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CLIMATE CHANGE, AGRICULTURE, AND FOODCROP PRODUCTION IN GHANA

ALESSANDRO DE PINTO, ULAÇ DEMIRAG, AKIKO HARUNA, JAWOO KOO, MARIAN ASAMOAH

Despite the recent transition to an industry and service sectors-led economy, agriculture still plays a fundamental role in Ghana. The sector comprises approximately 30 percent of the country's GDP to date and employs approximately 50 percent of the population (10). The agricultural sector is believed to have the potential to grow at rates as high as six percent (2), but climate change could potentially inhibit such progress in the long run, given that the sector is particularly vulnerable to this ongoing phenomenon.

The vulnerability of Ghana's agriculture to climate change is largely due to its dependence on rainfall (26), particularly in the country's semi-arid north. Climate change can also exacerbate underlying problems that affect the agriculture sector. Such problems include: 1. the north-south social divide and water allocation disputes between the two regions; 2. cross-boundary water issues; and 3. tensions arising from economic dependence on crops susceptible to changes in climatic conditions, such as cocoa (3).

Ghana's agriculture is not only vulnerable to climate change; it also contributes to the problem: Agriculture is estimated to be the second largest contributor to Ghana's greenhouse gas (GHG) emissions after the energy sector. Important sources of growth in emissions—especially of nitrous oxide (NO_2) and methane (CH_4)—are livestock, chemical fertilizers, rice farming, and biomass burning (3). NO_2 and CH_4 emissions in Sub-Saharan Africa are driven primarily by agriculture and are projected to steadily increase (20). As domestic and international demand for agricultural products continues to increase, emissions from Ghana's agricultural sector will likely increase as well.

CLIMATE SCENARIOS

Ghana has already experienced an increase in mean annual temperature of 1°C per decade since 1960. Monthly rainfall decreased about 2.4 percent per decade during the same period, though in the 1960s, the rainfall over Ghana was particularly high (8; 13; 14). Another study found that the decline in annual mean rainfall is the most severe in the southwestern regions divided by the Kwahu Plateau (17). In the remaining part of the country, the Volta Basin, prolonged dry seasons have replaced shorter dry spells(18).

Future climate scenarios, and the predicted effects that climate change might have on the country, vary considerably according to which Global Circulation Model is used. However, models generally agree on the general trend for temperature changes, which are predicted to increase more in the northern region than in the rest of the country. Based on a review of 15 different models, the mean annual temperature is expected to increase by 1.0°C - 3.0°C by 2060, and by 1.5°C - 5.2°C by 2090with changes expected to be more pronounced severe in the north (13). Model results for changes in rainfall precipitation are more uncertain than those for temperatures. Half of the models predict a decrease while the others showed an increase (14). Such variations in climate projections significantly affect estimates for future crop yield, which will be discussed later.

EFFECTS ON THE AGRICULTURAL SECTOR

Climate change is likely to intensify seasonal and inter-annual rainfall variation (for example, drought in one year and floods the next), as long -term changes and trends take place (for example, rising annual mean temperatures) (4). Climate change may create water and heat stress, the outbreak of pests and diseases, the loss of productive lands through the deterioration of ecosystems, and additional burdens to supply chains such as increased post-harvest losses during storage and distribution. The likely consequences of such stresses include yield reductions, decreased livestock values, post-harvest losses, and reduced food accessibility and consumption (25). In addition, natural disasters, migrations, and threats to human health can degrade human and social capital and devalue assets and infrastructure in agricultural communities. Rural populations in the Upper East, Upper West and Northern regions are more vulnerable to climate change than the people in other regions. This is attributed to the region's stagnated development and the dryland agriculture's vulnerability to climatic stresses (5,22).

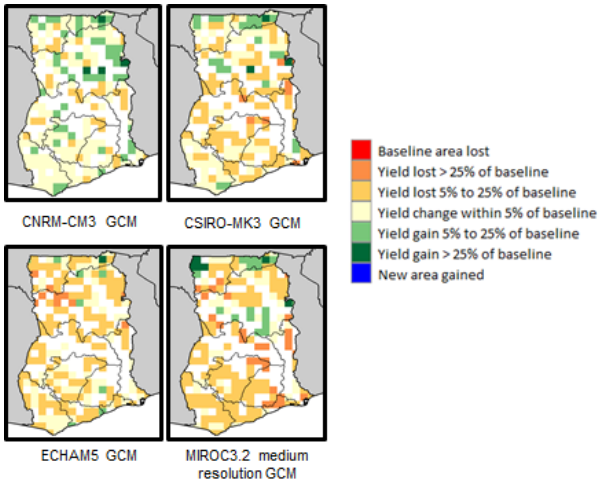
Researchers at the International Food Policy Research Institute recently completed a study on the impact that climate change will have on yields of rainfed maize, rice, and groundnuts by 2050. Results show an overall decrease in yields of all crops but also indicate regional variations, with some areas seeing increases in yields, while others experience losses. A summary of these results is reported on Table 1, while Figure 2 shows the spatial variation of the changes in yields (16).

