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Climate Change Impacts on Food Security in Sub-Saharan Africa

Insights from Comprehensive Climate Change Scenarios

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ABSTRACT

Climate change impacts vary significantly, depending on the scenario and the Global Circulation Model (GCM) chosen. This is particularly true for Sub-Saharan Africa. This paper uses a comprehensive climate change scenario (CCC) based on ensembles of 17 GCMs selected based on their relative performance regarding past predictions of temperature and precipitation at the level of 2o x 2o grid cells, generated by a recently developed entropy-based downscaling model. Based on past performance, the effects of temperature and precipitation across the 17 GCMs are incorporated into a global hydrological model that is linked with IFPRI's IMPACT water and food projections model to assess the effects of climate change on food outcomes for the region. For Sub-Saharan Africa, the paper finds that the CCC scenario predicts consistently higher temperatures and mixed precipitation changes for the 2050 period. Compared to historic climate scenarios, climate change will lead to changes in yield and area growth, higher food prices and therefore lower affordability of food, reduced calorie availability, and growing childhood malnutrition in Sub-Saharan Africa.

Keywords: climate change, hydrology, crop yield, food security, Sub-Saharan Africa

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ABBREVIATIONS AND ACRONYMS

IPCC	Intergovernmental Panel on Climate Change
GCMs	General Circulation Models
CCC	Comprehensive Climate Change
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
CMIP3	Coupled Model Intercomparison Project
RMSE	root mean square error
DSSAT	Decision Support System for Agrotechnology Transfer

1. INTRODUCTION

Over the coming decades, climate change will affect food and water security in significant but highly uncertain ways. There are strong indications that developing countries will bear the brunt of adverse consequences. This is largely because of high poverty rates, high vulnerability levels, and low adaptation capacities in the developing world. Furthermore, the rural populations of developing countries—for whom agricultural production is the primary source of direct and indirect employment and income—will be most affected because of agriculture's direct exposure to climate change. Among developing regions of the world, Sub-Saharan Africa is expected to fare worst, given that temperatures are generally already high, and most of the region's inhabitants depend for their livelihoods on rainfed agriculture. Only 5 percent of cultivated area in the region is irrigated, compared with 37 percent in Asia and 14 percent in Latin America. Finally, national government funds and local incomes that could be brought to bear on adaptation are extremely scarce in Sub-Saharan Africa, and support to agriculture in the region remains low.

According to the Intergovernmental Panel on Climate Change (IPCC 2007), warming in Sub-Saharan Africa is expected to be greater than the global average, and in parts of the region rainfall will decline. These projections are generated by highly sophisticated General Circulation Models (GCMs). While these models converge acceptably at the global scale, they tend to show a wide range of variation at the local scale (Giorgi and Mearns 2003; Schmittner, Latif, and Schneider 2005; Connolley and Bracegirdle 2007; Laurent and Cai 2007; Whetton et al. 2007), which is problematic for impact assessments at the regional level. For Sub-Saharan Africa, the GCMs tend to agree on temperature increase across the region, while precipitation decreases from June to August for Southern Africa and increases from December to February for Eastern Africa. More recent results suggest that local circulation effects could result in decreased precipitation in East Africa (Funk et al. 2008). Whether the Sahel will be more or less wet in the future remains uncertain (IPCC 2007).

Regional variability in results is recognized as one of the major sources of uncertainty for climate change projections (Giorgi and Francisco 2000; Murphy et al. 2004). Differences among models are generally due to different regional responses to global climate change and to multidecadal variability within models through chaotic behaviors and modes of climate variability, especially multi-decadal variability (Cai et al. 2009).

This paper analyzes impacts of climate change for Sub-Saharan Africa, using a Comprehensive Climate Change (CCC) scenario that integrates projections of 17 GCMs, based on their relative past performance in predicting temperature and precipitation for two degree grid cells across Sub-Saharan Africa. This research is based on a newly developed entropy-based downscaling model (Laurent and Cai 2007). The CCC scenario is incorporated into a process-based crop simulation model and a semi-distributed global hydrological model that is linked with IFPRI's International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) water and food projections model to assess the effects of climate change on food outcomes for the region (Zhu, Ringler, and Rosegrant 2008). While modeling tools and assumptions are global, we only report results for Sub-Saharan Africa. The following sections describe the development of the CCC scenario, its incorporation into a global food and water supply and demand modeling system, and implications for food and water supply and food security in Sub-Saharan Africa.

