Final Draft

Is Climate Change a Threat or an Opportunity for Africa?

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Abstract. Climate change is widely seen as a threat to Sub-Saharan Africa. Higher and more variable temperatures could lead to faster desertification, rising sea levels, and more frequent droughts, floods and typhoons. With its high dependence on rain-fed agriculture, prevalence of water-borne diseases such as malaria, and explosive combination of natural resource dependence, rapid population growth and violent conflict, Africa may be the continent that is hardest-hit by the effects of climate change. Furthermore, global pressures to mitigate carbon emissions may require African countries—many of which are, after twenty years of stagnation, experiencing a resurgence in growth—to curtail their growth in energy demand, possibly slowing economic growth. But climate change could also be an opportunity for Africa to accelerate growth and poverty reduction. Many of the measures that need to be taken, such as increased use of irrigation, better use of the continent's hydropower resources and strengthened efforts at curbing malaria, are good for African development. One of the reasons they have not been done up to now is that shorter-term, politically-driven priorities have dominated. The need to adapt to climate change could tip the balance in favor of such poverty-reducing actions. In terms of mitigation, curtailing energy demand is unlikely to affect global greenhouse gas emissions much since Africa today makes up only 4 percent of the world's total emissions. However, some African countries such as D.R. Congo, Cameroon and Ethiopia can contribute to mitigation by slowing or reversing deforestation. If the Clean Development Mechanism of the Kyoto Protocol or alternative market-based mechanisms could be extended to include the avoidance of deforestation, African countries could receive significant amounts of money for their contribution to the mitigation of global climate change. This paper assesses whether climate change is a threat or an opportunity for Africa. We find that the prospect of climate change does provide an opportunity for African countries to accelerate development in water, energy and disease control, although some of the obstacles to these policies still exist. We also find that avoiding deforestation, while potentially quite lucrative for some African countries, entails opportunity costs and implementation challenges. Whether it is a threat or an opportunity, the prospect of climate change calls for early and concerted action to enable hundreds of millions of Africans to escape poverty.

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* The findings, interpretations and conclusions expressed in this paper are those of the authors and should not be attributed to the World Bank.

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I. Introduction

There are two ways to view the impact of climate change on Africa. One is that it is a major threat. Two-thirds of the continent is fragile desert or dry land. Agriculture, which contributes some 30% of GDP and employs 70% of the population, is mainly rainfed—only 7% of cultivated land is irrigated—and highly sensitive to droughts and floods. Africa has the lowest water storage capacity in the world. Malaria, which is already the biggest killer in Africa, is spreading to higher elevations thanks in no small part to climate change. Africa's rapidly urbanizing population are vulnerable due to poorly defined property rights, weak land use planning and informal settlements, frequently on land subject to erosion or flood plains. Finally, armed conflict, terms of trade shocks and aid dependence add to the weight of these factors. Africa's vulnerability could lead to "low human development traps" (UNDP 2007) from ex ante losses in productivity, and erosion of assets (land productivity, livestock, water resources) and capabilities (health, nutrition, and education).

Furthermore, Africa accounts for only 4% of global CO_2 emissions, reflecting low levels of income and energy consumption (Figure 1). Climate change has been caused largely by the activities of industrialized countries. Efforts to curb global greenhouse gas emissions may require African countries to curtail energy demand. If this slows economic growth, it would be particularly unfortunate as African countries are for the first time in 20 years experiencing sustained growth as fast as developing countries outside China and India (Figure 2). With only 25% of the population at present having access to electricity, energy consumption must grow in Africa.

An alternative view is that climate change presents an opportunity for Africa to accelerate growth and poverty reduction. The reason why such a small percentage of cultivated land is irrigated is that the costs of extending irrigation (including short-term political and opportunity costs) exceeded the longer-term benefits. The increased threat of climate change may, at the margin, tip the balance in favour of irrigation. Similarly, with the prospect of the disease spreading, malaria may rise in policymakers' priorities, resulting in benefits for current and future victims.

Even mitigating climate change could be a benefit to Africa. With land and forest degradation accounting for over 60% of CO_2 emissions in Africa, compared with about 30% in the developing world as a whole, Africa could help mitigate climate change by more sustainable management of natural resources. To be sure, most existing carbon trading mechanisms, which focus on emissions reductions from energy and industry, are currently not well adapted to Africa's needs, but the potential is there.

Moreover, the continent has the world's highest level of untapped hydropower resources. One reason these remain untapped is that the rivers cross national boundaries, so that hydropower development requires multilateral coordination and cooperation. Inasmuch as mitigating climate change is a global public good, there is a better chance that the global community would be willing to facilitate the cooperation required for African countries to realize their hydropower potential.

This paper assesses both sides of the debate on whether climate change is a threat or an opportunity for Africa. While we find the evidence that it is a threat compelling, we also find that this same evidence could be used, in some instances, to tip the scales in favour of pro-development policies in Africa. However, many of the obstacles to "climate-resilient" development remain. We conclude that, regardless of whether it is a threat or an opportunity, the prospect of climate change requires early and concerted action.

Figure 1. CO_2 Emissions & Income (2004)

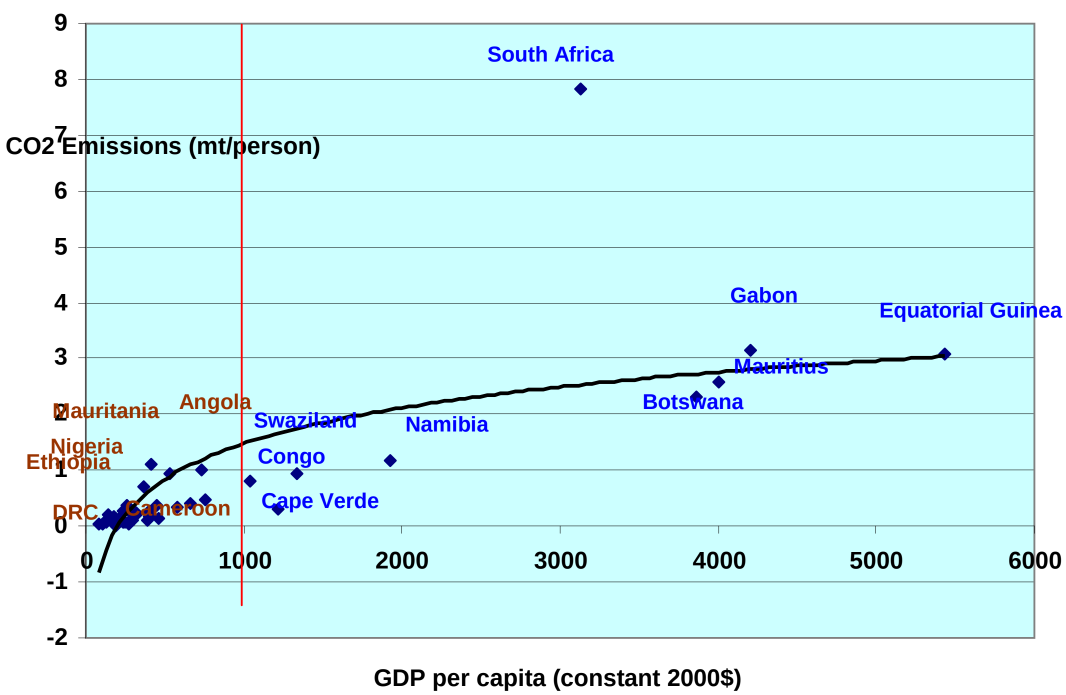
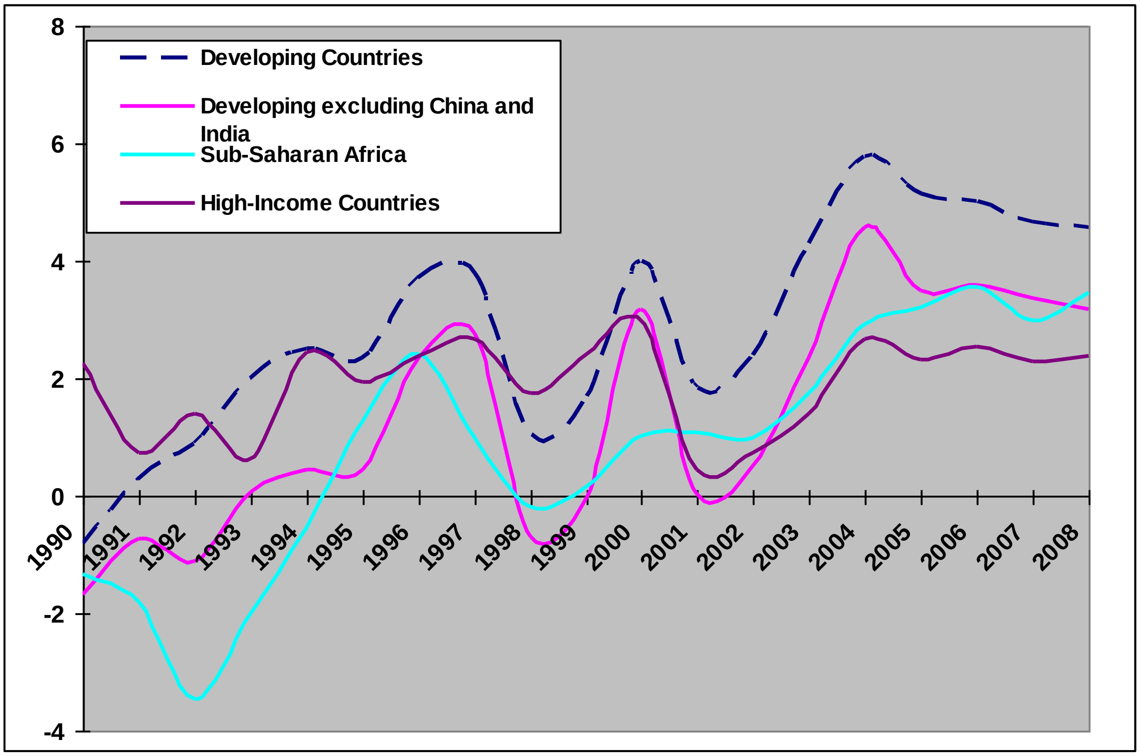


Figure 2. Annual Change in Real per capita GDP (%)



Source (Data from Arbache et al. 2007)

II. Climate change as a threat

A. Prospective changes to Africa's climate

Temperatures are rising and rainfall is becoming more unpredictable. Africa experienced important shifts in climate over the past millennia, but likely changes in the next few decades may present some of the greatest challenges (Toumlin 2005). The six warmest years on record in Africa have occurred within the last 20 years; the average temperature rose approximately 0.7°C during the 20th century. In addition, the continent has seen a decrease in rainfall over large parts of the Sahel and southern Africa, and an increase in parts of east and central Africa. The number of weather-related disasters, droughts and floods, has doubled in Africa over the last 25 years, and Africa has higher mortality rates from droughts than any other region.

According to the IPCC (TAR 2001 and FAR 2007), potential future climate changes in Africa include: (i) increase in global mean temperatures between 1.5°C and 6°C by 2100; (ii) temperature warming across the continent ranging from 0.2°C per decade to more than 0.5°C per decade, with warming expected to be greatest over semi-arid regions of the Sahara and central and South Africa; (iii) varying precipitation: southern Africa will become hotter and drier, while central Africa is expected to become hotter and wetter; some of the dry lands may get higher rainfall, but in the form of heavier torrential rains; (iv) increasing probability of occurrence of extreme weather events: droughts, floods, and typhoons; and (v) sea levels projected to rise by 15-95 cm by 2100. Projections suggest that the number of people at risk from coastal flooding could increase from 1 million in 1990 to 70 million in 2080, forcing major population movements.

Along with rising temperatures, there is also likely to be increased rainfall variability leading to more extreme precipitations and growing water stress. Crop-growing seasons will be affected. There are likely to be more intense and unpredictable weather events in countries such as Kenya, Ethiopia, Malawi, Mozambique, and Madagascar (Figure 3).

Figure 3. Most Affected Countries by Climate-Related Threats

Droughts	*Floods*	*Storms*	*Sea Level rise (1m)*	*Agriculture*
Malawi	Bangladesh	Philippines	All low-lying Island States	**Sudan**
Ethiopia	China	Bangladesh	Vietnam	**Senegal**
Zimbabwe	India	**Madagascar**	**Egypt**	**Zimbabwe**
India	Cambodia	Viet Nam	**Tunisia**	**Mali**
Mozambique	**Mozambique**	Moldova	Indonesia	**Zambia**
Niger	Laos	Mongolia	**Mauritania**	**Morocco**
Mauritania	Pakistan	Haiti	China	**Niger**
Eritrea	Sri Lanka	Samoa	Mexico	India
Sudan	Thailand	Tonga	Myanmar	**Malawi**
Chad	Viet Nam	China	Bangladesh	**Algeria**
Kenya	**Benin**	Honduras	**Senegal**	**Ethiopia**
Iran	**Rwanda**	Fiji	**Libya**	Pakistan
Note: The typology is based on both absolute effects (e.g., total number of people affected) and relative effects (e.g., number affected as a share of GDP) – Source: IDA15 Background Paper.				

