Climate Change and Variability in the Southern Africa:
Impacts and Adaptation Strategies in the Agricultural Sector

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Climate Change Climate and Variability in Southern Africa:
Impacts and Adaptation in the Agricultural Sector

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Contents

1. Introduction

1.1. About this report

This paper proposes to discuss the current vulnerability of the southern African region to climate variability, the projected impacts of climate change and the various strategies and policies that are being deployed to address climate issues, focussing mainly on the agricultural sector. The potential role of research and technology in building a resilient agriculture is also analysed.

Why climate variability and climate change? While in the international climate negotiations some parties consider the two as totally different processes and insist that they should be treated separately, there is growing evidence that some link can be established between climate variability and climate change. It is now widely accepted that climate change will, among others, lead to an increase in the frequency and intensity of climatic extremes such as droughts and floods, some of the very elements that define climate variability.

This report does not intend to be a policy document. Its aim is simply to take stock of the existing knowledge that could be useful in the formulation of adaptation strategies geared at improving the resilience of the rural communities in southern Africa, who depend heavily on agriculture for their livelihood.

1.2. Presentation of the study area

The Southern African countries (Figure 1) are all members of the Southern African Development Community (SADC) political ensemble, which currently comprises 14 countries distributed as follows:

- Southern Africa: Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe
- Indian Ocean Islands: Mauritius, Seychelles
- East Africa: Tanzania
- Central Africa: Democratic Republic of Congo

Southern Africa has a combined population of nearly 119 million people and a GDP of US$ 142 billion (Table 1). However, there is a great disparity between countries in relation to areas, size of economies and populations. For instance, South Africa alone represents close to 40 percent of the population and 73 percent of the GDP of the region whereas Swaziland represents less than 1 percent of the regional population and less than 1 percent of the regional GDP.

The climate of Southern follows a pronounced gradient, with arid conditions in the west and humid conditions in the east. The rainfall regime is characterised by a great variability at various time scales from intraseasonal, through interannual to decadal and multidecadal. Inter-annual variability is particularly pronounced in the drier part, where the coefficient of variation can be as high as 40 percent. Also, a marked latitudinal distribution of rainfall exists in southern Africa, which divides the region into two climatic groupings:

Figure 1. Geographic location of the southern African countries

Table 1. Population and GDP (2002 estimates) of the southern African countries (SADC, 2004)

	Population (million)	GDP (US$ billion)	GDP per capita (US$)
Angola	14.0	9.80	697
Botswana	1.7	4.88	2796
Lesotho	2.2	0.88	368
Malawi	10.7	1.98	182
Mozambique	18.1	3.50	193
Namibia	1.9	3.10	1667
South Africa	45.4	104.40	2300
Swaziland	1.1	1.20	1109
Zambia	10.3	3.70	363
Zimbabwe	13.9	9.06	652
Total Southern Africa	119.3	142.40	1194

- The South (Botswana, Lesotho, Namibia, South Africa and Swaziland) has a low rainfall index and a variability that exceeds that of the Sahel. The years 1973, 1982, 1983 and 1992 were particularly dry. The 1991/1992 drought was the most severe in the last century.
- The North (Angola, Malawi, Mozambique, Zambia and Zimbabwe) has higher annual rainfall and lower inter-annual variability than the first group. The years after 1974 have been characterised by marked fluctuations, with peaks in 1985 and 1989 and lows in 1987 and 1992.

Most of the area did not experience serious droughts between 1960 and 1982. However, the 1991/92 and 2001/2002 droughts seriously affected these countries.

1.3. Agriculture and food security in southern Africa

Agriculture is a very important sector in southern Africa in terms of subsistence, contribution to GDP (about 35 percent), employment (70-80 percent of the total labour force) and foreign exchange earnings (about 30 percent) (Abalu and Hassan, 1998). With an annual per capita consumption averaging 91 kg (excluding South Africa), maize is the most produced and most consumed cereal in the region and contributes 40 percent of the calories consumed in peoples' diets (www.cimmyt.org). Millet and sorghum are also important crops, especially in the drier areas, whereas wheat is mainly produced under irrigation in South Africa and Zimbabwe. Cotton and tobacco are important export crops although South Africa and Zimbabwe have been major maize suppliers to neighbouring countries and the rest of Africa.

Farmers in southern Africa can be classified in two broad categories. There are the large commercial farms, which occupy the best soils and intensively use technologies such as improved seeds, fertilisers and mechanisation. Maize yields of more than 5 tonnes per hectare are common in these conditions. However, the overwhelming majority of farmers in southern Africa have small land holdings and use rudimentary methods for crop production. As a result, average regional maize yields revolve around 1 tonne per hectare (Figure 2), a far cry from the potential 10 tonnes per hectare shown by research experiments (Zambezi and Mwambula, 1996).

The analysis of regional maize production over the last 4 decades reveals two distinctive phases (Figure 3). There was an upward trend between 1961 and 1981, when annual maize production increased from less than 10 million tonnes to more than 20 million tonnes. In fact, southern Africa has long been a food exporting region, with Zimbabwe and South Africa being the major suppliers. In the last 2 decades, however, maize production has, if not declined, largely stagnated. The recent increases in harvested area (Figure 4) have done little to enhance overall crop production. This stagnation in food production, combined with a fast growing population, is rapidly transforming southern Africa from a food exporting to a food insecure entity. Currently, half of the population is under the threat of food insecurity and one quarter of the children is malnourished. The average person in southern Africa consumes less than 90 percent of the calories needed for a healthy and productive life (Abalu and Hassan, 1998).

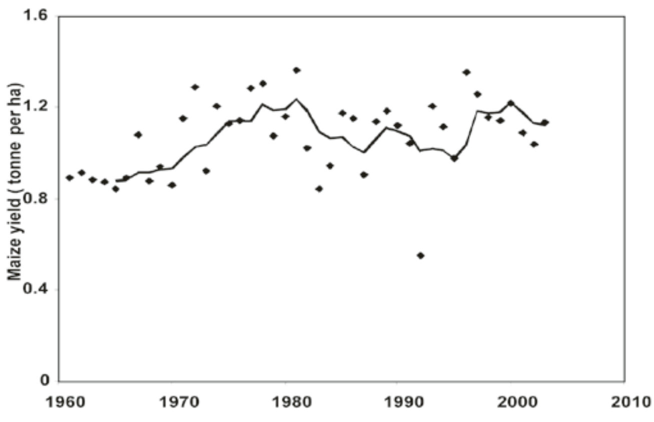

Figure 2. Annual and 5-year running average maize yield in the Southern African region between 1961 and 2003 (source FAO-STAT)

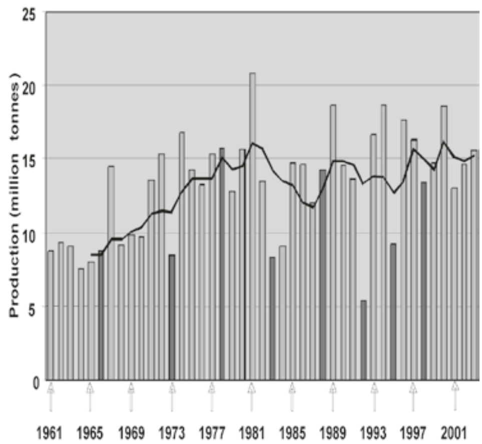

Figure 3. Annual and 5-year running average maize production over the last 4 decades in the southern African region. Red columns indicate years following the development of an El Niño event (source FAOSTAT).

In Africa, the subsistence farmers face a double jeopardy when annual crops fail: (1) locally produced food is not available; and (2) since these farmers depend almost entirely on agriculture for employment and income, they often cannot find the money needed to purchase food even if it is available in the market. In recent years, food importations by both governments and the private sector have significantly increased. Yet, a growing fraction of the southern African population is finding it more and more difficult to afford food even at subsidised prices. Extreme poverty is condemning millions of people to rely on relief food.

The precarious food situation that has been afflicting the southern African region in recent years stems from a combination of factors including: unfavourable climatic conditions (erratic rainfall, drought and floods); poor and depleted soils; environmental degradation; failed sectoral and macro-economic policies; inadequate support systems; and political upheavals (Van Rooyen and Sigwele, 1998). Environmental degradation caused by soil erosion, desertification, deforestation and inappropriate agricultural practices is a major threat to agricultural sustainability. It is estimated that 80 percent of rangelands and rainfed croplands in southern Africa are degraded (Abalu and Hassan, 1998). The rapid decrease of the forest cover is equally worrying. In the 1980s about 664,000 hectares of forest were cut down in southern Africa compared to a reforestation rate of only about 92,000 hectares (Pinstrup-Andersen et al., 1997). Agricultural drought (inadequate availability of water to crops) causes 10 to 50 percent of annual yield losses on 80 percent of the area planted to maize in southern Africa (Short and Edmeades, 1991). Below-normal rainfall years are also occurring more and more frequently, resulting in poor harvests especially with the lack of early-maturing and drought-tolerant varieties. The shortage of dry-season fodder has also become a major impediment to livestock production, exacerbating food and income insecurity in the region. HIV/AIDS is now bringing a new dimension to the food crisis, making the populations even more vulnerable to climatic shocks (de Waal and Whiteside, 2003).