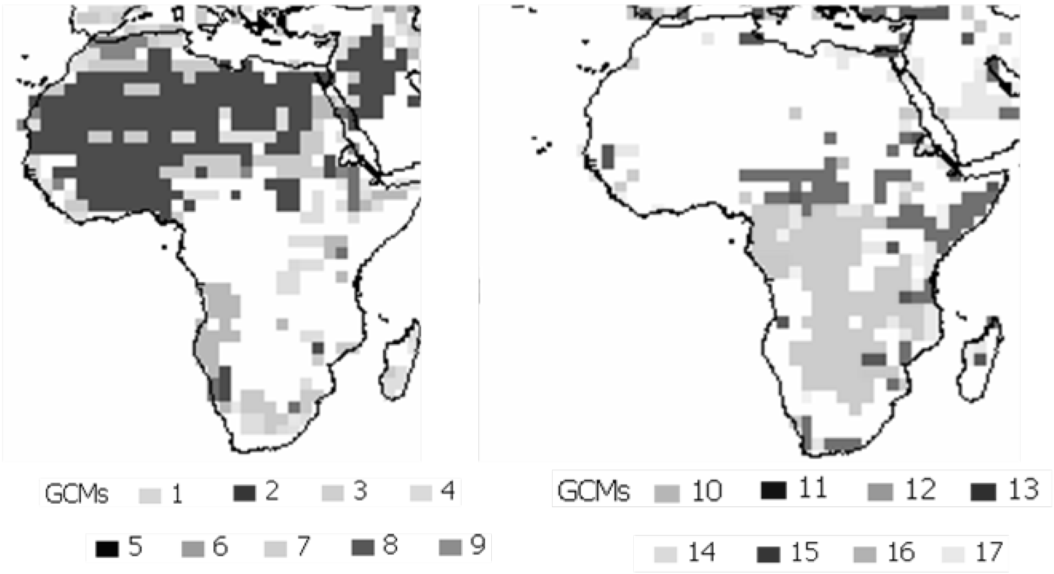
2. MODELING APPROACH

Development of GCM Ensembles—The Comprehensive Climate Change Scenario

Climate projections of 17 GCMs, based on their relative performance regarding simulations of temperature and precipitation for the historical periods 1961–90 and 1931–60 for 2o x 2o grid cells, are used for this analysis (Cai et al. 2009). Monthly data for temperature and precipitation were obtained from the World Climate Research Programme's Coupled Model Intercomparison Project (CMIP3) (WCRP-CMIP 2008). A list of the 17 GCMs is presented in Table A1 of the Appendix. GCM performance is assessed based on the root mean square error (RMSE) of the model prediction relative to observed temperature and precipitation (Laurent and Cai 2007). The comparison between GCM predictions and actual observations is based on the average variable value in each month during the period 1961–90. The period 1931–60 is used to verify the results. The RMSE is calculated for each of the 17 GCMs. RMSE values are then normalized to values between 0 and 1. Thus, the sum of the normalized values equals 1 and the average skill or performance score is 1/17≈0.06. GCMs that score more than 0.06 are performing above average in the analyzed grid cells or zones.

Results for Africa[1] are shown in Figures 1 and 2. Figure 1 presents the GCMs with the best performance for temperature in Africa and Figure 3 presents the best for precipitation. For temperature, GCM 5 scores highest for Northern Africa (GISS AOM of the Goddard Institute for Space Studies, United States), and GCM 10 performs best for Central and Southern Africa (IPSL CM4, Institute Pierre Simon Laplace, France). Results are less clear for precipitation. However, we find that for Northern Africa GCM 14 (MRI CGCM2.3.2, Meteorological Research Institute, Japan) performs relatively well, while GCM 13 (MPI ECHAM5, Max Planck Institute for Meteorology, Germany) is best for Central Africa and GCM 10 (IPSL CM4, Institute Pierre Simon Laplace, France) for Southern Africa (see also Figure 2).

Figure 1. Map of GCMs with the highest performance/skill scores for temperature, Africa



Source: Based on Cai et al. (2009).

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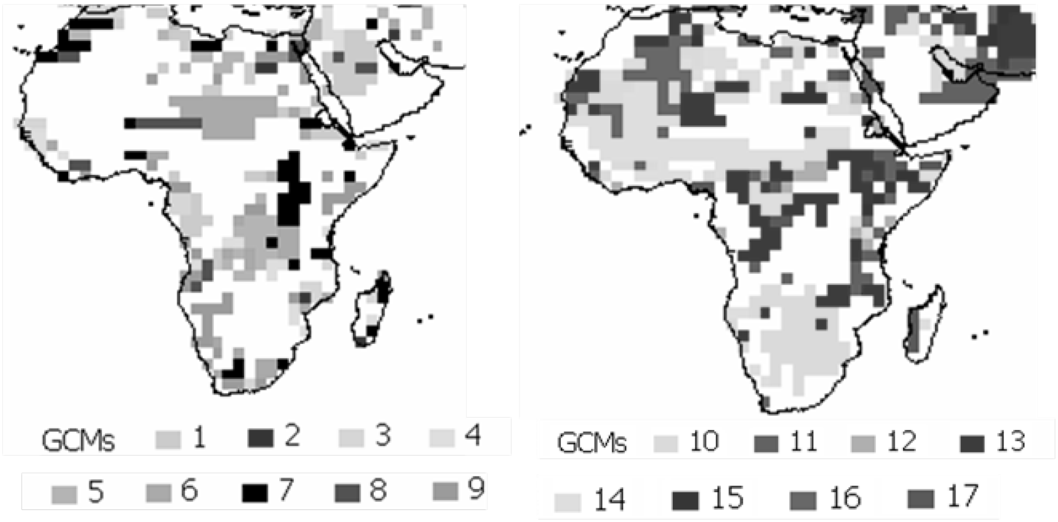
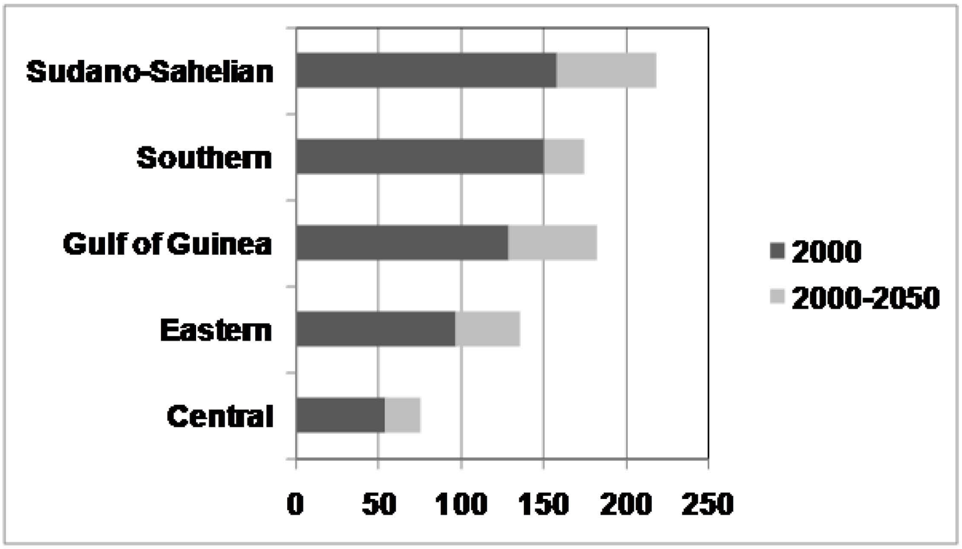
[1] While Figures 1-3 show results for all of Africa, the remainder of the paper focuses on Sub-Saharan Africa.

