled seed

[b] Includes area planted to recycled OPV seed

The adoption of new technologies, especially improved seeds, is not straightforward in Africa. Rohrbach et al. (1999) identified three critical conditions for the adoption of new varieties: the early involvement of farmers in varietal selection, the rapid release in response to farmer preferences and government commitment to the rapid multiplication and dissemination of high-quality seed. Farmers' inability to access seeds is a recurring problem in Africa, and this can be due to a lack of information, a lack of incentives (poor links to output markets) or means to purchase them. As a general rule, African governments have largely failed to develop and implement effective seed production and delivery schemes. Meanwhile most of the private seed companies target the large commercial farmers.

There is a strong need to find solutions to the seed problem among the smallholder farming communities. Strategic partnerships between the CGIAR centres and their partners from national programmes, NGOs and community-based organisations are needed to achieve this objective. Training farmers so that they can produce high quality seeds and helping them enter into partnerships with seed companies is one way forward. Another promising strategy is the voucher programme suggested by ICRISAT. The premise is to give vouchers to vulnerable households who take them to identified rural retailers instead of being given seed directly by relief organisations. This may lay the foundation for an effective seed system, even after the withdrawal of relief organisations. The development of market links is also an important factor encouraging adoption of new varieties. NGOs and the private sector have a strong role to play in this process (ICRISAT, 2005)

Conclusion

With weather patterns changing due to climate change, the introduction or development of new crop varieties is essential. Therefore, plant breeding has an important role to play in climate change adaptation. In East Africa, international research institutions such as CIMMYT and ICRISAT have been involved in the development of crop varieties that are better adapted to less favourable conditions. There are some success stories that can be replicated as shown by the CIMMYT maize work and ICRISAT's pigeon pea work . However, the biggest challenge remains how to establish a policy framework that will facilitate the widespread use of these stress tolerant varieties among the poor smallholder farmers of East Africa. Achieving this requires the involving many stakeholders including international research organisations, national programmes, the private sector and community-based organisations. However, since future climate change may alter temperatures and weather patterns in a way that communities have never experienced , new research questions arise. These are a few of them:

- How will today's stress tolerant varieties behave in conditions of increased atmospheric carbon dioxide, higher temperatures and altered rainfall pattern?
- How can heat tolerance genes be effectively incorporated into existing drought-tolerant varieties?
- What will be the changes in agricultural pest and disease incidence and how will this affect crop production?
- What will be the role of biotechnology in developing sturdy varieties that can respond to the challenges posed by climate change?
- How can we find the right strategies for an efficient seed production and distribution system that can suit the smallholder farmers' circumstances?

4.2. The role of rain water harvesting

Land degradation has a magnifying effect on climate extremes. In many areas of Africa, a very small proportion of rainwater is used by crops, the remaining being lost through runoff and deep percolation. Therefore, since climate change is likely to result in reduced or erratic rainfall over large areas of East Africa, techniques that can improve rainwater infiltration or its storage for immediate or future use by crops or livestock are increasingly needed. Rainwater harvesting (RWH) is defined as a method for inducing, collecting, storing and conserving local surface runoff for agriculture in arid and semi-arid regions (Hatibu and Mahoo, 2000). RWH comprises two major components.

In situ rain water harvesting

There are numerous techniques that improve the infiltration and storage of rain water where it falls to allow its better use by crops. Many of these also come under the umbrella of soil and water conservation (SWC). Techniques such as deep tillage, manure application, terracing, soil bunds and micro-catchments are in use in many areas of Africa and significantly improve the water holding capacity of soils and mitigate the negative effects of agricultural drought.

A study conducted in eastern Kenya has revealed that farmers in the area use a number of SWC techniques, the most common being trash lines, stone bunds, *Fanya Juu* and log lines (Tengberg et al., 1998). Trash lines are made of crop residues that are placed in surface strips that follow the contour. Stone bunds are permanent structures of stones also aligned along the contour; they are common on stony soils. They form a semi-permeable type of barrier but with time an impermeable barrier develops. *Fanya Juu*, which means 'make it up' in the Swahili language, refers to structures in which a type of back slope trench is dug and soil from the trench is thrown up slope to form a riser bank. The premise is to trap rainwater.

