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CLIMATE CHANGE AND ECONOMIC DEVELOPMENT: SUB-SAHARAN AFRICA EXPERIENCE

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ABSTRACT
This study empirically examines the interrelationship between climate change and economic development in sub-Saharan Africa. The study use a trend analysis and descriptive study to drive home the implications for climate change adaptation. The study observed that major investments and policy reforms is needed for radical transformation in development to a more climate sensitive path of low carbon-growth. The study noted that urgent attention is needed to predict more robust local future climate and to account for uncertainties associated with climate risks of ecosystems. The study therefore recommends perfect information on the costs and benefits of potential actions to avoid negative consequences of climate change.

Keywords: Climate change, Investment, Economic development.

Introduction
The twin objectives of increasing the pace of socioeconomic development in sub-Saharan Africa (SSA) and, at the same time, coping successfully with the huge negative impacts of climate change (CC) are stoutly coupled. Numerous structural, technological and institutional weaknesses, low asset base, and high poverty are the main reasons for the high susceptibility of SSA to climate change. On the other hand, winning the fight against these same constrain actors through accelerated economic growth and social development is the best measure for enhancing the capacity of SSA to adapt to the adversities of CC. To achieve faster growth and development, however, SSA requires more hostile efforts and major investments in many sectors that would require much higher levels of energy use and emissions and increase the pressures on the already

strained land, water and other natural resources of the region. Development and adaptation challenges for SSA are accordingly inseparable.

In the first place, tackling contemporary development challenges for SSA given predicted future changes in the climate is to comprehend well how observed climatic changes have influenced the evolution of current and socioeconomic systems. Against these background, the paper intends to examine the impact of climate change on development in Sub-Saraharan Africa. The rest of the study is structured as follows. Section 2 reviews literature.

Section 3 of the paper accordingly discusses how knowledge gained from analysis of past trends and linkages between CC and the natural, social, and economic systems have been used to support proper assessment and analyses of likely future impacts of CC and the gaps to be filled. Available response options and development challenges facing SSA under predicted new climatic circumstances and attempts to quantify their costs and benefits and needed resources to implement climate actions are then evaluated in section 4. Section 5 concludes with policy implication and the way forward in successfully addressing the twin challenges of achieving faster development in SSA.

Selected Existing Literature

Detailed and historical validation has provided comprehensive empirical evidence on the relationship between climate change and development in developed economies. Notable among these studies are provided by (IPCC, 2015). The Fourth Assessment Report (PAR) of IPCC indicates relatively faster warming in tropical rain forest and southern regions compared to the rest of Africa. On the other hand, observed regional variations in rainfall show higher irregularities. Mean annual rainfall registered a 20—40 per cent decline between 1960 and 1998 in West Africa (Sahel). Lower reductions in rainfall of between 2 and 4 per cent were observed in tropical rain forest regions, whereas the Guinean Coast experienced a 10 per cent increase in rainfall over the past 30 years. A mixed pattern of higher rain in the north and declining trends in the southern parts of East Africa was also recorded.

Evidently, no long term trend in mean annual rainfall was observed in Southern Africa, inter-annual variability has increased since 1970 showing evidence of change in seasonality and extreme weather events (IRS. 2014d). There is also evidence of more forceful droughts and inter- annual fluctuations in levels and warming of surface- and deep-water temperatures of the major East African lakes since 1900 (IPCC, 2014b). Many studies have analyzed available data on observed trends and attempted to measure the relationship between variations in levels of some climate attributes, such as temperature and rainfall and several variable representing responses of affected systems. The commonly used approach to study impacts of CC on agriculture are the crop growth models based on data from controlled agronomic experiments to determine the response of specific crops and crop varieties to different climatic and other conditions. Most of this work was conducted at the international agricultural research centers— CGIAR (Alliance and CCAFS, 2009; Van de Steeg et a1., 2015). Similar efforts have been carried out at national research systems (Muchena, 1994; Magadza, 1994; Makadho, 1996; du Toit eta!., 2002; Durand, 2006; Abraha and Savage, 2006). Agronomic models are useful for understanding the biophysical responses but they do not account for economic factors such as human capital and other resource constraints affecting actual farm-level adaptation decisions. Economic analysis based on these estimates will therefore inherit biases of overestimating damages (or underestimating potential benefits) of CC. Experimental agronomic research is also costly and the robustness of generalizing inferences based on results from few experimental sites to large areas and diverse agricultural production systems is problematic (Adams, 1999; Mendelsohn eta!., 2013).

