Food Security Implication Of Climate Change

In Developing Countries: Findings From A Case Study In Mali

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FOOD SECURITY IMPLICATION OF CLIMATE CHANGE IN DEVELOPING COUNTRIES: FINDINGS FROM A CASE STUDY IN MALI

Abstract: We investigated the impact of climate change on food security in developing countries and various adaptations that can be pursued by presenting findings from a case study conducted in Mali. A suite of biophysical models is used to project the impact on crop and livestock sectors. Following biophysical results, an economic model is used to project the availability of food for human consumption and the consequent impact on the incidence of malnourishment in Mali. We found that while malnourishment in the country may double its present level, adaptations to climate change may improve food security conditions considerably.

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1. Introduction

The Food and Agriculture Organization (FAO) in its report *World Agriculture Toward 2015/2030* (7), estimated that 776 million people located in 98 countries were food insecure during 1997/99, mostly concentrated in South Asia and Sub-Saharan Africa. They also argued that the greenhouse gas induced climate change would further worsen the food security situation, especially in the tropics.

Findings from agronomic studies (4 and 12) suggest that food security conditions may become even more tenuous under climatic change as does (10). However this has not been extensively examined other than in terms of crop yield effects[1]. In this study, we examine food security implications of climate change in a linked economic and agronomic case study for Mali. We also consider mitigative policy and research based adaptations that might be implemented.

2. Mali Background and Climate Change Projections

Mali is located on the southern edge of the Sahara desert. Malian agriculture confronts extreme dry conditions and substantial climate variability - critical features

[1] The Intergovernmental Panel on Climate Change (2001) asserts there are few, if any, economically based climatic change impact assessments focused on developing countries.

impacting food security. An FAO report (6) asserts that 34 percent of the population was malnourished during 1996-97 and is at risk of hunger in times of food shortages.

Climate change projections from the Hadley Center Coupled Climate Model (HADCM) and Canadian Global Coupled Climate Model (CGCM), suggest that by year 2030, Malian average temperatures may increase by 1 ^{o}C – 2.75 ^{o}C, with precipitation declining slightly, as shown by the incidence of regional projections in the hot dry quadrant of Figure 1.

This climate change would likely impact agricultural yields negatively as it would cause reduced soil moisture, faster depletion of soil organic matter, pre-mature drying of grain, and increased heat-stress. Changes in yields, all other things held constant, would lessen food production and consumption, worsening food security conditions as argued in (4); and (12). However, society may also adapt to climate change by altering production practices, developing new technologies, changing regional cropping patterns, altering consumption patterns, or increasing imports (1); (12); and (9).

3. Analytical Framework

To assess the impact of Mali climate change and adaptations on food security, we integrated a number of modeling frameworks. First, to assess the yield impacts we used the following biophysical models: (a) the EPIC crop growth simulator (16) for crops, (b) the PHGROW forage simulator (13) for forage yields, and (c) the NUTBAL animal simulator (14) for livestock feed demand and yield. Second, to assess changes in production, prices, and trade plus use of adaptation strategies, we used the Mali Agriculture Sector Model (3). MASM represents crop and livestock production in nine geo-graphical regions in the country for seven crop and six livestock commodities[2]. Third, a methodology, as presented in (5), was used to compute a Risk of Hunger (ROH) measure indicating incidence of malnourishment and, hence, food insecurity in a country[3]. The ROH measure estimates the percentage of the population whose daily caloric intake falls below requirements for a healthy life. Each of the modeling steps used input from the previous step.

For the climate change analysis the biophysical models were run under base, HADCM and CGCM climate projections for 2030.[4] In turn, the biophysical responses were incorporated into MASM along with changes in world trade conditions derived from the US National Assessment (11) to get simulated changes in production, exports/imports, and food for consumption as in (2). Then the MASM results were incorporated into the ROH calculation to estimate food security implications.

4. Climate Change Impact

Table 1 shows the national level average[5] yield implication estimates arising under climate change as developed by the biophysical models. Except for cotton[6], yields are projected to decrease. Sorghum, the major staple diet in Mali, is the most susceptible crop with a national average yield decrease of up to 17 percent. Regional yield

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[2] The commodities included in MASM constitute about 85 percent of the caloric intake in the country.