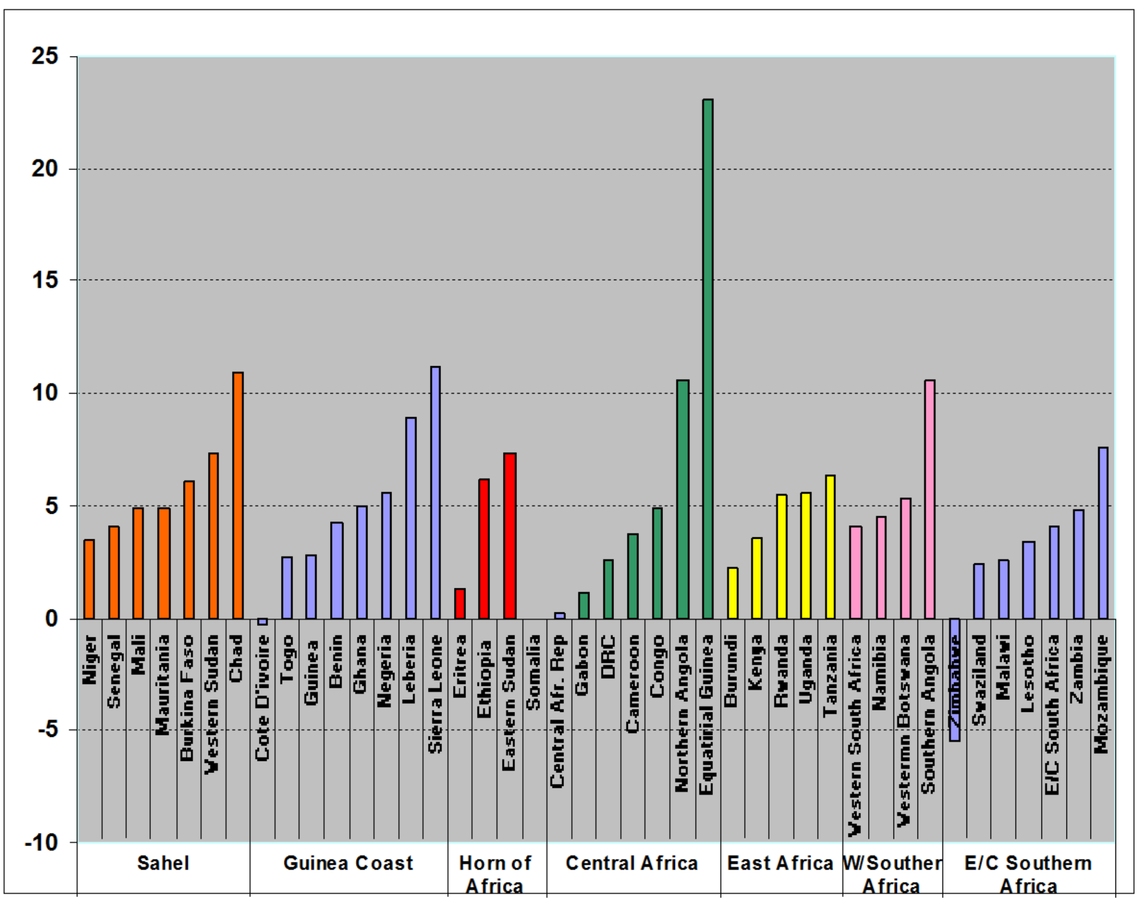
Although Africa is not unique in experiencing these changes, it is particularly vulnerable to the effects of climate change because of its high dependence on rain-fed agriculture (which is highly vulnerable to changes in climate variability, seasonal shifts and precipitation patterns) and very low capacity for water storage (the best endowed country, South Africa has half the water storage capacity of Southeast Asia and one-tenth of the North American level). And compared to other regions of the world, sub-Saharan Africa is severely constrained by the lack of climate-related information and weak adaptive capacity.

B. Effects on economic growth

After stagnating for much of 45 years, economic performance in Africa has been improving. In recent years GDP growth has been accelerating to its strongest point at about 6 percent a year while inflation registered below the two-digit level, its lowest point ever (Arbache et al., 2007). The current growth performance has lasted over a decade, and average incomes in Africa have been rising in tandem with those in other regions (Figure 2).

This economic performance appears to be invariant to climate characteristics. The distribution among countries between high and low performers is similar across the main climate zones in SSA (Figure 4). While average GDP growth over 2000-2006 was highest in central Africa (6.6%), closely followed by west southern Africa (6.1%), the Sahel (6%), and the Guinea coast (5.0%), it was lowest in the horn of Africa (4.9%), east Africa (4.6%), and east southern Africa (4.2%). Interestingly, the Sahel region, for which climate predictions (IPCC 2007, Washington 2008) project possible further drying conditions, large uncertainties, and shortening of the main growing period, has seen solid economic performance of late.

Figure 4. Economic Performance by SSA's main climatic regions % 2000-2006



Source: (Data from Arbache et al. Table 1, 2007

This is clearly an indication that some measure of resilience to climate variability is already built into African economies. Present development strategies and models already include important adjustments and adaptations to weather, climate and hydrologic risks, in the form of water storage, flood control and drainage infrastructure, crop varieties and practices, irrigation infrastructure, diversification of water supply sources, coastal defences, health systems, etc. But *climate change* introduces a new set of risks and challenges. Past variations and patterns are a poor guide to what might be expected in the future. Extremes such as droughts, floods and cyclones are predicted to increase in frequency and magnitude (Figure 6); sea levels are expected to rise adversely affecting not only coastal zones but drainage far inland in many cases; seasonal patterns of rainfall intensity and magnitude are predicted to change, increasing in some sub-regions and seasons and decreasing in others. Parts of Sub-Saharan Africa have already experienced an increase in temperature, and this important change is predicted to increase and affect larger areas.

While all of Africa's major economic sectors are vulnerable to climatic change, agriculture is the most vulnerable. In most African countries, there is a close association between GDP growth and rainfall. The persistent correlation between rainfall and GDP growth in Ethiopia (as shown in Figure 5-a) is striking; this is not the case in countries with higher incomes and highly diversified economies such as China or India, or Africa's middle-income countries (e.g., Botswana, Namibia, Mauritius). Moreover, long-term projections indicate that Africa's agricultural output could be reduced more than any other regions of the world (Figure 5-b).

Droughts and floods cause significant economic and social losses (Figure 6). Recent country-level studies suggest that the impacts of hydrology and rainfall variability on economic development are significant, estimated at 8-9 percent of GDP in Zimbabwe and Zambia in 1992, and 4-6 percent in Nigeria and Niger in 1984. In Ethiopia, it was estimated that droughts and floods have reduced economic growth by more than one third. Annual damages in Kenya due to flooding and drought in 1998–2000 range from 10 to 16% of GDP (the 1997/98 flood alone caused $1.8 billion destruction of infrastructure and property). The Mozambique 2000 floods cost the country US$ 550 million (1.5% reduction GDP growth rate). In addition to direct and immediate impacts, floods and droughts can also have persistent impacts through destruction of productive capital and/or, in the absence of safety nets, disposal of productive capital for survival (for example, the sale of livestock by poor households).

Climate change also affects the availability and reliability of energy. Lower annual rainfall in some parts of the continent has sharply reduced the power generation capacity of hydroelectric dams. Meanwhile, twenty-eight countries in Africa have been affected by power crises in the past two years. This energy scarcity, compounded by high fuel prices, has resulted in high costs for transport, industrial and commercial sector operations in most African countries.

Figure 5: Links between Rainfall and GDP Growth (Ethiopia)

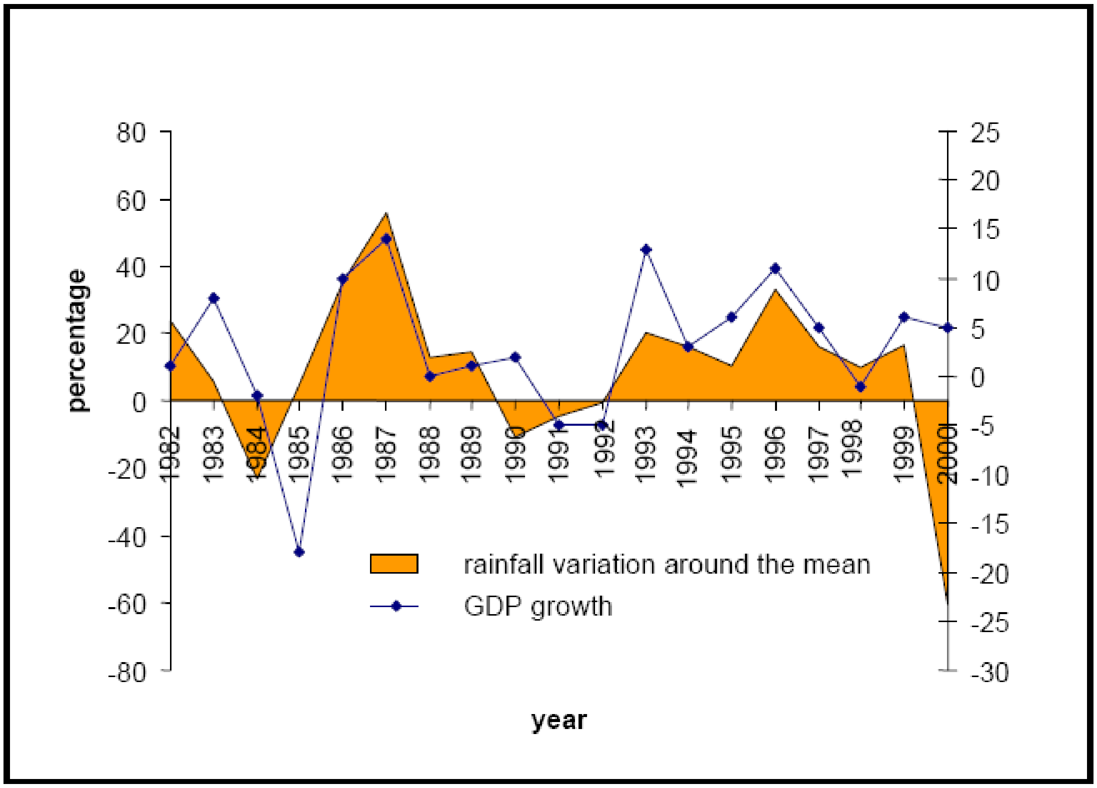
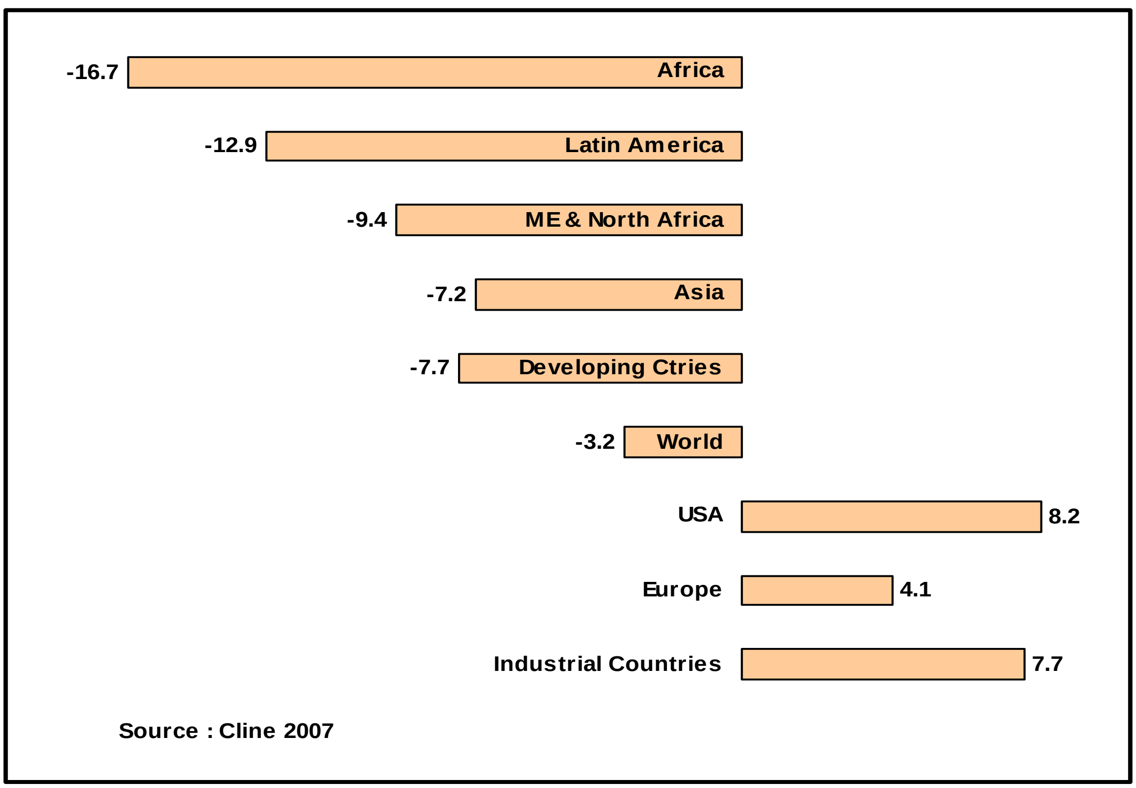