Few studies cited in the Intergovernmental IPCC Fourth Assessment Report on Africa attempted to estimate the impacts of CC on other sectors including soil and water, health and settlements, and infrastructure (IPCC, 2015). Like other similar sector-specific studies, e.g., effects of temperature on mortality and migration (Curriero et a!., 2002; Deschene and Moretti, 2016), on crime (Jacob eta!., 2015), on tourism (Hamilton eta!., 2015), and impacts of drought and floods on health, migration, social conflict, and disruption (Few et al., 2004, Miguel et at., 2004), these studies consider effect of climate change through particular direct and indirect channels separately. Such sector-specific impact measures do not capture the complexity of the many dynamic interactions and feedback effects involved among various components of an entire system when analysis forms an integral part.

Alternative analytical models were developed to tackle deficiencies by accounting for interactions between various elements of a system in measuring the total or net effect of changes in the model; A group of models known as the integrated assessment models adopted such an approach using estimates of response parameters obtained from the above described family of sector-specific impact models in system-wide formulations. These include applications spanning modeling approaches from partial equilibrium agronomic' models (Easterling et al., 2013; Iglesias et al., 2015; Chang, 2002); the spatially referenced agro-ecological zone (AEZ) models; to equilibrium models (Darwin eta!., 1995; Calzadilla eta!., 2009). F. impact parameters from crop growth models and other sources of statistical correlations with variations in climate attributes and a number of IAMs to assess susceptibility of agricultural production in food security to CC in Africa (Downing, 2012; Benson an' Fischer and van Velthuizen, 2013; Thornton et al., 2015). other attempted to measure impacts of CC on world agriculture including SSA (Rosenzweig and Parry, 2014; Rosegralhl et al).. 2014).

Total impact assessment models

Some applications of JAMs did go beyond sector-specific evaluations to measure and assess total impacts of CC (Darwin et al,, 2015; Desanker, 2015; Tol, 2015). It remains however, that in spite of their very wide use in the CC impact literature. IAMs are based on aggregation of effects on selected subsets of sectors and impact mechanisms separately measured under a host of strong assumptions (Stern, 2015, Dell et al., 2015). To address this shortcoming of adding up effects of separately specified impact pathways, Dell et al (2015) analyzed effects of annual variations \of rainfall and temperature on aggregate growth indicators for countries across the world. This approach avoids the need to make assumptions about what impact impactto include and how they interact to generate aggregate impacts While it is a shortcut attempt to directly measure aggregate outcomes of CC. this approach like most of the above models, is based on observed annual variations in temperature and rainfall. They accordingly measure short-term responses to more weather-like temporary climate shocks, the effects of which generally draw away quickly and affected systems adjust back to the normal long- term climate conditions (with the exception of lasting effects of importunate climate episodes such as drought). These treatments therefore do not properly measure long-run responses to lasting shifts in the climate, which is what CC is about) No doubt that CC produces drastic long-term effects that may lead to irreparable changes, flipping into new equilibrium and change the functioning and dynamics of key ecosystems that are quite different weather influences (IPCC, 2015a).

Cross-section impact assessment models

As climate change happens over a very long time horizons, one needs long time series data to capture its impacts. Such data may be available for key climate attributes. However, records over very long periods (covering decades) on changes in economic choices such as production and consumption decisions in response to CC for the same sample do not exist, even in countries with well organized information systems.

The Ricardian model represents the key modeling approach to analyze impacts of CC based cross-section variations in long-term climates. Pioneered by Mendelsohn el al. (1994). the cross-section method builds on the early observation of David Ricardo (1817) that farmland rents capture long term farm productivity and value. This model therefore represents a net (land) valuation method which postulates that farmland value reflect present value of future net farm revenue from all activities. It assesses performance of farms by quantifying impacts on agricultural productivity across the landscape, revealing the effects of variations between different climate zones. Measured changes in farmland value are used to estimate long-run sensitivity of agriculture to CC. many studies under a recent CEF funded Africa-wide project applied the Ricardian approach to analyze impacts of CC on African crop and livestock agriculture at country and continental levels (Kur-ukulasyriya et at., 2015; Kurukulasyuriya and Mendelsohn, 2008; 1-lassan and Nhemachena, 2008; Dinar et al., 2015; Hassan etal., 2015; Deressa and Hassan, 2015; Seo et at., 2009; Hassan, 2015; Nhemachena et at., 2015).

