

THE IMPACT OF CLIMATE CHANGE ON MAIZE AND BEANS IN BUSOGA AND LANGO SUB- REGION IN UGANDA

MAY 2025

INSPIRE PROJECT



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Executive Summary

Climate change poses a significant threat to Uganda. Weather patterns are changing, and extreme weather events such as droughts, floods, and landslides are becoming more frequent and intense across the country. Therefore, climate change threatens agricultural production and ultimately people's livelihoods.

In support of the INSPIRE project, this report provides an overview of the methodologies, including data and key findings used to assess the impact of climate change on maize and bean, which are two major crops for smallholder farmers in the Busoga and Lango sub-regions.

The findings indicate that temperatures and precipitation are expected to increase in the future (by the 2040s) across the Busoga-Lango sub-regions. Despite the increase in rainfall, yields of maize and beans are projected to decline in the future, particularly under the worst-case (high-emission scenario) climate scenario, primarily due to the expected rise in temperature. Using the appropriate planting window will be crucial to minimising climate-induced yield losses.

1. Introduction to Climate Change in Uganda

The climate is changing, temperatures are rising worldwide, and extreme weather events are becoming more frequent. These changes are also being felt in Uganda, where climate change is already impacting human health, nature and biodiversity, economic stability, and migration. According to the World Bank Report 2020¹, Uganda has experienced an increase in the frequency and intensity of extreme weather events, such as floods, droughts, and landslides. The most recent floods in April 2024 alone resulted in the displacement of more than 4,000 families, loss of life, destruction of crops, and hindered access to essential services such as healthcare, education, and business operations². In 2022, a prolonged drought led to more than 500,000 people going hungry and over 200 people starving to death³. This was followed by a flooding event that destroyed over 2,000 hectares of crops, left 400,000 people without access to water, and 30 people lost their lives⁴.

Climate change poses major challenges for agricultural systems worldwide. Rising temperatures, changing rainfall patterns, and changing climatic conditions directly impact crop growth and development, reducing yields. In Uganda, the economy is heavily reliant on agriculture, which is predominantly rain-fed. More than 70% of the population is engaged in agriculture, making the country vulnerable to the effects of climate change. The sector is dominated by smallholder farmers, who plant maize and beans, and are still struggling to meet their household food needs, which prevents many from participating in the market to earn an income. The Ugandan National Agricultural Research Organization has prioritized maize and beans, in particular, as strategic commodities to drive improved food and nutritional security and contribute to household income in Uganda⁵, including the Busoga and Lango regions. Despite the potential of these crops for sustainable intensification, the average yield remains low. Additionally, little is known about how climate, particularly temperature and rainfall, is projected to change in the future at a local scale and how this change will affect maize and bean yields.

2. Research Questions

In support of the INSPIRE (Integrated & Sustainable Production for Inclusive Resilient Economies) project, which aims to increase the income and livelihood resilience of smallholder farmers in Lango and Busoga regions to climate change and market failures, this report seeks to answer three research questions:

- *How will temperature and precipitation change in the future under different climatic conditions?*
- *What is the impact of climate change on maize and bean yields?*
- *What is the effect of a low-cost adaptation measure, such as changing planting dates on maize and bean yields?*

The Lango and Busoga sub-regions are located in the north-eastern part of Uganda (Figure 1). Busoga and Lango are separated by Lake Kyoga. The sub-regions have several bodies of water that support local agricultural activities and could also be affected by climate change, including the Victoria Nile, Lake Victoria, and Lake Kwana. In the Busoga region, the INSPIRE project targeted districts of Kamuli, Kaliro, Jinja, Buyende, and Luuka, and the districts of Lira, Dokolo, Amolatar, and Alebtong in the Lango region (Figure 1). Uganda has two main seasons, from September to December and from March to June.