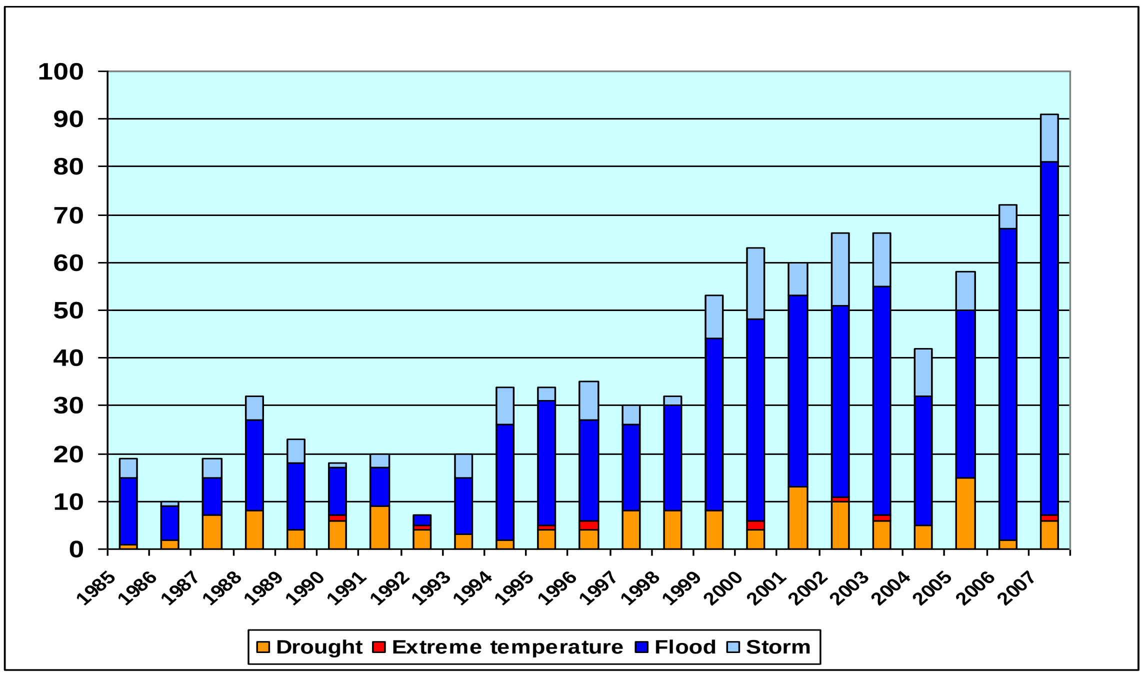
Figure 5-b Change in Output Potential (2080 as % of 2000)



C. Effects on Progress towards the Millennium Development Goals

A search of the literature revealed no systematic assessment of the impacts of climate change on the sectors (social and economic) that are central to the achievement and sustainability of the MDGs across African countries. Nevertheless, many assertions are made about the effect of climate change on the timing of the achievement of different MDGs and the way climate change will challenge the processes required to achieve the MDGs. For the MDGs concerned with income levels and hunger, human health and access to water and sanitation, there is insufficient momentum to meet the targets by 2015 across wide areas of Africa. The MDGs most susceptible to direct climate change impacts are MDG 7, particularly increased access to potable water, MDG 1 progress on food security, and MDG 6, prevalence and death rates associated with malaria.

Figure 6: Increase in the Number of Reported Disasters Hydro-Meteorological Disasters in SSA (1985-2007)



Source: "EM-DAT: The OFDA/CRED International Disaster Database

1. MDGs: goals, targets and current status

Table 1 below sets out the Millennium Development Goals, some targets associated with goals and the current status of Sub-Saharan Africa for the targets.

Table 1. Progress on Millennium Development Goals targets across Africa

	1990	2004	2015 target
MDG 1: People living on 1$ (PPP) as % of population	44.6	44	22
MDG 2: Net primary enrolments rate (%)	53	64	100
MDG 3: Promote gender equality			
Ratio of girl-to-boy in pr3imary completion (%)	51	61	100
Ratio of illiterate women to men of 15 – 24 age groups (%)	80	88	100
MDG 4 - Under 5 mortality per 1000 births	185	168	62
MDG 5 - Proportion of deliveries attended by skilled health workers	42	46	100
MDG 6 – Combat malaria, tuberculosis, HIV/AIDS and other diseases			
Adult HIV/AIDS prevalence	2.7	5.8	Stop increa
Tuberculosis prevalence (cases per 100,000 excluding HIV infected)	337	492	Stop increa
MDG 7 - Ensure environmental sustainability			
Access to improved water source (% of population)	49	56	75
Access to improved sanitation (% of population)	32	37	66
MDG 8 - Develop a global partnership for Development			
Share of ODA flows (% of donor GNI)	0.33	0.22	0.7

2. *Evidence of climate change effects*

Table 2 shows the different ways that current climate variability and climate change will continue to impact on the sectors that are central to achieving and sustaining the MDGs across Africa. It is important to note that no studies were encountered in the review of literature that assessed how climate change will impact on the MDGs across Africa. Some general assertions have been made by the UNDP and the UNFCCC as to what are the likely impacts of climate and climate change on the MDGs but these have not been followed up with empirical studies. The table provides information on the likely climate impacts on the MDG, taken from the UNFCCC National communications by non Annex 1 Parties.

Table 2. Evidence of the ways that climate change will affect the achievement and sustainability of the MDGs across Africa

Climate impacts	Sector	Information from climate projection research work
MDG 1 - Eradicate extreme poverty and hunger		
Productivity declines --in terms of crop yields, animal products off-take, & fish catches-- reduce household incomes and/ or worsen food security	Crops	• Productivity of mixed rain-fed and semi-arid systems, particularly in the Sahel expected to decline. • Agricultural GDP losses range from 2% to 4% with some model estimations. • Food security, already a humanitarian crisis in southern Africa, is likely to be further aggravated. • Wheat production is likely to disappear from Africa by the 2080s. • Southern Africa likely to experience notable reductions in maize production under possible increased ENSO conditions.
	Livestock	• Changes in disease distribution, range, prevalence, incidence and seasonality can all be expected. However, there is low certainty about the degree of change.
	Fisheries	• A greater intrusion of salt water into lagoons will affect the species that are the basis of inland fisheries or aquaculture.

MDG 2 - Ensure that all children remain in school and receive a high-quality education		
Loss of livelihood assets (natural, health, financial and physical capital) may reduce opportunities for full time education in numerous ways	Food security	• Experiences in several African countries (Ethiopia, Ghana, Niger) show that children aged five and under are more likely to be stunted if they were born during a drought year. • In Kenya, being born in a drought year increases the likelihood of children being malnourished by 50 percent.
MDG 3 – Promote gender equality and empower women		
Climate change affects women more than men exacerbating gender inequalities	Agri-culture	• Rural women in developing countries are the primary producers of staple food, a sector that is highly exposed to the risks that come with drought and uncertain rainfall.
Women and girls have to cope with fewer resources and a greater workload	Water	• Climate change means that women and young girls have to walk further to collect water, especially in the dry season.
MDG 4 - Reduce child mortality & MDG 5 - Improve Maternal Health		
Children and pregnant women are particularly susceptible to vector-borne diseases	Health	• Some 800,000 children under the age of 5 in sub-Saharan Africa die as a result of malaria each year, making it the third largest killer of children worldwide. Rainfall, temperature and humidity are three variables that most influence transmission of malaria — and climate change will affect all three. • In eastern Africa, flooding in 2007 created new breeding sites for disease vectors such as mosquitoes, triggering epidemics of Rift Valley Fever and increasing levels of malaria.
.MDG 6 – Combat malaria, tuberculosis, HIV/AIDS and other diseases		
Water stress and warmer conditions encourage disease	Environ-ment	• The highlands of eastern Africa and areas of southern Africa are likely to become more suitable for malaria transmission.
MDG 7 - Ensure environmental sustainability		
Alterations and possible irreversible damage in the quality and productivity of ecosystems and natural resources	Water & sanitation	• Increase in numbers of people who could experience water stress by 2055 in northern and southern Africa. In contrast, more people in eastern and western Africa will be likely to experience a reduction rather than an increase in water stress • Parts of southern Africa are projected to experience significant losses of runoff, with some areas being particularly impacted (e.g., parts of South Africa) • There is no clear indication of how Nile flow will be affected by climate change because of the uncertainty about rainfall patterns in the basin and the influence of complex water management and water governance structures
MDG 8. Develop a global partnership for development		
Funding for development and adaptation must be greatly increased to meet the needs of the poor	Diploma-cy and policy	• Developed countries have fallen short of targets they have set for themselves to achieve wide-reaching development objectives • Climate change challenges will require significant additional resources,

Source: IIDE (2007).

D. Costs of adapting to climate change

In a world of rapid climate change, estimating adaptation costs is very difficult. First, climate change affects all sectors making it difficult to separate adaptation from general development. Second, it is increasingly difficult to extrapolate future impacts of climate change from past patterns -- making any estimate of the costs of adaptation highly speculative. With these important caveats, there have been several attempts to provide ballpark estimates of the financing required for adaptation. Most have focused on "climate-proofing": that is, they looked principally at the cost of adapting current investments and infrastructure to protect them against climate change risks.

(i) World Bank/UNDP approach

The first estimate is based on preliminary calculations by the World Bank of the additional cost of adapting or climate-proofing new investments financed each year by development aid, domestic resources and foreign direct investments. Of the US$ 3 trillion per year of investments in the developing world, the majority of which are domestic investments, and assuming that the percentage of these investments that are sensitive to climate risk vary between 5 and 20%, total yearly adaptation costs are estimated to range from US$ 4 to 37 billion. A recent update by UNDP[1] using 2005 as a base year put the mid-range of the costs of adaptation at about US$ 37 billion a year (see Table 3).

Table 3: The cost of climate proofing development (estimates based on 2005 figures)

	Developing countries (US$ billions)	**Estimated portion sensitive to climate change**	**Estimated cost of climate adaptation (US$ billions)**	**Estimated cost (US$ billions)**	**Mid-range of estimated cost (US$ billions)**
Domestic investment	2724	2-10	5-20	3-54	30
Foreign direct investment	281	10	5-20	1-6	3
Net official development assistance	107	17-33	5-20	1-7	4

Source: UNDP (2007) using broad estimates from various sources and assumptions on climate sensitivity and cost from Stern 2006.

(ii) Oxfam's NAPA-based estimate

Extrapolating from the project cost of some 13 national adaptation action plans (NAPA), Oxfam puts the financing needed for immediate 'climate-proofing' at between US$1.1 billion and US$2.2 billion for the least-developed countries, rising to US$7.7–33 billion for all developing countries (see Table 4). Using a different approach, Oxfam attempted to estimate the broad financing requirements for community-based adaptation. Drawing upon a range of project-based per capita estimates, it reaches an indicative figure of around US$7.5 billion in adaptation financing requirements for people living on less than US$2 a day.

[1] UNDP, Human Development Report (2007), pp. 192-95.

Table 4: NAPA-based Estimates

Grouping	Population (millions)	GDP ($ billions)	Land use (sq. km)
NAPA 13, submitted	218	83	349
All LDCs	741	257	2,262
All developing countries	5,094	8,347	15,178
	Population basis	GDP basis	Land use area basis
Scaling up from NAPA budgets	$1.1 bn	$1.0 bn	$2.2 bn
Scaling up for all LDCs	$7.7 bn	$33.1 bn	$14.4 bn

Source: Oxfam (2007).

(iii) UNFCCC Sectoral Adaptation Estimates

The third estimate comes from an analysis by the UNFCCC [2] to estimate additional investment and financial flows needed for adaptation in 2030 in selected sectors (see Table 5). Due to the difficulties in estimating the adaptation costs to climate change in sectors such as ecosystems, these estimates may be low because the adaptation needs of some sectors were not included. Estimates are based on climate modelling assumptions. For the world as a whole, it was estimated that additional investments needed for adaptation in 2030 could be as high as US$ 170 billion a year, a large share of which is accounted for by infrastructure (representing some 0.2 percent of an $80 trillion global economy). The costs for developing countries are estimated at US$ 57 billion and could be as high as US$ 100 billion per year several decades from now.

Table 5: UNFCCC Estimates of Adaptation Investment needs in 2030 (US$ billions)

Sector	Global	Share of developing countries	Sources of-funding
Agriculture, forestry and fisheries	14	50%	Private sector
Water supply	11	80%	Public sector
Human health	5	100%	Families
Coastal zones	11	40%	Public sector
Infrastructure	8-130	25%	Public sector

The study also identified possible sources of funding. In agriculture, forestry and fisheries, a large share of additional investment will be in production and processing and thus will likely be covered by private sector agents. But public resources will likely be needed for research and development, extension and direct support to small scale farmers.

[2] UNFCCC, Report on the Analysis of Existing and Potential Investment and Financial Flows Relevant to the Development of an Effective and Appropriate International Response to Climate Change, (2007). These estimates are being revised.