The cross-section method automatically captures farmers' adaptation responses, assuming that cross-section variations reflect different states of long-term equilibria (inter-temporal changes). It does not, however, control for dynamic costs of adjustments between different states (Kelly et a!., 2005). Moreover, while the Ricardian model controls for the effects of farm and household attributes (size, soil type, market access, assets, current technology, etc.), it does not account for future change in technology, policies, and institutions, which are important to keep in mind when interpreting results Among its other limitations is the fact that it may overestimate welfare effects under large price shifts that can have offsetting effects to CC damages. The Ricardian framework also does not account for the effect of factors that do not vary across space such as CO2 concentrations that can be beneficial to crops. Changes in country level policies (e.g., taxes and subsidies) that distort observed states would also weaken the robustness of cross-section model estimates (Kurukulasuriya et at., 2006). The main limitation of the Ricardian approach is its focus on agriculture where all its empirical applications are found.

Vulnerability assessment models

A quite a number of studies on the impacts of observed climate change and variability in Africa comes from studies on vulnerability and adaptation, with recent shift in emphasis from what is known as 'impact-led' to the so called 'vulnerability-led' approaches (Adger et al., 2014). Research on vulnerability to climate risks addresses a wide range of interest areas but particularly sensitivities and impacts of risks associated with extreme events (floods, droughts, and storms) and hydrological consequences and water resources. Stresses (Schulze et at., 2001; Few et al., 2014; Brooks et al., 2015; Thornton et al., 2016; New et al., 2016; IPCC, 2016c; Deschenes and Moretti, 2016; Thornton and Herrero, 2016). There is evidence to propose that Africa bears a significant share of a droughts in the world (OFDA/CRED, 2015) and large populations, particularly in coastal areas, are under the risks of flooding and other natural disasters (IPCC, 2015). Efforts to apply recent advances in vulnerability assessment modeling and indicators to climate change risks in SSA have recently emerged (Deressa et al., 2015; Gbetibouo et al., 2015). Nevertheless, much more information and better knowledge of the magnitude of the overall economic damages inflicted by climate change and variability and how sensitive SSA is to those, especially climate extremes, are needed.

With all of their discussed limitations, the above approaches and model formulations have been used to simulate regional and global impacts of predicted future climate scenarios. Moreover, estimates of economic damages (and gains) of climate change impacts simulated using the above models provided the basis for much of the recent adaptation cost—benefit assessment work (Stern, 2015; UNFCCC, 2015; World Bank, 2015), the limitations of which will be discussed later.

Current development lags and future growth scenarios for SSA

Attempt to predict how future climate will affect SSA, one needs able to generate more credible forecasts not only of how climate in the region will change, but also how the natural, social, and economic systems will mutually evolve over the long time horizon during which climate change takes effect. The doubts challenging our current ability to future climate have been discussed in the previous section and turn to how able we are to project the future path of associated and socioeconomic changes. Given the inbuilt uncertainty a future, it is a common practice for future impacts' assessment framework in general, and the climate change impacts literature, to use reasonable development scenarios. The IPCC, for example, bases its prediction of future climate on a whole set of assumptions to build emission scenarios based on projections and assumptions made regarding likely population and economic growth in different countries and levels of production and consumption activities, particularly food, water, and other key resource inputs (IPCC, 2015). The general criteria is to build scenarios informed mainly by observe patterns augmented with variations in some key processes to compare alternative growth options to aid better decisions makes for climate change management. Uncertainties surrounding the ability to build a likely future development scenario for SSA are quite large and stem from major obstacles currently hindering the region from transcending the serious lags in achieving basic development goals, to which climate change adds further complications. Contemporary development challenges to be addressed in SSA in light of predicted future climate scenarios relate mainly to structural features and systemic vulnerabilities as explained below.