Research has been going on to assess the impact of these SWC techniques in terms of crop yield. For example, research from CIMMYT evaluated the potential of open and tied ridges for mitigating the effects of drought in northern Tanzania and eastern Kenya. During years of inadequate moisture, ridging has been shown to significantly increase maize yield, especially when early-maturing varieties are used. Using tied ridges in moderate drought year resulted in more than 100 percent yield increase in the Arusha region of Tanzania and in the Jijiga region of Ethiopia, respectively compared to the control (flat planted maize). In a good rainfall year, ridging can allow the later-maturing varieties to attain their full potential (CIMMYT (2004). Similar results have been shown by Jensen et al. (2003).

Macro-catchment techniques

These systems involve the collection of runoff from large areas which can be at an appreciable distance from where it is being used. When large volumes of rain water are harvested, this water can be stored in dams or water holes. Small dams are normally constructed in rolling topography where creeks can be found and the dams are constructed across them. However, the macro-catchment system may have its downside in relation to soil conservation since it can create erosion in one part of the land (the catchment) and siltation in the other (the cropped basin). Through this process, a great amount of fine particles, nutrients and organic matter can be lost in the eroded fraction from catchment areas. For this reason careful planning of macro-catchment systems is necessary so as to avoid the degradation of land from which runoff is occurring (Hatibu and Mahoo, 1998).

Although there have been some success stories, many governments have failed in their efforts to implement RWH or SWC projects mainly due to the fact that most of these techniques are labour intensive and/or demanding in energy. For example, deep tillage is an efficient technique for absorbing and storing water in the soil. However, it requires high draft power which is normally in short supply in many parts of East Africa (Hatibu and Mahoo, 2000). But even if the labour exists, farmers may not want to invest much effort on SWC especially if they can have access to off-farm income sources (Mbaga-Semgalawe and Folmer, 2000). Low market-prices for agricultural produce often make the opportunity costs of SWC techniques too high and can discourage farmers from adopting them. This, coupled with uncertain land tenure, makes soil and water conservation financially unattractive. Thus, external support from governmental institutions and development agencies is needed to implement soil and water conservation projects.

In the west Usambara and north Pare areas of Tanzania, for instance, GTZ has provided various forms of support to help farmers adopt SWC techniques. These include the revival of the labour sharing groups (locally known as *kiwili* and *vikwa*); providing inputs such as improved seed varieties and implements at subsidised prices; and assistance in the establishment of trees nurseries for agroforestry (Mbaga-Semgalawe and Folmer, 2000). While providing such incentives helps initiate a project, it has its own setbacks as well. Adopters may be more interested in the incentives rather than being driven by a genuine concern to solve a pressing environmental problem. This is why in many instances the withdrawal of programme funding has led to the abandonment of introduced technologies. The challenge, therefore, is to find the right strategy to achieve a sustainable adoption of these technologies.

4.3. The role of agroforestry

The role of agroforestry in sequestering carbon and contributing to climate change mitigation is well documented. What is less understood is its potential for mitigating the negative effects of climate variability and climate change. Agroforestry provides a rich set of promising technologies that can (biophysically and economically) buffer against current climate variability and food/income risks (Table 4).

Table 5. Agroforestry options for climate change adaptation

Agroforestry technology	Relationship with climate change adaptation
Trees on farm	Microclimate for reducing heat stress; tree products to buffer against crop failure
Boundary planting	Fencing for allowing off-season farming; microclimate effect; erosion control
Rotational woodlot	Soil fertility; erosion control; better water infiltration
Improved fallows	Increase water infiltration and holding capacity of soils; reduce weeds that compete with crops for water; mitigate dry spells/ drought; reduce soil temperatures through mulching.
Fodder bank	Mitigation of drought-caused fodder shortages
Domestication of indigenous trees	Economic buffer through production of high value products (fruits, wood, honey, resins, medicine, etc).

Given the role of land degradation in exacerbating the impacts of climatic extremes such as drought, agroforestry technologies that improve soil conditions have the potential to help ease the stress caused by climate change in the future. Improved fallow (a rotational system where trees or shrubs that fix atmospheric nitrogen are rotated with agricultural crops) is one such strategy and has been tested in all three East African countries with some success. Figure 5 shows how the continuous cultivation of maize without fertiliser results in the rapid decline of yields in western Kenya. However, when improved fallow is used, maize yield can be maintained at 4-5 tonne per hectare. Similar experiments conducted in Tanzania and Uganda have had similar results.

