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Climate change impact under alternate realizations of climate scenarios on maize yield and biomass in Ghana

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ABSTRACT

Climate change is unequivocal and these changes have increased over the past few years. The recent vulnerability and prospect of climate variability and change impact, thus, warrants measures now to reduce the adverse impacts. This study presents an estimate of the effects of climate variables on potential maize productivity and an assessment of the most limiting climatic drivers in the future climate scenarios for maize production in central Ghana, constituting major maize production areas. The time-slices 2000, 2030 and 2080 were chosen to represent the baseline, near future and end century climate, respectively. Furthermore, two Representative Concentration Pathways (RCP_s) namely RCP 4.5 and RCP 8.5 from the GFDL-ESM2M, GISS-E2-H, and HadGEM2-ES, General Circulation Models (GCMs), were selected. Simulations based on the model LINTUL5 were used to estimate the crop responses.

There is an average increase in the maize yield and aboveground biomass in the projected scenarios by 57% and 59% respectively under HadGEM2-ES (RCP 8.5) in the time horizon 2030. However, variability in the projected average maize yield and above ground biomass compared to the baseline values, is ranging from 183.6 kg ha^{-1} under HadGEM2-ES (RCP 8.5) by time horizon 2080 to a maximum of 1326.8 kg ha^{-1} under HadGEM2-ES (RCP 8.5) by 2030 and a minimum increase of 169.9 kg ha^{-1} under GFDL-ESM2M (RCP 8.5) by time horizon 2080 to a maximum increase of 2386.1 kg ha^{-1} under HadGEM2-ES (RCP 8.5) by time horizon 2030.

The reasons for potential benefit in maize yields across the climate scenarios was attributed to the positive effect of CO_2, reduced water stress reflected by lower atmospheric water demand during crop growth period. It also indicates that water is the limiting factor for maize production in the study region. However, temperature (through shortening of the maize growing cycle), and solar radiation may remain the limiting factors for maize production.

1. Introduction

Africa as a whole is one of the most vulnerable continents in the face of climate change due to its high exposure and low adaptive capacity (Sultan and Gaetani, 2016; Niang et al., 2014). In the Sahel and savannah parts of Africa in particular, climate scientists have shown that extreme temperatures have increased, while precipitation has reduced over the last fifty years (Frimpong and Kerr, 2015; Seneviratne et al., 2012). In the coming decades, global climate change will have an impact on all sectors of the global economy. But most impacts will fall on the agricultural sector, creating food insecurity particularly in the developing world (Ringler, 2008; Nelson et al., 2009).

The impact assessment of future climate change in Ghana has received much attention due to increasing drought and flood events in the last four decades (Asante and Mensah, 2015; Tachie-Obeng et al., 2014). In Ghana, the agricultural sector is dominated by smallholder farmers who cultivate about 1–2 ha of land and produce 80% of the country's agricultural output. In spite of the importance of the agricultural sector, it is the most vulnerable sector, when issues of climate change are discussed since the sector mostly depends on rainfall to undertake its activities (Asante and Mensah, 2015). According to the General circulation model (GCM) HadGEM2-ES (RCP 8.5) prediction, there would be a reduced precipitation by -32.1 mm and increased mean temperature in the tune of 11.7 °C as per HadGEM2-ES (RCP 4.5) in the central Ghana region by the time horizon 2080 compared to baseline 2000. Given the fact that West Africa constitutes about 27% of the population of Africa and 16% of its population is undernourished,

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Table 1a
Projected carbon dioxide (CO_2) concentration (in ppm) used in the study for different climate scenarios and time periods.

Climate scenarios	CO2 concentration (in ppm)
Baseline	369
GFDL-ESM2M (RCP 4.5 - 2030)	450
GFDL-ESM2M (RCP 4.5 - 2080)	575
GFDL-ESM2M (RCP 8.5 - 2030)	475
GFDL-ESM2M (RCP 8.5 - 2080)	950
GISS-E2-H (RCP 4.5 - 2030)	450
GISS-E2-H (RCP 4.5 - 2080)	575
GISS-E2-H (RCP 8.5 - 2030)	475
GISS-E2-H (RCP 8.5 - 2080)	950
HadGEM2-ES (RCP 4.5 - 2030)	450
HadGEM2-ES (RCP 4.5 - 2080)	575
HadGEM2-ES (RCP 8.5 - 2030)	475
HadGEM2-ES (RCP 8.5 - 2080)	950

Table 1b
Correction of radiation use efficiency as a function of atmospheric carbon dioxide (CO_2) concentration (in ppm) used in the crop model.