A High dependence on rain-fed agriculture and natural ecosystems

It is recorded that income and livelihoods of large segments of the population of SSA are extremely dependent on agriculture. In 2008 agriculture contributed on average 14 per cent of the gross domestic product (GDP) in SSA with some key member countries (Congo, Ethiopia, and Tanzania) showing in excess of 40 per cent income dependence and the most populous country (Nigeria) deriving more than 30 per cent of its income from agriculture (table 1). The World Development Report on agriculture (World Bank, 2015) estimates that 82 per cent of the rural population in SSA Jives in countries where agriculture contributes more than 32 per cent of GDP growth. The major cause of high weakness of SSA to climate change, especially to fluctuations in levels and distribution of rainfall, is the fact that agricultural production is mainly rain-fed with as little as below 4 per cent of cultivated land under irrigation (IAC, 2014; World Bank, 2015). Farming in SSA is also mainly practiced in regions that are already under climatic stresses (e.g., high temperatures, inherent low soil fertility, and considerable water stress), as two-thirds of the rural population lives in arid and semi-arid regions (World Bank, 2014). In addition to crop and animal farming, millions of rural people in SSA especially the poor) rely heavily on direct extraction of food, timber, fish, water, and other products and services from natural ecosystems that are highly sensitive to climate adversities (MEA, 2015).

B. Low productivity and poor infrastructure and access to capital, information, and markets

Among the key factors contributing to the weak adaptive capacity of SSA is the low availability and use of modern technologies (including IT) and hence the low productivity particularly in agriculture, which is the backbone of the region's economy (Sachs et al., 2014; World Bank, 2014; Cooper at al., 2014). Most countries in SSA also have poor physical infrastructure (road, irrigation, and power networks) and weak economic institutions (markets, credit, insurance, etc.). Coupled with a low capacity to innovate due to insignificant investments in science, information and technology generation, and dissemination, these factors inflict serious limits on the capacity of most countries in SSA to respond to and cope with temporary and permanent climate shifts and natural disasters (Barrett et al., 2015; Sachs, 2015; World Bank, 2015). The influences of such structural deficiencies and macroeconomic stress factors on vulnerability of SSA to CC are expected to be exacerbated under the predicted risks of future climate (IPCC, 2007b).

C. High poverty and social underdevelopment

The strongest basis of susceptibility and major development obstacle for SSA are the very low income and high poverty levels among its population. Per capita incomes are the lowest in the world with most of the population (more than 70 per cent) in countries where about half the people of SSA live (Nigeria, Ethiopia, Congo, Tanzania, Sudan) are under the poverty line of $2 per day (table I). The asset base and real wealth of people in SSA has also been dwindling at higher rates than other regions of the developing world (Arrow et a!., 2014; World Bank, 2015). The noticeably high level of social underdevelopment and the huge burdens that places on the most vulnerable groups (women and children) in SSA are evident from key human development indicators compared to the rest of the world (table 1). Dismal records on the status of human health indicate that diseases such as malaria and HIV/AIDS continue to be the main cause of death of millions, particularly women and children in SSA (Sachs, 2015; Ferguson, 2016; Patz and Olson, 2016). Coupled with increased incidences of natural disasters (droughts) and prevalent civil conflicts, these factors have induced large population displacements and net out migration leading to rapid urbanization and increased pressures on and dreadful conditions of key environmental resources, e.g., land, water, forests, etc. (IPCC, 2015b).

D. Low levels of energy use and emissions and high dependence on biomass

It is recorded that only 3 per cent of total global energy consumption in 2005 (table 2), about 80 per cent of which was from biomass sources (lEA, 2015; Hall and Scrase, 2015). Per capita energy consumption in SSA is also lowest in the world less than half a ton ol oil equivalent (toe) compared to a world average per capita energy consumption that is more than four times that of SSA (table 2). With the exception of South Africa, use of electric power is very low across SSA (table 2) and only 8 per cent of the region's rural population enjoys such access compared to much higher rates in the rest of the world (lEA, 2012). While these statistics decode to low emissions (table 2) and negligible share contribution to global warming and climate change from SSA, they are pinpointing of high susceptibility and a formidable basic development challenge facing the region. The above-discussed development lags and challenges of overcoming the current gloomy state of social welfare in SSA propose that energy consumption (consequently emissions) in these countries is bound to grow to meet demands for defectively needed to haste economic growth for higher social wellbeing and poverty reduction. This implies hard tradeoffs between improved flexibility and adaptive capacity to be attained by accumulating sufficient economic, technological, and social (improved health and educational status) wealth through development, and the needed higher levels of energy and emissions to fuel such growth. Also as indicated above, this has important implications for what measures would be echo for SSA to take now in response to projected climate change and thus adds to the uncertainty of what energy consumption path and development scenario to use for SSA over the next 50—100 years.