Figure 2. Map of GCMs with the highest performance/skill scores for precipitation, Africa



Source: Based on Cai et al. (2009).

Figure 3. Per capita food demand for cereals, 2000, and change over 2000–50, by agroecological zone, Sub-Saharan Africa, under historic climate (kg/capita)



Source: Authors.

Crop Yield Responses to Climate Change

We use the Decision Support System for Agrotechnology Transfer (DSSAT) crop simulation model to assess impacts of climate change from the CCC on crop area and yield. DSSAT is a detailed process model of the daily development of a crop from planting to harvest-ready (Jones et al. 2003). It requires daily weather data, including maximum and minimum temperature, solar radiation, and precipitation, a description of the soil physical and chemical characteristics of the field, and crop management, including crop, variety, planting date, plant spacing, and inputs such as fertilizer and irrigation. DSSAT models the biophysical responses to soil, nutrients, and climate change.

Direct temperature impacts on crops are modeled for maize and groundnut. Results are extrapolated to additional crops in the model, based on relative yield changes under climate change obtained from the Integrated Assessment model IMAGE (Bouwman, Kram, and Klein Goldewijk 2006).

Use of the CCC Scenario in the Water and Food Modeling Framework

The CCC scenario is incorporated into a global hydrological model that is linked with IMPACT. This semi-distributed global hydrology model parameterizes the dominant hydrometeorological processes taking place at the land surface–atmosphere interface at global scope. The model runs on a 30-minute latitude-longitude grid, and global 30-minute climate, soil, and land surface cover data are used to determine a number of spatially distributed model parameters. The remaining parameters are determined through model calibrations with global river discharge databases and datasets available elsewhere, using genetic algorithms. For river basins where data are not available for detailed calibration, regionalized model parameters are applied. The global hydrology model is able to convert projections of future climate made by GCMs into hydrologic components such as evapotranspiration, runoff, and soil moisture.

The global hydrologic model is linked with IFPRI's IMPACT model to assess the implications of climate change for water and food outcomes in the region. IMPACT is a partial equilibrium model of the agricultural sector, representing a competitive agricultural market for crops and livestock. Demand is a function of prices, income, and population growth. Growth in crop production in each country is determined by crop and input prices and the rate of productivity growth. World agricultural commodity prices are determined annually at levels that clear international markets. IMPACT generates projections for crop area; yield; production; demand for food, feed, and other uses; prices; and trade. For livestock, IMPACT projects numbers, yield, production, demand, prices, and trade. IMPACT includes 30 agricultural commodities and 115 economic regions, representing most developing countries; 126 global (aggregated) river basins; and 281 global food production units, defined by intersections of economic regions and river basins.

3. RESULTS FOR FOOD SUPPLY AND DEMAND UNDER HISTORIC CLIMATE

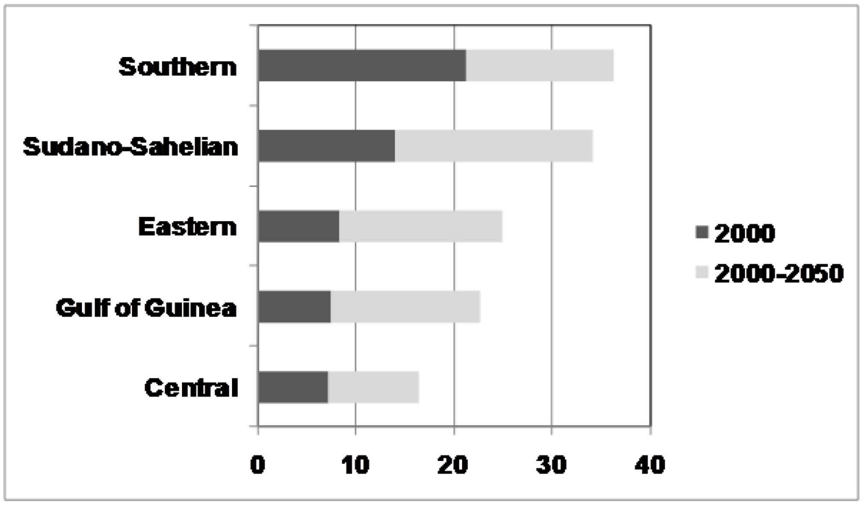
Food Supply and Demand Outcomes

Under historic climate, global cereal demand increases 1.03 percent per year during 2000–50. Demand growth in Sub-Saharan Africa is much faster, at 2.43 percent per year for the same period, as a result of both economic growth and increased diversification of diets. Moreover, while global cereal demand slows after 2025, demand in Sub-Saharan Africa accelerates, from 2.26 percent per year during 2000–25 to 2.60 percent annually during 2025–2050. Global demand for meat products (beef, sheep and goat, pork, and poultry) grows more rapidly than demand for cereals, at 1.42 percent annually. Demand is again stronger in Sub-Saharan Africa, at 3.65 percent per year.

While growth in Sub-Saharan Africa is projected to be relatively rapid, developments start from a low base. Per capita meat demand in Sub-Saharan Africa was 11 kilograms (kg) in 2005, compared with an average of 84 kg in North America and Europe, 57 kg per capita in Latin America and the Caribbean, 31 kg per capita in Asia, and even 20 kg per capita in the Middle East and North Africa. Similarly, per capita cereal demand was 153 kg in Sub-Saharan Africa, of which 76 percent was used as food, whereas demand in North America and Europe was 677 kg per capita in 2005, but only 19 percent was used as food: most of the rest was used as animal feed.

Figures 3 and 4 present results for per capita cereal food demand and per capita meat demand, respectively, for the various agroecological zones in Sub-Saharan Africa[2]. For both cereals and meats, per capita demands are highest in the Southern and Sudano-Sahelian zones and lowest in the Central zone, which is dominated by the Democratic Republic of Congo, with 66 million people, and which also includes Angola and Cameroon, with about 19 million people each.