For water resources, 80 percent of the estimated need will be in developing countries and the majority of financing will come from the public sector, both domestic and foreign. The totality of the additional investment needs in human health will be in developing countries with most of the cost to be shouldered by the families of those affected. But external support is expected to play an important role. For coastal zones, about half of the adaptation needs will be in developing countries with the large coastal deltas in Asia and in Africa and small island states being most affected. Additional sources of external development assistance will likely be needed. In infrastructure, the very wide range of the estimate reflects the significant uncertainty of the climate impacts.

III. Climate change as an opportunity

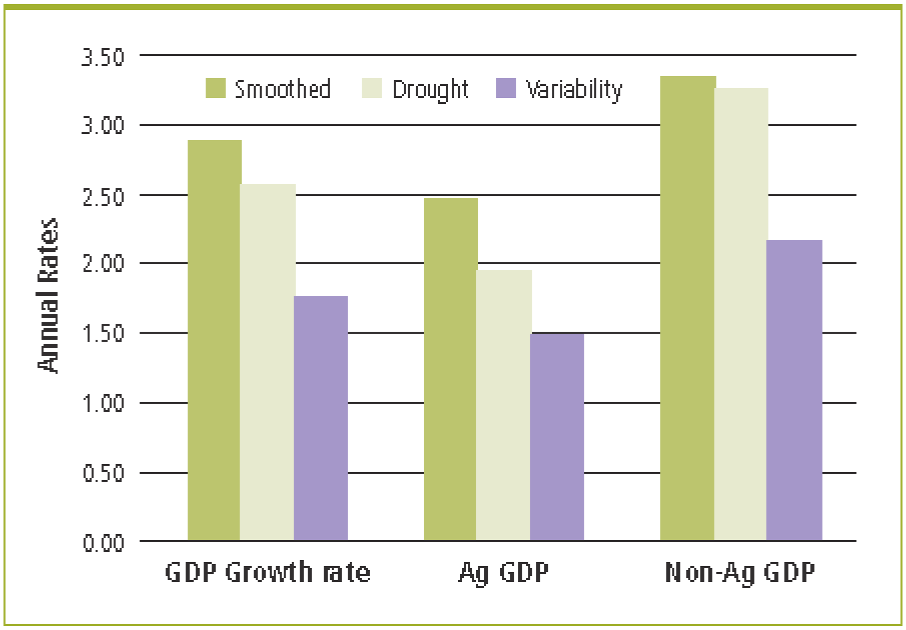
As shown above, the impacts of climate change are expected to be very significant in Africa because of limited institutional capacity, as well as their greater reliance on climate-sensitive sectors like agriculture. For African countries that have always faced hydrologic variability and have not yet achieved water security, climate change will make water security even more difficult and costly to achieve. For others that have enjoyed reliable water supply in the past, climate change may introduce new water security challenges. The impacts on agricultural output are exacerbated by an almost complete lack of irrigation and water storage infrastructure.

Farmers and water practitioners have learned to cope with variability in hydrology. Implementing good practices such as efficient irrigation technologies, water harvesting, increased storage would go a long way in confronting the climate change challenge. But because of the speed and intensity of climate change impacts, conventional interventions are not sufficient. Adapting to climate change requires a major shift in thinking in planning and designing water investments which are key not only for increased access to safe supply but also for hydropower generation and irrigated agriculture.

Work done by the World Bank on Ethiopia[3] showed that long-term, historical levels of hydrological variability diminish growth projections for the Ethiopian economy by over one-third and raise poverty rates by some 25 percent—clearly demonstrating the extraordinary impact of drought, and particularly variability, on the Ethiopian economy. A single drought event in a 12-year period—a very conservative estimate for Ethiopia—will decrease average GDP growth rates by 5–10 percent. If historical levels of variability and the partial impacts of floods are incorporated, GDP growth rates fall 20–40 percent. Figure 7 shows the difference in GDP growth rate projections when rainfall is modelled as a smoothed average, when a single drought event is incorporated, and when historical levels of variability are assumed.

Figure 7: Effects of Hydrology on Growth

[3] See Sadoff (2006) and World Bank (2006) for more detail.



Source: World Bank 2006.

In order to de-link economic performance from rainfall and enable sustained growth and development, countries such as Ethiopia must make major investments in water resources infrastructure, institutions, and management capacity. While investment on this scale have traditionally shown low returns, climate change and hydrological variability add a new dimension to the picture: by adding greater volatility and uncertainty, growth and poverty reduction will be further hindered making the cost of inaction even more acute. With the greater severity of the impacts expected from climate change, ensuring the resilience of the primary engines of economic growth is no longer an option but a necessity. The combination of water, irrigation, hydropower, roads, and other market infrastructure investments should produce dramatic synergies and provide the incentives and opportunity for farmers to shift out of subsistence agriculture into commercial agriculture and nonagricultural activities.

In short, the challenges of climate could enhance the returns and create new opportunities to shift the pattern of development and the structure of the economy away from the country's heavy reliance on rainfed agriculture.

A. Energy

The lack of or unreliable energy has been systematically identified as a major impediment to growth and competitiveness of African exports. Not only is energy important for growth, access to electricity also helps power other MDGs and meet the population’s basic needs. Underlying the low level of access are the exceptionally low levels of installed generation capacity in sub-Saharan Africa of which 60% is in South Africa alone. The mismatch between power demand and available supply has grown. Twenty eight countries are being or have been affected by the energy crisis in the past two years--an unprecedented situation. With more than 550 million Africans without access to electricity services, energy production and consumption are expected to soar in the future on this continent.

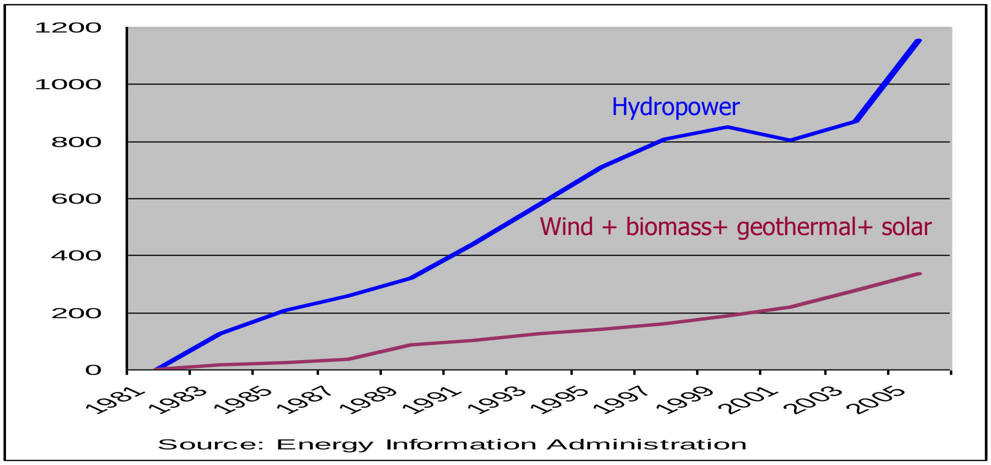
In the global context, hydropower accounts for about 20 percent of the world's electricity supply and 88 percent of that which is renewable. But production is irregularly distributed, with nearly 45 percent located in developed countries such as Norway, Canada, and the United States. In these countries, hydropower is the backbone of the electrical system and water resources management, and has helped shape economic growth. Ninety one percent of unexploited economically feasible hydropower is located in developing countries, with one quarter in China. Compared to OECD countries which have exploited over 70 percent of economically feasible potential, developing countries have only developed 23 percent of their potential. The amount of potential power is particularly significant in Sub-Saharan Africa with about 250GW or four times the current installed electricity generation capacity.

Climate change is also repositioning hydropower infrastructure's role in development. As noted in section II. B above, Africa is particularly vulnerable to hydrological variability and the very low water storage capacity sharply limits its ability to manage extreme weather events. In addition to bringing electricity to the 2 billion people who lack access, hydropower infrastructure also plays two critical roles in meeting the climate change challenge: first, renewable hydro energy offers an alternative to fossil fuels with much lower GHG emissions; second, larger water storage capacity can help countries adapt to changes in hydrology. Furthermore, hydropower offers a hedge against rising energy prices and can play an important role in energy trade and regional power pools.

Following a decade of learning about environmental and social risks, and a more favorable position by the World Commission on Dams on large reservoirs, there is a growing openness, including in the NGO community which has been very critical of large hydropower projects in the recent past, to consider hydropower as a useful tool in a low-carbon future. Key constraints in scaling up hydropower infrastructure lie in lack of financing, shortage of comprehensive planning and adequately assessed project pipelines, limited hydrological data and analysis, and unsettled conditions for private sector participation. Also, the inherent complexities and the multi-sectoral, multi-objective nature of hydropower projects further emphasize the importance of a strong risk management approach to the sector while implementing good practices is challenged by lack of human capacity in countries, and weak regulatory and policy frameworks.

Industry statistics indicated a sharp rise in investment in the recent past (Figure 8). This reflects rising energy prices, efforts to reduce carbon emissions and a fragile but growing confidence in the sector. Much of this growth has come in developed and emerging economies.

Figure 8: Growth in Renewable Energy (TWh)



But according to a recent report[4] released at the Africa Carbon Forum in Dakar, Senegal, Africa also has an unprecedented opportunity by choosing a cleaner development pathway through low-carbon alternatives that can reduce greenhouse gas (GHG) emissions to meet its future energy needs and, at the same time, receive support from carbon finance schemes[5] and the Clean Development Mechanism (CDM) of the Kyoto Protocol (see Box 2)..

Box 2. The Clean Development Mechanism.

CDM projects in developing countries provide an option allowing Annex I Parties to purchase emission credits and help them comply with their commitments under the Kyoto Protocol. CDM investments are market-driven in the sense that prices and volumes of emission reductions are negotiated between individual buyers and sellers. In addition to providing Annex 1 Parties and their entities with access to cost-effective emission reductions, The CDM allows 'carbon projects' – that reduce or avoid GHG emissions into the atmosphere in developing countries. Examples of such projects include the use of renewable energy (such as wind, hydro, bio-thermal or solar), the use of biomass residues (such as bagasse for electricity generation in a sugar factory), the implementation of energy efficiency measures (such as the introduction of compact fluorescent light bulbs or more efficient cook stoves), and waste management practices (such as capturing the methane emissions from waste water treatment plants, landfill dumps or animal waste). Thus, CDM projects are also supposed to promote sustainable development. CDM project developers must comply with relatively strict rules and procedures.

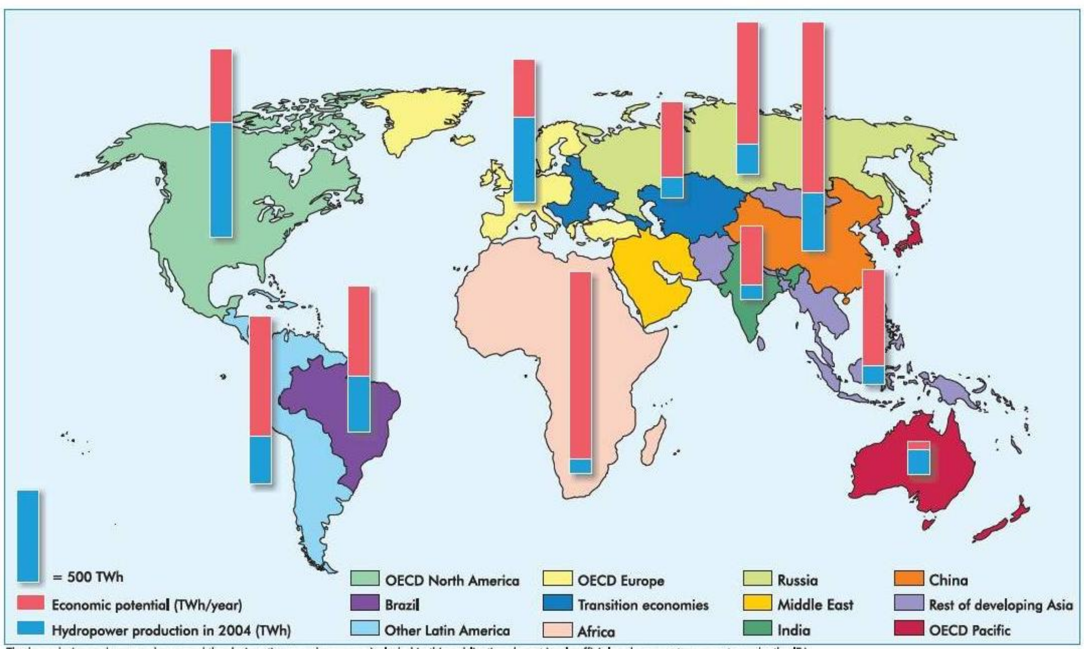
For 44 SSA countries and using 22 technologies that have been approved by the CDM Executive Board, the report estimated a technical potential of more than 3,200 low carbon energy projects. If fully implemented, this estimated pool of potential projects could provide more than 170 GW of additional power-generation capacity, more than twice the continent's current installed capacity. It is estimated that the achievable

[4] de Gouvello et al (2008).
[5] The carbon market is the most tangible result of efforts to mitigate climate change. By creating a market for emission reductions, in effect paying people and businesses to reduce GHG emissions, the carbon market provides a financial incentive to invest in clean energy projects, energy efficiency, in fuel switching, in waste management and in forestry.

avoidance of future GHG emissions would total about 740 million tons of carbon dioxide equivalent per year[6]. A conservative estimate of the total capital cost for the potential is about $150 billion, although detailed economic analyses of the potential investments remain to be done. Unlocking this potential would require important reforms such as filling the regulatory gaps needed to allow the sale of renewable energy to national electricity grids—most of which are managed in monopolistic arrangements—the collection and transport of the renewable energy and the dissemination of clean energy technologies, among others.