Global studies on crop yields also predict losses, but they also point out that some potential gain in yields is possible if adaptations are made (Table 2). Such projections indicate that if adaptations are made, major staple crops in Ghana may be able to sustain current yields or even increase yields.

TABLE 1: ESTIMATES OF YIELD CHANGE OF MAIZE, RICE AND GROUNDNUTS

Rainfed Maize	Overall small decrease, mostly below 25 percent in each region. Some models, such as that of the Centre National de Recherches Météorologiques (CNRM) predict an increase in the Upper East, West, and Northern regions.
Rainfed Rice	Moderate yield decrease, with variation seen between the models: CNRM's provided the most optimistic figures; the Microindustry Credit Rural Organization's (MIROC) showed many areas with a yield decrease up to 25 percent.
Rainfed groundnuts	High rates of yield decrease. The Commonwealth Science and Industrial Research Organization's (CSIRO) model and MIROC's showed more than 25 percent of loss in the Central and Southern regions. The European Centre Hamburg Model (ECHAM5) projected a high rate of loss in the Northern Region, while the other models predict some degree of gain in the northern part of the country.

FIGURE 1: REGIONAL VARIATION IN YIELD CHANGES FOR



Source: Nutsukpo et al. (forthcoming)

TABLE 2: ESTIMATES OF YIELD CHANGES, GLOBAL MODELLING APPROACHES

Study	Estimate
Jones and Thornton (2003)	10 percent loss in maize yield in 2050 without intervention. This degree of loss will be sufficiently compensated with intervention (authors' comment).
Fischer et al.(2005)	Ghana will increase overall cereal production until 2080, if expansion of agricultural land and farmers' adaptive practices to climate change are implemented (change of crop varieties and planting timing). Sub-Saharan Africa as a whole will lose up to 12 percent of its production potential.

CLIMATE CHANGE ADAPTATION OPTIONS

The term, "climate change adaptation" refers to a set of actions, strategies, processes, and policies that respond to actual or expected climate changes so that the consequences for individuals, communities, and economy are minimized.

In Ghana, some coping mechanisms have already been developed as a result of farmers' historical experience with weather variability and extreme events (22). Generally speaking, good development policies are also good adaptation policies. Adaptation policies can sustain a country's economic development while coping with significant stresses to society and to the economy (21). These policies should be mainstreamed into national development policy (12).

Table 3 reports a list of potential adaptations and recommendations for Ghana's agricultural sector.

Dealing with risk and uncertainty: One of the likely effects of the increased variability in yields and the increased uncertainty of the return on investments is that farmers will tend not to make

the proper investments and production choices (25). Weather information services, insurance mechanisms and other adaptations could be put in place to reduce producers' risk exposure and to increase the overall economic efficiency of production. A feasibility study of crop insurance shows that a variety of insurance products can help reduce the negative effects of making decisions in an uncertain environment and might benefit Ghanaian farmers (24). R&D on improved seeds and varieties and better seed distribution systems would have similar effects.

At the same time, current efforts to reduce uncertainty in climate projections will help in formulating the proper policy responses to climate change. These current efforts will also help create a favorable economic environment for investments in agricultural adaptive capacity. Using multiple simulation models and scenarios to assess likely impacts would give policy makers the ability to identify vulnerable areas and the possible effects on the economy. However, dealing with multiple possible outcomes, does not necessarily make it easier for policymakers to identify the ideal policies. Currently, the research community makes pointed efforts to develop tools that provide policymakers with a portfolio of development options that weigh tradeoffs among the agricultural sector's productivity, adaptive capacity, and GHG emissions.