CO_2 concentration (in ppm)	Correction factor
40	0
360	1
720	1.1
1000	1.1

the impacts of global climatic changes could particularly exacerbate the already poor performance in food production being experienced in this region. In relation to Ghana, the cropping systems are highly varied and this reflects the dynamic adaptations to increasing population pressure, land insecurity, climate variability, and new trading opportunities or markets (Stanturf et al., 2011) and hence, ability to meet the future demands may hinge upon proper assessment of medium-and long-term maize production vulnerability to climate change and the measures taken to adapt accordingly. Maize can grow at higher temperatures compared to many other cereal crops and therefore be a suitable crop for warmer conditions. Maize is well adapted to well-drained soils (Landon, 1991) but sensitive to water stress (Doorenbos and Kassam, 1979). Thus, maize productivity under future climates depends to a large extent on the future rainfall conditions in the central Ghana (Tachie-Obeng et al., 2014). However, Srivastava et al. (2017) have pointed out that in the central Ghana, radiation and temperature are the limiting factors for observed as well as simulated actual maize productivity.

One source of uncertainty regarding the impact of climate change is uncertainty about the most appropriate choice of climate model and greenhouse gas emissions scenario. It is assumed that climate change will fall within the range of future conditions predicted by different climate models (Araya et al., 2015; Asseng et al., 2013; Challinor et al., 2013). Impact assessments on crop production, therefore, must be based on multi-model climate projections, which are assumed to provide a more representative range of climate change impacts than single-model approaches (Tao et al., 2009; Taylor et al., 2009).

Crop models are useful tools for exploring the impact of climate and management scenarios on agricultural response indicators such as crop yield (Ruane et al., 2013; Rosenzweig et al., 2013). Detailed climate change impact assessment studies on maize are scarce for central Ghana, constituting a major maize production area in the country. Better knowledge of how climate will change in central Ghana and how such changes will impact crop productivity is crucial to inform policies that may counteract the adverse effects. In this backdrop, the objective

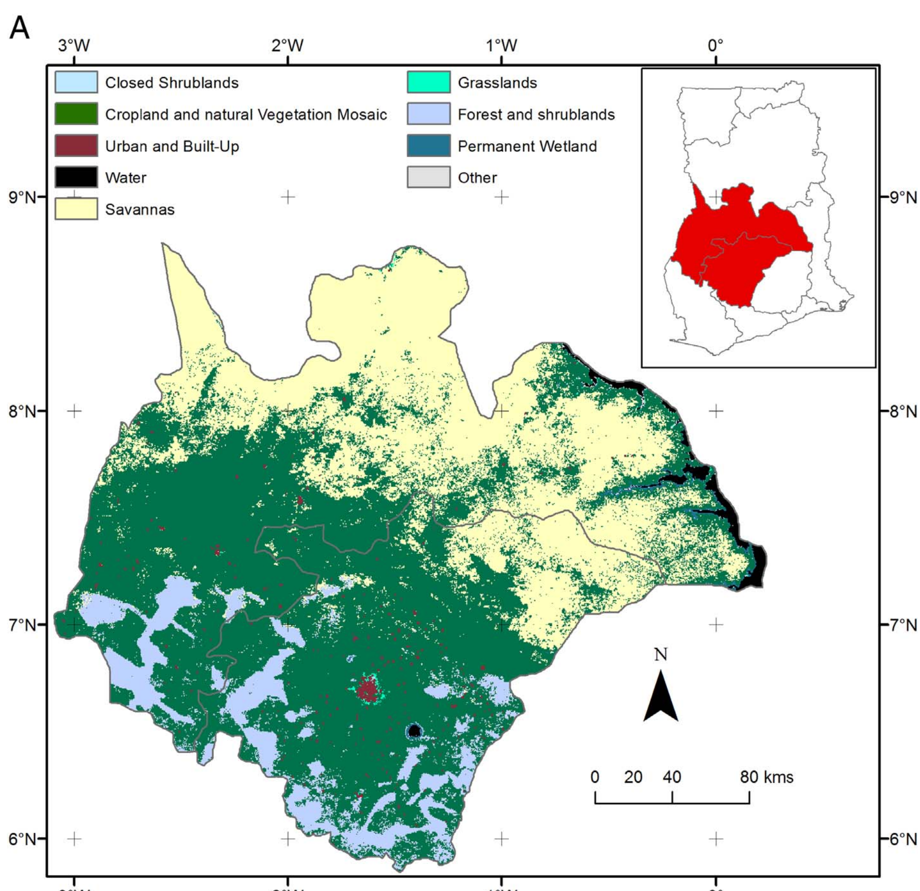

Fig. 1a. Land use map of Central Ghana covering the study region.