1.4. El Niño/Southern Oscillation (ENSO) and climate variability

Climate variability is the most important cause of food insecurity in southern Africa. The major driving force behind this variability is the ENSO phenomenon. The term 'El Niño' was coined in the 16th century by Peruvian fishermen and given to the periodical warming of the Pacific Ocean that they observed around Christmas time. El Niño events usually last for a few weeks to a few months although occasionally, they go for a much longer period, as observed in 1997/1998. The Southern Oscillation component is the associated change in sea-level pressure in the southern Pacific (Phillips et al., 1998).

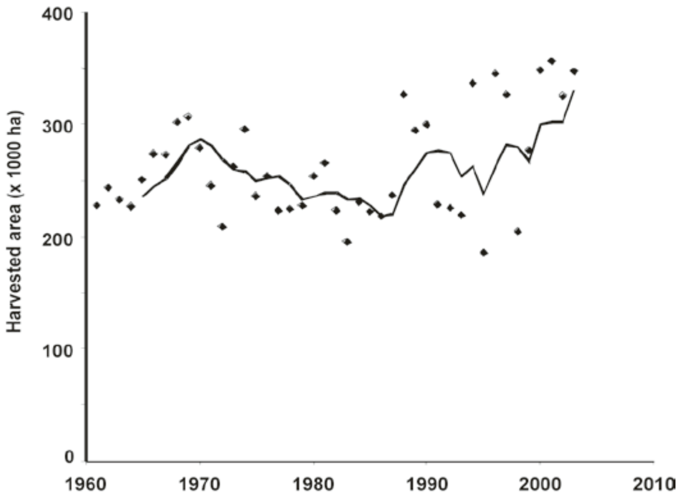

Figure 4. Annual total and 5-year running average area harvested to maize in southern Africa between 1961 and 2003 (data from FAOSTAT)

One particularity of El Niño is that while it originates in the Eastern Pacific, its warming effect is rapidly spread by the winds that blow across the ocean altering the weather patterns in more than 60 percent of the planet's surface. Some of the major disasters associated with El Niño events include floods, droughts, heavy snowfalls and frosts. These extreme meteorological events (teleconnections) can be extremely costly to the global community. The 1982/1983 warm episode has been one of the most devastating in recent years. The extreme warming of the equatorial Pacific (surface sea temperatures in some regions of the Pacific Ocean rose 6° C above normal) had a devastating effect on the fishing industries in South America, where catches were 50 percent lower than in the previous year. During the same period, California, Ecuador and the Gulf of Mexico were hit by heavy rains, and severe droughts were recorded in Australia, Indonesia, India and southern Africa. Dry conditions in Australia resulted in a 2 billion dollar loss in crops, and millions of sheep and cattle died from lack of water. Worldwide the drought associated with the1982/1983 warming is estimated to have caused between US$8 and US$15 billion worth of damage.

Several teleconnection studies (WMO, 1984; Ogallo, 1987; Rasmussen, 1991; Cane et al., 1994; Glantz, 1994) have established links between ENSO events in the Pacific and rainfall in southern Africa. Of the 24 El Niño events recorded between 1875 and 1978, 17 corresponded to rainfall decline of at least 10 percent of the long-term median in the region (Rasmussen, 1987). Conversely, the floods associated with the heavy rains caused by the cold episode of ENSO (La Niña) have equally negative consequences on the people and economies of the region. Typically, la Niña events result in the killing of humans and livestock by drowning and landslides, reduction in crop production, displacement of people, and damage of assets and infrastructures, as was observed in Mozambique in 2000. The heavy rainfall associated with La Niña also leads to water logging of soils, leaching of soil nutrients and the proliferation of agricultural pests and diseases. In Botswana, for instance, pest and disease outbreaks during the 1999/2000 rainfall season (in particular quelea birds) caused a 50 percent reduction in the yield of the major crops (Government of Botswana, 2001).

2. Recent climatic trends in southern Africa

2.1. The facts

The warming trend observed in southern Africa over the last few decades is consistent with the global trend of temperature rise in the 1970s, 1980s and particularly in the 1990s. According to the IPCC (2001), temperatures in the region have risen by over 0.5° C over the last 100 years. Between 1950 and 2000, Namibia experienced warming at a rate of 0.023° C per year (Government of Namibia, 2002). The nearby Indian Ocean has also warmed more than 1°C since 1950, a period that has also witnessed a downward trend in rainfall (NCAR, 2005). Below-normal rainfall years are becoming more and more frequent and the departure of these years from the long-term normal more severe (USAID, 1992).

Between 1988 and 1992, over 15 drought events were reported in various areas of southern Africa. There has been an increase in the frequency and intensity of El Niño episodes. Prior to the 1980s, strong El Niños occurred on average every 10 to 20 years. However, the early 1980s marked the beginning of a series of strong El Niño events: 1982/1983; 1991/1992; 1994/1995; and 1997/1998. The episodes of 1982/1983 and of 1997/1998 were the most intense in the last century. Paradoxically though, the 1991/1992 El Niño, which was considered as a moderate event, caused a major drought throughout southern Africa (Glantz et al., 1997).

2.2. The consequences

The increased frequency of extreme climatic events, particularly El Niño related droughts, is exacting a heavy toll on the inhabitants and economies of southern Africa. Five out the eight El Niño events recorded between 1965 and 1997 resulted in significant decreases in agricultural production, exacerbating food insecurity throughout the region (see Figure 3).

The Pacific warming of 1991/1992 caused over southern Africa what many describe as the worst drought of the last century (Glantz et al., 1997). The resulting crop losses and death of cattle herds led to widespread food shortages and devastated the fragile economies of various countries. Regional maize production in 1992 was approximately 5 million tonnes (the lowest since 1961), putting an estimated 30 million people at the brink of famine (Battersby, 1992; Chiledi, 1992; Harsch, 1992). This was 60 percent below the 1991 level (an already below average production year) and the 1991-2000 average. Damage to the herd was also great. For example, in Zimbabwe the drought resulted in the death of an estimated 423,000 cattle out of 4.4 million and the doubling of the normal off-take. But even the animals that could be sold only fetched a pitiful Z$24 per head as compared to an average normal price of Z$500 per head (Thompson, 1993). In Botswana, the national herd reduced by a third (Government of Botswana, 2001).

In 1995, following an El Niño-related drought, regional cereal production was only 15.7 million tonnes, a time when direct consumption needs were 23.3 million tonnes. Only 9 million tonnes of maize (half of the previous year's production) were produced in the entire region, an output comparable to that of the early 1960s (Figure 3). Maize deficit represented 4.9 million tonnes out of the 7.6 million tonne deficit for all cereals (SADC/FSTAU, 1993).

Since 2001, consecutive dry spells in some areas of southern Africa have led to serious food shortages in many countries. In 2001/2002 six countries, namely Lesotho, Malawi, Mozambique, Swaziland, Zambia and Zimbabwe, faced a food deficit to the tune of 1.2 million tonnes of cereals and non-food requirements at an estimated cost of US$611 million (SADC, 2002). The 2002/2003 drought resulted in a food deficit of 3.3 million tonnes, with an estimated 14.4 million people in need of assistance. The World Food Program (WFP) analysed the food situation in the southern African region in 2001/2002 and identified 7 major factors that are contributing to the crisis (WFP, 2002):

- Severe dry spells/drought: Malawi, Mozambique, Zambia and Zimbabwe
- Heavy rain/floods: Lesotho, South and Central Mozambique
- Disruption to commercial farming: Zimbabwe
- Depletion of strategic grain reserves: Malawi, Zambia
- Poor economic performance: Lesotho, Zimbabwe
- Delays in importation of maize, particularly from South Africa: region-wide
- Sharp rises in prices of staple foods: Malawi, Mozambique, Zambia, Zimbabwe.

In addition to being a major obstacle to the achievement of food security, climate variability can also have dire macroeconomic consequences. Droughts and floods are very important factors influencing economic growth in the southern African countries and can frustrate development efforts undertaken for many years. For instance, Zimbabwe's GDP fell by 3 percent and 11 percent after the 1983 and 1992 droughts, respectively. In South Africa, the 1992 drought was estimated to have reduced the agricultural GDP by about R1.2 billion and caused a 0.4-1.0 percent loss in economic growth (Glantz et al., 1997). The same drought cost the Zambian government US$300 million, bringing its 1992 deficit to US$1.7 billion. A 39 percent drop in agricultural output was largely responsible for the 2.8 percent decline in GDP in the country. In fact, over the last decade, only twice did the Zambian economy expand for two consecutive years. As a result, the ten-year average economic growth rate of Zambia was only about one percent annually, the lowest in the entire SADC region. During this period GDP per capita fell by more than 25 percent, sending a growing number of people into poverty.