Figure 4. Per capita food demand for meat products, 2000, and change over 2000–50, by agroecological zone, Sub-Saharan Africa, under historic climate (kg/capita)



Source: Authors.

Total cereal demand in Sub-Saharan Africa is projected to almost double to 317 million metric tons (mt) by 2050; 24 percent of the increase is expected for maize, 20 percent for millet, 19 percent for wheat, 18 percent for sorghum, 14 percent for rice, and 5 percent for other grains. Whereas, globally, 38 percent of cereal demand increase is projected to be used as animal feed during 2000–50, in Sub-Saharan

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[2] Countries belonging to each zone are shown in the Appendix, Table A.2.

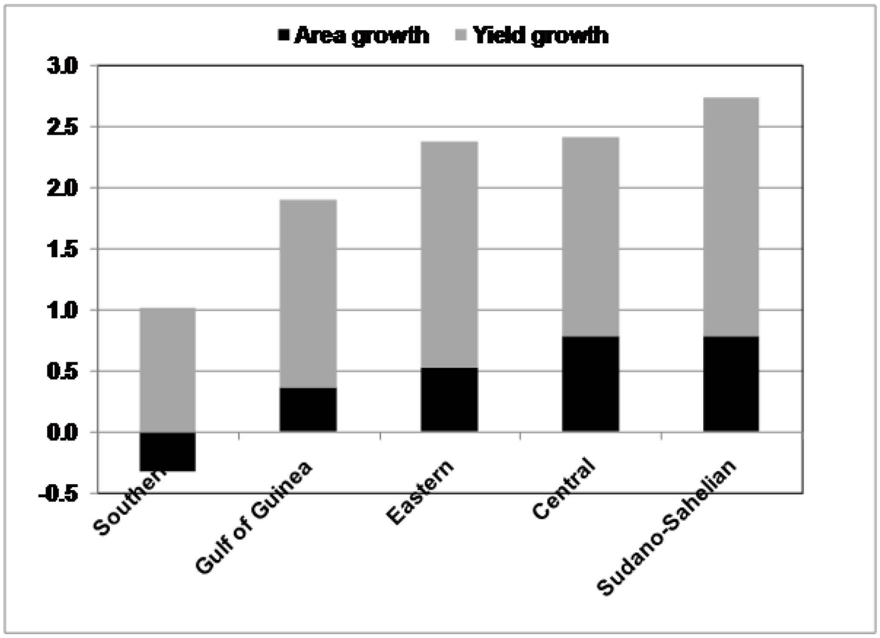
Africa, only 6 percent of total cereal demand increase is projected for use as animal feed. Finally, total demand for root and tuber crops is projected to increase by 388 million mt globally; half of this demand increase will be accounted for by Sub-Saharan Africa, where roots and tubers are important staple foods.

How will the expanding food demand be met? For meat in developing countries, increases in the number of animals slaughtered have accounted for 80–90 percent of production growth during the past decade. Although improvements in animal yields are expected, growth in numbers will continue to be the main source of production growth. For the crops sector, Sub-Saharan Africa is one of only two regions with significant expansion of agricultural land. Globally, total crop area is projected to increase by 115 million hectares from 1.2 billion hectares in 2000, with land expansion in some parts of the world almost balanced by land contractions in other parts; however, global area planted to cereals is projected to decrease by 30 million hectares. In Sub-Saharan Africa, total area is projected to continue to increase by 70 million hectares, from 155 million hectares in 2000, and cereal area is expected to increase by 17 million hectares, accounting for 22 percent of food production growth.

Both land degradation and climate variability are expected to increasingly constrain food production growth in Sub-Saharan Africa, and poor infrastructure development will continue to constrain access to both agricultural inputs and markets for outputs. Once plants are weakened from abiotic stresses, biotic stresses tend to set in and the incidence of pest and diseases tends to increase.

As a result of slow area expansion, yield growth is expected to account for most future food production growth in Sub-Saharan Africa. The global yield growth rate for cereals is expected to decline from 1.96 percent per year in 1980–2000 to 1.14 percent per year in 2000–50. Somewhat higher yield growth is expected in Sub-Saharan Africa at 1.57 percent per year. Zone-specific results for the contribution of area and yield growth to total cereal production growth in Sub-Saharan Africa are shown in Figure 5. The largest contribution from area expansion to cereal production growth is projected for the Sudano-Sahelian and the Central African zones, while the contribution of area is projected to contract in Southern Africa. The contribution of yield growth to total production growth is projected to be largest in the Sudano-Sahelian zone, followed by Eastern Africa.

Figure 5. Contribution of area and yield growth, by agroecological zone, Sub-Saharan Africa, historic climate (percent per year)



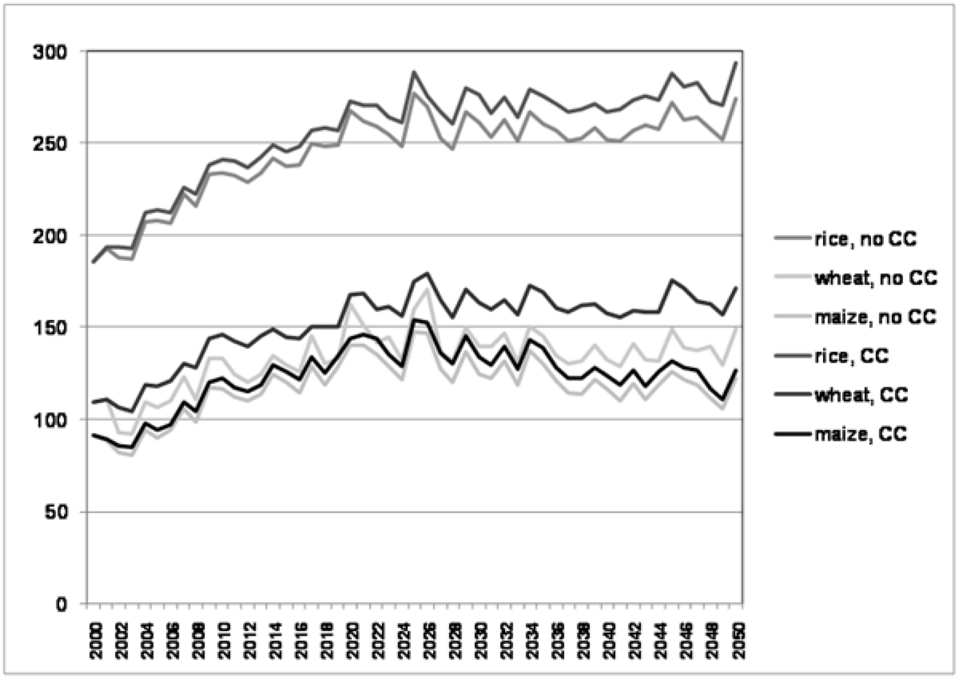
Source: Authors.

