# *Policy Brief*

## Impact of Recent Climate Change on Maize Production Systems in Northern Ghana

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## Executive Summary

The main aim of this study was to investigate how climate change and variability, together with current and alternative soil management practices have affected maize yield in northern Ghana and to address the policy implications. This was done by employing the employs simulation methods using the Agricultural Productions Systems sIMulator (APSIM) crop model. Specifically, the impact of sowing windows, soil fertility management practices, and different varieties on the yield of maize over a thirty-year period (1980−2009) was assessed. Additionally, the impact of different soil types on the nitrogen (N) response of maize was also determined. The improved maize varieties investigated were *obatanpa* and the *dorke*. The soil fertility management options simulated were Conventional Practice (No fertilization), Inorganic manure (60 kg N/ha fertilizer) and Organic Manure at 2500 kg/ha. For the N response, fertilizer rates of 0, 30, 60, 90 and 120 kg/ha were used on three different soils. The three soil types were classified according to their plant water holding capacity.

The key findings are as follows:

- In general maize yield responded positively to nitrogen fertilization, however, beyond 30 kg N/ha it declined and levelled off at 60 kg N/ha, confirming that 60 kg N/ha is the optimum rate of application for the study area.
- Without inorganic fertilization, the yields of the maize varieties were generally low.
- There was no significant difference in the type of fertilizer used so long as sowing is undertaken in the first or second windows.
- However, after the second window, inorganic fertilizer delivers significantly higher profitability compared to organic fertilizer.

The following are the recommendations:

- Smallholder farmers must be incentivised to apply inorganic fertilizer in order to improve crop output.
- Given that productive use of inorganic fertilizer crucially depends on the availability of adequate amounts of rainfall, there is an urgent need for improved site-specific weather forecasting.
- Such information must be transmitted to farmers in a timely manner.
- We recommend construction of a database for farmers, whereby the information can be sent to them via text messages.

## Introduction

Maize is an important food crop in Sub-Saharan Africa where it is widely cultivated in countries such as Nigeria, Malawi, and Ghana. For instance, in Ghana, maize is grown throughout the country with about 63% of food farmers involved in its cultivation. It is an important dietary source accounting for about 20% of the population's caloric intake (Fosu-Mensah *et al.* 2012). In the northern region of Ghana, maize is an important cash crop that contributes significantly to the farm household's income. In spite of significant population growth, overall maize production in Ghana (in terms of area harvested and volume) has remained stable because of reliance on traditional farming methods (Millennium Development Authority, 2010). These methods have been adversely affected for some time now by factors such as climate declining soil fertility and low application of external inputs and continuous mono-cropping. However, to date, no empirical evidence exists on these impacts. Thus, this paper investigates how climate change and variability has affected maize production in a semi-arid region of Ghana as a case study under conventional practices and analyses how crop productivity could be improved with alternative practices.

The study has three key objectives. First, it seeks to analyze changes in key climate variables in the study area over the period 1992–2005 and how these have affected maize yield over time with current and alternative crop and soil management practices. Second, it evaluates the response of maize growth to nitrogen application for different soil types. Finally, it evaluates the usefulness of the APSIM-maize model for simulating maize growth and yield in the semi-arid environment of northern Ghana.

This was done by employing the employs simulation methods using the Agricultural Productions Systems sIMulator (APSIM) crop model. Specifically, the impact of sowing windows, soil fertility management practices, and different varieties on the yield of maize over a thirty-year period (1980–2009) was assessed. Additionally, the impact of different soil types on the nitrogen (N) response of maize was also determined. The improved maize varieties investigated were *obatanpa* and the *dorke*. The soil fertility management options simulated were Conventional Practice (No fertilization), Inorganic manure (60 kg N/ha fertilizer) and Organic Manure at 2500 kg/ha. For the N response, fertilizer rates of 0, 30, 60, 90 and 120 kg/ha were used on three different soils. The three soil types were classified according to their plant water holding capacity. Three levels of plant available water were used: Soil 1 – 46.80 mm; Soil 2 – 37.65 mm and Soil 3 – 41.55 mm. In this policy brief, we report results for only the *obatanpa*, however, the results for *dorke* are fairly similar.