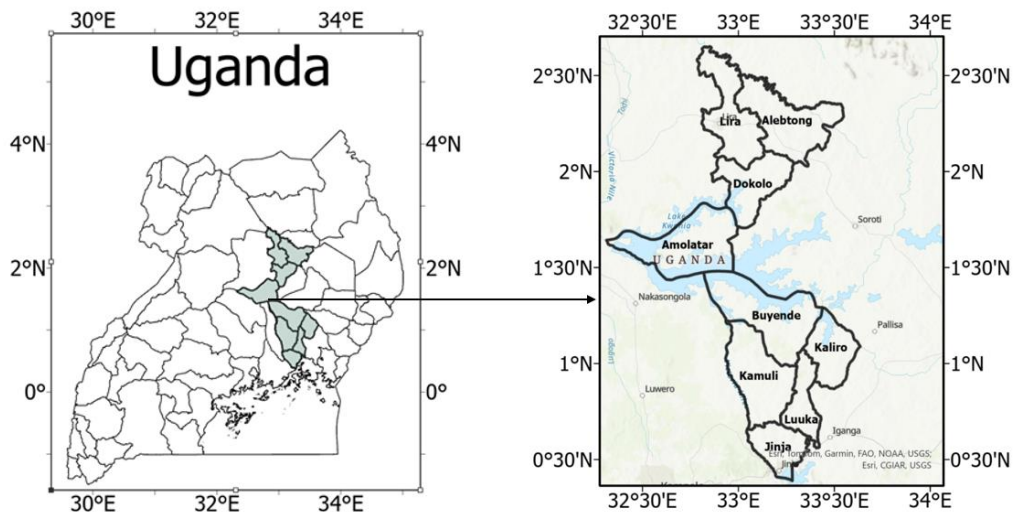


Figure 1: The map of Uganda highlighting the location of Busoga and Lango.

2.1 How to Assess Crop Yield Response to Climate Change?

Crop yield modelling is crucial in climate impact assessments of agriculture because it enables the quantification of climate change effects on crop productivity, the exploration of different scenarios, and the development of effective adaptation strategies. It supports evidence-based decision-making and provides guidance on improving agricultural resilience and sustainable food production in the face of a changing climate.

The World Food Studies (WOFOST) crop growth model has been developed to assess the response of maize and bean yields to climate change. The WOFOST (World Food Studies) model is a widely used crop growth simulation model designed to assess crop yield and productivity under varying environmental conditions⁶. It is a process-based model that integrates knowledge of plant physiology, agronomy, and meteorology to simulate the growth and development of various crops. The WOFOST model considers factors such as temperature, radiation, precipitation, soil characteristics, and management practices to estimate crop growth, biomass accumulation, and final yield.

We have employed the WOFOST model to simulate water-limited yields of crops. Water-limited yield refers to the maximum potential crop yield that can be achieved under conditions where water availability becomes the limiting factor for plant growth and development. It represents the upper limit of crop productivity that can be attained in rainfed systems. However, the model did not consider other limiting factors, such as poor fertility, poor management, weeds, and diseases that can affect the actual yield. The model requires input data, including climate variables (temperature, precipitation, and solar radiation), soil characteristics, crop-specific parameters, and management practices.

Climate data and climate scenarios: Historical climate data and future climate projections on daily rainfall, minimum and maximum temperature, solar radiation, wind speed, and vapour pressure were obtained from the sixth phase of the Coupled Model Intercomparison Project (CMIP6) and the Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP), which provide data for climate scenarios based on the different Shared Socio-economic Pathways (SSPs)⁷. We used data from five global circulation models (GFDL-ESM4, IPSL-CM6A-LR, MPI-ESM1-2-HR, MRI-ESM2-0, and UKESM1-0-LL). The CMIP6 climate data are driven by SSP scenarios that integrate global economic, demographic trends, greenhouse gas emissions, and subsequent radiative forcing by 2100.

In this simulation study, we have examined the impact of future climate under optimistic (SSP126), most likely (SSP370), and worst-case (SSP585) scenarios, which represent low, intermediate, and high emission scenarios, respectively. The impact of climate change and the effect of changing planting dates on maize and bean yields were assessed for the near future (2040s, 2031-2050) compared to a historical period (2000-2019). The seasonal change in the climate variables was calculated as the difference between the climatology of the future time slice (2040) and the current simulations (2009), representing the model responses to global warming.

Cropping calendar: Cropping calendar information (e.g., current planting season) was provided by INPSIRE local partners based on extensive local knowledge and interaction with farmers.

Soil data: We have incorporated available spatially explicit data for East Africa into the WOFOST soil database, including field capacity, wilting point, saturated water content, and maximum rooting depth. These data were obtained from the World Soil Information (ISRIC). The WOFOST soil database comprises six soil classes categorised by their sand, clay, and silt content. Each soil class contains information on various physical soil characteristics such as soil water retention, percolation parameters, soil depth, and soil workability parameters. To adapt the soil database to the East African context, we initially classified the study area into six classes based on sand, clay, and silt content, aligning with the existing WOFOST soil classes. This classification was conducted using data obtained from ISRIC and following the original WOFOST approach. Subsequently, for each grid cell, we replaced the soil water retention and soil depth parameters in each soil class with the corresponding data obtained from ISRIC.

Crop growth parameters: WOFOST uses crop growth parameters for generic tropical varieties contained in its own database. Historical climate data are used to calibrate the model and validate its performance against observed crop yields in the past. Due to the lack of spatially disaggregated observed crop yield data, calibration was performed by comparing simulated yield data to the regional average yield provided by INSPIRE. This allowed us to ensure that simulated yields were at least within the attainable limits for each crop in each region. Each crop was simulated for the March-May season, which corresponds to the main season for growing these two crops.