Some analysts also argue that, in addition to reducing the local investment capital available, the prevalence of El Niño in the region is likely to scare off potential foreign investors who would not want to risk business ventures in an 'unfriendly' environment. To illustrate this assumption, the months preceding the 1991/1992 El Niño were characterised by a downward trend in the Zimbabwe stock exchange. During the drought, the country's stock market declined 62 percent.

2.3. The responses

If General Circulation Model (GCM) outputs are anything to go by, the ongoing droughts in southern Africa are not going to end any time soon. Indeed, the situation is expected to get worse with global warming. The objective of this section is to highlight some of the strategic responses that are being put in place to address the recent trend of climate variability at the regional and national local level, and to analyse some of the coping mechanisms that the local people have traditionally used in the face of climate variability.

2.3.1. Responses at regional level

The series of damaging El Niño related droughts that started in the 1980s, and the profound societal, economic and environmental impacts that they have had in southern Africa, could not have left the various governments and the global community indifferent. The severity of the food crisis associated with the 1991/1992 drought sounded like an alarming bell to the southern African region as a whole and drought preparedness has significantly improved since. One major step was the formation by the SADC of a task force under its Food Security, Technical and Administrative Unit, specifically to monitor weather conditions. The task force comprises the SADC's Regional Early Warning Unit, the Regional Remote Sensing Project, the Drought Monitoring Centre and the Famine Early Warning System Project, all based in Harare, Zimbabwe. The early warning unit issues alerts to help member countries prepare for the prospect of drought or flooding and consider ways of mitigating their effects (SADC, 2002).

Having a regional climate outlook is useful in a region like southern Africa, where (in normal times) two countries are net food exporters and all the others are net importers. A drought may occur over large areas of southern Africa and still have no major impact for regional food security as long as South Africa and Zimbabwe are not affected. However, when these two countries are hit as was the case in 1992, food has to be obtained from outside the region. It is obvious that for any of the landlocked countries, importing food from another continent is a much longer and costlier process than getting it from the neighbouring suppliers. Regional climate forecasting can help the whole region to secure food imports or food aid early enough and reduce the financial, socio-economic and human costs of climatic disasters.

There have also been plans by the SADC to establish a Regional Drought Fund from which affected member countries could borrow. Consultations with the World Bank and other donor agencies have already been initiated. The Fund, once established, is expected to operate like an export-import guarantee scheme and will enable affected countries to borrow and repay within a stipulated time frame (SADC, 2002).

2.3.2. Responses at national level

Almost all countries in southern Africa have now established national Early Warning Systems (EWS) that monitor their national food situation. A major benefit of these national EWS is that they allow governments and their partners enough lead time to advise the various stakeholders as well as plan for relief operations in the case of a pending disaster (Thomson, 2003). For instance, when the 1997/1998 El Niño was announced, all governments in southern Africa took a number of precautions. In Swaziland, farmers were advised to grow drought resistant crops, reduce and cull livestock and store their current food stocks properly. Botswana, Mozambique, Namibia, South Africa, Zambia and Zimbabwe initiated water saving measures. In Mozambique, vulnerable farmers in the drought-prone provinces were advised to plant their crops on low-lying ground, which retains moisture for longer periods. The Zambian Early Warning Unit encouraged farmers to plant early-maturing and drought-tolerant crops such as sorghum and millet and to improve food storage (SADC, 2002). Although the 1997/1997 did not cause the damage that many anticipated, the southern African countries seemed to be much more prepared to face a crisis than in 1991/1992.

2.3.3. Responses at local level

Local people in southern Africa are no strangers to climatic risks and have developed useful mechanisms to cope with them, except for the most extreme events. Like in other regions of Africa, southern African farmers monitor a number of indicators to predict rainfall including plant and animal behaviour and can adjust labour and allocate resources accordingly (Kihupi et al., 2003; Dilley, 2003). Research is needed to better understand the usefulness of these traditional indicators and to see how they can be used as en entry point to operationalise science-based climate forecasting in the region.

Local communities 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; Blench, 2003). Opportunistic gathering of wild products such as fruits, wood and honey for home consumption and for sale have also been used at times of crop failure. In a survey carried out in Malawi and Zambia, as much as 80 percent of the 323 rural households sampled reported having faced severe food shortages, especially during the months of November to January. About 50 percent of these households in Malawi and 26 percent in Zambia reported having resorted to fruit trees as a strategy to cope with the famine period in 2001 (Akinnifesi et al., 2002).

Traditional coping methods are based on experience accumulated over the years and transmitted from generation to generation. Prior to the 1970s, climate extremes such as strong El Niño events occurred every 10 to 20 years, i.e. a rhythm that enabled the local communities in southern Africa to deal with these problems either at the individual/household level or through well established social networks. Climate change is eroding these coping mechanisms by causing climatic extremes with a frequency and intensity never seen in the past. The recurrent droughts in Africa have led to the degradation of the resource base and forced many farmers to sell their assets and migrate to cities or neighbouring countries.

In conclusion, climate change may bring about a new set of weather patterns and extremes that are well beyond what the local communities in southern Africa are capable of dealing with. External help is necessary to rebuild or enhance the social and ecological resilience among rural communities. Indigenous coping mechanisms, albeit not enough on their own to respond to climate change, can serve as a useful entry point for interventions by governments, relief organisations and development agencies.

3. Future climate change in southern Africa

3.1. Regional outlook

There is widespread acceptance that the climate of southern Africa will be hotter and drier in the future than it is today. By 2050, average annual temperature is expected to increase by 1.5-2.5° C in the south and by 2.5-3.0° C in the north compared to the 1961-1990 average (Ragab and Prudhomme, 2002). Temperature rises will be greater in the summer than in winter, exacerbating stress on crops. Recent model outputs obtained by scientists from the US-based National Centre for Atmospheric Research (NCAR) and the National Oceanic and Atmospheric Administration (NOAA) revealed '*very clear and dramatic warming of the Indian Ocean into the future, which means more and more drought for southern Africa*' (NCAR, 2005). This study showed that monsoons across southern Africa could be 10 to 20 percent drier than the 1950-1999 average. Annual regional precipitation is expected to reduce by 10 percent, with greater reductions in the north than in the south (Ragab and Prudhomme, 2002). In the third assessment report of the Intergovernmental Panel on Climate Change (www.ippc.ch), it is indicated that climate change may increase the frequency of ENSO warm phases by increasing the warm pool in the tropical western Pacific or by reducing the efficiency of heat loss.

3.2. Climate change and development in southern Africa

More than anywhere else, understanding the link between climate change and development is crucial in Africa, where agriculture and other climate sensitive sectors are the mainstay of most national economies. Since the millennium development goals (Box 1) are the most widely agreed targets for the developing countries to measure their progress towards sustainable development, it seems interesting to see how climate change can affect the realisation of these goals.

Box 1. The Millennium Development Goals (MDGs)

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

It was obvious, right form the outset, that meeting the goals (targets have been set for the year 2015, using the situation in 1990 as baseline) was never going to be easy, and that a considerable amount of efforts was needed from the developing countries with the support of the global community. In southern Africa, while some countries, especially those that were formerly under armed conflict (Angola and Mozambique) are making commendable progress in some areas, other countries are witnessing a drop in their Human Development Index (HDI). In many cases, this can be attributed to a decrease in life expectancy as a result of HIV/AIDS and/or a collapse in national income. For instance, between 1990 and 2001 Botswana, Lesotho, South Africa, Swaziland, Zambia and Zimbabwe regressed rather than progressed in developmental terms (UNDP, 2003).

As described in the above sections, the food situation is already worrying in southern Africa, with about half of the populations at risks. Between 1990 and 2001, the number of undernourished people rose in Botswana, Swaziland and Zambia. Together with South Africa and Zimbabwe, these countries also experienced an increase in child mortality. Income poverty also became more widespread in Angola, Zambia and Zimbabwe.

The challenge posed by climate change, when superimposed on the multitude of structural problems the African countries are facing, means that meeting the MDGs can actually be a much greater task than previously thought. In many of these countries, climate is likely to be one among many other factors that determine whether the MDGs will be met or not. Where people are unprepared or adaptation strategies are inadequate, climate change can easily set back development gains by affecting key sectors such as agriculture, water resources, infrastructures and health. On the other hand, meeting the goals means that stronger economies and more resilient societal and environmental systems will emerge, thus reducing the vulnerability of the populations to the negative impacts of climate change.

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

1. a warmer and drier climate, characterised by increased frequency and intensity of El Niño events, will drastically reduce soil moisture and water runoff to rivers, 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, a set of processes that are not compatible with environmental sustainability (Goal 7);
3. a long-term rise in temperatures, and occasional flooding due to La Niña 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 2) and the heavy dependence of many southern African economies on natural resources mean that more intense and frequent droughts 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).

Box 2. 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.