3.3 Uncertainty about impacts on and resilience of key ecosystems

In spite of all advances achieved so far in the science of climate change, our current knowledge and ability to predict the specific nature of future impacts On ecosystems and how they will counter to project climate shifts remain with fundamental challenges. This is due to the complex dynamics involved between climate and ecological systems, given the very long time horizon over which climate change unfolds- The likelihood of what is known as 'tipping points', thresholds and irreversible effects, are the main sources of uncertainty about impacts and responses of ecosystems to long- term changes in the climate system- For instance, whether impacts on ecosystems will be of a permanent nature. And what new equilibrium these systems will flip to after a climate disturbance pushes the system beyond a critical porch. These have major implications for the nature of costs and benefits involved in evaluating appropriate courses of action and response measures to take (Pindyck, 2014; IPCC, 2015; Stern 2015; World Bank, 2015). A number of key ecosystems in SSA have been studied, including forests, wetlands, grass lands. mangroves, and many animal species and were found to have endured significant impacts and projected to be at risk of radical transformations and extinction under forecasted future climate regimes (IPCC, 2015) Large knowledge gaps and uncertainties remain, however, about the exact nature and magnitude of these risks.

4. Response options for a climate-sensitive development path for SSA

The world development report on 'Development and Climate Change' (World Bank, 2015) asserts that immediate action, by all and in fundamentally different ways, is necessary if disastrous consequences of climate change are to be averted. Deep apathy in the dynamics of climate and socioeconomic systems propose that future economic and social costs are much higher than savings and benefits from a delayed action (IPCC, 2015a; Stern, 2015). Mitigation measures to calm future global climate at below 2°C and coping with and/or adaptation to a relatively warmer and more irregular climate in the medium term are the two response options available in today's world. However, the allotment of roles and commitments among countries and regions and sequencing of mitigation and adaptation actions in a global deal to respond to

Table 1. Selected economic performance and development indicators for sub-Saharan Africa

	Population Millions in 2008	Per capita GDP ($) 2008	% GDP agriculture 2008	Female life expectancy (years)	Adult literacy rate (%)	Population below $2 a day (%)	Under 5 mortality rate/1000	% with access to sanitation	Net migration in 000 (2005)
World	6,692	9,054	3	71	84		68	60	0.0
High income	1,069	40,402	1	82	99		7	100	18,091
East Asia & Pacific	1,931	2,930	12	74	93		150	66	-3722
European & Caribbean	441	8754	6	76	91		45	78	-2,138
Middle East & North Africa	325	7517	12	72	73		200	74	5,738
South Asia	1,543	3438	18	66	63		500	33	1,850
Sub-Saharan Africa	818	993	14	53	62		900	31	3,181
Congo, DRC	64	1207	41	48	NA	79.5	161	31	-237
Ethiopia	81	181	43	56	NA	77.5	119	11	-340
Kenya	39	327	21	55	NA	39.9	121	42	-25
Malawi	14	884	34	48	72	90.4	111	60	-30
Nigeria	151	304	31	47	72	83.9	189	30	-170
South Africa	49	1404	3	52	88	42.9	59	59	700
Sudan	41	5648	26	60	NA	NA	109	35	-532
Tanzania	42	1425	45	56	72	96.6	116	330.0	345
Zambia	13	1101	21	46	71	81.5	170	52	-82
Zambabew	12	NA	NA	44	91	NA	90	46	-700

Source: World Bank, World Development Indicators (2009).
“ All data for year 2007 except where indicators.

Table 2. Energy consumption and CO_2 emissions (2005)

	Total energy				Electrification	CO_2 emissions		
						% of total cumulative	Annual emissions	
	Million ton	% of total	Toe/capita	% fossil fuel	(Kwa/capita)	since1850 %	of total	Ton/capital
World	11,434	100	1.72	75.5	2,595.7	100	100	4.5
Low-income countries	426	3.7	0.59	62.8	392,4	2	2.66	0.5
Medium-income countries	5349	46.8	1.15	72.2	1,966.5	34	47.59	3.1
High-income countries	5659	49.5	5.29	69.4	9,789	64	49.75	12.6
Sub-Saraharan Africa	391	3	0.42	36.3	620,9	1	2.00	0.9
Africa’s biggest emitters		% of SSA	0.27					
Congo, DRC	17.5	6	0.27	4.5	144			0.02
Ethiopia	22.3	7	0.28	8.0	36,3			0.1
Kenya	17.9	4	0.46	18.6	143.9			0.3
Nigeria	105	33	0.69	21.6	136.6			0.8
South Africa	130	22	2.65	62.5	4847.6			8.7
Sudan	17.7	3	0.43	21.6	96			0.3
Tanzania	20.8	5	0.49	7.9	61.4			0.1
Zambia	7.3	2	0.56	10.6	709.5			0.2
Zambabew	9.6	3	0.80	30.5	961.1			0.9

climate change are to be determined by various equity and efficiency considerations (Stern, 2015; World Bank, 2015). Differences in responsibilities for contributing to present and future emissions, distribution and nature of predicted impacts, and ability to invest in and potential gains from these two measures vary significantly among regions, especially among developed and developing countries.