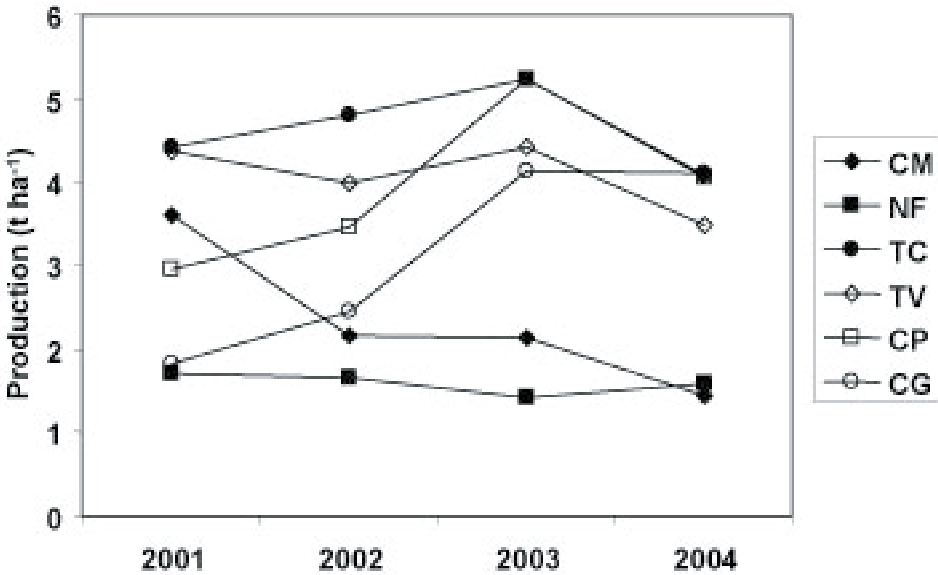

Figure 5. Maize yields in improved fallow systems (TC = *Tephrosia candida*; TV = *Tephrosia vogelii*; CP = *Crotalaria paulina*;
CG = *Crotalaria grahamiana*) as compared to maize yields in continuous maize (CM) and natural fallow (NF) systems in Luero, western Kenya.

The improvement in maize yield is to a great extent associated with the nitrogen added to the soil by the trees, but this is just part of the explanation. In fact, the general improvement in the soil conditions (chemical, biological and physical properties) plays a much bigger role than the nitrogen effects. Improvement of soil conditions by adding organic matter increases the capacity of the soil to take up water faster and hold it longer to boost crop production (Figure 6). There is anecdotal evidence from Zambia that improved fallows help reduce the effects of agricultural drought on maize yield (Kandji et al. 2005).

The role of trees in reducing income risks due to crop failures cannot be over-emphasised. In the semi-arid zone of Kenya, the parkland system (planting trees in a scattered manner in agricultural fields) is showing interesting results. The fast-growing indigenous species *Melia volkensii* is highly compatible with crops and can provide high value timber in 5-10 years (Stewart and Blomley, 1994). A study by Ong et al (1999) in Kitui district of Kenya showed that in an 11-year rotation period, the accumulated income from tree products exceeds the acumulative value of crop yield lost through competition. This income difference is worth US$ 10 or 42 percent during average years and US$ 22 or 180 percent if a 50 percent rate of crop failure owing to drought (reasonable for Kitui) is assumed. In hostile environments where crops oftenfail every other year, financial returns from *M. volkensii* even in drought years can provide significant relief for farmers. This will be all the more necessary as droughts and floods are likely to increase in frequency and in magnitude in the near future.