Besides, Africa has large, unexplored potentials for hydropower, solar, wind power and other new renewable resources. Of its huge hydroelectric power potential, only 7% is currently utilized, compared to over 30% in Latin America for instance (Figure 9). A recent UNEP funded study uncovered for example 2000 MW of wind power potential in Ghana. A geothermal potential of 7000 MW has been estimated, in particular in the Rift Valley in East Africa.

Figure 9: World Hydropower Potential



The boundaries and names shown and the designations used on maps included in this publication do not imply official endorsement or acceptance by the IEA.

Faced with the need to increase access to modern energy and the opportunity offered by Africa's vast potential in renewable energy and most particularly hydropower, the African Ministerial Conference on hydropower and sustainable development agreed on a plan of action for developing the huge untapped hydropower potential on the continent. It called for: (i) the development of a holistic Africa Energy Vision (2025) combining water and energy sectors under the auspices of the African Union; (ii) establishing a permanent secretariat in collaboration with the International Hydropower

[6] While it would be unwise to put a value on the GHG emissions reductions, the current price of a ton of 'certified emission reduction' in the European Union carbon market currently ranges from Euros 20 to 25.

Association; (iii) developing, in association with the UN-Energy Africa, a regular monitoring and reporting system on Africa's hydropower; and to devise a strategy to assist member countries in building, utilizing and exchanging technical expertise; and (iv) integrate energy and water sector ministries for holistic development of water resources. Building on the Ministerial Conferences on Hydropower, efforts are being made to directly engaging the private sector – financiers, investors, manufacturers, engineers and environmentalists – and getting this group as involved as governments in hydropower.

Notwithstanding the strong development rationale, enormous technical potential and robust body of knowledge on good practices, scaling up hydropower will face some important constraints and barriers. First, closing the financing gap, which is most severe in low-income countries will require accompanying actions to improve project preparation, reduce risk and improve the enabling environment required for increased private sector participation. Second, innovative business models will be needed to facilitate multi-purpose ventures and to capture synergies with environmental protection. Third, inadequate hydrological data, analysis and modelling hold significant risks for hydropower infrastructure. Climate change accentuates these risks for two reasons: (i) extrapolations of historical data are inadequate for infrastructure design as the past becomes an increasingly poor predictor of the future; and (ii) in the future, infrastructure will function in an ever-changing hydrology, placing a premium on flexibility and adaptive management[7].

In addition to the opportunities developed as a result of the need for urgent and massive efforts toward mitigation facilitated by the creation of new mechanisms such as the CDM, the option presented by the multipurpose development of cross-border water resources as developed above can also help promote regional integration through Regional Power Trading arrangements[8]. Removing borders through expansion of international transmission lines, greater trade and stronger regional bodies would expand generating capacity and reduce overall capital and operating costs. For example, electricity generation could take place near ports: transmission of power is cheaper than transporting high volumes of fossil fuels in-land by road and rail.

Hydro infrastructure has important spatial dimensions, with potential benefits to regional development. Hydropower's contribution to energy access goes beyond additional generating capacity to regional/transboundary system integration and efficiency. Increased regional integration through emerging power pools and coordinated electricity grids (particularly in west, east, and southern Africa) take advantage of hydropower's differentiated services in stabilizing and increasing efficiency of the system as a whole. For example, Ethiopia is in the process of developing significant hydropower capacity within an Eastern Nile pool for supplying power-hungry Egypt and Sudan. Moreover, the Ethiopia-Kenya interconnection under development takes into account hydrologic risk complementarity between the two countries.

B. Water

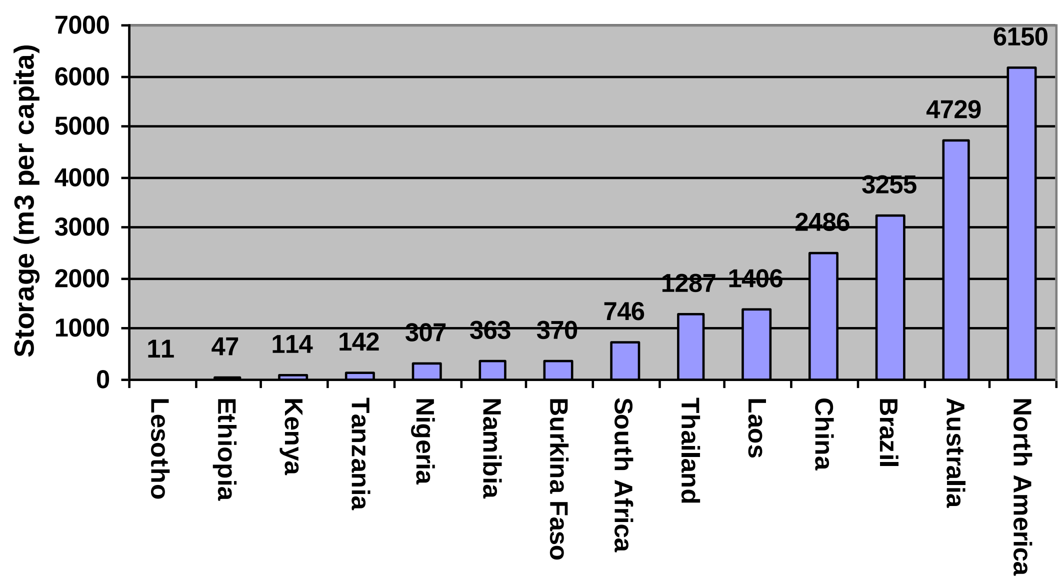
[7] See World Bank (2008b) for more detail.

[8] Currently, regional power pools exist in all sub-regions of Africa with the Southern Africa Power Pool (SAPP) and West Africa Power Pool (WAPP) being the most active.

Climate change will accentuate existing pressures on water resources and could increase exposure to water stress for 75 - 250 million people by 2020 (IPCC FAR, 2007). Given the multiple roles played by water, the impacts of climate change on water resources are multi-faceted. On the health and the well-being of households, climate change will most likely accentuate water scarcity, making it more difficult for Africa to achieve the MDG target on access to clean water. On agricultural and food production, because of the heavy dependence of most African economies on rain fed agriculture, long-term projections indicate that the agricultural output of Africa would decline more than any other region (see Figure 5-b). On hydropower generation, extended periods of drought in both Eastern and Western Africa compounded by high oil prices and poor regulations have led to energy crises in 28 countries in the past two years – an unprecedented situation.

Sub-Saharan Africa (excluding South Africa) has the world's lowest water storage capacity at around 43m³ per person per year and has developed less than 7% of its hydropower potential. North America, on the other hand, has a water storage capacity of 6150m³ per person per year and has developed 60% of its hydropower potential. Using the water storage capacity of South Africa (750 m³ per person per year) as a guide to other African countries, the World Bank estimates that Nigeria and Ethiopia alone have investment storage requirements of $67 billion and $46 billion respectively (Figure 10).

Figure 10. Water Storage (m3/capita)



The challenge brought about by climate change on the hydro-economy of most countries in Africa is the fact that water plays a central role as the significant input to almost all production. At the same time, most countries have to struggle to reduce the destructive impacts of water-related natural calamities such as floods and droughts. Water resources in most countries in sub-Saharan Africa can be characterized by two principal features, a natural legacy and a historical legacy. The natural legacy is one of high and rising hydrological variability coupled with rainfall seasonality. Due to Africa's colonial legacy, the continent has a disproportionate number of rivers and river basins that cut across country borders.

While climate change represents a significant impediment to economic progress in Africa, it has also led to the development of carbon finance and other financial mechanisms -- needed to promote the reduction of greenhouse gases (GHG) emissions -- that provide countries with the incentives to develop cleaner energy. The close connection between the urgent need to increase access to modern energy and rewards from GHG mitigation through clean energy – to be developed more fully in the next section -- presents Africa with the opportunity to take a bolder approach to water resources by adopting a multipurpose water resource development approach involving complementary water security infrastructure to manage hydrological variability -- encompassing storage, containment, ecological balances, water conservation, flood management, drought mitigation -- hydropower development, and water for navigation and irrigation.

Within this context, hydropower projects, and particularly storage projects, must adopt the principles of integrated water resources management (IWRM), to take into account multiple users of water and multiple objectives in managing and regulating water. IWRM goes beyond mitigation of project impacts to maximize environmental, social and broader economic ("triple bottom line") benefits from hydropower infrastructure. These benefits may be public or private, revenue-generating or non-revenue. IWRM calls for project identification, design and operations to take into account opportunities for such diverse water users as irrigation, navigation, fisheries and drinking water. While multiple uses require careful financing and project management, building on synergies can generate broader benefits at small incremental cost.

A corollary to regionalization of energy systems, water management is increasingly focused at the river basin level, regardless of national borders. A regional development approach addresses both upstream and downstream riparian needs, broadening the benefits of water management beyond physical distribution of water rights, and setting a foundation for regional cooperation. Africa in particular, is addressing fragmentation of its multiple states, markets and natural resources and moving hydropower and water infrastructure investments from a national to regional agenda. Water management also has broader security implications in many parts of the world. Turning regional hydropower projects from a source of possible conflict to a tool for regional cooperation and development is an increasingly important dimension of value.

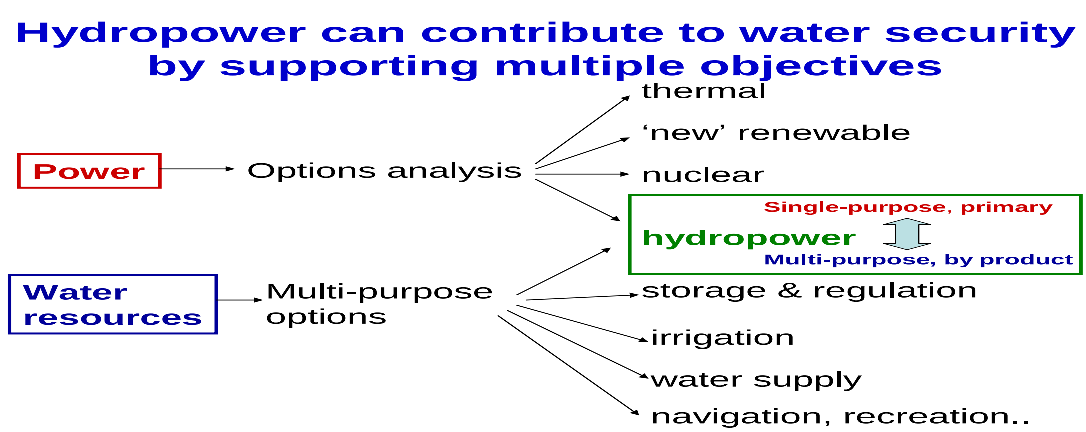
This multi-pronged approach has the clear potential not only to help countries build economic resilience to climate change but more importantly to diversify their economies through a more intensive irrigation-based agriculture and the development and/or deepening of new economic activities made possible by the availability of a larger and more stable supply of electricity (see Figure 11).

Furthermore, some of the investments may not be very costly. For example, by taking into account climate predictions in the design of a new storm water system today (with larger drainage pipes adding perhaps an extra 10% to the total cost of a new project), municipal decision makers would prevent a much more costly recovery from higher frequency and more severe storm surges in the future (possibly orders of magnitude the original project cost).

Another example relates to investment in irrigation. Recent work using a Ricardian approach (Karukulasuriya and Mendhelson 2008) estimates elasticities of temperature and precipitation with respect to revenue for dryland farming in Africa of minus 1.6 and 0.5 respectively, whereas irrigated farms are resilient to temperature changes and may actually increase in value. Therefore, notwithstanding the need to satisfy a number of criteria to ensure that irrigation is viable (Box 2), taking climate change into consideration increases the benefits of irrigated land, and provides an added incentive for decision makers to prioritize irrigation and water management decisions in dryland farming.

Investments in water and hydropower on a regional basis would also help to strengthen economic integration and peace. Developments in the context of the Nile River basin (in eastern and North Africa), the Senegal River basin (in West Africa) and the beginning of a similar process in the Zambezi River basin (in southern Africa) highlight the benefits of these regional arrangements.

Figure 11: Water in its Various Dimensions



Source: World Bank presentation (2005)

Africa's development partners have also realized the importance of transboundary water cooperation. Support has significantly increased since 2002 with 17 out of the 59 sub-Saharan transboundary basins currently receiving donor support. Recently, the Senegal and Niger Basins have been supported with about $400 million through multi-donor support, largely aimed at institutional development, eco-system management and infrastructure development. Similarly, the Nile Basin has been supported (about $300 million) with investments in irrigation, power inter-connection and capacity building. However, with the exception of SADC and ECOWAS, the establishment of regional coordinating mechanisms for water resources has not been successful in the other sub-regions of Africa.