## Results

*Response of maize to N fertilization on different soil types*

The simulated yield of maize in response to inorganic N fertilizer generally increased in an exponential manner and plateaued at N application rate of 60 kg/ha on all soils (Figure 1). This was associated with very high yield variability ranging between 63 and 74% partly due to several years of total yield loss.

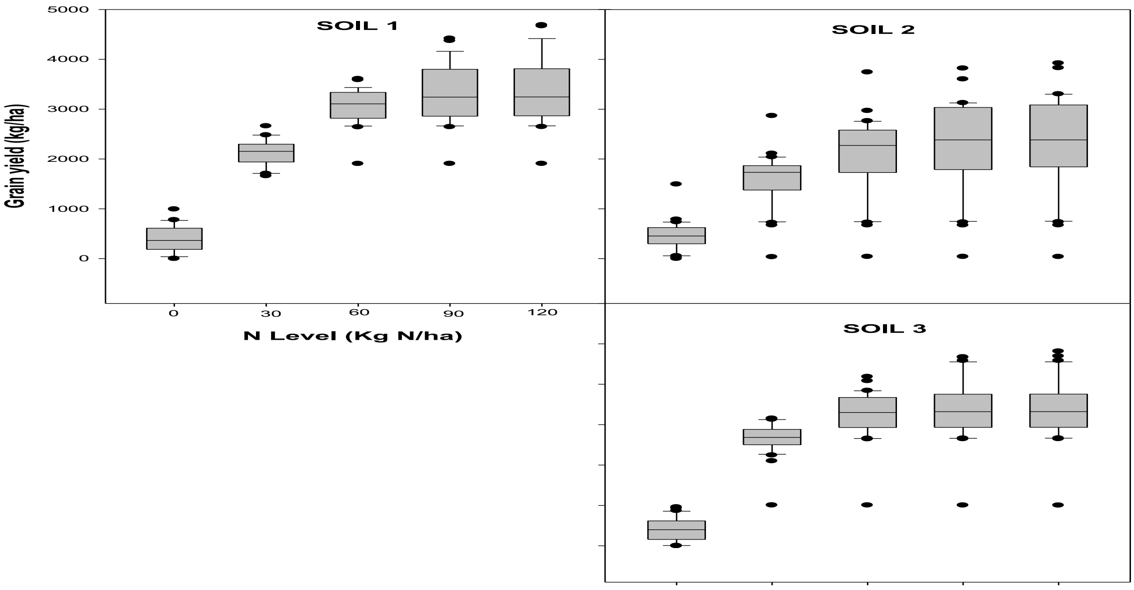


**Figure 1.** Simulated response of maize (*obatanpa*) grain yields to different N fertilizer applications on different soils

Applying 30 kg N/ha resulted in simulated yield increases ranging from 1594 to 2060 kg/ha for the *obatanpa* variety across all soil types. The rate of increase or response to N fertilization beyond 30 kg N/ha declined and levelled off at 60 kg N/ha, confirming that 60 kg N/ha is the optimum rate of application for the study area. The lack of an appreciable response to inorganic N beyond 60 kg N/ha could be attributed to other yield limiting factors such as erratic rainfall distribution, very shallow soil depths as well as the low water holding capacity of the soils. The response to inorganic N fertilization varied between the two varieties and among the different soil types. The highest average grain yield of 3370.86 kg/ha was observed for Soil 3 with a value of 120 kg N/ha for *obatanpa* (see Figure 1a). Under both varieties, the lowest average grain yields were obtained on Soil 1 when no inorganic fertilizer was applied.

*Impact of sowing window on grain yield*

The impact of sowing window on maize yield was analysed for three soil fertility practices: conventional (without organic or inorganic fertilizer), organic and inorganic. Generally, grain yields declined with delayed sowing. For all three farming practices, the results indicate that missing the first two sowing seasons of the year results in yield declines. However, the yield decline in the third sowing window was smallest for Inorganic fertilisation.