Results for Food Trade, Prices, and Food Security

In the last few years, real prices of food in the developing world have increased dramatically as a result of changes in biofuel/climate policies, rising energy prices, declining food stocks, and market speculation. Projections reported here show that higher food price trends are likely to continue as a result of increased pressures on land and water resources, adverse impacts from climate variability and change, and rapidly rising incomes in many developing countries. Given the long-term underinvestment in agriculture and poor government policies in response to rising food prices in many countries, it is unlikely that the supply response will be strong enough to significantly reverse higher food prices, even in the short-to-medium terms. The only short-term reprieve has come from the financial crisis of 2008/09.

International rice, wheat, and maize prices are projected to increase by 41, 28, and 36 percent to 2030, respectively, and by 48, 36, and 34 percent, during 2000–50 (Figure 6). Impacts of higher food prices on the net food purchasers will be substantial, depressing food demand in the longer term, increasing childhood malnutrition rates, and reversing progress made in several low-income countries in terms of nutrition and food security.

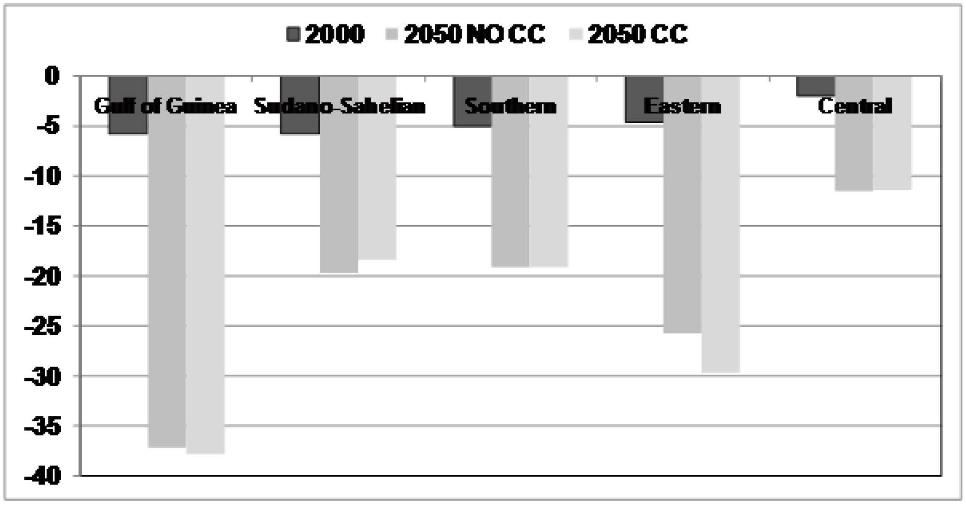
Figure 6. World prices for key staple crops, climate change and no climate change scenarios (US$/metric ton)



Source: Authors.

World trade in food is expected to continue to increase, with trade in cereals projected to increase from 253 million mt in 2000 to 646 million mt by 2050, with trade in meat products rising from 11 million mt to 57 million mt. Expanding trade will be driven by the increasing import demand from the developing world, particularly Sub-Saharan Africa, where net cereal imports are expected to increase by a factor of 5 during 2000–50. In fact, Sub-Saharan Africa will face the second-largest increase in food import bills, despite significant area and yield growth expected during the next 50 years under historic climate. Results for net cereal imports in zones of Sub-Saharan Africa, with and without climate change, are shown in Figure 7. The Gulf of Guinea and Sudano-Sahelian zones were the largest net cereal importers in 2000. By 2050, the Gulf of Guinea zone is still expected to be the largest net cereal importer, but it will be followed by Eastern Africa. The Gulf of Guinea, Eastern Africa, and Central Africa are all expected to increase net cereal imports by a factor of 6 during this period, as a result of high but insufficient food production growth in the face of growing population and economic growth (see also Figure 5).

Figure 7. Net trade in cereals by agroecological zone, Sub-Saharan Africa, 200,0 and projected to 2050 with and without climate change (million metric tons)

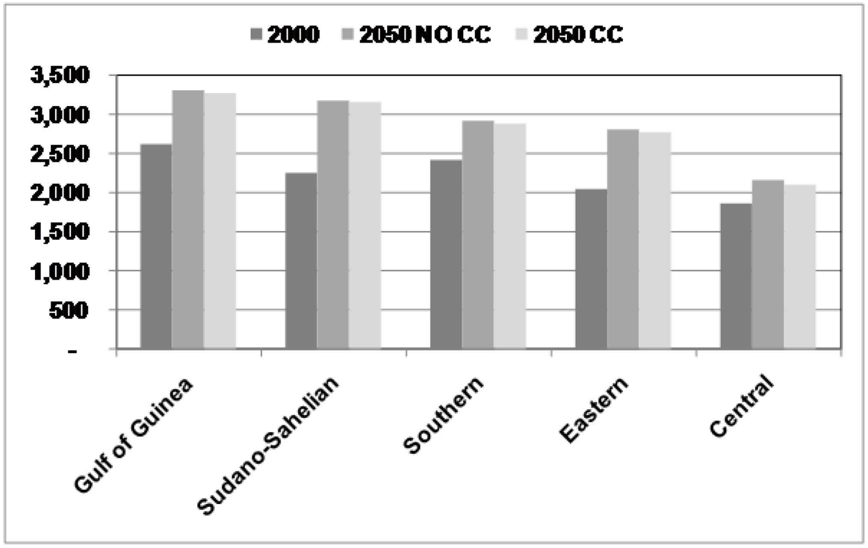


Source: Authors.