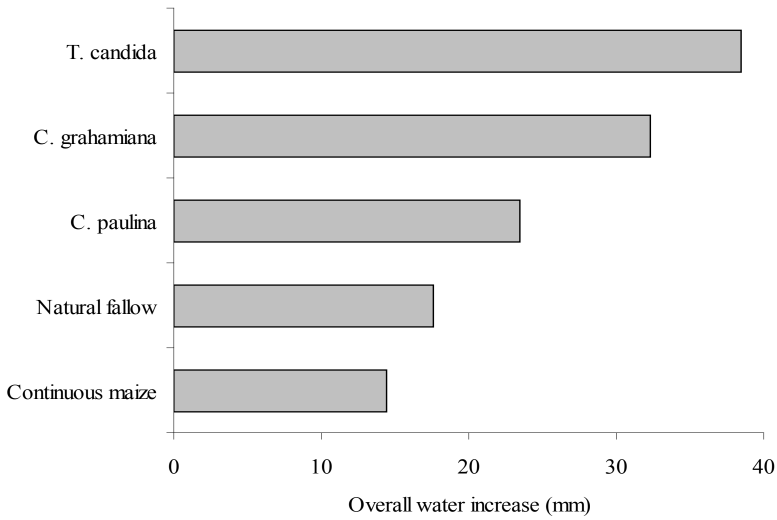

Figure 6. Change in soil water stocks (0–60 cm depth) in a western Kenyan soil under continuous maize, natural fallow and improved fallow systems using either *Tephrosia candida*, *Crotalaria grahamiana* or *Crotalaria paulina* (data from Orindi, 2002)

Knowledge gaps and research needs
Whereas the potential of agroforestry systems as a biophysical and economic buffer against current climate variability and food/income risks is well recognised, little is known on the possible impacts of higher temperatures, increased atmospheric carbon dioxide and shift in rainfall pattern on the agroforestry tree species on the one hand, and on their interactions with food crops on the other hand. In a drier or warmer climate tree–crop competition for water could intensify. What will be the trade-offs between such effects and positive impacts such as microclimate effects and soil protection? Information on pests and diseases in agroforestry systems is limited. Understanding how climate change will alter the susceptibility of trees to pests and diseases and the effects this will have on their interactions with crops is an area in need of further research.

4.4. The role of seasonal climate forecasting

Efforts to adapt to climate variability combine strategies that minimise the negative impacts of extreme climatic events and those that take advantage of the good years. As climatic extremes such as droughts increase in frequency and intensity, predicting the inter-annual and inter-seasonal variation in rainfall will be paramount for short-term decision making. WMO, together with leading climate research institutions such as the US Centre for Climate Prediction, the United Kingdom Hadley Meteorological Centre, the European Centre for Medium Range Weather Forecasting, and the International Research Institute for Climate Prediction (IRI), transmits seasonal forecasts to national meteorological services in Africa (Ingram et al., 2002). The African Centre for Meteorological Applications for Development (ACMAD) has also been promoting the application of seasonal forecasts in the region.

Relevance of seasonal forecasting for the communities

While seasonal forecasting and EWS have been used to alert governments and relief organisations over pending climatic disasters, they have seldom been exploited to empower the local communities whose lives are affected by these climatic extremes. A new thrust for research and development therefore is how to use seasonal forecasting to help the farmer and pastoralist communities make informed decisions based on accurate information. Many pilot projects, involving IRI, CGIAR centres such as ICRISAT and NARS are under way in western, eastern and southern Africa. In the Machakos district of Kenya, for instance, yield simulations using the APSIM model suggest that average maize production could increase by 61 percent compared to farmers' current practices if farmers accessed climate outlook information and adjusted their farming techniques accordingly (Rao and Okwach, 2005). These researchers are now field testing this concept. A similar initiative is ongoing to help pastoralists manage the Rift Valley Fever (RVF) in East Africa. Lessons learnt from these projects will be useful to operationalise seasonal climate forecasting in East Africa and beyond.

Although some improvement is needed in the output quality, seasonal forecasting is now accurate enough to benefit farmers, pastoralists and other end-users. There is a need to downscale regional and national forecasts to a sub-national level to capture variability at the local level. High resolution (less than 50km x 50km) regional climate models (RCMs) such as PRUDENCE (Europe), NARCAAP (North America), CERAS (South America) are now emerging and can give much more detailed outputs at a lower scale. The PRECIS (Providing Regional Climates for Impact Studies) regional climate model developed by the Hadley Centre for Climate Prediction is being used in India, China and in the southern African region to generate scenarios. Such models should be extended to other climatically sensitive areas such as East Africa.