With so much of Africa's natural resources shared between countries, effective institutions that help to ensure shared benefits from cooperation are important. Only a few basin organisations (Nile Basin Initiative, Niger Basin and Senegal Basin) are currently implementing transboundary water resource management (TWRM). These basins are preparing investment plans with similar plans in the pipeline for the Gambia and Volta basins. Many other river basins still suffer from lack of resources and above all governance issues, such as on-going conflicts and the primacy of national agendas at the expense of cooperation.

Box 1: The Senegal River Basin

The four riparian countries of the Senegal River Basin—Guinea, Mali, Mauritania and Senegal—rank among the twenty-five poorest countries in the world. All riparian countries are facing energy shortages and growing water constraints, which is hampering their economic performance. The Basin's hydropower potential is estimated at 1200 MW, of which less than 25 percent is currently exploited. Similarly, potential irrigable area is estimated at 320,000 ha, of which less than 32 percent is currently developed. Although the Senegal River Basin Organization (OMVS) has existed since 1972, the structure has not been fully inclusive due to the lack of involvement of upstream riparian Guinea. This has limited the development opportunities and shared benefits that could arise from cooperative and integrated management of the entire basin.

With support by development partners, the four riparian countries have worked to enhance regional integration of the Senegal River Basin for multipurpose water resources development that supports supported joint ownership of water infrastructure and fosters growth. The focus is placed on three activities to reach this objective: (i) regional institutional development for water resources; (ii) local level multi-purpose water resources development to promote income generation activities and to create tangible basin-wide benefits at the ground level; (iii) regional multi-purpose and multi-sector master planning.

Integrated river basin management coupled with the development of multi-purpose water resources infrastructure is expected to yield expanded opportunities for growth, reduced immigration and poverty, and improved health and livelihoods of the population while also preserving the environment. The multi-purpose approach will also broaden the scope of potential investments, generate a wider range of direct and indirect benefits (e.g., the development of a least-cost energy market in the context of the West Africa Power Pool), and enhance the participation of local communities in water management.

Source: IDA at Work: Water Resources

While multi-purpose water resource development has the potential to offer significant potential benefits to the countries of Africa, infrastructure alone is not a panacea without the development of appropriate water institutions. Badly managed infrastructure will not support growth and complex dynamics of multi-country development will need to be recognized (see Box 1 on the Senegal River basin initiative). In addition to water- and hydropower-related infrastructure, the development of roads and other market infrastructure investments must also be considered to provide the incentives and opportunity for farmers and other economic actors to shift out of subsistence agriculture into commercial agriculture and non- agricultural activities.

The very large investments required for the development of multipurpose water resource development infrastructure will necessarily require a more thorough analysis of the returns to investment and has important implications for the way in which we assess the cost-effectiveness of early investments in water resources infrastructure. Without taking into consideration the impact of climate change, current low-yielding agricultural practices partly justify the severe inadequacy in irrigation investment in most of Africa. Analyses done in the context of the preparation of Ethiopia's water resources assistance strategy highlights the fact that the returns to irrigation and drainage are significantly higher if the enormous costs of hydrological viability – caused by severe droughts and floods – were taken into consideration. By causing much larger damages and losses, climate change would contribute to justify the undertaking of larger infrastructure projects to help manage the impact of extreme natural events.

In a similar vein, the benefits from transboundary water projects will need to consider besides the direct economic benefits arising from improved agricultural and power production, environmental benefits through improved eco-system sustainability, broader economic benefits from regional economic cooperation and integration and political benefits through a shift from the competition for a scarce resource to cooperation and development.

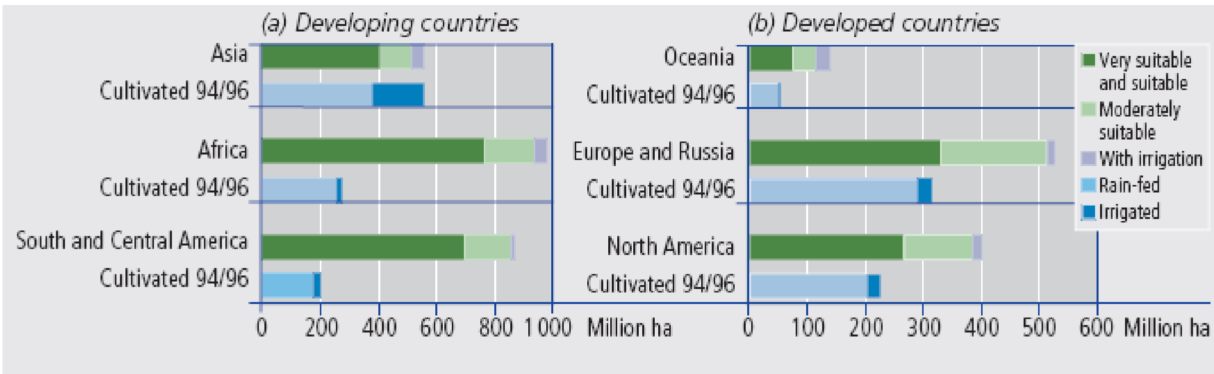
Some important issues related to hydropower's role in climate change need further consideration. First, it is imperative to understand and mitigate methane emissions from reservoirs and to embed such risks into project assessment. While it is thought that emissions are most common in anoxic, shallow reservoirs, the science is still emerging and predicting and measuring emissions still pose technical challenges. Second, climate change will alter the hydrological resources on which hydropower depends; factor which needs to be better understood and incorporated into design and operations of new and existing hydropower facilities. The specific impact will vary from location to location but could affect economic and environmental feasibility as well as the long-term role of dams and reservoirs.

C. Agriculture

The recent food crisis has highlighted the important fact that climate change may become a threat multiplier, and thus the urgency for policy makers to decisively move the agricultural agenda forward. In addition to warming, rainfall, flooding, extreme heat events, pests and weeds, and loss of irrigation water resources, have an impact on yields. Most studies predict that impacts will vary by region, but will be more pronounced in Africa (Figure 5-b).

Despite the dire predictions, the continent is endowed with significantly undeveloped resource base; about a third of potential cropland is currently used for cultivation and only a tiny fraction is irrigated (Figure 12).

Figure 12. Cropland Potential and Land Used for Cultivation (IIASA, 2002)



As already shown through the performance of some countries, agriculture productivity growth will require expanding irrigated area and improving productivity in rainfed areas, as well as improving production technology (including water and land management). We illustrate this point with the case of agriculture in the Zambezi river basin (Box 3) and Eastern Africa.

Under current hydrologic risk, characterized by erratic and unreliable rainfall over much of the region, and with a very low percentage of runoff occurring in the dry season, agriculture, which is the source of livelihoods of 80 percent of the Zambezi's basin's rural population, is very risky (World Bank 2008a). The average yield of maize (70 percent of cereal area) is 1.06 Mt/Ha, a fraction of the potential irrigated yield of 7.5 Mt/Ha. In addition, the average yield of rice is about 1.1 Mt/Ha, compared to potential irrigated yields of 4-5 Mt/Ha. Because of climate variability and low productivity, the Zambezi basin countries tend to be chronically short of food, requiring large amounts of food imports and donor food assistance. FAO studies have projected that the value of net agricultural trade in Southern Africa between 1997 and 2030 will worsen for cereal crops (expected to constitute about half of the agricultural production) (Bruinsma 2003 and Westlake & Riddell 2005). To achieve a cereal requirement of 163 kg /cap /year (equivalent to self-sufficiency), it is estimated that tripling the area under irrigation (from a base of about 200,000 hectares), at a rate of 32,000 hectares across the basin, would require about 7% of water available in the Zambezi annually and would benefit 30% of the rural population in the basin.

The trend toward drier rainy seasons in southern Africa has also been observed for parts of eastern Africa which directly impacts agricultural productivity. Findings from a recent simulation study (Funk et al. 2008) concluded that if current trends in declining rainfall and agricultural capacity continue unabated, by 2030 the number of undernourished people in eastern Africa will increase by more than 50 percent. At the same time, a mere 15% increase in yields per decade could come close to achieving the MDG of halving the number of undernourished people by 2030.

Thus, there is very large scope for increased production and food availability if water is available for timely irrigation and farmers have better water control and modern inputs. At the same time, since climate projections for southern Africa indicate a drying trend over large parts of the region, with intensifying occurrence of floods and droughts, irrigation investments will also serve as a buffer against increased climate variability in the future. But irrigation needs to be part of a package of technology and institutional reform (Box 3).

D. Biofuels[9]

Biofuel production has the potential of supplying a clean and renewable source of energy, and producing local economic benefits. Driven in part by rapidly rising oil prices, and private entrepreneurs seeking lucrative investment opportunities with potential climate change mitigation benefits, many African countries, spanning different agro-ecological zones (e.g., Ethiopia, Kenya, Ghana, Mozambique, and South Africa) are already investing (or developing plans) in biofuel production-- ethanol and biodiesel.

However, and not withstanding the apparent success of the Brazilian experience in particular, it is important to first evaluate lessons learned from biofuel production in Africa. Comprehensive studies, particularly in countries that already have commercial-scale production in place, are needed in terms of economic justification, feedstock supply, impact on food security, supply chain, market size, etc. It is perhaps also important to evaluate the relative merits of large-scale commercial biofuel growing and refining, versus biofuel as a supplemental crop, pursued profitably on a small scale by farmers who grow the crop to enable themselves, and possibly the immediate community, to become energy independent.

For example, in recent years, Jatropha, a low-cost plantation growing on marginal land, has shown promise as feedstock for biofuel production (World Bank 2007). However, from a scientific perspective there is little proven data (on issues such as crop yields, optimal phenotype selection, etc.) for commercial application. Therefore, while it is reasonable to expect significant crop yields from Jatropha Curcas per hectare, it is imperative to ensure that the agronomic and economic assumptions surrounding the projected crop yield are sound[10]. Overall however, a realistic and objective assessment of the feasibility of domestic biofuel production in niche markets is urgently needed.

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[9] This section is not meant to constitute a comprehensive assessment of biofuels, but rather

[10] According to a Biodiesel entrepreneur, many factors have to be aligned before a biodiesel plantation is to be profitable, including: no dependency on subsidies, vertical integration of farms and refinery, location in developing country, large scale production, use of a perennial crop, and availability of a local market for biofuel sales

Box 3. Importance of Irrigation in Agriculture Sector Growth and Poverty Reduction- The Case of the Zambezi River Basin

Both land and water resources are ample at the basin level (*), although water is not always in the right place at the right time, and there are a number of important factors and problems that strongly influence the profitability of smallholder irrigated agriculture. A major scaling up of irrigated agriculture is possible based on new models and approaches already emerging in the region.

Potential Benefits

- A high growth scenario, under which the current estimated rate at which the riparian countries could expand irrigated area is tripled, the irrigated area in the basin would rise to about 551,000 ha and about 6% of the rural population in 2020 would have access to improved irrigated land and direct increases in income.
- Indirectly, an additional 6%–12% of the rural population would benefit through employment (on- and off-farm), lower food prices, increased food availability, and the general rise in rural economic activity induced by the expansion of profitable irrigated agriculture. Hence, a total of about 12%–18 % of the basin's rural population in 2020 would directly or indirectly benefit.
- About 80% of the rural population is not directly or indirectly reached by this investment in irrigated agriculture. If irrigation expansion takes place as a part of comprehensive water for agriculture strategy to improve agriculture productivity, then a wider impact on rural poverty and food security could be achieved through the introduction of conservation farming and water harvesting supported by strong extension services and improved inputs.

Learning From Existing Models - Key Lessons

- Programs should address the issues that undermine smallholder profitability at each step of the value chain, and to do this the existing and potential private sector actors must be brought into the program by providing incentives, such as favorable policy reforms and access to financing.
- Program financing mechanisms should be structured to impose high appraisal standards and commercial discipline on sub-project sponsors to ensure that the programs remain demand driven, and do not creep steadily towards traditional bureaucratic, government supply-driven approaches.
- Cost minimization and cost-effectiveness are paramount in ensuring that sub-projects are financially and economically sound.
- Governments' desires are high and their capacities to administer and manage a scaled-up water for agriculture program are extremely limited. Hence, it will be essential for governments to outsource the essential technical and social services needed to implement accelerated programs.
- Governments' capacities to coordinate, manage, and supervise the programs must be strengthened. Decentralization remains crucial for the sector in order to locate the most important strategic expertise – such as, irrigation and rainfed agriculture advisory services strongly linked to a revitalized research system – as close as possible to the rapidly expanding number of new smallholder farmer groups.
- Continuing training of farmers and farmer groups in skills ranging from leading and managing their own businesses and organizations, to cropping systems and water management, is critical for long-term success.
- A key part of the enabling environment—which will improve capacity to attract investment financing--involves improved planning, and upgrading monitoring networks and information systems.

(*) It is estimated that annual availability of water resources in the Zambezi is about 110 Km3, of which 3% is used for agriculture, human consumption and industry, 13% is used for hydropower production, and 85% is discharged to the Indian Ocean. Even with expected lower runoff due to climate change, an integrated approach to managing the water resources of the Zambezi will benefit both the local populations and their economies, as well as the critically important delta ecosystem.