Louis Verchot, ICRAF

3.3. Responding to climate change

Southern African countries have recognised the challenge posed by climate change and are working with the global community to address the problem. A strong indication that the southern African region is committed to tackling climate change is that all the ten countries covered in this study have ratified the UNFCCC, and as of 29th April 2005 seven of them (Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa and Zambia) had ratified the Kyoto Protocol. Eight countries have submitted their Initial National Communications (INCs). Except for Angola, Mozambique (not yet submitted) and Zambia (only hard copy available), these documents can be accessed on the UNFCCC website: www.unfccc.int.

3.4. Climate change impacts and adaptation in the agricultural sector: an analysis of the INCs

3.4.1. Country-level impacts of climate change

The preparation of the INCs provided the southern African governments with an opportunity to carry out impacts assessment studies in climatically vulnerable sectors including agriculture (Table 2). Although a warmer climate is generally predicted in all countries by the middle or the end of the twenty first century, there is no such agreement on rainfall. In Botswana, Lesotho, Malawi and Namibia, both wet and dry scenarios are possible depending on the model used. South Africa and Zimbabwe predict a drier climate whereas Swaziland's climate is expected to be wetter in the future. Since agriculture in southern Africa is predominantly rainfed, anticipating on the effect of climate change on crop production is not easy since this will strongly depend on the direction the shift in rainfall is going to take. The limited knowledge that we have on the future interactions between increased atmospheric carbon dioxide, temperatures and precipitations, and their combined effect on plant development is another factor adding to the uncertainties surrounding future food production in southern Africa.

3.4.2. Analysis of the proposed adaptive measures

Countries in southern Africa have proposed a number of strategies and measures geared at adapting their agricultural sector to the adverse effects of climate change (Table 2). However, if providing a list of adaptation measures is one thing, it is quite another to ensure that the appropriate policy and institutional environment is in place to make this agricultural transformation happen. Most of the strategies proposed to address future climate change are even valid today and the rural communities in southern Africa would be much less vulnerable if these strategies were widely implemented. Factors constraining the widespread use of improved technologies today are not likely to change significantly in the future. Thus, unless the political will to remove these technical and policy barriers exists, no breakthrough can be expected in climate change adaptation.

Another important issue that has been largely overlooked in the impacts and adaptation studies is that of the inter- and intra-seasonal variability of rainfall. Long-term changes in climatic parameters such as temperatures and rainfall may be dealt with quite successfully if the right crop species/varieties or cropping techniques are used. What communities and development planners should be more worried about is the increased frequency of climate extremes such as droughts and floods. Therefore, developing the necessary skills to produce timely seasonal forecasts and communicate them to all relevant stakeholders should be a major priority for the various governments. Unfortunately, this has not been clearly addressed in the INCs.

Table 2. Future climate change, its expected effects on crops and the various adaptive strategies proposed by southern African governments in their Initial National Communications (INCs) to the UNFCCC

Country	Baseline period	Predictions	Effects on crops	Adaptive measures	Source
Botswana	1961-1990	(1) 10-20% rainfall decrease shown by most models; (2) 10% rainfall increase shown a a few models; (3) shorter and less reliable rainy seasons.	(1) 30% decrease of maize and sorghum yields in the dry scenario; (2) light increase in sorghum yield in the wet scenario.	(1) develop capacity for drought early warning units; (2) import of cereals and relief package for rural people; (2) wider use of early-maturing varieties; (3) adjusting planting dates; (4) addressing major yield limiting factors.	Government of Botswana (2001)
Lesotho	1961-1990	(1) Warming by 0.7, 1 and 2° C around 2030, 2050 and 2075, respectively; (2) lower rainfall in spring and summer; higher rainfall in winter; and a gradual increase in autumn; (3) shift in precipitation patterns, and growing season pushed forward and shortened	(1) marginal maize production increase in normal rainfall years; no clear effect on sorghum and dry bean; (2) extensive crop destruction in wet years; (3) dramatic improvement for maize (20%), sorghum (108-115%), and dry bean (350%) in dry years.	(1) drought tolerant and fast maturing cultivars; (2) shift from maize monocrop to crop diversification, irrigation and intensification; (3) rescheduling of planting dates; (4) promotion of soil liming, organic fertilisers, and soil conservation activities; (6) abandonment of marginal land/slopes; (7) improved flood control activities and planting of trees for windbreaks.	Government of Lesotho (2000)
Malawi	1961-1990	(1) 2-3° C temperature rise by 2100; (2) 3-50% increase or 2-40% decrease in monthly rainfall depending on model.	(1) gradual decrease of maize yield from 2020 to 2100 showed by 3 out of 4 models; (2) marginal increase in maize yield shown by 1 model.	(1) changes in cultivated land area in line with projected climate change; (2) changes in crop types; (3) changes in crop location; (4) use of irrigation and fertilisers; (5) control of pests, weeds, parasites and diseases; (6) soil drainage and erosion control; (7) development of farm infrastructure.	Government of Malawi (2002)

Country	Baseline period	Predictions	Effects on crops	Adaptive measures	Source
South Africa		(1) 1-3° C warming at the 2050 horizon; (2) 5-10% decrease in annual rainfall.	10–20% decrease in maize production	(1) change in planting date, row spacing, planting density and cultivar choice; (2) planting drought resistant crops such as sorghum and millet, or shifting from crop to livestock; (3) promoting practices such as conservation tillage, furrow dyking, terracing, contour plantings and planting windbreaks	Government of South Africa (2000)
Swaziland		warmer and wetter climate at the 2025 horizon.	(1) maize yield decrease of 59 to 30% in the lowveld area; (2) sorghum yield decrease of 78 to 59% in the lowveld and 25 to 8% in the middleveld; sorghum yield increase of 38 to 191% in the highveld area; (3) bean yield decrease of 23 to 11% in the highveld area and 46 to 30% in the middleveld area; bean yield increase of 8 to 60% in the lowveld area.	(1) change of planting date; (2) promotion of varieties adapted to higher temperatures and higher rainfall; (3) change of crops, for example the transfer of sugarcane from the lowveld and middleveld to the highveld; and replacement of crop like potatoes by more adapted crops such as cassava.	Government of Swaziland (2002)
Zimbabwe		Warmer and drier climate by 2075	(1) Low-lying areas will cease to be suitable for maize production; (2) Growing season 25 percent shorter than it is currently.	(1) introduction of livestock and dairy production in areas where maize production becomes uneconomical; (2) promotion of drought tolerant crops; (3) improvement of irrigation techniques and promotion of agricultural diversification; (3) adjustment of the timing of farming operations and changing planting density; (4) installation of medium to large dams throughout the country for the development of irrigation projects; (5) and shift from subsistence to cash-crop economy to boost rural income	Government of Zimbabwe (1998).

4. The role of research in climate change adaptation

4.1. Exploring the use of seasonal forecasts

The fact that long-term climate change is likely to exacerbate both the frequency and magnitude of extreme climatic events in southern Africa (McCarthy et al., 2001) means that seasonal climate forecasts should have a more important role to play in the future. Timely seasonal forecasts have the potential to help both governments and the local people cope with climate variability. Enhanced skill to predict ENSO, combined with an improved understanding of the correlation between ENSO and rainfall in the region, has provided a useful input to seasonal forecasts in recent years. Since the 1997/1998 rainfall season the Southern African Climate Outlook Forum (the recognised regional body in charge of communicating clear and consensual forecasts) has been disseminating seasonal climate forecasts throughout the region.

Smallholder farmers could greatly benefit from seasonal forecasts in a number of ways. For example, knowing in advance whether the rainfall will be normal, below or above average could help them chose the right crops/varieties, adjust their cropping practices or take other necessary measures to maximise benefits or minimise losses (Rao and Okwach, 2005). One of the reasons why African farmers are reluctant to adopt improved technologies such as high-yielding crop varieties and chemical fertilisers is that they do not want to invest their scarce resources without knowing whether the rains will be adequate or not. Seasonal forecasting can significantly reduce these uncertainties.

There exist a number of constraints that need to be addressed before the potential of climate forecasts can be fully exploited by governments, relief organisations and local communities. Poor interpretation and communication of forecast outputs have been a major problem, and this has much to do with the probabilistic nature of seasonal forecasts. In the specific case of southern Africa, ENSO strongly influences the weather in the region. However, using ENSO signals to predict rainfall carries some elements of risk. Experience has shown that not all warm episodes create drought conditions, nor are all cold episodes followed by excessive rainfall. In addition, the severity of droughts or floods in southern Africa is not always proportional to the magnitude of the ENSO event. For instance, the moderate warming of 1991/1992 caused the worst drought southern African has experienced in the last 100 years whereas the 1997/1998 event, which was considered as the 'El Niño of the century', only created moderate drought conditions to which the region responded almost without external help. While the relationship between SSTs in the Pacific and rainfall in southern Africa is undeniable, ENSO is not the only factor influencing the whether in the region.