Access to information has been a major problem for the potential end users of climate forecasting in the rural areas. However, some initiatives such as the Radio and Internet (RANET) project are addressing the problem. RANET's goal is to promote the use of climate information to reduce the community vulnerability in the Nakasongola district of Uganda (Waiswa, 2003). The project is supported by USAID and NOAA, and has helped the population improve their farming activities. For example, many farmers start preparing their land in advance based on predictions given by the project and this has improved crop productivity. In addition, people are more prepared to mitigate the impact of disasters. The 2002 El Niño was a good example where improved preparedness as a result of the RANET project enabled the communities to minimise damage.

5. Conclusions and recommendations

5.1. Conclusions

The EAC countries are highly vulnerable to climate change due to a combination of factors including: geographic location; structural problems; inadequate infrastructure; and weak institutions. One major cause of vulnerability, however, is the overly strong dependency of the region's population and economies on agriculture. The low use of modern technologies such as improved crop varieties, fertilisers, mechanisation and irrigation makes the agricultural sector in the EAC particularly vulnerable to climate variability and climate change.

Agricultural research has an important role to play in climate change adaptation. Many programmes involving partnerships between the CGIAR, national programmes and NGOs, have been implemented to tackle the constraints that are holding back agricultural productivity in Africa. Although agricultural and natural resource management research through these programmes was not meant to respond to climate change *per se*, the results produced can be of great relevance in the design and implementation of climate change adaptation strategies. For instance, there are some success stories with drought tolerant and/or drought escaping varieties; a more widespread adoption of these varieties wouldplay a valuable role in mitigating the negative effects of climate change. The use of climate information, coupled with an improvement in crop management, including the use of rainwater harvesting, soil conservation and agroforestry can enhance productivity among smallholder farming systems and buffer them against the uncertainties related to climate change.

The greatest challenge posed by climate change, however, is that nobody knows exactly the magnitude (and sometimes direction) of the changes in climate variables, especially precipitation. Climate models are based on scenarios and can, at best, give a range of possible (sometimes conflicting) outcomes. Given these uncertainties, it is difficult to know whether the technologies that are used to cope with current climate variability will be effective to respond to future climate change. It is imperative, therefore, to develop a mix of no-regret technology options and policies geared at promoting productive, sustainable and flexible agricultural systems resilient to climate change. Some of the options discussed in this paper could play a role in that process since they are useful even without climate change. There are clear links between poverty and vulnerability to climate change. Therefore, using agricultural development as an engine for development in general has the potential to help both local communities and African governments to be better prepared to face climate change.

Climate change is going to be one of the biggest challenges for the African continent and developing resilient agricultural systems to face these changes will require more important investments by governments and their development partners. There is widespread consensus that at least 10 percent of national budgets need to be dedicated to agriculture within the next 5 years in order to significantly address food insecurity and poverty in Africa. In the framework of the New Partnership for African Development (NEPAD) process, African heads of state and government committed themselves to that, as expressed in the Maputo Declaration of 2003. These commitments are yet to be translated into practice, however. There is still an immense gap to bridge between the generation of scientific knowledge and its application to produce the expected benefits for the local people to whom it is targeted. Reasons why many useful technology options are under-utilised include high input prices and low output prices resulting from under-investments in markets and infrastructure; structural adjustment programmes; and distortions in international markets.

There is now a strong commitment from the international community to tackle the issue of climate change. Existing funding sources should be tapped to carry out vulnerability and adaptation studies and develop priority projects for funding in the agricultural sector. For example, adaptation funds to be made available through the UNFCCC, the Kyoto protocol and other bilateral sources should be utilised in a more effective way to strengthen agriculture in southern Africa. Debt cancellation initiatives are also freeing upadditional resources to a growing number of countries. Some of these resources should be used to strengthen the agricultural sector in the beneficiary countries.

5.2. Recommendations

Given the immense problems facing the agricultural sector in East Africa, it is not possible to give an exhaustive list of recommendations on the way forward. The following recommendations are not a strict prescription of what has to be done. They provide a number of useful steps that could make the people who depend on agriculture for their livelihood less vulnerable to current and future climate change.