The fact that SSA contributes as little as 2 per cent to current global emissions indicates that potential gains from investment in mitigation actions in SSA are insignificant compared to the huge potential from reducing the high shares (more than 95 per cent) of high- and medium-income countries (table 2). Equity and fairness suggest that the developed world should take the lead in the mitigation responsibility, being the source of almost all the historical loading of carbon emissions through which it was able to accumulate substantial economic wealth and technological advancement and hence a much bigger capacity to invest in innovation. Moreover, higher future levels of energy consumption are inevitable and necessary for SSA to address the above-discussed develop challenges of accelerated growth and poverty reduction.

While mitigation is not the focus and priority for & adaptation and coping strategies and measures are necessary the evident negative consequences of climate change. This is due to a.
discussed above—weak economic infrastructure; poor access to markets, information, and credit; low technology, incomes, and ability to invest and innovate; and high poverty—that suggest high vulnerability and weak capacity of the region to cope with the eminent risks of climate change and variability. This section therefore begins with a discussion of adaptation response options and then returns to mitigation issues in SSA.

Adaptation opt ions for SSA
Body of knowledge and research on how human and natural systems in SSA have adapted to climate fluctuations in the past and how they might adapt to future climate is limited. Recent research efforts have focused on analyzing vulnerabilities and adaptation responses of rural communities and agricultural systems in SSA (Hassan and Nhemachena, 2015; Kurukulasuriya and Mendelsohn, 2015; Seo and Mendelsohn, 2015; Deressa et al., 2015; Gbetibouo at al., 2015). Results of these studies indicate that switching from specialized cattle-based beef and dairy systems (where hybrid species dominate) to small ruminants (goats and sheep) systems, which are predominantly of local breeds well adapted to the climate of the region, is an important adaptation strategy among livestock farmers in SSA. African farmers were also found to use more irrigation and choose multiple cropping and mixed crop livestock systems over specialized mono systems to adapt to climate change and variability

Agricultural activity in SSA has also seen other major adjustments in response to climate change and variability. Examples include growing different crops and high migration out of agriculture and rural areas in search of non arm income and employment opportunities to diversify and supplement sources of livelihoods, particularly in urban systems. This indicates that reducing vulnerability to future climate risks in SSA has important inter- sector and macroeconomic linkages to be innovatively exploited (IPCC, 2014; World Bank, 2015; Dinar et at., 2015).

It is argued that with accelerated economic growth and rapid industrialization and urbanization, the role and size of agriculture in the developing world, including SSA, is bound to shrink (World Bank, 2015). However, SSA needs to produce enough food for the many millions of additional people predicted to populate the region in 2015 (IPCC, 2015; World Bank, 2015). Agricultural productivity needs to accordingly increase substantially over the next few decades. No doubt there is high potential for achieving sizable growth in agricultural productivity in SSA through marginal gains from additional adoption of new farming methods and plant and animal breeds with better tolerance to pest, disease, water, and low fertility stresses. Nevertheless, the high reliance on agriculture, especially rain-fed farming systems, is a major source of vulnerability to climate change and variability in SSA, where currently only less than 4 per cent of the cultivated land is under irrigation (compared to more than 30 per cent in Asia). The fact that future climate in SSA is predicted to be warmer and dryer with increased changeability indicates that expanding irrigation is a critical adaptation option. Although future climate scenarios forecast reductions in water availability in SSA (lPCC, 2015), the fact that the region is endowed with large water storage capacity that is currently highly underutilized propose a high irrigation potential (World Bank, 2016). Investment in expanding water storage infrastructure therefore holds an important potential for expanding irrigation agriculture in SSA. Policy measures to provide effective incentive systems to improve efficiency of water use (i.e., adoption of more efficient methods such as drip irrigation, greenhouses, etc.) and promote small farmers' investment in water harvesting are necessary for increased agricultural productivity in SSA.