3. Findings

3.1 Projected Changes in Temperature

The temperature in the Busoga-Lango region is projected to rise in the 2040s compared to 2009s in all scenarios during the MAM season (Figure 2). In an optimistic scenario, the temperature is expected to increase by 0.7°C on average, with most districts expected to experience a temperature increase of up to 0.75°C. Temperatures are expected to rise with the severity of the climate scenario, reaching an average of 1°C under the worst-case scenario. Recent climate assessments in Uganda have also shown that this temperature increase in the Busoga-Lango region will be accompanied by an increase in droughts and dry spells (up to 7 consecutive dry days), especially under the worst-case scenario.

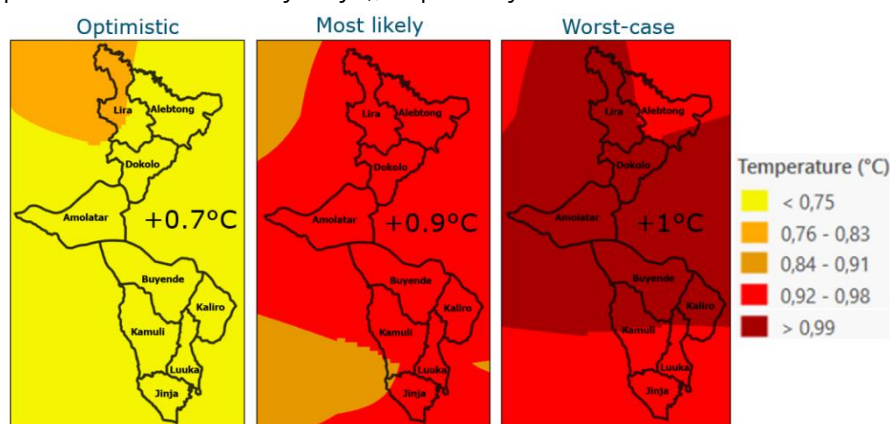


Figure 2: Projected changes in average temperature in the MAM season under the optimistic, most likely, and worst-case scenarios in the Busoga-Lango region.

3.2 Projected Changes in Precipitation

During the MAM season, precipitation is also projected to increase in the 2040s in the Busoga-Lango region (Figure 3). Under an optimistic climate scenario, rainfall is likely to increase by an average of 18% (~68 mm), from 378 mm in 2009 to 444 mm in the 2040s, on average. However, the magnitude of the increase in rainfall decreases with the severity of the climate scenario, with an average slight increase of 12% (45 mm) expected under the worst-case scenario.

Recent climate assessments in Uganda have also shown that the number of consecutive wet days is expected to decrease (by up to 6 days) across the country, including the Busoga-Lango region, particularly under the worst-case scenario. Based on historical climate projections (1961-2005), the onset of rainfall in the Busoga-Lango region ranges between 21 March and 20 April. The recent climate assessments also indicate that an

early onset of rain (3 - 6 days) can be expected in the 2030s. (2030-2040). In the 2050s (2040-2069), however, the onset of rainfall is expected to be early in some areas (by up to 4 days), while a delay of up to 6 days is projected in other areas. Rainfall alone is not a sufficient indicator of water availability for agriculture. A combination of increased precipitation and higher temperatures can lead to increased evapotranspiration, which reduces water-use efficiency and potentially stresses crops.

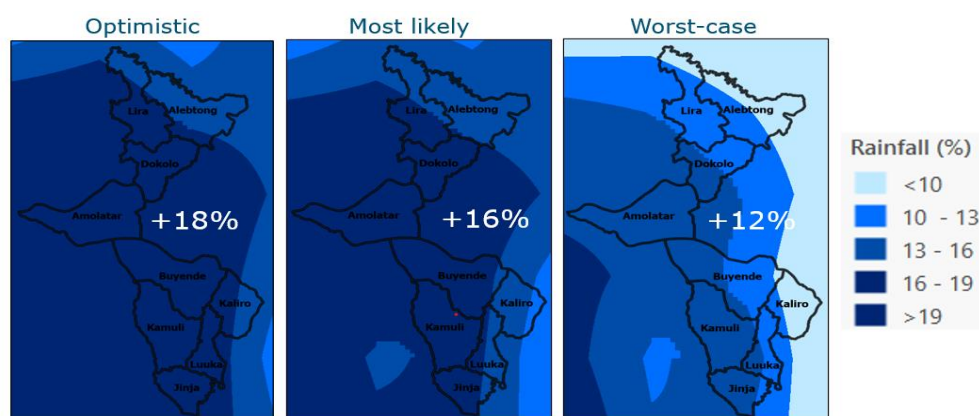


Figure 3: Projected percentage changes in total precipitation in the MAM season under the optimistic, most likely, and worst-case scenarios in the Busoga-Lango region

3.3 The Impact of Climate Change on Maize Yield

Climate change might impact maize yield and bean production in different ways. Climate change, particularly a rise in temperature, increased drought risks, and erratic rainfall, will adversely affect maize yields, especially in the worst-case scenario if no adaptation measures are implemented (Figure 4).