In conclusion, seasonal climate forecasting could play a major role in climate change adaptation in the future, but before that happens, more research is needed to:

- better understand the role of the Indian Ocean and possibly the Atlantic Ocean in modifying the ENSO effect in southern Africa;
- improve regional model outputs by using more powerful models and better quality data;
- produce forecasts that are tailored to the needs of local farmers/end users by downscaling regional model outputs to a national and sub-national level;
- improve skills to include more useful information such as the start and the end of the rainy season and the probability of dry spells, or a proxy of these;
- ground-truth model outputs through targeted pilot projects using farmers' plots for demonstration;
- better interpret and communicate forecasts outputs to various stakeholders and end-users.

4.2. Combating drought through improved crop varieties

Drought is likely to be the biggest obstacle to the achievement of food security in southern Africa. Zimbabwe provides a compelling example of this. In the first years of its independence from Britain (the 1980's), Zimbabwe performed what was called the 'maize-based Green Revolution' (Eicher, 1995) or the 'smallholder agricultural miracle' (Mabeza-Chimedza, 1998). During this period, production of maize and other crops such as cotton and groundnut experienced a dramatic increase, making Zimbabwe a major maize exporter. Indeed, the conventional wisdom according to which hybrid maize could not compete with dryland crops such as sorghum and millet in low rainfall areas appeared to be totally challenged. Then came the repeated droughts from the early 1980s and suddenly the varieties and cropping techniques that played a significant role in the Zimbabwean miracle were no longer appropriate. What happened in Zimbabwe was also observed in many other countries: the climatic conditions were changing. There was a clear need to develop, test and release new varieties that would be adapted to the changing climatic and ecological conditions of southern Africa. It is in this context that research partnerships have been built around organisations such the International Maize and Wheat Improvement Centre (CIMMYT) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), both supported by the Consultative Group on International Agricultural Research (CGIAR).

4.2.1. Maize research

The CIMMYT (www.cimmyt.org) plays a leading role in the improvement of the maize crop in southern Africa. A major focus of the Centre's work over the last few decades has been to breed and release a variety of maize cultivars that can thrive under drought and low nitrogen conditions, which have become common occurrences throughout the SADC space (CIMMYT, 2003). With financial contribution from development agencies, a whole range of new varieties has been developed and released in various countries. The private sector also plays an important role in the development of new maize varieties. For instance, the Seed Cooperative of Zimbabwe devotes 50 percent of its resources to the development of short season hybrids that are effective in escaping drought (Eicher, 1995).

In 1996, the Southern African Drought and Low Soil Fertility Project (SADLF) was launched with funds from the Swiss Agency for Development and Cooperation and the Rockefeller Foundation. This project, which was built around a strategic partnership between the CIMMYT and national agricultural research programmes of the SADC region, has led to the release of stress-tolerant, open-pollinated varieties (OPVs) such as ZM421, ZM521 and ZM621 in Malawi, South Africa, Tanzania, and Zimbabwe, with spill-over effects in Angola and Mozambique. These improved varieties have been proven to be more productive under the current conditions of soil degradation and diminishing rainfall than the traditional varieties used throughout the region. On-farm trials carried out from Ethiopia to South Africa in 1999 revealed that ZM521 produces 34 percent more grain on average than the formerly improved varieties that are currently grown by farmers in the SADC region. Another generation of drought-tolerant OPVs that produce 15 percent more grain than ZM521 are being widely tested and should be released soon in the southern Africa region as well (CIMMYT, 2003).

The emergence of these improved maize varieties has been a gigantic step forward in the development of appropriate technologies for the smallholder farming sector. While hybrid seeds and mineral fertiliser technologies have significantly boosted large scale commercial maize production, they have largely by-passed the majority of subsistence farmers in the region, who are normally cut off from the market and credit systems. Outside South Africa and Zimbabwe where almost all maize farmers purchase new seed every cropping season, a large number of farmers in southern Africa still rely on their owned saved seed (Table 2). OPVs fit well in the local farmers' practice since they can use their saved grain at least for a few seasons before needing to purchase new seed, something which is not possible with hybrid seeds.

Table 2. Maize area planted to traditional and modern varieties in southern Africa in 1997 (source: CIMMYT global maize impacts survey)

	Area planted (000 ha)	Planted to farm-saved seed (%)	Planted to modern varieties		
			OPVs (%)	Hybrids (%)	Total
Angola	620	74.5	25.0	0.5	25.5
Lesotho	144	25.2	10.9	63.9	74.8
Malawi	1,234	88.6	4.4	7.0	11.4
Mozambique	1,154	92.0	8.0	0.1	8.0
South Africa	4,023	2.4	3.1	94.5	97.6
Swaziland	61	24.6	2.2	73.2	75.5
Zambia	649	80.8	0.6	18.6	19.3
Zimbabwe	1,640	4.5	4.5	91.0	95.5
Southern Africa	9525	49.1	7.3	43.6	50.9

4.2.2. Millet and sorghum research

Despite recent efforts in maize-based technologies, the over-reliance on this commodity for national and regional food security has often put southern Africa in a precarious food situation. Except South Africa and Zimbabwe, all the other countries are net maize importers even in normal or good rainfall years. So, when yields fail in these two supplier countries, the whole region comes under the threat of food shortage. Unfortunately, this has often been the case in the last 2 decades. The truth is that, despite its popularity and importance in peoples' diet, maize is highly demanding for water and nutrients compared to many other tropical crops. For this reason, only a few areas of southern Africa would be suitable for maize production under rainfed conditions. Dryland crops such as millet and sorghum should be given more emphasis in the elaboration and implementation of food security policies in southern Africa.

Following an appeal by the SADC heads of state to help ease the persistent food deficits caused by drought, the Sorghum and Millet Improvement Programme (SMIP) was launched by ICRISAT (www.icrisat.org) in 1983/84, with funding from the United States Agency for International Development (USAID). The prime goal of the programme was to ensure the establishment of a technological base for the region over a 20-year period (IPS, 2004). Two major objectives were identified for pearl millet. The first was to improve widely available regional varieties by supplying national breeding programmes with enhanced germplasm and information to stabilise yields. The second was to raise the level of information available for pearl millet breeding, production, and utilisation, and to develop strong national programmes for generation of elite germplasm (Monyo, 2002). The results have been quite impressive. Prior to SMIP, sorghum and pearl millet research in the region was rudimentary at best. There was only one improved variety released and grown in the southern Africa: Serere 6A in Bostwana. Now, thanks to the programme all southern African countries have functional sorghum and millet breeding programmes and 19 varieties have been released by NARS in Botswana (2), Malawi (2), Mozambique (3), Namibia (4), Tanzania (2), Zambia (4), and Zimbabwe (2). Table 3 gives information on some of the SMIP varieties. These varieties are known for their better performance in yield-limiting environments and have other useful traits that are comparable or superior to those of the local varieties. An important feature that has been pursued while selecting for these varieties was drought avoidance or drought tolerance.

Table 3. Some pearl millet cultivars recently released in the southern African region (source Monyo, 2002)

Country	Variety	Year of release	Yield potential (t ha-1)	Drought adaptation
Bostswana	Legakwe Bontle	1999 1999	2.3-3.2 1.5-1.8	Escapes Resistant
Malawi	Tupatupa Nyankhombo	1996 1996	1.9-2.5 1.5-1.8	Resistant Resistant
Mozambique	Kuphanjala 1 Kuphanjala 2 Changara	2000 2000 2000	1.5-2.7 1.3-2.1 1.6-2.2	Resistant Escapes Resistant
Namibia	Okashana 1 Okashana 2 Kangara	1990 1998 1998	0.8-1.9 1.0-2.0 0.8-2.2	Resistant Resistant Resistant
Zambia	Kaufela Lubasi Sepo	1989 1991 1998	2.4-3.2 1.2-3.9 1.4-3.4	Escapes Escapes Escapes
Zimbabwe	PMV 2 PMV 3	1992 1998	2.3-3.2 1.5-3.2	Escapes Resistant

4.2.3. Potential impacts of new varieties

The widespread adoption of improved varieties provides clear food security, socio-economic and environmental benefits. Studies conducted in southern Africa have showed an interesting return to public investments for these varieties since the use of germplasm from international research organisations such as ICRISAT or CIMMYT significantly reduces the time and costs involved in variety development and testing in the target countries. One success story is the pearl millet variety Okashana 1, which was developed jointly by ICRISAT and the Namibian national programme. Currently, this variety is reported to be grown on 50 percent of the pearl millet area in Namibia and the internal rate of return to public investments in the development and dissemination of this variety was 50 percent. The net value of this return was more than US$ 11 million in 1998. In Zimbabwe, the benefits from investment in the sorghum variety SV2 and the millet variety PMV2 are expected to grow from US$ 7.8 to 28.9 million.

Environmental benefits associated with the use of improved varieties include their potential for reversing land degradation. Because of the high risk of drought, many farmers tend to grow large areas of maize to compensate for poor yields. If the fear of crop failure is reduced through the use of adapted varieties, farmers may be more inclined to invest in their crop and purchase fertiliser, or take other steps to improve soil fertility and conserve water. Since drought-tolerant maize varieties can ensure improved food security on smaller areas, farmers may be able to allocate more land and labour to legumes and cash crops, thereby improving income, enhancing soil quality and reducing land degradation, which is rampant in southern Africa.