Other important harmonizing policies to enhance the adaptive capacity of SSA's agriculture include: strengthening local (community) credit and savings mechanisms and other forms of social capital; providing insurance against climate risks and safety nets; and improved infrastructure, particularly access to electricity and markets to increase income and employment opportunities outside agriculture and in downstream agro-processing activities. The above essentially means mainstreaming climate sensitivity in all agricultural and broader economic development planning and policy design (e.g., national poverty reduction, notional adaptation action and macroeconomic development plans).

On the other hand, work on identifying and evaluating adaptation options and coping mechanisms for SSA outside agriculture is very scarce. Few studies have examined some nonfarm response options such as investments in improved climate information and weather forecasts dissemination, economic infrastructure, energy and water management, and helter functioning economic (markets, credit and insurance) and social and community networks (Brooks et a!,, 2015; Reid and Vogel, 2015; lPCC, 2015c; World Bank, 2015). Most of the non agriculture adaptation measures, however, have been identified and evaluated in global studies lint attempted to assess the aggregate costs and benefits of adaptation responses to be discussed in a subsequent section (Stern, 2007; UNFCCC, 2014; Nelson et al., 2015; World Bank, 2015).

The potential for mitigation responses in SSA

Current empirical research suggests that the world needs immediate action to calm global emission levels at the target of between 450 and 550 parts per million (ppm) of C02e atmospheric concentration of GHG to avoid disastrous future climate consequences. This is forcasted to result in a warming of between 2°C and 4°C but will require reducing global average per capita emissions from the current 7 tons to 2 tons (IPCC, 2015; Stern, 2015). As discussed above, SSA contributes less than 2 per cent of the global emissions and per capita rates are far below this target (table 2). This indicates that potential gains from mitigation in SSA are insignificant compared to industrialized countries where per capita emissions are currently far above target levels. Added to this are the huge challenges facing SSA in its struggle to accelerate economic growth and reduce the high poverty and social underdevelopment, achievement of which entail higher levels of. energy consumption and emissions.

It is believed that from equity and ethical points of view, the developed. Countries should lead the mitigation challenge given the high potential gains as well as their much better financial, technological, and institutional capacity to invest in mitigation compared to developing countries. Al current emission levels, most countries in SSA are unlikely to be required to meet climate stabilization targets and commit to emissions' reduction in the near future. This however does not mean SSA should not participate in global mitigation efforts. It is beneficial to all developing countries with currently low emission levels and to global future climate for these countries to take advantage of expected advances to be made in developed world towards low carbon growth and to adopt emerging carbon development technologies and mechanisms.

Energy intensity and emissions are highest in SSA from internal transportation, industry and construction and power generation activities (table 3). Due to the high potential gains, these sectors should be targets for mitigation actions in SSA. The power generation sets in South Africa and Zimbabwe stand particularly high among all in potential technologies.

They have substantial opportunities for reduction on fossil fuels and coal burning by switching to alternative renewable sources such as solar and wind. The high hydropower of SSA that is currently highly under used holds great promise for transforming energy supply and use and in meeting the expected growth in energy demand for accelerated development in the region 2015)

Table 3. carbon dioxide emissions by economic activity as present of total in SSA (2000)

	Electricity &heat production	Other energy ind.	Manufacturing & construction	Internal transportation	residential	Agriculture & other
SSA	47.1	2.7	17.2	18.4	3.4	2.7
Congo, DRC	1.1	1.1	35.4	26.3	15.4	38.3
Ethiopia	0.6	0	27.6	54.4	16.4	0

Kenya	23.1	6.5	16.7	45.5	10.9	4.1
Nigeria	12	11.5	11	41.6	9.3	0
South Africa	57.7	1.3	17.8	10.5	1.6	1.7
Sudan	20.8	1.7	15.3	53.6	2.7	4.3
Tanzania	11.2	0	15.9	56.2	13.4	3.3
Zambia	3.2	2.6	40.2	40.2	2.6	6.9
zimbabwe	53.8	0.5	15.4	15.8	1.4	12

innovative mechanisms such as REDD+ is of high precedence for enabling developing countries to take advantage of carbon trading- successful pricing and other appropriate policy instruments are to be introduced to reward improved energy efficiency in carbon intensive sectors and aid more participation of developing countries in the climate stabilization and mitigation challenge (IPCC, 2014; Stern, 2015; World Bank, 2015). Again, equity and ethical reasons necessitate provision of substantial external assistance from the developed world in financing necessary adaptations and transfer of new climate mitigation technologies. For SSA to position itself well to make use of carbon trading, it needs to invest in efforts to develop metrics for GHG credits and improve its capacity in carbon accounting in general- It is also crucial for SSA to streamline mitigation and adaptation in overall development planning and policy design to successfully manage the dual saddle of combating the negatives of climate change and achieving faster growth in economic and social wellbeing.