TABLE 3: ADAPTATION OPTIONS FOR GHANA'S AGRICULTURAL SECTOR

	Short-term options	Mid- to long-term options
Dealing with risk and uncertainty	• Weather and climate information services and early warning [1, 2, 3, 12] • Crop insurance [1, 5, 12] • Raising of awareness and access to information [1, 2] • Participatory planning or collective action [1, 2, 3] • Flood control [6]	• Climate modeling, impact and vulnerability assessment [2] • R&D on improved seeds and technologies [1,4 , 5, 12] • Strengthening seed systems [2]
Farming practices and technologies	• Indigenous knowledge [7] • Drought/flood resistant varieties [7] • Crop diversification and specialization [1, 5, 7, 8 , 11, 12] • Improved crop practices and production technology [1, 12] • Pest and disease control [5, 9] • Adaptive water management and moisture control [1, 5, 7] • Soil conservation and erosion control [1, 7] • Fertilization [1] • Changing of plot locations [1] • Irrigation [1, 4, 7] • Extension services and training [1, 10]	
Off-farm practices and strategies	• Improve post-harvest, food storage practices [1, 7] • Empower communities [2,8] and females [10] • Improve access to credit [10]	• Improve access to land or tenure rights [1, 10] • Migration [1] • Disease prevention [9]
National development policy	• Agricultural intensification and land use policy [1] • Access to and governance of water [11, 12] • Transportation and other infrastructure [5, 9, 12] • Market and price reform [1, 13] • Institutional reform [1,2, 4, 12] • Financial incentive for specific practices or inputs [12] • Education [10] • Reduce inequality or poverty, especially in the North [7, 11, 14]	

Sources: [1] Stanturf et al. 2011, [2] Challinor et al. 2007, [3] Dasgupta and Baschieri 2010, [4] Kurukulasuriya et al. 2006, [5] Stutley 2010, [6] Dovie 2009, [7] Armah et al. 2010, [8] Smit and Pilfosova 2001, [9] Stenek and Connell 2011, [10] Nakuja et al. 2012, [11] Brown and Crawford 2008, [12] Vermeulen et al. 2010, [13] Laube, Schraven, and Awo 2011, [14] Yaro 2010.

Farming practices and technologies: In order to cope with ongoing climate change, a variety of measures that can help farmers are laid out in Table 3. Scaling up the adoption of these practices from single farmers and projects to entire regions is a challenge. The great variety of farming systems and community needs present in Ghana mean that a one-size-fits-all approach will be inadequate (6) and that strong institutional support and efforts are required (22).

Off-farm practices and strategies: Improvement in post-harvest processing and storage methods are obvious ways to increase resilience to climate change even as they reduce crop loss. Investments in social and human capital, in malaria prevention (23) or female empowerment (15), also increase resilience. Research results indicate that addressing gender, education, or access to credit can enhance farmers' adaptation. In some cases, incremental climatic stress caused by climate change may erode farmers' capital reserves (4) and government intervention in this area might be necessary.

National development policy: Generally speaking, good development policies are also good climate change policies. For example, poverty reduction policies will reduce the poor's vulnerability to extreme weather events and the need for emergency interventions. Improving the economic and energy efficiency of value chains, reforming land tenure, improving road networks , integrating agricultural water use in an overall national water strategy— all these steps would help Ghana develop its economy and adapt to climate change (3).

CLIMATE CHANGE MITIGATION OPTIONS

"Climate change mitigation" refers to actions that reduce the potentially harmful effects of global warming by reducing the atmospheric concentration of GHG. Ghana's agricultural sector has the potential to contribute to global efforts to reduce GHG emissions and sequester atmospheric carbon while at the same time increasing the sustainability of agricultural production. There are various mitigation options available to Ghanaian farmers. These include: (1) appropriate use of chemical and organic fertilizers, (2) use of improved crop varieties that allocate more biomass underground, (3) rotations with legume crops that reduce the need for nitrogen fertilizer, (4) use of agroforestry, (5) adoption of no-till or reduced tillage, (6) use of cover crops, (7) use of crop residues for mulch and (8) improved water management for irrigated crops (20,25). Note that many of these options would also promote a sustainable increase in productivity by increasing soil organic carbon.

Scientists from the International Food Policy Research Institute carried out a national-level assessment of the potential for soil organic carbon storage for part of the food crop production sector. They identified the most common food crop rotations adopted by smallholder farmers and, based on these rotations, simulated the adoption of three different agricultural mitigation "packages" suited to local conditions. The mitigation packages are designed to enhance the stock of soil carbon in Ghana's farmland. The first package is nitrogen fertilizer application. The second is nitrogen fertilizer and manure application. The third is nitrogen fertilizer and manure application plus mulching using crop residues. The results indicate that Ghanaian farmers could store some half million tons of carbon per year in the soil, which, in the presence of functioning carbon markets, could generate up to $6 million per year.