With much of Sub-Saharan Africa still unable to increase food production rapidly enough to meet growing demand, the major exporting countries—mostly high-income countries and the Eastern Europe and Central Asia regions—will play an increasingly critical role in meeting global food consumption needs. The United States and Europe will act as a critical safety valve in providing relatively affordable food to developing countries. However, given the strong demand for food crops as feedstock for biofuels in the short-to-medium term, net cereal exports in these countries will compete with domestic use as transport fuels (see also Rosegrant et al. 2008).

The substantial increase in food prices will slow growth in calorie consumption, with both direct price impacts and reductions in real incomes for poor consumers who spend a large share of their income on food. As a result, there will be little improvement in food security for the poor in many regions. In Sub-Saharan Africa, daily calorie availability is expected to stagnate up to 2020 before slowly increasing to 2,867 kilocalories by 2050, compared with an average of more than 3,000 calories in all other regions. Among the various agroecological zones in Sub-Saharan Africa, in 2000, the Gulf of Guinea zone, which includes Nigeria, the Ivory Coast, and Ghana, and the Southern African zone, with South Africa and Lesotho, had the highest per capita calorie availabilities, whereas Central Africa (including the Democratic Republic of Congo) had the lowest caloric availability. In 2050, the Gulf of Guinea one is still expected to have the highest calorie availability per capita in the region, followed by the Sudano-Sahelian zone, which includes Senegal, Sudan, and Mali (Figure 8).

Figure 8. Calorie availability by agroecological zone, Sub-Saharan Africa, 2000 and 2050, climate change and no climate change scenarios (kilocalories per capita per day)



Source: Authors.

Globally, under historic climate, childhood malnutrition (in children of up to 60 months) will continue to decline, but it is unlikely to be eradicated by 2050. In developing countries, childhood malnutrition is projected to decline from 149 million children in 2000 to 127 million children by 2030 and 99 million children by 2050. Progress is slowest in Sub-Saharan Africa—despite significant income growth and large area and yield gains: the number of malnourished children is expected to have increased by 8 million children in 2030, before declining to 30 million children by 2050, approximately the same level as in 2000.

4. IMPACT OF CLIMATE CHANGE ON OUTCOMES FOR SUB-SAHARAN AFRICA

While climate change impacts in the form of yield declines are less severe in Sub-Saharan Africa than in Asia, for example in ADB and IFPRI (2009), Sub-Saharan Africa is much more vulnerable to climate change. This is because Africa's adaptive capacity is extremely low, which is linked to acute poverty levels and poor infrastructure, as reflected in a high dependence on rainfed agriculture (see, for example, Brooks, Adger, and Kelly 2005; Ikeme 2003; Tschakert 2007). As we have shown, Sub-Saharan Africa faces increased net food imports even under the historic climate scenario as a result of growing populations; faster economic growth than in the past; and growing urbanization, coupled with insufficient improvement in agricultural productivity.

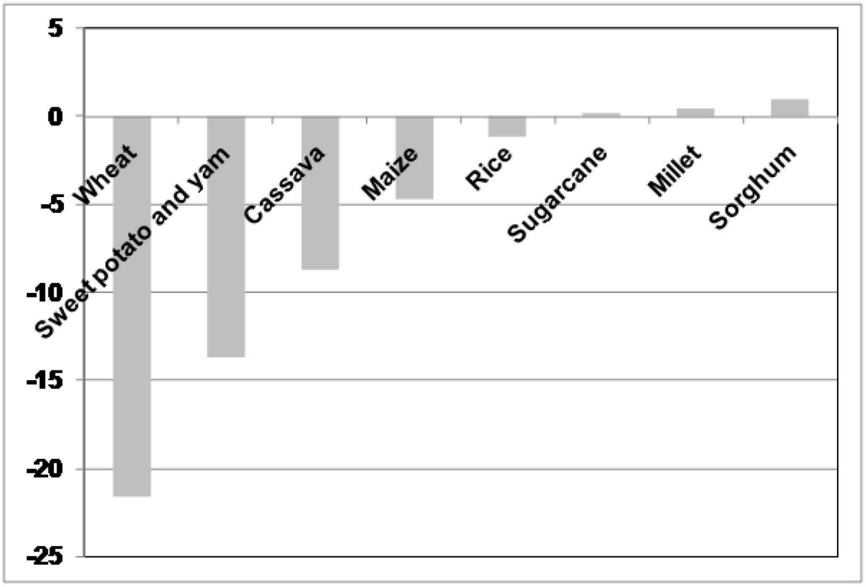
In the IMPACT model, climate change affects crop productivity through both crop harvested area and yield. IMPACT considers crop production effects from the perspective of altered temperature and precipitation patterns and changes in irrigation water availability and evapotranspiration potential. As the model also considers technological change over time as well as economic feedback effects through changes in international food prices, which, in turn, lead to a series of (autonomous) supply and demand responses. Thus three impacts on crop production from climate change are considered: (1) direct effects on rainfed yields through changes in temperature and precipitation; (2) indirect effects on irrigated yields from changes in temperature and in water available for irrigation (including precipitation); and (3) autonomous adjustments to area and yield due to price effects and changes in trade flows in the economic model. When IMPACT projections are compared with and without climate change scenarios, the "net" effects of climate change on agricultural production, demand, trade, and prices can be obtained.

The direct and indirect effects of climate change on agriculture play out through the economic system, altering prices, production, productivity, food demand, calorie availability, and, ultimately, human well-being.