5.2.1. Foster the use of climate information to inform decision making

With climate change, climate information will be critical if the local communities are to make the right decisions in their socio-economic activities. Studies conducted in East Africa and elsewhere have shown that seasonal climate forecasting holds great promise. There are two areas that need emphasis if seasonal forecasting is to be used: (1) good interpretation and communication of forecast outputs to build trust between producers and users of forecasts; and (2) establishment of effective insurance mechanisms so that farmers and other end users are not exposed in the case of bad decisions due to a 'wrong' seasonal prediction. After all, climate forecasting will still remain a matter of probabilities, which means that it is not always the most likely scenario that materialises in the end.

5.2.2. Promote improved crop varieties

There is a strong need to accelerate the adoption of improved technologies due to the changes that are happening in the environment. Climate change will add new constraints to agricultural production. The drying trend in many areas of East Africa over the last few years, especially in the drylands, coupled with the widely shared belief that this will continue or get worse in the future, calls for wider promotion of the drought tolerant and drought escaping varieties of maize, millet, sorghum, pigeon pea and other crops developed by the CGIAR centres. .

Designing and implementing policies that ensure smallholder farmers haveaccess to improved seed and to input and output markets will be paramount to make the transformation happen.

5.2.3. Improve water use and productivity

There is a strong need to improve the productivity of rainwater in Africa. Soil and water conservation can play an important role in that. Experience with conservation tillage in East Africa shows the feasibility of producing good crop yields during low rainfall years. Small-scale rainwater harvesting can also be useful for supplemental irrigation, off-season crops and livestock. All these techniques have the potential to buffer crops and animals against drought. The major challenge for governmental and non governmental development agencies is how to achieve a sustainable implementation of these technologies.

5.2.4. Encourage crop diversification

Diversifying crop production can greatly contribute to building both the biophysical and socio-economic resilience of farming systems and communities. Diversification should take into account the existing differences in agro-ecologies and exploit the complementaries among systems. With improved water management and cropping techniques, farmers will be able to reduce the areas cultivated to food crops and invest more resources in legumes and high value crops. Agricultural diversification can have the triple advantage of improving food/nutritional security, boosting household income and reducing risks of total crop failure.

5.2.5. Promote supplemental and small scale irrigation

Rain water harvesting with the help of retention basins or the boring of shallow wells can help provide supplemental irrigation for rainfed crops in the occurrence of dry spells and contribute to the development of off-season gardening. However, bearing in mind that global warming could exacerbate the scarcity of water resources through reduced rainfall/runoff and higher evaporation regime, technologies such as micro-irrigation that allow the economical use of water should be given priority. East Africa is already a highly water stressed region and the situation is likely to get worse in the future. Therefore, expanding large irrigation schemes may not be advisable given the great competition that will arise from other sectors.

5.2.6. Invest in pest and disease control

Agricultural pests and diseases constitute a major threat to food security in East Africa and climate change may aggravate the situation since a warmer climate could shorten the developmental cycle of many pests and disease agents. An integrated management approach combining biological and non-biological methods will be the best option to deal with an increased pest and disease pressure.

5.2.7. Develop low cost post-harvest technologies

Beside low farm production, the inability of farming households to store food and other agricultural produce after harvest due to damage by pests and diseases is a major cause of food insecurity in Africa. This often forces the small scale farmers to quickly sell their grains when the price is lowest. A warmer climate is likely to increase this pressure since the reproductive cycle of these pestiferous organisms might be shortened. One way of getting peasant farmers out of this trap, and hence reducing their vulnerability, is to reinforce their ability to store food using cheap conservation technologies. Techniques such as drum storage, solar disinfection, bagging technology and improved ash storage have real potential.

5.2.8. Promote agroforestry

Due to the multiple roles they can play in terms of restoring degraded lands, improving soil and water resources, providing microclimate effects and reducing income risks, agroforestry could play a key role in mitigating the negative effects of climate variability and climate change in Africa. In East Africa, a conducive policy environment should be in place to ensure that promising technologies such as improved fallow/no-till, biomass transfer and fodder trees are widely adopted by farmers. Strategic partnerships between research organisations, extension services, NGOs and CBOs that use a participatory approach may be the best way to promote agroforestry in the sub-region.