By and large, moderate increases in variability occurred with delayed sowing. The variability in yield can be attributed to variation in rainfall distributions across sowing windows and nutrient managements. The simulated yields were generally lower with the *dorke* variety due to its shorter growth duration compared with the *obatanpa* variety. In general, the use of inorganic fertilizers yielded the highest grain, while the conventional practice produced the least yield with both varieties.

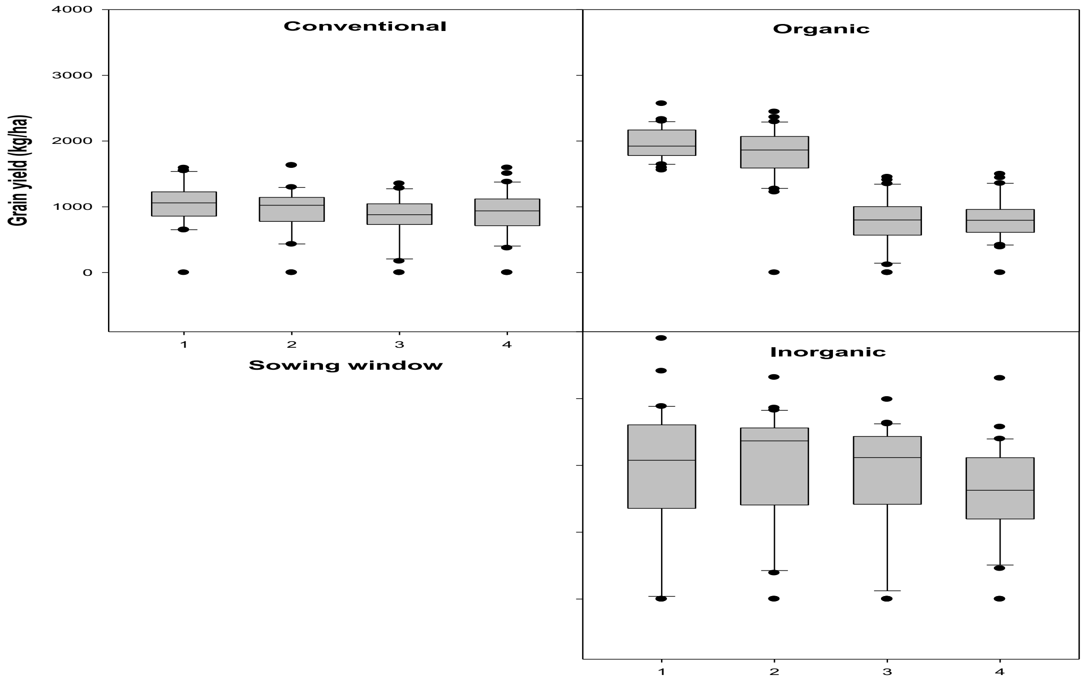


**Figure 2.** Simulated impact of sowing windows on the distributions of maize (*obatanpa*) yield under different soil fertility practices

*Impact of N fertilization and farm management practices on farm profitability*

Figure 3 shows results for the impact of nitrogen fertilization on the profitability of *obatanpa* for the different soil types. In general, increase in *N* levels increases gross margins of *obatanpa*, however, there are diminishing returns after 90 kg/ha. For the three soil types, there is no statistically significant difference in the gross margins for the 90 and 120 kg/ha nitrogen levels ($p$-value = 0.46). For every given level of nitrogen application except zero level, Soil 2 has the lowest gross margins compared to the other two. Soil 3 has a slightly higher gross margin than Soil 2 but the difference is not statistically significant.