Impacts on Crop Yields in Sub-Saharan Africa

Climate change will affect crop area, yield, and production. Figure 9 presents projected changes in yields as a result of climate change in 2050 for selected crops grown in Sub-Saharan Africa. Negative yield impacts are projected to be largest for wheat, followed by sweet potato, whereas overall yields for millet and sorghum are projected to be slightly higher under climate change. Although negative impacts are largest for wheat, the region grows very little of it (about 4.3 million ha in 2000).

Figure 9. Yield changes by crop as a result of climate change, 2050, Sub-Saharan Africa (percent change)



Source: Authors.

Table 1 gives changes in crop yields for major crops grown in Sub-Saharan Africa by agroecological zone. Interestingly, yield impacts are quite heterogeneous across crops and zones, and no crop or zone has consistently positive or negative results. Among the crops, the Sudano-Sahelian and Eastern zones show projected yield increases for four out of the five crops. Rice is particularly important in the Sudano-Sahelian zone, and maize is the key staple crop in Eastern Africa. The Central zone, on the other hand, shows yield declines for four out of five crops, but declines are minor. The Gulf of Guinea shows the largest yield declines for cassava and sweet potato, and the Southern zone has projected declines for maize, rice, and cassava.

Table 1. Yield changes, selected crops, under climate change, by agroecological zone, Sub-Saharan Africa, 2050, (in percent)

	Maize	Rice	Sweet potato and yam	Cassava	Sugarcane
Gulf of Guinea	0.24	1.38	(15.09)	(11.94)	(0.50)
Sudano-Sahelian	3.30	(0.80)	1.98	1.22	0.34
Southern	(0.91)	(2.32)	1.14	(0.75)	1.09
Eastern	(1.92)	0.24	1.06	0.42	0.31
Central	(0.79)	(0.63)	(0.11)	(0.14)	0.93

Source: Authors.

Impacts on Food Demand, Prices, and Trade

Under climate change, aggregate food demand for cereals in the Sub-Saharan region declines by 3.6 million mt or 1.5 percent by 2050. Among agroecological zones, declines are largest for Central and Southern Africa, at 2.5 and 2.1 percent, respectively, and lowest in the Gulf of Guinea, at 0.9 percent. These differences are due to the relative impacts on cereal area and yields in the regional food baskets, as well as relative changes in global food prices of individual cereals.

World prices are a key indicator of the effects of climate change on agriculture and even more importantly, food affordability and security. In Figure 6, which shows the price effects from climate change on key cereals, food prices increase for all staple crops because climate change acts as an additional stressor on the already tightening price outlook. Under climate change, maize, rice, and wheat prices in 2050 are 4, 7, and 15 percent higher than in the historic climate scenario. Moreover, prices of other crops of importance to the region also increase: sweet potato and yams by 26 percent, cassava by 20 percent, millet by 5 percent, and sorghum by 4 percent. Impacts of higher food prices on the net food purchasers will be substantial, depressing food demand in the longer term and increasing childhood malnutrition rates.

Research on the effects of climate change on world agricultural markets is still relatively limited. Climate change alters the comparative advantage, setting up the possibility of changes in trade flows as producers respond to changing opportunities. More generally, agricultural trade flows depend on the interaction between the inherent comparative advantage in agriculture, which is determined by climate and the resource endowments, and a wide-ranging set of local, regional, national, and international trade policies. Across Sub-Saharan Africa, little change in net cereal imports is expected as a result of climate change because increases and declines in net cereal imports balance out. Regarding changes in net cereal trade across agroecological zones (Figure 7), Eastern Africa is projected to experience the largest increase in net cereal imports, at 15 percent, as a result of climate change, probably due to the large decline in maize yields. For the Sudano-Sahelian zone, a steep decline in net cereal imports—6 percent—is also projected, again driven by changes in maize yields (see also Table 1).

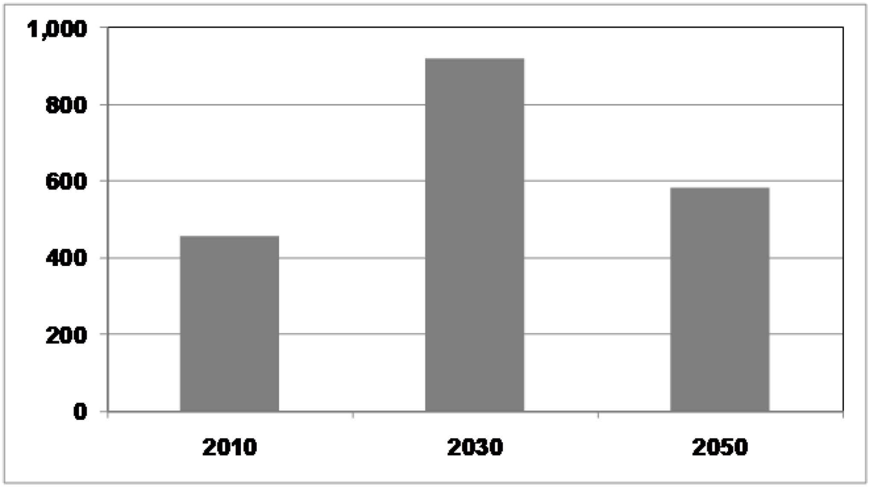
Impacts on Childhood Malnutrition

Higher food prices dampen demand for food, as affordability of nearly all agricultural commodities—including basic staples and livestock products—declines under climate change. As a result, per capita calorie availability across Sub-Saharan Africa declines by 1.3 percent or 37 kilocalories per capita per day. While this change appears rather small, distributional effects are likely significant and those who can least afford to reduce caloric intake are likely hardest hit.

Subregional results are presented in Figure 8. The largest drop in calorie availability, at 2.6 percent, is projected for the Central zone, which already had the lowest per capita calorie availability to begin with. As such, the Central zone, on average, would be close to the minimum per capita daily calorie availability of 2,000 kilocalories recommended for a healthy and productive life. On the other hand, the smallest impact on food availability is expected for the Sudano-Sahelian zone, where yield effects are mostly positive and crops with major price increases are of relatively less importance.