4.2.4. Obstacles to the widespread adoption of improved varieties

The 19 millet varieties that were released through the SMIP currently occupy 2-50 percent of the pearl millet growing area of the SADC region (IPS, 2004), suggesting that there is still some work to do before a more widespread use of improved varieties is achieved. Adoption of new varieties by smallholder farmers requires that a number of conditions are met, including 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 (Rohrbach et al., 1999).

Although reasons why new varieties are not rapidly and widely adopted in Africa are numerous and may vary from one place to another, accessing seeds is a common problem. There are many examples where smallholder farmers are not aware of the existence of new varieties or when they are, they just do not have access to them. This is due to the fact that very few governments in Africa have succeeded in maintaining an efficient seed production and delivery scheme. Moreover, purchasing seeds from the private seed companies is not an option for most African farmers due to poverty.

To tackle the challenge posed by the lack of seed, CIMMYT and ICRISAT teamed up with partners from national programmes, NGOs and community-based organisations (CBOs) to accelerate seed production and this has, to some extend, enabled the spread of new varieties. The major challenge, however, is how to design and implement a sustainable seed distribution system. Unlike maize, a functional seed market does not yet exist for sorghum and millet and many traders are reluctant to stock seed because of the periodical seed hand-outs going together with relief operations. This uncertainty in demand is not conducive to the involvement of the private sector in the production and commercialisation of seed.

Perhaps, one way to overcome these barriers is to create incentives for farmers so that they can become partners of seed companies or form seed cooperatives, which has the added advantage of providing them with an additional source of income. For instance EcoLink, a South African-based non-government Environmental Education Trust, plans to set up a Public Benefit Company, EcoLink Seeds, in which farmers that are trained in seed production will become partners. The voucher programme suggested by ICRISAT also offers interesting prospects. In this system, vulnerable households are given vouchers, which they take 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. Developing industrial demand, which is vital for raising prices, was a persistent challenge to the SMIP. In Zimbabwe, there has been some success in that area since demand for the small grains (millet and sorghum) increased exponentially, particularly from the stock feed industry.

4.2.5. Conclusions

Plant breeding has the potential to play an important role in climate change adaptation. The southern African experience has shown that strategic partnerships involving international research organisations, national programmes, the private sector and community based organisations, when backed by development agencies, can be effective in developing, testing and releasing new crop varieties that are adapted the changing climatic conditions. The biggest challenge remains how to find the appropriate policy framework that will facilitate the widespread use of these stress tolerant varieties among the poor smallholder farmers of southern Africa.

Climate change represents a major challenge to agricultural research organisations and if plant breeding is to significantly contribute towards mitigating the adverse effects of climate change in the future, more research will be needed in order to:

- understand how today's stress tolerant varieties will behave in conditions of increased atmospheric carbon dioxide, higher temperatures and altered rainfall pattern;
- test the incorporation of heat tolerance genes into existing drought-tolerant varieties either through conventional methods or biotechnology;
- understand the changes in agricultural pests and diseases incidence and how this will affect crop production;

- find the right strategies for an efficient seed production and distribution system that can suit the smallholder farmers' circumstances.

4.3. Soil and water management

Although stress tolerant varieties can contribute to stabilising food production, the 'cultivar-alone approach' may not be sufficiently effective to reduce the small farmers' vulnerability to climatic variability and climate change. Since water resources in southern Africa are likely to become increasingly scarce as a result of climate change, technologies that combine the improvement of soil fertility and the storage and efficient use of water will be necessary to build resilient agricultural systems (Ahmed et al., 2000; CIMMYT, 2004). Soil and water conservation techniques such as terracing, soil bunds and micro-catchments can significant improve the water holding capacity of soils and mitigate the negative effects of dry spells.

Conservation tillage has the potential to improve soil fertility, reduce erosion and enhance the water use efficiency of crops (Kaumbutho et al., 1999). In the semiarid regions of South Africa, for instance, sorghum producers have found a way of maintaining high yield levels by combining weed control in the off-season and cultivation to store water in the sandy soils with the use of high yielding varieties and moderate to high levels of fertilisation. An illustration of the importance of improving crop water use is that during the severe droughts of the 1980s and 1990s, sorghum yield in South Africa averaged 1.8 tonnes per hectare, a good performance compared to 0.8 tonnes per hectare in the rest of sub-Saharan Africa (FAO, 1998; Ahmed et al., 2000). Developing simple techniques for harvesting runoff water and use it for supplemental irrigation also has great potential when rainfall decreases or becomes more erratic as a result of climate change.

One major problem with soil and water conservation, however, is that many of the promising techniques are labour or energy intensive and require an appropriate training of extensions and farmers. Conservation tillage, for instance, is a useful option for improving the storage of rainwater in the soil and can help mitigate agricultural drought. However, it requires adequate draught power, appropriate machines and good training of farmers to be effective. Seldom are these conditions met in smallholder farming conditions. External support from governmental institutions and development agencies is often needed to implement soil and water conservation projects. One incentive for farmers to participate in such projects would be to pay them for the environmental services they provide to society. Erosion control has benefits well beyond the farmers' field as it can reduce the siltation of rivers and lakes, which can have deep ramifications in the mainstream economy and the environment. Well implemented 'food for work' schemes can also be an effective way of involving farmers in soil and water conservation.

4.4. Agroforestry

Agroforestry is emerging as a promising tool to improve and sustain agricultural productivity and to enhance rural income. Growing multipurpose tree and shrub species with crops and/or animals can provide additional benefits, which the farmers may not obtain with any of these three components alone. Products and services provided by agroforestry include the improvement of soil fertility; the provision of animal fodder; the creation of a favourable micro-climate for crops, reducing temperature stress; and fruits and wood for fuel and construction, etc. (Sanchez, 2000; Kwesiga et al., 2003).

In 1987, the International Centre for Research in Agroforestry (ICRAF) entered into a strategic partnership with the governments of Malawi, Tanzania, Zambia, and Zimbabwe, to create the Southern Africa Regional Agroforestry Programme. The programme's major vision was to tackle the entangled issues of food insecurity and poverty, based on an environmentally sound management of natural resources. Resource-poor smallholder farmers are therefore the major target of agroforestry research and development in southern Africa. Although agroforestry technologies can simultaneously provide a wide range of products and services, they can be broadly grouped into categories depending on the major function they play. Here we focus on two of them.

4.4.1. Agroforestry for soil and water conservation: the improved fallow system

In southern Africa, improved fallow is without question one of the most promising strategies to improve soil fertility, control erosion and enhance the water holding capacity of soils. In this agroforestry system, fast leguminous trees or shrubs (these species fix nitrogen from the atmosphere and recycle it in the system) are rotated with maize to improve yields of the cereal crops (Kwesiga, 2003). The efficiency of improved fallow systems in contributing nitrogen to the soil is well documented (Ikerra et al., 1999; Chikowo et al., 2003). In the Shire highlands of Malawi, pruning Gliricidia 2 to 4 times per year gives annual leaf biomass of 2-7 tonnes per hectare, adding between 60 and 120 kg of nitrogen per hectare to the soil annually. Trials carried out at different sites in southern Africa indicate that maize yield can increase as much as 300 percent after a 2-year rotational improved fallow compared to the continuous cropping system, which normally produces 1-2 tonnes of maize per hectare (Kwesiga et al., 2003).

Another technology that has been tested along with improved fallows to enhance land productivity in smallholders' farms in southern Africa is biomass transfer. This technology entails the cutting and carrying of leaves from tress grown outside the cropping area such as the field boundaries to be applied in relatively small areas for crop production. However, given the huge amount of biomass needed per unit area and the important labour required to cut, carry and apply this biomass to the fields, biomass transfer can only be justified when high value marketable crops such as vegetables are grown. For instance, farmers in eastern Zambia use leaves of leguminous trees such as *Gliricidia sepium* to fertilise garlic plots. Garlic farming usually takes place in wetland areas, where there is enough water to grow crops in the dry period. The retail price of garlic is US$ 5 per kg, which constitutes a good incentive for the cash-strapped farmers of Zambia.

If maize yields can significantly increase in the nutrient depleted soils of southern Africa in the first year following the clearance of the leguminous fallow, a minimal use of inorganic fertiliser may still be needed for crop production to be sustained in the long run. This is due to the fact that the nitrogen contributed by the trees tends to decline fast after the first maize crop but also because trees do not contribute much in the supply of other minerals such as phosphorus and potassium that are essential to maize production. Studies in southern Africa suggest that adding a quarter of the recommended fertiliser in the second and third maize crop following a *Sesbania* fallow helps maintain yield as high as in full use of inorganic fertiliser (Kwesiga et al., 2003). Arguably, using improved fallow and small doses of inorganic fertilisers provides the best inorganic/organic combination in terms of feasibility, acceptability, return, and risk resilience for the smallholder farmers of southern Africa.

Can improved fallow contribute to drought mitigation?