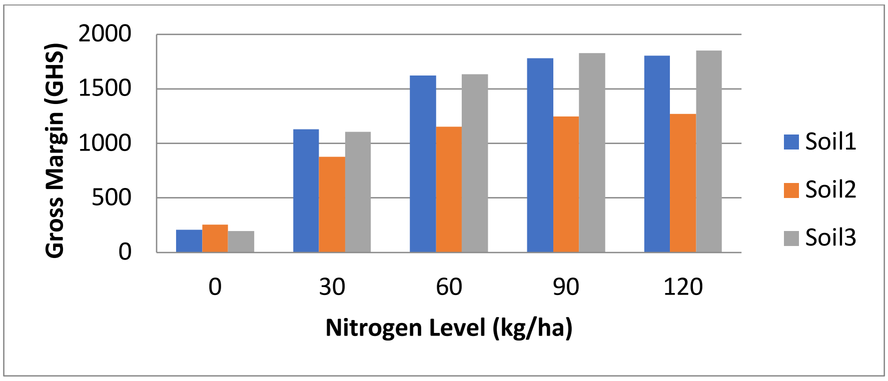


**Figure 3.** Impact of nitrogen fertilization on *obatanpa* gross margin for different soil types

In general, these results indicate that nitrogen fertilisation in the study area significantly improves farm profitability. For all soil types, profitability in terms gross margin increases rapidly from zero level to 60 kg/ha, slowing thereafter and reaching an optimum of 90 kg/ha. Although there is a slight increase at 120 kg/ha, we did not find this to be significantly different from profitability at 90 kg/ha.

We also investigated the impact of management practices such as soil fertility practices and sowing window on profitability. A number of conclusions are evident for the *obatanpa* variety. Regardless of the sowing window, using some form of fertilizer (whether organic or inorganic) results in significantly higher gross margins (Figure 4).

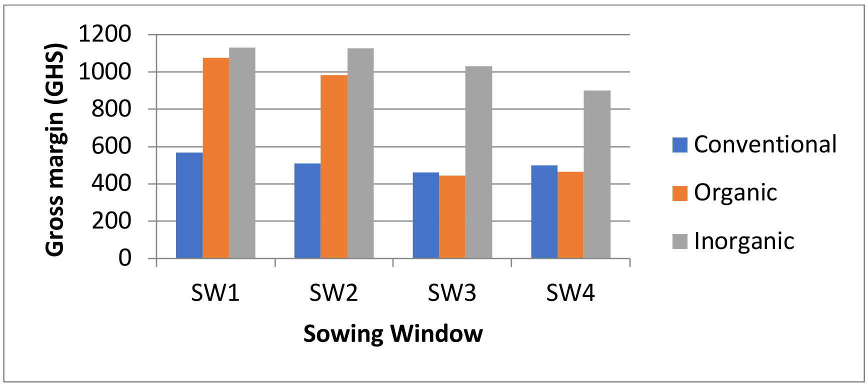


**Figure 4.** Impact of different sowing windows on the gross margin of *obatanpa* under different soil fertility practices

However, using inorganic fertilizer results in relatively higher gross margins compared to using organic fertilizer and this difference increases with the sowing window. In the first two sowing windows, there is no statistical difference in the gross margins for organic and inorganic fertilizer. However, for the last two sowing windows (i.e. SW3 and SW4), the gross margin from using inorganic fertilizer is much higher than for organic fertilizer. In fact, it can be seen that the profitability of *obatanpa* when sowed in the later windows under organic fertilizer is not statistically different from the conventional practice (i.e. not using fertilizer).

## Conclusions

On the basis of the foregoing results, we are able to draw the following general conclusions about the effects of farm management practices on maize yield and profitability.

- In general maize yield responded positively to nitrogen fertilization, however, beyond 30 kg N/ha it declined and levelled off at 60 kg N/ha, confirming that 60 kg N/ha is the optimum rate of application for the study area.
- Without inorganic fertilization, the yields of the maize varieties were generally low.
- There was no significant difference in the type of fertilizer used so long as sowing is undertaken in the first or second windows.
- However, after the second window, inorganic fertilizer delivers significantly higher profitability compared to organic fertilizer.

## Implications and Policy Recommendations

These results have important implications for future climate change, which is projected to be associated with the delayed onset of rains. It means that with the delay in the sowing windows, farmers will increasingly have to rely on improved varieties and inorganic fertilizer to guarantee their farm incomes.

The following are the recommendations.

- Smallholder farmers must be incentivised to apply inorganic fertilizer in order to improve crop output.
- Given that productive use of inorganic fertilizer crucially depends on the availability of adequate amounts of rainfall, there is an urgent need for improved site-specific weather forecasting.
- Such information must be transmitted to farmers in a timely manner.
- We recommend construction of a database for farmers, whereby the information can be sent to them via text messages.