[3] See (5) or (6) for more on this computation and the underlying assumptions.

[4] The model predictions are available under two scenarios; these are Greenhouse Gas Integrations (GG), and Greenhouse Gas plus Sulphate Aerosol Integrations (GS). In this study, we used GG, as this scenario has captured the observed signal of global-mean temperature changes better than GS scenario for the recent 100-year record (Data Distribution Center).

[5] The results are averaged across biophysical runs in 92 agro-ecological zones in the country; see Butt (2002) for detail.

[6] We simulated crop yields under climate change with the projected high levels of atmospheric CO_2; 450 ppmv in 2030 (Reilly et al. 2002) compared to 355 ppmv presently. Of the two plant species category, C3 and C4, cotton falls in C3 category plants that benefit more from increase in the atmospheric CO_2 levels.

reductions were found that were as high as 30 percent. Forage yields decrease by 5 to 36 percent. Cattle show reductions in intake and in growth in the neighborhood of 15 percent, while small ruminants are essentially robust exhibiting slightly reduced feed intake.

Table 2 shows selected MASM results and the subsequent ROH projection along with later discussed adaptation strategy implications. Cereal production is projected to decrease between 16 to 19 percent, leading to a rise in cereal prices by more than two fold. Consumers loose, while producers gain due to high prices. In overall, the sectoral losses are projected to be between $96-116 million.

Production and prices of cereals are strongly tied to the incidence of malnourishment in countries like Mali, where more than 70 percent of the daily calories requirements are met from cereals. The climate change induced decline in cereal production results in lower per capita availability of cereals, leading to an increase in the ROH. As shown in Table 2, the ROH is projected to increase from a base level of 34 percent of the Malian population to a range of 64-70 percent. The ROH also varies across regions as shown graphically for the CGCM scenario in Figure 2. Under climate change, the population at risk of hunger is projected to rise to about 75% in Sikasso, the most productive area in Mali, and in Tombouctou and Gao, the two dry northern areas. An abrupt increase is projected for Bamako, which is a non-producing area in Mali. The ROH in Bamako is projected to rise from 6 percent to 47 percent of the population. This sharp projected increase in ROH is indicative of subsistence farming where farmers react to production shortfalls by reducing their marketable surplus greatly affecting urban markets.

5. Adapting to Climate Change

The results thus far portend deteriorating food security for Mali under climate change. These results, however, were obtained without considering a number of possible adaptations to climate change as while crop mix and consumption patterns could change but food imports were limited to the largest level observed and no customized crop breeding or cropped area expansions were allowed. Ignoring such adaptations can lead to overestimates of the climate change impact (1). Hence, we further assess climate change impacts under two levels of adaptations.

Level 1 Adaptations

Following a number of agronomic studies like (12); and (9), we used EPIC to simulate management practices adaptations involving changed planting dates and adoption of heat resistant crop cultivars. We found that changing planting dates was not an effective adaptation strategy in the Mali setting as farmers begin planting with the beginning of the rainy season, which remained unchanged under the projected climate. However, we did find heat resistant varieties, to be an effective adaptation.

Under economic adaptations, we considered how changes in market conditions, prices and production of food and non-food commodities, might reduce climate change impact, where market conditions impacted most importantly trade (1). We projected changes in imports of cereals and exports of cotton as prices and production changed due to yield losses. We also considered how shifts in regional cropping patterns might reduce climate change impact by moving cropping patterns from hotter drier areas into the more temperate areas. For example, Sikasso is a relative less hot region compared to Segou. We found that under climate change, Sikasso benefited by adopting its cropping patterns in line with those in Segou. Similar analysis of shifting cropping patterns was extended to other regions.

Level 2 Adaptations

Under the government action or policy adaptations, we considered development/dissemination of improved crop technologies and expansion in cropland. We expanded crop yields reflective of improved crop technologies now available in Mali that have been adopted by a limited number of farmers (3). We also examined expansion of cropland that requires government policy action since the land is owned by the government through its Commune system (3).