In addition to supplying nitrogen to the maize crop, the improved fallow technology has the potential to ameliorate the physical and biological properties of the soil. The organic matter contributed by the tree biomass (litterfall, roots and prunings) fuels the activities of micro-organisms. Increased biological activities result in more stable aggregation, which in turn enhances the soil environment for better crop production. Typically, soils after fallows are less compact and have a better porosity so that rain water can infiltrate more easily. Also, since these soils are enriched in organic matter, they are more capable of retaining water than the degraded soils under continuous cultivation. The role of improved fallow in enhancing soil water storage has been demonstrated in western Kenya (Orindi, 2002; Kandji et al., 2005).

Crop failures in semi-arid areas are often due the poor utilisation of rain water by the crops, especially when the soils are degraded (Jonsonn et al., 2003). Research in Zambia has shown that improved fallow can help the maize crop make better use of rain water. Figure 4 shows that the rainfall use efficiency (RUE, defined as the quantity of maize in kilogramme per hectare produced with each millimetre of rainwater) is generally higher after a 2-year fallow of *Sesbania* s*esban* than after a maize crop. In low rainfall years, the efficiency with which water is used by crops is paramount as it can be the dividing factor between absolute crop failure and reasonable food production. The experience in Zambia showed that agroforestry has the potential to buffer agricultural crops against water deficiencies, which are likely to become more frequent in southern Africa due to climate change.

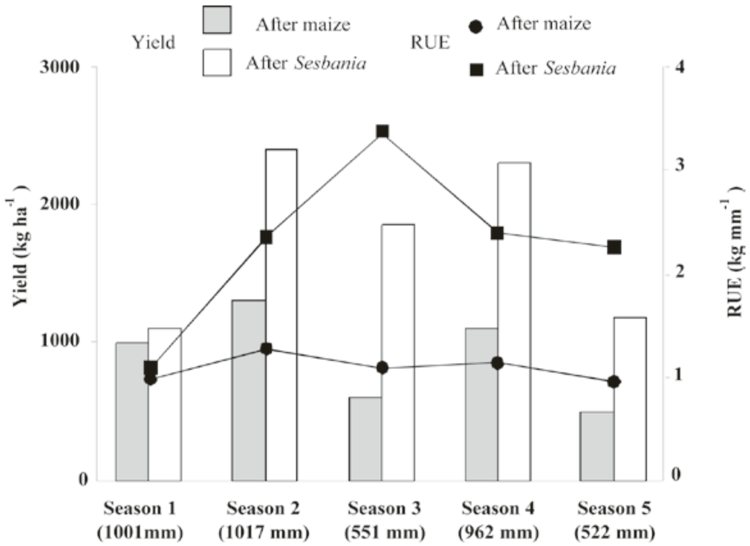

Figure 4. Grain yield and rainfall use efficiency (RUE) of maize in continuous maize and improved fallow (IF; Sesbania sesban) systems across five seasons in Makoka, Zambia (adapted from Kandji et al., 2005)

4.4.2. Agroforestry for high-value tree products: domestication of wild fruits

Indigenous fruits have always played an important role for the rural communities in Africa, particularly in the southern Africa region. According to a recent survey, more than fifty tree species growing in the wild are used for food and income by the local people (Campbell, 1997). In recent years, these 'wild' fruits have regained importance due to the mounting food insecurity associated with the recent droughts. It is likely that with climate change these trees will have an even bigger role to play. In Malawi and Zambia, as much as 80 percent of the 323 rural households surveyed in 2001 reported having faced severe food shortages, especially during the months of November to January. About 50 and 26 percent of these households in Malawi and Zambia, respectively, said that they resorted to fruit trees during the famine period (Akinnifesi et al., 2002).

However, most of these useful trees are threatened and may disappear due to increased anthropogenic pressure and adverse climatic conditions. Under these circumstances, the idea of domesticating these wild fruit trees so that farmers can cultivate them as tree crops makes great sense. ICRAF and its collaborators in the region have initiated work in that direction, following a three-pronged approach.

First, it was necessary, through ethnobotanical surveys, to identify the most important trees species on which the local people have relied for direct consumption and cash. These surveys revealed that *Uapaca kirkiana*, *Parinari curatellifolia* and *Strychnos cocculoides* are the three most preferred species in the region but there is a host of other species that were differently popular depending on countries and locations within the same country (Maghembe et al., 1998).

The second major thrust was on tree propagation techniques and management. Genetic improvement is crucial, and among the various features addressed are tree height, the number of year before fruiting, fruit size, taste and pulp content (Akinnifesi et al., 2002; ICRAF, 2004). Without improvement, many of the indigenous trees take more than 10 years before setting fruits, which is one of the reasons why no farmer was interested in planting them. Yet, research has shown that these trees respond well to grafting and can produce fruits as early as 2–4 years after planting. The inclusion of other desired traits such as taste, size and fruit load is being considered using clonal selection.

The third aspect of ICRAF's work in relation to fruit trees is related to value addition through processing, packaging and marketing. In Malawi and Zambia, ICRAF has trained women in pilot cottage processing of indigenous fruits into juice, jam, wine, yogurt and many other products. Collaboration with South African universities has been initiated by ICRAF and its partners to foster product quality improvement, assurance and certification through the Commercial Products from Africa Wild (CPWild Consortium). In Zimbabwe, collaboration with the NGO Safire and a private company, Tulimara Speciality Products Ltd, has been critical in addressing issues of packaging to meet city market standards (ICRAF, 2004).

Domestication of indigenous trees for fruit production can provide farmers with an alternative or additional source of income, thus strengthening the socioeconomic resilience of rural populations. In general, trees have a much higher drought resistance compared to annual crops because of their strong root system that can track water and nutrients much deeper in the soil. In addition, tree products (timber, fodder, resins and fruits) tend to be of higher value than maize or other grains and can provide a useful fallback in the case of crop failure.

4.4.3. Level of agroforestry technology adoption in southern Africa

Despite the great promise, agroforestry has not yet spread sufficiently to have a significant aggregate effect in the region. For instance, recent estimates revealed that only 1.5 percent of maize farmers in southern Africa are using the improved fallow technology (ICRAF, 2004). This shows the magnitude of the task ahead if the millions of small scale farmers scattered throughout the region are to be reached. In an effort to scale up the improved fallow technology, ICRAF scientists in southern Africa have set themselves the ambitious but realistic objective of reaching 400,000 farmers by 2006 and donors such as the Canadian International Development Agency (CIDA) and the United States Agency for International Development (USAID) have provided funds to support the initiative. There are claims that at present, half of that number has already been reached (ICRAF, 2004). It is also estimated that by 2001, over 5000 farmers across the region were experimenting with approximately 20,000 indigenous fruit tree germplasms on their farms (Bohringer et al., 2001).

4.4.4. Conditions for agroforestry adoption

Research on the factors influencing the adoption of agroforestry technologies in southern Africa has been going on for some time. The socio-economic variables studied include wealth level, farm size, gender, age, level of education of the household head, and labour availability (Franzel et al., 2001; Ajayi et al., 2003; Thangata and Alavalapati, 2003). In Malawi, studies on improved fallow showed that younger heads of households were either more eager to adopt the technology (Thangata and Alavalapati, 2003) or use it more intensively (Keil, 2001) probably because they have a longer planning horizon and may be less risk averse than more elderly people. Wealth status could also play some role in the farmers' decision to adopt agroforestry. In the Eastern Province of Zambia, farmers with more resources tend to adopt improved fallow more than their poorer counterparts (Peterson, 1999; Phiri et al., 2003). A study by Keil (2001) showed that fairly well-off farmers are more likely to adopt improved fallow than the well-off farmers. This is not surprising for the simple reason that the well-off farmers can afford to purchase fertiliser and may not have any need to plant fertiliser trees. Thangata and Alavalapati (2003), on the other hand, argue that diversified sources of income, rather than wealth status, had more influence on agroforestry adoption in Malawi.

The fact that relatively richer farmers have so far made the largest proportion of agroforestry adopters does not mean that poor farmers are not potential adopters. A study by Phiri et al. (2004) in Eastern Province in

Zambia revealed that 22 percent of the farmers who were classified as poor and 16 percent of the farmers who were classified as very poor planted improved fallows. The number of people working on the farm may be a critical factor since agroforestry practices require that labour is diverted from other farming activities (Ajayi et al., 2001; Franzel et al., 2001; Thangata and Alavalapati, 2003). Although the importance of variables such as wealth, age, gender or level of education of the farmer can vary from place to place, contact with extensionists seems to be a decisive factor for agroforestry technology adoption regardless of the area studied (Ajayi et al., 2001; Place et al., 2002; Kuntashula et al., 2002; Thangata and Alavalapati, 2003). Therefore, unlike fertiliser use which is the preserve of well-to-do growers, agroforestry can be used by anybody including poor and female farmers. The challenge from governments is to strengthen extension services so that they can reach the most vulnerable segment of the community. It is essential that the limited means which are available for extension should be used more effectively with for example the introduction of para-extensionists such as literate local farmers or unemployed secondary school graduates (Thangata and Alavalapati, 2003).