Eva/noting the costs and benefits of climate actions

The overall advantage of observed successful coping mechanisms and potential adaptation strategies is to be evaluated on the basis of net gains in averting the projected negatives of climate change, efficacy, social and environmental suitability, among other desirable features and outcomes. The evaluation process provides information guiding decisions on which actions to place top priority and accordingly, where to invest needed resources- Cost—benefit and cost-effectiveness methods have been used to evaluate the costs and benefits of private and mainly reactive (autonomous) adaptations. Another category of studies evaluated planned (mainly anticipatory) adaptations, undertaken or directly influenced by governments employing, in general, the multiple criteria evaluation which considers a range of objectives not only economic costs and benefits (Dolan et al., 2014; Smith et al., 2015).

Regrettably, patchy work has been carried out in SSA to evaluate the economic, social and environmental costs and benefits of autonomous or planned adaptation measures. Major efforts, however, have recently been made to generate information on the costs and benefits of global actions to manage climate change for improved decision making at the global and national levels and for identifying priorities for investments and external assistance needed. In spite of all the above-described uncertainties and challenges in predicting a future climate and the difficulty with developing plausible scenarios for socioeconomic development, attempts have been made to evaluate the costs and benefits of climate actions in SSA as part of the said global efforts.
A number of studies attempted to generate information on likely costs and benefits to the world of actions in the face of climate change, using a wide range of the above-described impact assessment models and making strong assumptions about the many uncertainties surrounding the ability to predict future climate and probable development scenarios.

Implications for climate-sensitive development policy and action research

The forceful efforts to address the key structural, technological, and institutional constraints weakening the capacity of SSA and its poor to cope with forecasted unfavorable future climate are tardy. One major source of climate susceptibility in SSA is the fact that rain-fed agriculture continues to be the main source of employment and livelihood for the vast majority of the population. increasing irrigation farming is the best strategy to address this weakness through tapping the regions' largely under exploited water storage potential. Programs and investments in increasing income and employment opportunities outside agriculture will also be necessary to reduce the risk of high dependence on farming.

Considerable effort is needed to unlock current barriers to technological advancement and productivity growth to ensure food security for the additional millions predicted to populate SSA. This will require major breakthroughs in progress and deployment of crop varieties and animal breeds adapted to heat, water, low fertility and pest infestation stresses, and more efficient water use and soil management practices, given projected future climate scenarios and their implications for crop and livestock productivity and water availability.

Accelerated social development is a strategic precedence for reducing poverty related climate weaknesses. Substantial investments are urgently needed to address the current dismal state and serious backlogs in provision of improved access to clean water and sanitation, basic education and public health services, and rural electrification to enhance the adaptive capacity among the poor and vulnerable in SSA, with special focus on women and children. suitable complementary policies and public support programs to strengthen local institutions, community self-help, and provision of climate insurance and safety nets were also found to enhance resilience to CC in poor communities.

Major gaps, however, currently exist in the science and empirical research and policy analyses capacities in SSA to support the design and implementation of needed development and climate management actions.

One priority area for investment and urgent action is improving the currently weak capacity in climate forecasting to reduce the uncertainties surrounding prediction of future local climate. It is also necessary to promote better communication and interaction between providers and users of climate information, which requires creation of new technical capabilities in both groups as well as appropriate facilitating institutional frameworks. Another important area where gaps in our current scientific knowledge need better attention is the ability to project plausible future development trajectories for SSA. Major research efforts are needed to improve the ability to better project plausible future development scenarios for SSA that address uncertainties associated with likely impacts of CC on ecosystems and probable irreversibilities and catastrophic outcomes.

More research is also needed on identifying potential climate adaptation and mitigation actions and evaluating their costs and benefits to improve information necessary to support sound climate policy and decision making. Initiating research and programs on carbon accounting and metrics for greenhouse gas credits will be necessary to take advantage of emerging opportunities and participation in global carbon trading systems.

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