5.2.9. Develop processing industries

Developing small scale agro-processing industries may be the best way of diversifying rural economies and reducing food insecurity and poverty in Africa. This can be an important engine for rural development through the creation of market opportunities for farm produce, value addition to grains and contribution to job creation. The primary objective is to satisfy the high food demand from the rapidly growing urban population. However, given the frequency of droughts and the associated fodder shortages, promoting the use of grains in the formulation of animal feed could also contribute to addressing livestock development problems in the region.

5.2.10. Foster institutional links for agricultural sustainability

The diffusion of technologies to reduce the vulnerability of agricultural systems needs the participation of a wide range of stakeholders, partners and institutions. Since climate change may exacerbate rainfall variability, a close collaboration between meteorological and agricultural services will be necessary for a more effective use of climate information. Extension services need to be strengthened and agents provided with the necessary equipments and logistics that would allow them to reach the farmers more easily. Experience in Africa has shown the important role of NGOs in rural development. Thus, a healthy collaboration between research and extension services, NGOs and community-based organisations (CBOs) such as youth associations, women's groups may be more fruitful. On-farm research directly involving farmers should be encouraged as much as possible since it creates a sense of ownership, facilitates technology uptake and saves time and resources. Policies should also be put in place to encourage the contribution of the private sector for example through the signing of contracts with research organisations.

5.2.11. Develop special rural microcredit schemes for small-scale farmers

Most of the new technologies that are proven to improve productivity and resilience of agriculture are often too expensive to serve the interests of the smallholder farmers. Since the removal of government subsidies in the 1980s and 1990s as part of the ESAPs (Economic Structural Adjustment Programmes), these farmers have been left on the fringe. The failure of African governments to design and operationalise lending mechanisms that suit the circumstances of the smallholder farmers has resulted in the rapid degradation of living conditions in rural communities. Although some agricultural banks exist, they are often reluctant to lend to smallholder farmers since they cannot provide any collateral. Thus, allowing farmers, and particularly women, to own land through title deeds gives them the collateral needed to secure loans. But, one proven way of enhancing the rural communities' chance of attracting loans is through group lending as the Grameen Bank in Bangladesh has shown.

5.2.12. Improve information delivery systems

Information delivery is critical in the process of enhancing the adaptive capacities of the rural areas to climate change. Information on weather or new technologies can be transmitted to the farmers using rural radios and other media such as churches and gatherings like traditional beer drinking ceremonies. The rapid development of mobile telephone and the internet is opening up new opportunities and should be exploited fully to reduce the informational divide between the urban centres and the rural areas. Farmers' field days are also effective for the rapid spread of new technologies.

5.2.13. Invest in rural infrastructure

A productive and competitive agriculture will develop where movement is restricted by bad roads, the disease burden is high and access to water, and where education and information are inadequate. Unfortunately, these are the conditions in which the overwhelming majority of the poor and destitute people in Africa live. Climate change will make these communities even more vulnerable. Thus, a serious investment in these key areas is paramount.

Better road infrastructure is needed in many areas vulnerable to the El Niño/La Niña weather phenomenon, in view of the probability that extreme events may become more frequent due to climate change. Focussing on strategically selected feeder roads may be an efficient way to allocate scarce resources.

Alleviating the disease burden in East Africa through the establishment of a good network of rural clinics is also critical. The HIV/AIDS pandemic is now recognised as a major threat to the development of the EAC countries. Uganda has made significant efforts and is hailed as a success story in containing the disease, yet the country cannot afford to be complacent. More important efforts should be made in Kenya and Tanzania.

5.2.14. Improve links to regional and global markets

Investing in market infrastructures is a necessary step for the development of agriculture in East Africa. Regional organisations such the EAC, IGAD and COMESA (Common Market for

East and Southern Africa) all provide conducive frameworks that can enhance market integration in eastern and southern Africa. The mobility of persons and goods within the region should be made easier and the trade bottlenecks between the various countries removed. It is imperative that the major railway line and road linking the port of Mombassa to Uganda be revamped and well maintained. Good transport infrastructure improves the access of agricultural products to the global market. The issue of agricultural subsidies from the North that prevent African countries from fully benefiting from global trade needs to be addressed as well.

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