Particularly in Sub-Saharan Africa, the most potent force for reducing malnutrition is raising food availability through increased agricultural productivity, as well as trade. Key nonfood determinants of child malnutrition include the quality of maternal and child care, female secondary education, and health and sanitation (Smith and Haddad 2000). Depressed food demand translates into direct increases in malnutrition levels, with often irreversible consequences for young children. Climate change increases the number of malnourished children in both 2030 and 2050 (Figure 10). Without climate change, child malnutrition levels are projected to decline from 28 percent in 2000 to 24 percent by 2030 and 19 percent by 2050, while absolute numbers would increase from 30 million children in 2000 to 38 million by 2030, before reverting to 30 million by 2050. Under climate change, child malnutrition numbers would increase by 460,000 children by 2010, to just below 1 million children by 2030; the number would still be 585,000 children higher by 2050, compared with the baseline without climate change.

Figure 10. Incremental number of malnourished children under climate change, Sub-Saharan Africa, compared with historic climate (thousand children)



Source: Authors.

5. CONCLUSIONS

This paper analyzes the impacts of climate change on Sub-Saharan Africa, using a CCC scenario that integrates climate projections from17 GCMs and considers the GCMs' relative performance regarding their prediction of temperature and precipitation for the region. The CCC scenario is generated using a newly developed entropy-based downscaling model. It is incorporated into a process-based crop growth simulation model and a global hydrological model that is linked with IFPRI's IMPACT water and food projections model to assess the implications of climate change for food outcomes in the region.

When incorporated into IFPRI's IMPACT water and food projections' model, the impacts of the scenario with climate change (compared with the historic climate scenario) include changes in area and yield expansion, higher food prices, small changes in net cereal trade, slightly reduced calorie availability, and growing childhood malnutrition in Sub-Saharan Africa.

However, even without climate change, Sub-Saharan Africa remains the most food-deprived region, and the only region with projected increases in childhood malnutrition over the next two decades, despite recent increases in economic prosperity and GDP generated in agriculture.

Cereal production growth in Sub-Saharan Africa is projected to decline by 3.2 percent as a result of climate change, with declines in yield growth of 4.6 percent partially compensated for by increased area expansion (2.1 percent). Among staple crops, negative yield impacts are projected to be largest for wheat, followed by sweet potato, whereas overall yields for millet and sorghum are projected to be slightly higher under climate change. Under climate change, by 2050, maize, rice, and wheat prices are expected to be 4, 7, and 15 percent higher, respectively, compared with the historic climate scenario. Higher food prices contribute directly to lower food demand, which declines for Sub-Saharan Africa by 1.5 percent by 2050. Little change in net cereal imports is expected as a result of climate change for Sub-Saharan Africa as a whole because increases and declines in net cereal imports in different agroecological zones balance out. However, it is projected that Eastern Africa will experience large increases—15 percent— in net cereal imports as a result of significant maize yield declines.

Most important, childhood malnutrition levels are projected to increase as a result of climate change across Sub-Saharan Africa, with incremental increases from climate change alone of just below 1 million children by 2030. By 2050, 585,000 children will still be malnourished.

APPENDIX: SUPPLEMENTARY TABLES

Table A.1. Global circulation models used in the study

Index	Name	Institute	Country
1	CCCMA CGCM3.1(T47)	Canadian Centre for Climate Modelling and Analysis	Canada
2	CNRM CM3	Center National de Recherches Meteorologiques	France
3	GFDL CM2.0	Geophysical Fluid Dynamics Laboratory	USA
4	GFDL CM2.1	Geophysical Fluid Dynamics Laboratory	USA
5	GISS AOM	Goddard Institute for Space Studies	USA
6	GISS EH	Goddard Institute for Space Studies	USA
7	GISS ER	Goddard Institute for Space Studies	USA
8	IAP FGOALS-g1.0	Institute for Atmospheric Physics	China
9	INM CM3	Institute for Numerical Mathematics	Russian
10	IPSL CM4	Institute Pierre Simon Laplace	France
11	MIROC3.2(hires)	Center for Climate System Research	Japan
12	MIROC3.2(medres)	Center for Climate System Research	Japan
13	MPI ECHAM5	Max Planck Institute for Meteorology	German
14	MRI CGCM2.3.2	Meteorological Research Institute	Japan
15	NCAR CCSM3	National Center for Atmospheric Research	USA
16	NCAR PCM1	National Center for Atmospheric Research	USA
17	UKMO-HadCM3	Met Office's Hadley Centre for Climate Prediction	England

Source: Cai et al. (2009).
Note: See also Connolley and Bracegirdle 2007.

Table A.2. Agroecological zones of Sub-Saharan Africa

Zone	Countries in zone	Characteristics
Sudano-Sahelian	Burkina Faso, Cape Verde, Chad, Djibouti, Eritrea, The Gambia, Mali, Mauritania, Niger, Senegal, Somalia, Sudan	Dry; low population density. Large-scale use of irrigation limited to Sudan. Some successful use of irrigation elsewhere for food and cash crops.
Eastern	Burundi, Ethiopia, Kenya, Tanzania, Uganda, Rwanda	37% of arable area under production. Large arid zones unsuitable for crops. Other large areas of fragile agroecology. Irrigation has boosted cash crops in Ethiopia and Kenya.
Gulf of Guinea	Benin, Côte d'Ivoire, Ghana, Guinea, Guinea-Bissau, Liberia, Nigeria, Sierra Leone, Togo	Great variation in climate, including precipitation. Varied scope for irrigation.
Central	Angola, Cameroon, Central African Republic, Congo (Republic of), Democratic Republic. of Congo, Equitorial Guinea, Gabon, Sao Tome and Principe	Generally well supplied with water, but imbalance in distribution of groundwater resources. Low population density; much rough terrain.
Southern	Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Zambia, Zimbabwe	Oceans temper climate in coastal areas. Wide variation in precipitation, water availability, and agroecological conditions: some tropical (Mozambique), some dryland (South Africa).
Indian Ocean Islands	Comoros, Madagascar, Mauritius, Seychelles	Conditions vary from semi-arid to tropical humid.

Source: FAO (2005).

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