Adaptation Results

Our results show that adaptations to climate change reduced the impact considerably. Under level 1 adaptations, more than 1/3 of the losses in producers' and consumers' benefits are reduced, and cereal production and prices are close to those under the base conditions, as shown in Table 2. When level 2 adaptations were considered, the adaptations more than offset the losses from climate change. Cereal production was about 12 percent higher, while cereal prices were around 33 percent lower compared to the base conditions.

The adaptations had a positive effect on the ROH measure. As shown in Table 2, the Level 1 adaptations reduced ROH to a range of 38-45 percent, while level 2 adaptations reduced it to nearly 20 percent of the population—less than the base level.

6. Conclusions

Our results project that Mali will experience economic losses under the 2030 greenhouse gas induced climate changes projected by HADCM and CGCM models. The losses fall in the range from $96 to $116 million. However, when distribution of losses is considered across producers and consumers, producers gain at the expense of consumers due to rise in prices. Furthermore climate change causes the risk of hunger to increase from 34 percent of the population to 64-70 percent. In terms of the FAOs' ranking of world countries by the risk of hunger, the study found that Mali might move from category 4 to category 5, which was the highest risk category[7]. Adaptations, however, can play an important role in reducing the overall economic losses and ROH.

To counter the effects of adverse climatic conditions, technical, policy and research based adaptation strategies may be employed. Regional shifts in cropping patterns, heat resistant varieties, land expansion, development of high yielding varieties and trade adjustments were found to be very important in providing higher economic benefits and improving food security conditions.

Our results suggest that regions with hot and dry climatic conditions, where many developing countries are located, the projected increase in temperature may cause decreases in crop yields, in turn, leading to a loss in agricultural production and possibly a deterioration in food security condition. As we found in Mali, adaptations may help

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[7] FAO has developed a ranking of world countries based on the 'risk of hunger' criteria that was used in this study. The ranking ranges from 1 to 5; 1 being the countries that have lowest exposure to hunger, while 5 being those countries that have the highest exposure to hunger.

mitigate climate change considerably. An anticipatory adaptation plan of actions, such as investing in heat resistant varieties, might be prudent.

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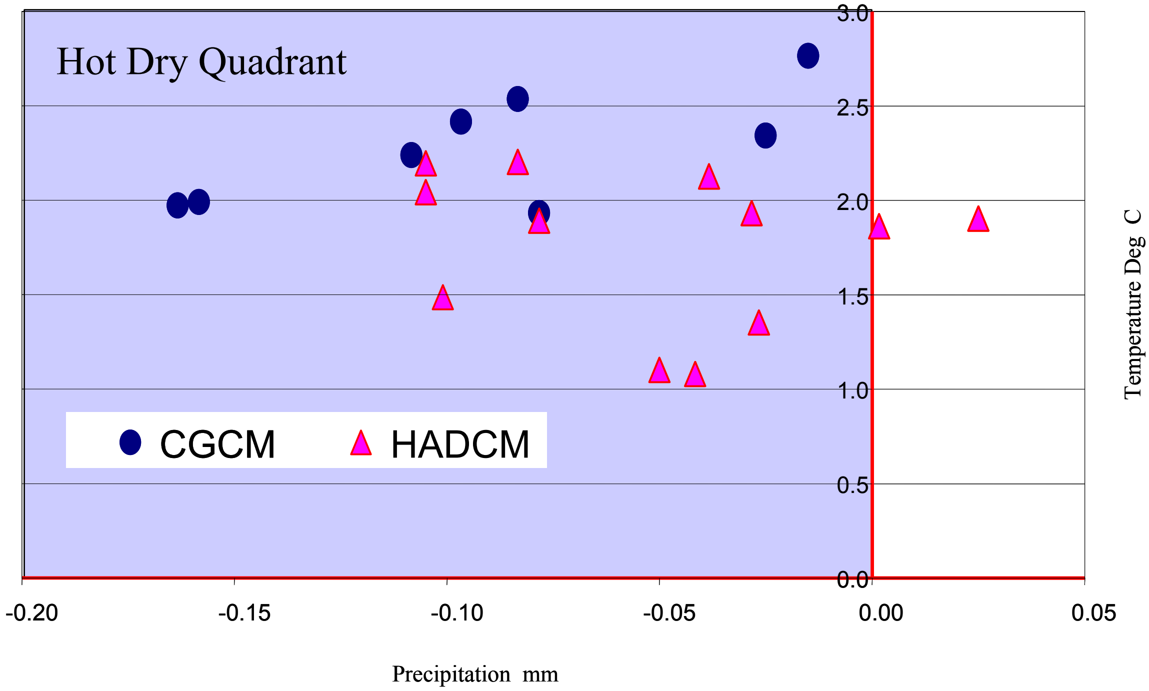