TABLE 4: SOIL ORGANIC CARBON STORAGE POTENTIAL FOR FOOD-CROP AGRICULTURE IN GHANA – FOUR CLIMATE CHANGE SCENARIOS

Climate model and SRES emission scenario	Simulated mitigation practices (Unit: Carbon sequestered (mt/yr))		
	Package 1 Nitrogen fertilizer (60 kg ha^{-1})	Package 2 N fertilizer (60 kg ha^{-1})+ manure (0.7 tons ha^{-1})	Package 3 N fertilizer (60 kg ha^{-1}) + manure (0.7 tons ha^{-1})+ 50 percent of crop residue left on the ground
CNRM-CM3, A2	71,510	103,409	333,230
CSIRO-Mk3.0, A2	77,697	110,321	350,011
ECHam5, A2	75,794	108,869	351,250
MIROC3.2, A2	94,287	129,773	410,184
Highest mitigation potential expressed in US$/yr (Assumed price of CO_2eq $15)	$1,414,298	$1,946,597	$6,152,764

* 1 kg of carbon is equivalent to 3.67 kg of CO_2.

THE ROLE OF ORGANIZATIONS

The presence of well-functioning institutions is essential to translate the potential for agricultural adaptation and mitigation into actual actions and gains for farmers. Successful adaptation to climate change does not require the creation of new institutional structures. In general, investments and projects that address agricultural development are also beneficial for adaptation. Climate change exacerbates the need of millions of households and communities. So, proper investment in and revitalization of national research programs, extension systems and north-to-south information sharing are essential.

Mitigation of climate change from agriculture requires that existing institutions perform some additional tasks. If some form of compensation for climate change mitigation is to be provided, smallholder farmers need to be aggregated in relatively large groups, receive the proper information and instructions, and farmers' compliance with the program needs to be carefully monitored and verified. Existing institutions, such as extension services, farmer organizations, or NGOs may be able to take such role. However, investments in their resources and knowledge are necessary. Significant amounts of mitigation services are provided only over long periods of time. Therefore, for projects to be viable, they must also be sustainable over the long run. Long-term sustainability depends on the degree of community involvement in the project's design and implementation, the legitimacy and effectiveness of community representatives and on the degree to which the project meets other needs of the community (such as an increase in food security). In fact, in view of the high transaction costs, market-based incentives for GHG emission reduction may not, by themselves, provide sufficient motivation for farmers to participate.

CONCLUSIONS

Current climate change scenarios predict an increase in temperatures and in rainfall variability in Ghana. Despite the uncertainty about the likely effect, multiple studies have found that, in aggregate, a decrease in the yields of major crops (maize, rice, ground-

nuts) in Ghana is likely if no adaptations are made. Ghana needs to develop strategies to cope with the stress and damage that climate change can impose on the country's agricultural sector. As variability in the global food supply increases due to climate change, building a climate-resilient agricultural sector will help Ghana to address domestic food security and remain a stable commodity supplier for Africa and the globe.

As far as the potential for GHG mitigation in agriculture, further study should focus on the viability of the adoption of mitigation techniques that also contribute to adaptation objectives and increase the sustainability of the production system. The various options have to be analyzed to assess their potential benefits and outcomes for the farm enterprises. Existing institutions, such as community organizations, NGOs, and extension services, play a fundamental role in the farmers' uptake of climate change adaptation and mitigation practices. Investing in their capacity to tackle these new challenges and engage with smallholder farmers would be a first step towards tackling the challenges of climate change in Ghana.

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INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
2033 K Street, NW • Washington, DC 20006-1002 USA
T: +1.202.862.5600 • F: +1.202.467.4439
Skype: ifprihomeoffice • Email: ifpri@cgiar.org

GSSP – IFPRI
c/o IWMI, PMB CT 112 • Cantonments, Accra, Ghana
CSIR Campus (Opposite Chinese Embassy) • Airport Residential Area
T: +233 (0) 302 780 716 • F: +233 (0)-302 784 752
gssp.ifpri.info
Contact: Shashi Kolavalli - Senior Research Fellow and Program Coordinator

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