E. Malaria

Despite remarkable improvements in global health, Sub-Saharan Africa continues to face significant challenges in controlling communicable diseases and improving population health. Malaria infects millions of people each year. The World Health Organization (WHO, 2007) indicates that there are 500 million newly infected cases annually. The Centers for Control Disease (CDC) estimates that 700,000 to 2.7 million people die of malaria each year and 75% of those are African children. In recent years, there has been a resurgence of malaria in areas where the disease was once eliminated or under control. Following the 1997-1998 El Niño event, malaria, Rift Valley fever and cholera outbreaks were recorded in many countries in East Africa (UNEP Grid 2000).

Projections indicate that climate change will cause varying shifts in ecosystems that will affect insects, animals and plants, which will be forced to shift, expand and adapt to new environments. As temperature increases, some regions in sub-Saharan Africa, once hyper-arid or semi-arid, will receive higher precipitation or become more humid. These areas may provide hospitable environments for new emerging vectors or the expansion of known infectious disease vectors. A warmer and higher precipitation environment may open up new areas for malaria; altered temperature and rainfall patterns could also increase the incidence of yellow fever and dengue fever.

Projections and modelling of climate change effects on malaria indicate with high confidence that malaria will surge in southern Africa and the East African highlands, and that the global population affected by malaria will increase by an extra 260-320 million people by the 2080s (IPCC FAR, 2007). Research also shows that malaria not only imposes significant burdens on population health, but also impedes economic growth. Using cross-country data from 1965-1990, Gallup and Sachs (2001) show that in countries where malaria has been eliminated, economic growth has usually been substantially higher than in neighbouring countries. The same study shows that--controlling for initial poverty, economic policy, tropical location, and life expectancy--countries with intensive malaria grew 1.3% less per person per year, and a 10% reduction in malaria was associated with 0.3% higher growth. Micro-level studies also indicate that malaria is associated with reduced household socioeconomic status (Tanzania case study - Somi et al. 2007).

Clearly, climate change is likely be exacerbate the incidence and impact of malaria, and a lower burden of the disease will be the best resilience, thus providing an opportunity for African countries to strengthen their health system and scale up investment in treatment, human resources, monitoring and evaluation, and surveillance systems, particularly at the sub-regional and regional level.

F. Compensation for avoided deforestation

Deforestation and forest degradation are responsible for some 15%- 30% of human induced GHG emissions (Houghton 2005). Forest losses each year are equivalent to an area 4 times the size of Belgium. Brazil and Indonesia are the worst-affected countries, but 6 of the 10 largest forest losses are in sub-Saharan Africa (DRC, Nigeria, Sudan, Tanzania, Zambia and Zimbabwe). In Africa, forest loss from 1990-2003 was estimated at 15 million hectares (or some 4.3 million hectares annually).[11]

Conversion of forests to croplands and to shifting cultivation, and harvest of timber are the main causes of deforestation. They are likely to be even more important in the future as requirements for food and biofuels increase. If current trends continue, forests will continue to be converted to other uses, and the resulting climatic effects may become more influential. On the other hand, the development and growth of carbon markets may offer opportunities for financing the preservation and expansion of forest area for carbon sequestration, alleviating poverty at the same time (Laporte et al, 2007). Clearly, the management of forests for timber, carbon sequestration, biodiversity, and other ecosystem services is critical for both mitigation of climate change and adaptation to it.

Storing carbon in forests and agricultural soils presents an immediate option to reduce atmospheric carbon dioxide and slow global warming. Governments, forest owners, and farmers who adopt practices that store carbon in soil may be able to "sell" the stored carbon to buyers seeking to offset greenhouse gas emissions. But before carbon credits can be sold, “owners” need to be able to verify that forests are managed sustainably and remain standing, and changing soil management has increased the soil organic carbon in agricultural fields.

Avoiding deforestation is not currently eligible under the Clean Development Mechanism. But under the Bali Action Plan, negotiations of a post-2012 international framework will consider policy approaches and positive incentives to promote and support reduced emissions from deforestation and forest degradation (REDD or Reducing Emissions from Deforestation and Forest Degradation). Given that sustainable agriculture practices can also contribute to sequestering significant amounts of carbon in soils and improve productivity, African countries would potentially greatly benefit from the development of incentive mechanisms that promote agricultural carbon on compliance and voluntary markets. However, as we argue below, REDD is not without risks and it is important to undertake extensive economic analysis of the benefits and costs, and the political economy of adopting an implementing a REDD program.

Allowing African tropical forests to grow and cutting deforestation in half would prevent some 150 million tons of carbon to be released into the atmosphere into the next century[12], or about half of Africa’s current emissions, thus contributing to the global mitigation effort. Therefore, for SSA protecting natural forests not only serves the purpose of maintaining a large carbon sink with associated benefit flow for the foreseeable future, but also would provide a number of ecological services including

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[11] Chomitz (2007) reports that annual net forest loss in tropical Africa estimates vary widely, from country 5.2 million to just 376,000 hectares).

[12] Still less that 1.5% of global emissions, but more that the total emissions from all other sectors combined in SSA.

water recharge and reliability of supplies for down stream users, ecosystem integrity, etc. (ref. the Millennium Ecosystem Assessment).

A simple analysis of potential revenue from avoided deforestation, assuming away the political, economic and social transactions costs of such a policy, indicates a wide range of possibilities, depending on both the carbon content of forests, and the price of carbon. Table 6 covers a number of scenarios, some more plausible than others, but provides a good indication of the range of revenues that can be generated from a REDD policy. Overall, annual revenue could conservatively range from as little as $14 million/year (under a scenario of 10% avoided deforestation and 65 tons of CO2 equivalent per hectare[13] priced at $5/ton) to as much as $5.7 billion (under a scenario of 30% avoided deforestation and 217 tonnes of CO2 equivalent per hectare per priced at $20/ton). In the latter case, this is equivalent to about 25% of net ODA to the continent. Scenarios whereby forest loss could be cut in half would seemingly lead to annual carbon revenue between $5 and $10 billion.

Table 6. Potential Annual Carbon Revenue From Avoided Deforestation (US$ Billion)

	(a) Scenario 1: 100% Avoided Deforestation		
(100% AD)	65T/Ha	180T/Ha	217T/Ha
$5/T (#)	1.4	3.9	4.8
$10/T	2.9	7.9	9.5
$15/T	4.3	11.8	14.3
$20/T	5.7	15.8	19
	(b) Scenario 1: 30% Avoided Deforestation		
(30% AD)	65T/Ha	180T/Ha	217T/Ha
$5/T	0.4	1.2	1.4
$10/T	0.9	2.4	2.9
$15/T	1.3	3.6	4.3
$20/T	1.7	4.7	**5.7**
	(c) Scenario 1: 10% Avoided Deforestation		
(10% AD)	65T/Ha	180T/Ha	217T/Ha
$5/T	**0.014**	0.395	0.476
$10/T	0.029	0.79	0.952
$15/T	0.043	1.185	1.428
$20/T	0.057	1.58	1.904

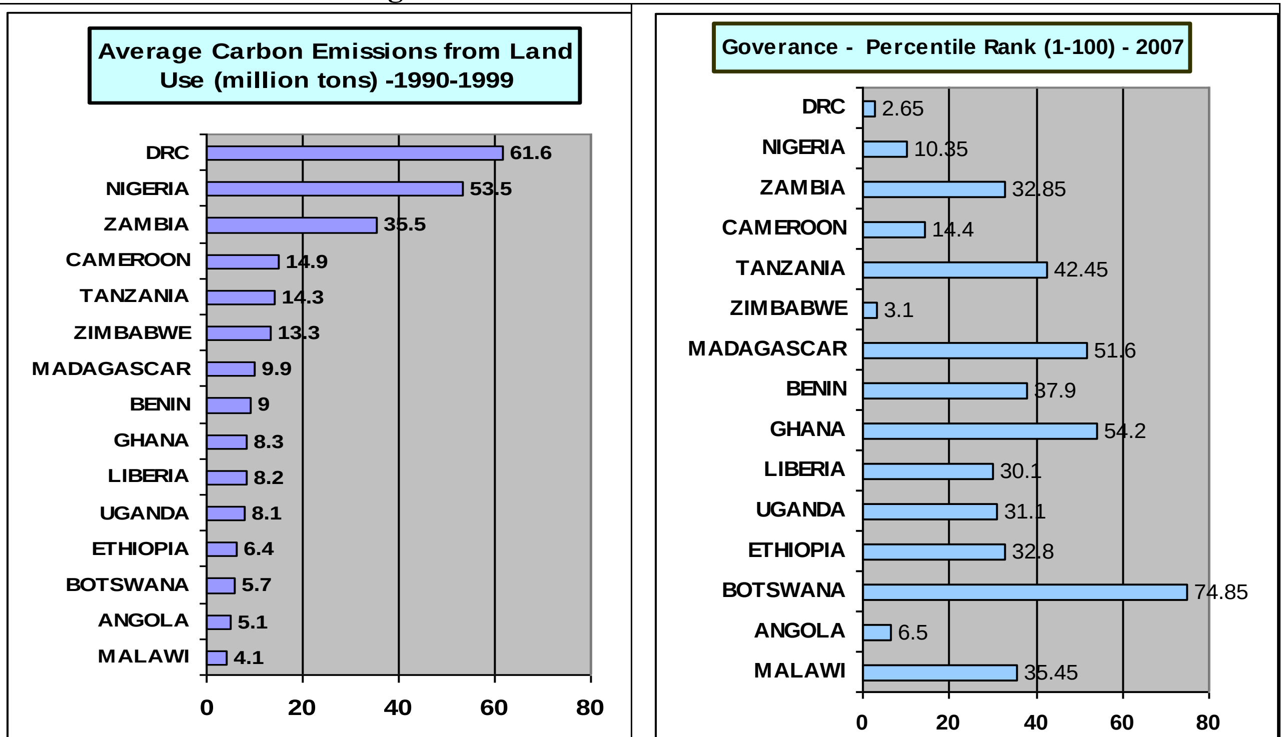
(#) T = Tons of CO_2 equivalent

[13] Using estimate on SSA from Hougton et al. 2008, and other conversion factors used in Latin America (Potvin et al. 2008), ….., and IPCC estimates (ref.)

Other possible approaches to estimating potential carbon revenue for Africa is through an idealized trade and cap trading scheme, whereby emissions rights would globally be allocated on a per capita basis, and countries would be able to sell rights in excess of their total populations emissions (Collier et al. 2008), potentially leading to annual carbon revenues of the order of $40 billion (assuming two tons of CO2e allocation per person, priced at $30 per ton, and current emissions of 0.5 tons per capita).

However, it is important to note that the potential carbon revenue would benefit only a few countries, with 80% of the revenues going to seven countries (DRC, Nigeria, Zambia, Cameroon, Tanzania, Zimbabwe and Madagascar), most of whom have significant governance problems (Figure 10).

Figure 10. Average annual emissions of carbon from land-use change & governance in Sub-Saharan Africa



Source: Laporte et al. (2008)

Source: Governance Matters (2007) (average of corruption and the rule of law indicators)

The proposal of REDD notes the need to establish baselines at the national level to avoid leakage (Brown et al. 2007, Chomitz 2002). However, in addition to the challenges of establishing baselines, another important issue is the use of past deforestation rates, which do not account for the stage of development of African countries compared to other parts of the world.

Notwithstanding the issue of baseline, there is a need to better understand the economics of avoided deforestation in order for African countries to be able to fully take advantage of the proposed market-based mechanisms. In what follows, we use case studies from Madagascar and Cameroon to provide a simplified analysis of the economic feasibility of avoided deforestation in Africa, pointing to areas where more detailed research will be needed. The overall conclusion is that while gross income from avoided deforestation within a voluntary carbon market could be substantial, actual net benefits could be very small.

We use a net benefit valuation approach to estimate a break even opportunity cost of land under different uses, using case studies from Madagascar and Cameroon, and five scenarios: business as usual (S1), conservation (biodiversity focus) (S2), low impact timber production (S3), traditional agriculture (cereal production) (S4), and agricultural plantations (S5). The choice of land use options to consider is reflective of the most important land uses that are causing deforestation in Africa (Table 7).

Table 7. Average annual emission of carbon for different land uses (Million Tons of Carbon/year)

	Cropland	Pasture	Shifting Cultivation	Timber Harvest	Forest Plantations	TOTAL
West	**57**	1.5	**25.6**	8.5	-0.4	92.2
East	**14.6**	0.1	**13.2**	6.2	-0.1	34
Central	5.1	0.6	**69.8**	8.5	-0.2	83.8
South	23.4	2	**45.5**	6.5	-0.7	76.7
All SSA	100.1	4.2	154.1	29.7	-1.4	286.7
Proportion	**35%**	1%	**54%**	10%	0%	100%

Source: (tbc)

The data and assumptions used for scenarios S1 and S2 are derived from the longstanding biodiversity conservation program in Madagascar (World Bank, 2004). In this program, it was estimated that in order to halt deforestation (which was progressing at an average one percent per year), the conservation of some additional 2.0 million hectares under three different conservation management modalities (protected areas, conservation sites; and community-based forest management) would be beneficial (positive NPV over 25 years a 10% discount rate). For scenarios S3, S3 and S4, we use data on crop and timber production (rice, maize, and wheat, bananas, palm oil, and limber/logs) (FAOSTAT) and commodity price data (World Bank DEC/GEM). Finally, data from the Cameroon Forest Environment Sector Program (CFESP) was used to estimate conservation costs for the benefit cost analysis.

