Food and Agriculture Organization of the United Nations

Global Agro Ecological Zones

Case study: Ghana

High-end climate change impacts on rain-fed crops in Ghana

Agro-ecological zoning in support of climate change adaptation planning for the agricultural sector

Context

Climate change threatens vulnerable communities in sub-Saharan Africa, which face significant challenges for adaptation to global warming. Agriculture provides the livelihood for the majority of the population. High-resolution assessments of the effects of climate change on crop production are urgently needed for targeted adaptation planning. In Ghana, next to food needs, agriculture plays an important role on international cocoa markets, producing almost one fifth of global cocoa production.

Actors and stakeholders

The project is a spin-off of the "Deltaic Environments, Vulnerability and Climate Change: The role of mitigation as an adaptation and its policy implications (DECCMA)" (GCP/GLO/546/USH). The DECCMA project analyzes the impacts of climate change and other environmental drivers across contrasting deltas in Africa and Asia and includes development and application of National Agro-Ecological Zoning (NAEZ) Ghana and for a geographical window in South Asia. Devastating results of unmitigated climate change impacts on cash and food crops triggered the International Institute for Applied Systems Analysis (IIASA) to produce a special report to alert policymakers and agricultural development planners for global warming impacts on agricultural resources across Ghana. Ghana NAEZ builds on activities starting in the 1990s coordinated by the Soil Research Institute, Accra, Ghana.

Objectives

- Development of a National Agro-Ecological Zoning (NAEZ) system to analyze impacts of global warming on agricultural production potentials until the end of this century.
- Establishment of a geospatial database of relevant agro-climatic indicators, assessment of suitability and attainable yields for selected main agricultural crops under current and future climate conditions, and identification of adaptation needs for mitigation of high-end climate change impacts with special attention to cocoa, Ghana's, most important export crop.

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Challenges and next steps

The current NAEZ model, in addition to assessing suitability and potentially attainable yields, provides underlying production constraints in terms of temperature regime factors, moisture regime factors, pest and disease pressures, climate related field management factors as well as soil and terrain constraints and land utilization details such as crop calendar and best suited cultivar for each-and-every 30 arc-second grid (about one km) across Ghana. Using these constraint factors alongside crop adaptation catalogs, climate change impact adaptation measures can be specified for in-situ crop production (e.g., current cocoa plantations and/or concentrations of small holder cocoa farmers). In case adaptations for in-situ crop production appear unfeasible (for bio-physical or economic reasons) the NAEZ model can locate alternative areas with less constraints within current cropland or even in new cropland to be opened-up.

Replicability and upscaling

This study is suitable for replication to other countries/regions to address specific global warming issues for agricultural sectors, provided sufficiently detailed reliable natural resources databases and climate change scenarios data is available or can be compiled.

Approach and results

Agro-ecological suitability and production potential for a total of 18 currently grown rain-fed crops were assessed for base-line climate (1981–2010) and for future climates of the 2050s (2041–2070) and the 2080s (2071–2099) to quantify potential impacts of global warming on agricultural production. NAEZ Ghana uses an ensemble mean of the CORDEX Africa Regional Climate Models. The 18 crops include banana/plantain, beans, cashew, cassava, cocoa, coconut, robusta coffee, cotton, groundnut, maize, mango, oil palm, pearl millet, rubber, sorghum, sugarcane, sweet potato, and yam.

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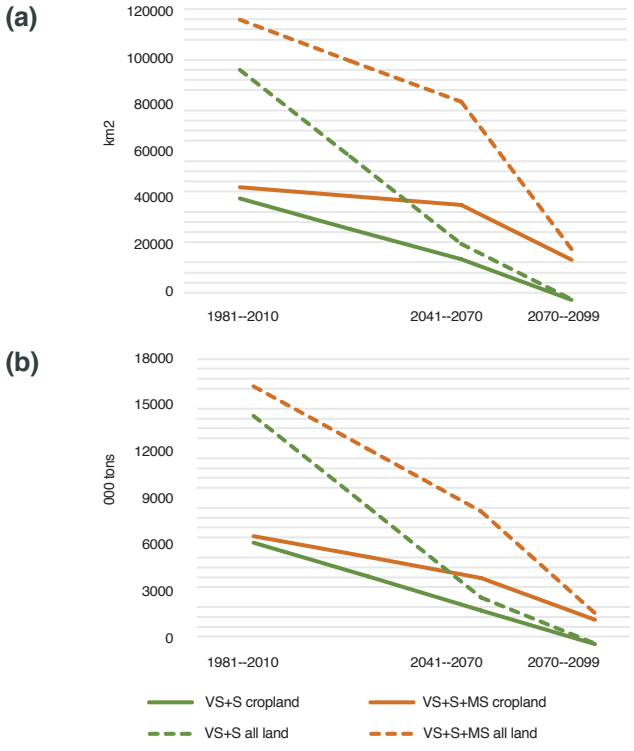
Approach and results (continued)