As in the case of crops, policies should be put in place to ensure a good tree seed distribution system, which is critical for the spread of agroforestry. At the moment, seed distribution is a highly fragmented business in which many actors (national seed systems, NGOs, research organisations such as ICRAF, private organisations, community based organisations (CBOs) and individuals) are involved without a clear definition of roles. It appears that a healthy collaboration between these various entities will be needed to make good quality seed available to end users.

4.4.5. 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 this type of effects and positive impacts such as microclimate effects and soil protection? Unlike in row crops, 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 represents one area in which research would be needed.

4.5. Conclusions

Climate and agricultural research have an important role to play in climate change adaptation. Even if improvement is still needed in some areas, seasonal climate forecasting is already sufficiently developed to enable the international community, African governments and the local communities to be better prepared in the face of extreme climatic events such as drought. Agricultural research, spearheaded by the international organisations under the Consultative Group on International Agricultural Research (CGIAR), has shown that it is possible to find solutions to the constraints that are currently maintaining crop yields at a very low level. The development and release of productive varieties that mature early or are tolerant to drought and various other stresses such as nitrogen deficiency, pests and diseases, is already making an impact in the region and could perhaps play a role in responding to climate change in the future. Combining improved varieties, soil and water conservation, and better crop management has a great potential for stabilising crop production in small scale farming systems. Agroforestry, by enhancing crop production through improved soil conditions (improved fallow) or by providing wood, fruits and other valuable products for home consumption or for sale (tree planting in farms), can provide an effective means to buffer the vulnerable farmers against current climatic uncertainties.

One major problem with 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 can be used to cope with current climate variability will be effective to respond to future climate change. The challenge, therefore, is to develop a mix of no-regret technology options and policies geared at promoting the emergence of productive, sustainable and flexible agricultural systems that show enough resilience regardless of the direction and magnitude of 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.

5. Building a resilient agricultural sector to face climate change

To develop a resilient smallholder agricultural sector in southern Africa requires 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 problems related to 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 agricultural 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 programs; and distortions in international markets. This section gives a list of recommendations which, we believe, could make agriculture in southern Africa more productive and more resilient to various shocks, including climate change. This list is not exhaustive nor are the recommendations given in any order of importance.

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

Inter-annual variability of rainfall is perhaps the biggest constraint to agricultural sustainability in southern Africa. The bad news is that rainfall variability both within and between seasons is expected to be more pronounced with climate change. However there is some good news as well: it is becoming more and more clear that this variability can be predicted quite successfully in advance. Therefore, reliable seasonal climate forecasting will be critical to help farmers, herders and other end-users to make the right decisions depending on the most likely scenarios. The collaboration between national, regional and international climate research centres needs to be reinforced to acquire timely weather information. Even if great progress has been made in the area of output accuracy, 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. Therefore, good interpretation and communication of forecast outputs is critical for trust building between producers and users of forecasts. It may be useful to develop and operationalise some kind of insurance scheme so that farmers and other end users can be supported in the case of bad decisions due to a 'wrong' seasonal prediction.

5.2. 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 southern Africa over the last few decades and the widely shared belief that this will continue or get worse in the future dictates that the drought tolerant and drought escaping varieties of maize, millet and sorghum developed by CIMMYT and ICRISAT should be widely promoted. Designing and implementing policies that ensure the access of improved seed by the smallholder farmers will be paramount to make the transformation happen.

5.3. Invest in soil and water conservation

Conserving soil and water is useful because this has the potential to (a) enhance soil fertility; (b) improve water storage in the soil; and (c) buffer crops against droughts and floods, which are likely to become more frequent with climate change in southern Africa. Experience in South Africa has shown that, with conservation tillage, producing decent crop yields during low rainfall years is feasible. However, some of these technologies may need good skill and high energy or an abundant labour force. External intervention from governmental and development agencies is often needed to initiate soil and conservation projects.

5.4. 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.

5.5. Promote supplemental and small scale irrigation

Rain water harvesting with the help of retention basins or the boring of shallow wells can help to 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. Southern 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.

5.6. Invest in pest and disease control

Agricultural pests and diseases constitute a major threat to food security in southern 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. Controlling pests such as locusts that have a regional scope warrants a strong regional and international cooperation.

5.7. Develop low cost post-harvest technologies

Damage of grain stocks by insect and other storage pests is responsible for a significant share of production losses in Africa. The African small scale farmers are permanently haunted by the fear of losing their harvests to storage pests, which forces them to quickly sell their grains when the price is lowest. Paradoxically though, they would have to purchase those same grains at very high prices later in the year if they can afford it. 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 (Murdock et al., 2003).

5.8. Promote agroforestry

Agroforestry research and development need to be strengthened given its immense potential for mitigating the negative effects of climate variability. Policies should be put in place to rehabilitate the degraded lands of southern Africa using proven agroforestry technologies. Improved fallow–an agroforestry technology whereby plants that fix nitrogen from the atmosphere are rotated with agricultural crops– supplemented with low levels of chemical fertilisers may provide a winning combination to maintain land productivity in small scale farming. The use of green manure for off-season market gardening is another promising technology that could contribute to reducing rural poverty. The role of trees in improving microclimate, reducing soil erosion and generating income could be more needed in the advent of climate change.

5.9. Develop processing industries

The development of agro-processing industries is a necessary step in the quest for food security and poverty reduction in Africa. Small and medium scale processing industries can be an important engine for rural development by creating market opportunities for farm products, adding value to grains and contributing to job creation. The primary objective is to satisfy the high food demand from the rapidly growing urban population. However, given the severe fodder shortages that occur during the dry season, promoting the use of grains in the formulation of animal feed could also contribute to addressing livestock development problems in the region. Lessons can be learnt from Zimbabwe, where the increasing demand from the stock feed industry is fuelling the rapid growth of the small grains (millet and sorghum) sector.

5.10. Foster institutional linkages 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. To avoid intergenerational conflicts, religious and customary chiefs should also be consulted right from the beginning of the process. 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.

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

One of the reasons why smallholder farmers have often been by-passed by new technologies is their inability to access credit. The agricultural banks that exist usually target big commercial farms and are reluctant to lend to smallholder farmers because they often consider them 'unbankable'. Permitting farmers, and particularly women, to own land through title deeds could perhaps allow them to have the collateral needed to secure loans from financial facilities. But, one proven way of enhancing the rural communities' chance of attracting loans is to organise them into some kind of groupings. For instance, in Bangladesh Grameen Bank has been promoting group lending to the rural poor with tremendous success (Sachs, 2005). The major advantage of group lending is that: (1) it allows the poorest members who cannot secure loans individually to do so under a joint collateral; and (2) it greatly reduces the transaction costs associated with individual lending. The very low default rates with the Grameen Bank facility constitute a measure of success. Valuable lessons can be learnt from this experience

12.12. Improve information delivery

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 is opening up new opportunities and should be exploited fully to reach the otherwise remote and unreachable areas. Encouraging farmers' field days has also proven effective for the rapid spread of new technologies.

5.13. Invest in rural infrastructure

A positive correlation has been found between remoteness (expressed by the distance from roads) and the incidence of poverty (Stifel et al., 2003), hence vulnerability to future climate change. As in many African countries, the vast majority of farmers in southern Africa have only limited access to input and output markets because of defective road and information systems. Climate change can isolate these farmers even further since more frequent La Niña-related floods can damage rural infrastructures and make roads impracticable. Without adequate investments in rural infrastructures, adaptation efforts through agricultural development will be a futile exercise. Feeder roads are more effective in linking remote areas to the mainstream economy and should be given high priority.

Investment in health is necessary to eradicate infectious diseases. Rural health clinics can go a long way in improving sanitary conditions in rural areas. The HIV/AIDS pandemic is becoming a major threat to development in southern Africa, and a strong effort should be made to address the problem. Access to clean water and education are also paramount and investments should be done in those areas.

5.14. Improve links to regional and global markets

Investing in market infrastructures is a necessary step for the development of agriculture in southern Africa. The SADC provides an ideal situation to enhance market integration. To make this happen requires the development and/or reinforcement of mobility within the region. The major railway lines and roads linking the ports of the Indian and Atlantic coasts to the landlocked countries of Southern Africa should be revamped and well maintained. Good transport infrastructures (roads, rails, ports and airports) can also improve access to the global market although other issues such as agricultural subsidies from the North that prevent African countries from fully benefiting from global trade need to be addressed as well.

5.15. Tapping the opportunities offered by the Climate Convention and other processes

There is now a strong commitment from the international community to tackle the issue of climate change. The various funding sources that exist should be tapped to carry out vulnerability and adaptation studies and develop priority projects for funding in the agricultural sector. The NAPA process constitutes an important framework for the least developed countries in the region. The adaptation funds, which are going to be 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 affording additional resources to a growing number of countries. Some of these resources should be used to strengthen the agricultural sector in the beneficiary countries.

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