Table 8 summarizes the estimates of the opportunity cost of different land uses and the break-even opportunity cost of carbon for the five scenarios. The break even opportunity cost—on a carbon basis—ranges from \$0.40 to \$387 per ton of CO_2 equivalent, reflecting both the carbon content of African forests and the land use options, with the lowest value per hectare for extensive use by communities in Madagascar, and with palm oil providing the highest opportunity cost, followed by bananas, low impact timber production (including fuelwood collection), rice, wheat, maize, and biodiversity conservation. It is important to note that the very low opportunity cost of land under conservation is due to the difficulty in estimating the true value of the many services provided by conservation.

Table 8. NPV and Break-Even Opportunity Cost of Land

	NPV(10%, 25 years) ($/Ha)	**Break-Even NPV/[CO2] ($/TCo2e)#**
S1: Business as usual (extensive use) (a)	144.0	**0.4**
S2: Conservation program (EP) (b)	271.0	**0.8**
S3: Low impact timber production (c)	7,420.0	**31.7**
S4: Cereal production (d)		
• Maize	1,875.0	**8.0**
• Wheat	2,832.0	**12.1**
• Rice	5,129.0	**21.9**
S5: Cereal production (e)		
• Bananas	29,880.0	**127.7**
• Palm oil	90,537.0	**387.9**

(a) Benefits from fuelwood, non timber forest products (NTFP), and slash and burn agriculture (tavy), net of management costs (Madagascar)
(b) Benefits form biodiversity conservation, eco-tourism, watershed protection and sustainable fuelwood and NTFO collection (Madagascar)
(c) Based on timber yield data from Cameroon
(d) and (e) Based on averaging data from Cameroon and Madagascar
(#) A conservative estimate of 234 tons of Co2 per hectare (corresponding to 65 tons of carbon content per hectare of forest land.

Table 9 provides a conservative estimate of the potential revenue from avoided deforestation using the opportunity cost of maize, an important crop in Africa, with an opportunity cost of $8.0 per ton of CO2 equivalent. This estimate is of the same order of magnitude as the one estimated in table 6 without reference to specific land use; thus the importance of more detailed site-specific analysis.

A REDD Policy can provide significant recurrent income, but is not without risk and implementation costs. Given the many direct (e.g., fuelwood/charcoal supply, agriculture and urban expansion, logging, fires) and indirect (e.g., roads, access to markets, access to credit fiscal policy) drivers of deforestation, and the many interest involved, the political economy of establishing national baselines, sustainable management strategies, and monitoring and verification systems could be daunting and fraught with political risk, and would require significant negotiations and conflict resolution. In addition the management costs involved in implementing a REDD program could be significant. Although more detailed analysis is needed, cost estimates from a few conservation projects show that while the net benefits of a REDD program over 25 years could range from $140 - $91,000 per hectare (Table 8), the costs of conservation could range from $60 - $1000 (Table 9). This shows that implementing a REDD program could in fact be quite costly, and in some cases would result in net welfare losses. Therefore, a REDD policy needs to be informed by a careful economic evaluation of costs and benefits. A similar conclusion was reached in a case study involving Panama, where the authors point to the risks involved in countries entering into voluntary commitments to reduce deforestation if they are uncertain of the marked-based carbon income (Potvin et al. 2008). A REDD program that is not able to pay the opportunity cost of land and the transaction costs of fulfilling contractual agreements and commitment, could lead to conflict and even more deforestation.

Table 9. Conservation costs of selected projects

Project	Area Under Conservation Management/	NPV(10%,25) ($ per hectare)
Cameroon Protected Area (GEF project) (a)	176,000	**129.00**
South Africa CAPE Program (GEF-funded) (b)	240,000	**250.00**
Madagascar EPIII Program	4,500,000	**62.00**
Cameroon Forest Sector Environment Program (FSEP) (c)	220,000 (d)	**967.00**

(a) This project is a GEF-funded component within the government FSEP program
(b) The CAPE biodiversity Conservation program is jointly funded by the government of South Africa, GEF, the World Bank, and UNDP
(c) FSEP is a forest sector reform program supported by the World Bank and GEF
(d) In this case, we assume that the program's aim is to lead eventually to reducing deforestation from its current annual level of 220,000 hectares.

Since in Africa, 89% of deforestation is driven mainly by the expansion of agriculture (cropland and shifting cultivation in Table 7), assuming that a conservative maize-based production with a yield of 1.7 ton per hectare (FAOSTAT) is the most attractive land use, then SSA would need to sell carbon resources (called CRs for compensated Reductions) for a yearly value of $0.84 – 2.4 billion in order to compensate for the opportunity cost of 10%-30% avoided deforestation for 25 years (Table 10). This estimate is clearly a lower bound as other land uses, such as palm oil or banana plantations generate far greater income. Therefore, a REDD policy would require at least a billion dollars a year of funding for its implementation for every 10% reduction in deforestation. This figure represents about 5% of net official ODA inn Africa.[14]

[14] Net official ODA in Africa was $ 20 billion in 2003 (http://www.oecd.org/dataoecd/53/35/34895243.pdf)

Table 10. Forest Loss and Value of Avoided Deforestation Africa

	Hectare	Carbon Value of avoided deforestation (Million US$)
Total forest area (FAO –Year 2000)	633,000,000	
Total forest loss (1990-2003)	57, 038,200	
Average annual loss (1990-2003)	4,488,755	
Avoided annual deforestation (10%) – AD1 (#)	448,875	841,640,625
Avoided annual deforestation (30%) – AD2 (#)	1,316,266	2,467,998,750

(#) Based on a $1,875 NPV per hectare of maize production at 10% for 25 years, and assuming value added equals half of gross income using international price for maize (2008).

G. Promoting environmental fiscal reforms

An important source of increasing growth and reducing poverty is improving the regulatory frameworks for natural resources, specifically in water, mining, rural land, fisheries and forestry. Overexploitation and mismanagement of these resources have many causes but ill-defined rules about property rights and the absence of proper valuation of natural resources are generally at the core of the problems. Climate change will add to the pressure to address these issues, be it for water pricing payments or ecosystems.

Environmental Fiscal Reform (EFR)[15] can play an important role in this regard, helping countries raise revenues, while creating incentives that generate environmental benefits. By encouraging more sustainable use of natural resources (such as forests or fisheries), reducing pollution from energy use and industrial activities, and stimulating the use of innovative “clean” technologies, EFR can also improve management of the environment. EFR encompasses a wide range of taxation and pricing instruments, including taxes on the exploitation of natural resources, taxes and charges on water or air pollution, and the reform of water or energy subsidies.

The suitability of individual instruments to specific countries will vary according to the country’s level of development, resource endowments, and institutional capacity. Although one should not underestimate the challenges of undertaking such reforms, EFR is of particular relevance to countries that rely heavily on natural resources for their development. Work done in Mozambique [16] on the proper costing of different environmental resources shows that it would not only ensure a sustainable exploitation of natural resources but also generate additional fiscal resources to cover the public sector’s role in helping to ensure their sustainable management.

[15] See World Bank (2005).
[16] World Bank, *Mozambique CEM, Chapter 6. The role of natural resources in faster growth and poverty reduction.*

Stronger regulatory frameworks and improved resources pricing will help to establish the incentives for stronger public-private partnerships for climate change adaptation. The majority of adaptation practices, with the exception of large infrastructure investments, are managed directly by private actors. Given the very large costs of climate adaptation (as per existing estimates), contributions by the private sector plays an important role. Private operators are generally better suited than their public counterparts to deal with the additional risk brought about by climate change (analysis and mitigation).

H. Promoting the use of indigenous knowledge

As in many parts of the world, Africa has a rich body of indigenous knowledge and related technologies (e.g., flood irrigation, pastoralism, hunting and fishing, medicine), many of which are linked to its indigenous people whose identities and cultures are inextricably linked to the land on which they live and the natural resources on which they depend. This ecological and cultural diversity has been the basis for sustaining livelihoods and environmental services for many centuries. However, by all accounts (e.g., Bollig and Shulte 1999, and Salyck and Byg 2007) indigenous knowledge is in serious threat of being lost and not passed on to younger generations, and the livelihoods of indigenous people—who often inhabit economically and politically marginal areas in diverse, but fragile ecosystems--depend on natural resources that are directly affected by climate change.

Moreover, while climate change is emerging as a new threat to the survival of indigenous communities, their traditional knowledge, and the ecosystems in which they live, local peoples' dependence and close relationship with the environment and its resources put them in a unique position to help enhance the resilience of these ecosystems. Moreover, the rich traditional knowledge usually held by community elders, on medicine, environmental stewardship, natural resources and land management, cultural practices, and trade and justice can be a source of innovation to address some environmental problems.

Indigenous knowledge and technologies play major roles in biodiversity conservation, sustainable use and prospecting for In addition, their contributions to increasing food production, fighting HIV/AIDS and other diseases, and stemming environmental degradation are considerable (Kamara 2008).

Globally, there is increasing acknowledgement of the relevance of indigenous knowledge as an invaluable and underused knowledge reservoir, which presents developing countries, particularly Africa, with a powerful asset in environmental conservation and natural disaster management. Indigenous people have a wide knowledge of the ecosystems in which they live and of ways of using natural resources sustainably. For example, shifting cultivation, flood irrigation, moisture conservation, and pastoralism have proved to be highly durable, and are the precursors of modern integrated conservation farming and range management technologies, among others. Similarly, for centuries, natural disaster management in Africa has been deeply rooted in local communities which apply and use indigenous knowledge to master and monitor climate and other natural systems and establish early warning indicators for their own benefit. This knowledge is a precious resource that continues to contribute to environmental service and natural disaster management across Africa, and should be incorporated into modern development programs.

IV. Concluding remarks

Recognition of the risks associated with climate change is a valuable first step towards better planning of new infrastructure investments and mitigating potential damage to existing infrastructure. This paper has highlighted areas to turn the climate challenge into an opportunity to accelerate growth and poverty reduction in Africa. But there are major potential obstacles to undertaking the appropriate and required actions, including the lack of perception of a need for action, and the lack of perception of a benefit from the action. Important uncertainties remain as to the timing of action.

The complexities of the tasks that involve multi-jurisdictional participation will likely delay the implementation of adaptation and perhaps also impair its efficacy. A better understanding of the risks and challenges by both African governments and development partners is needed. Economists and the AERC have an important role to play.

Specific areas of research include: (i) estimation of the costs and benefits of climate action in the short and long runs; (ii) approaches to policy making under high levels of uncertainty; (iii) incentive structures including insurance and other ways to minimize risk and to induce economic agents to self-protect.

The proper estimation of costs and benefits is important because there may be trade-offs between policies that are optimal from a climate change perspective and policies that are best for the poor (World Bank 2008b). The case of the expansion of biofuels leading to the rise in food prices, with particularly severe impacts in West Africa and the Horn of Africa, illustrates this point.

As to approaches to policymaking, there is a need for capacity building and to incorporate climate change policy making in developing planning. A good example is Mexico’s creation of an Inter-Ministerial Commission on Climate Change, which has enabled the integration of climate change policy in sectoral planning.

Understanding the nexus between temporal and spatial dimensions of climate change, economic growth and poverty, with particular attention to the vulnerability of the poor, can take us a long way towards action. Building on the recent initiatives in Africa (Ethiopia’s Productive Safety Nets Program, and Malawi’s weather-based insurance scheme), a research program on the impact of climate change on risk and the expansion of risk insurance markets could yield high dividends.

Inasmuch as Africa's social and economic development is strongly linked to climate conditions, climate variability and change can damage African people and their economies. Extreme weather events (droughts, floods, and epidemics) already have significant impacts on the poor and vulnerable groups, and the evidence is mounting that other, more subtle changes are beginning to take place (changes in growing seasons, disease vectors, etc.). Moreover, projections into the future show that worldwide development needs will continue to exert pressure on natural resource and use even more fossil fuels, further increasing greenhouse gas emissions and accelerating climate change.

While African countries must continue to grow and grow fast, they will have to do it with the added challenge posed by climate change, and therefore country development strategies need to internalize the needs to reduce vulnerability to climate change (climate-resiliency) as well as participate in the global effort to promote less-intensive carbon strategies. The interdependence of development and climate change means that there exist many opportunities for synergies between pursuing development and dealing with climate change (renewable energy and energy efficiency, reduced deforestation and sustainable land management, efficient multi-modal transport) as well as situations where trade-offs are necessary (e.g., attention to climate may require costlier infrastructure designs and land zoning regulations, increased spending on disease surveillance, and information systems).

The existence of these trade-offs is what has led some political leaders to argue that combating climate change shifts already over-stretched fiscal resources away from promoting development. However, there is an emerging consensus among economists that a development approach integrating climate change will be less costly and will lead to more sustainable outcomes in the long-run. While climate variability has always been a major factor in Africa's development, climate change adds urgency to the development process. Timing is of the essence to ensure that growth and poverty reduction objectives are not made more difficult and more costly to achieve. Climate change will accelerate trends we are already seeing and increase the urgency of taking actions that are already needed.

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