Results highlight differential impacts across the country. Especially due to the significant increase in the number of days exceeding high-temperature thresholds, rain-fed production of several food and export crops could reduce significantly compared to the historical 30-year average (1981–2010). Plantain production, an important food crop, achieves under climate change less than half of its current potential already in the 2050s and would lose more than 90 percent of its production potential by the 2080s. Suitable areas for cocoa production decrease strongly resulting in only one third of production potential compared to today. Other crops with detrimental effects of climate change include oil palm, sugarcane, robusta coffee, and rubber. Production of maize, sorghum, and millet copes well with a future warmer climate.

Results for cocoa

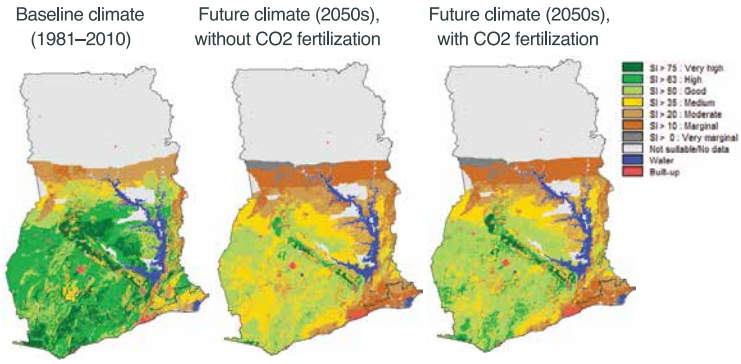
Cocoa is the export crop in Ghana. It is mainly grown by small holders using traditional varieties producing yields of about 500 kg/ha cocoa beans. Potential agronomically attainable yields under rain-fed conditions on prime and good land, assuming high level inputs and advanced management with improved plant species (hybrids) would harvest on average a three-fold i.e., 1500 kg/ha beans. Major constraints causing this substantial yield gap include inferior planting material, sub-optimal spacing, insufficient shading, inadequate timing of mostly insufficient fertilizer applications as well as low efficacy of control of pest and diseases due to insufficient control (Climate Smart Cocoa, Bunn *et al.*, 2019). Yield improvements could be achieved by applying irrigation (drip) in critical periods of soil moisture deficits.

Trends of suitable area extents (a) and production (b) of rain-fed cocoa with climate change assuming no CO_2 fertilization



The graphs opposite and maps below show decreases of suitable area and productivity of rain-fed cocoa. Overall temperature increase, intensification of extreme temperature events, changes in relative humidity and rainfall distribution as result of concentration of rainfall, affects cocoa production. At base-line climate about 45 719 km^2 of cropland are suitable for cocoa. With climate change the extents of suitable cropland for cocoa shrinks in the 2050s by respectively 12 percent assuming CO_2 fertilization and 15 percent without CO_2 fertilization effects and in the 2080s by respectively 55 percent and 63 percent.

Suitability for rain-fed Cocoa under high level inputs and advanced management



Future climate (2050s) in (b) and (c) refers to the climate ensemble mean of results of period 2041–2070.The suitability index (SI) is the weighted sum of extents of the suitability distribution in a grid-cell: SI = 90*VS + 70*S + 50*MS + 30*mS + 15*VmS

Conclusion

Climatic constraints for cocoa increase significantly between base-line climate and future climates of the 2050s and 2080s. High temperatures and occurrence of extreme maximum temperatures as well as intensified dry periods but also concentration of rainfall are main bio-physical causes for production losses.

Related resources

FAO and IIASA. **Global Agro Ecological Zones version 4 (GAEZ v4)** http://www.fao.org/gaez/

Günther Fischer and Harrij van Velthuizen (2018). **Climate Change Impacts on Suitability of Main Crops in the DECCMA study areas in Ghana and in South Asia. Deltaic Environments, Vulnerability and Climate Change: The role of mitigation as an adaptation and its policy implications** (DECCMA) GCP/GLO/546/USH. IIASA, Laxenburg, Austria.

Günther Fischer, Sylvia Tramberend, Harrij van Velthuizen and Enoch Boateng (2021), **RCP 8.5 GHANA High-end climate change impacts on crop production.** IIASA, Laxenburg, Austria. Forthcoming.

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