Figure 1: Projected Changes in Temperature and Precipitation in Multiple Regions in Mali from the Hadley and Canadian GCM Models

Table 1

Nationally Area Weighted Impacts Under the Projected Climate (Estimates From Biophysical Simulation Models).

Crop Yields (Percent change)	HADCM	CGCM
Cotton	8	5
Cowpeas	-3	-7
Groundnuts	-3	-7
Maize	-6	-9
Millet	3	-4
Sorghum	-9	-17
Livestock Forage Yields (Percent change)	-16	-25
Animal Intake Rate (Percent change)		
Cattle	-13	-13
Sheep	-3	-6
Goats	-4	-5
Animal Weight (Percent change)		
Cattle	-14	-16
Sheep	0	0
Goats	0	0

HADCM: Hadley Coupled Model; CGCM: Canadian Coupled Model.

Table 2

Economic Impact of Climate Change With and Without Adaptations

	Cereal Indices		Benefits in $ Mil. To			Risk of
Scenarios	Production	Price	Consumers	Producer	Total	Hunger
Base climate	100	100	447	515	962	34
Without Adaptations						
HADCM climate	84	229	219	647	866	64
CGCM climate	81	274	157	689	846	70
With Adaptations						
HADCM climate[1]	99	107	391	512	903	38
CGCM1 climate[1]	95	120	366	526	892	45
HADCM climate[2]	113	66	431	620	1050	20
CGCM climate[2]	112	68	422	622	1043	21

HADCM: Hadley Coupled Model
CGCM: Canadian Coupled Model
1: Economic and technological adaptations
2: 1 + Technology adoption and land expansion

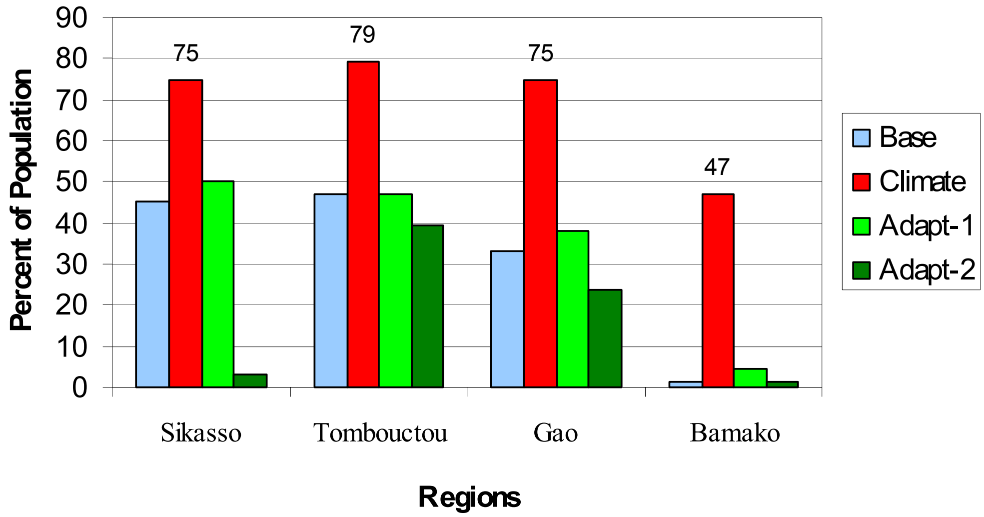

Figure 2. Risk of Hunger in Selected Regions of Mali Under the Canadian Model Projected Climate With and Without Two Levels of Adaptations