In Busoga, maize yields are expected to consistently decline across the three scenarios, particularly under the worst-case scenario, where yields are projected to decrease by up to 8% from ~9800 kg/ha to ~9000 kg/ha. In Lango, on the other hand, maize yields benefit slightly from favourable climate conditions in optimistic and most likely scenarios, with yields projected to increase by up to 2% from ~8700 kg/ha to ~8870 kg/ha. However, a significant yield decline of 13% is projected under the worst-case scenario.

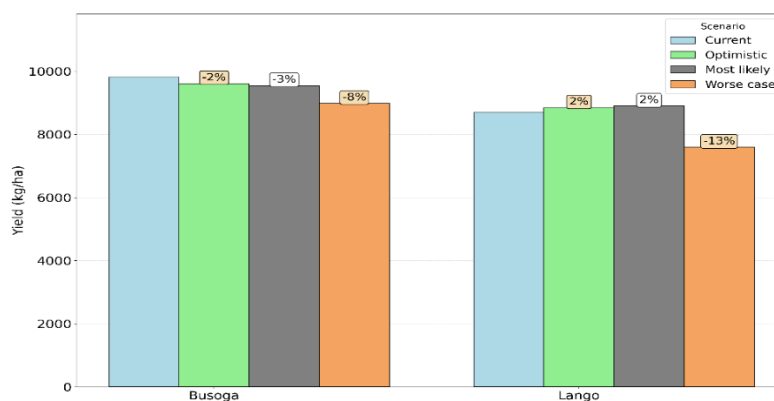


Figure 4: Current (2009s) and projected (2040s) maize yields under optimistic, most likely, and worst-case scenarios in Busoga and Lango.

3.4 Effect of Planting Date on Maize Yield Under Different Climates

The maize planting season in Busoga and Lango is from the beginning of March to the end of April, while the harvest season lasts from mid-June to the beginning of July. The actual planting date and the entire growing season depend on the practices of individual farmers, especially the onset of the rainy season, which is influenced by the farm's location, altitude, and local weather conditions. Therefore, we explored how maize yield responds to different planting dates, ranging from early March to Early May (Figure 5). In the Busoga region, early planting of maize between early and mid-March can lead to the highest yields in all scenarios, exceeding ~10000 kg/ha in the optimistic scenarios. Late sowing after early April, on the other hand, can lead to significant yield losses, especially until late April-early May, when yields are expected to fall below 7,000 kg/ha. Unlike Busoga, the Lango region shows greater resilience in yields, with those planted around mid-March and early April projected to remain above 8,000 kg/ha. Regardless of the region and planting date, the maize yields will consistently be relatively lower under the worst-case scenario, mainly due to increased exposure to higher temperatures and heat stress. From a climate change perspective, therefore, early to mid-March is probably the optimal planting window for the Busoga region. In contrast, mid-March to early April may be the best planting window for the Lango region. However, without adaptation measures, the yield is expected to decrease slightly compared to current climate conditions.

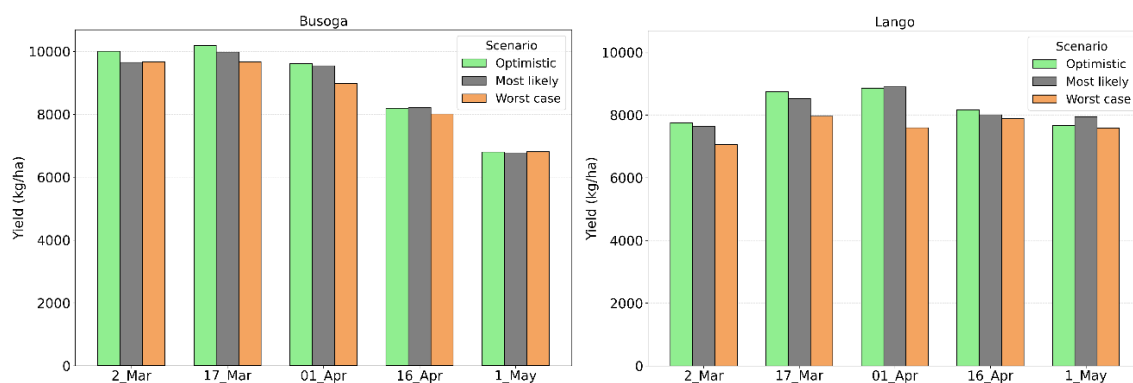


Figure 5: Effect of different planting dates on maize yield under different climate scenarios in Busoga (left) and Lango (right)

3.5 Impact of Climate Change on Bean Yields

Beans appear to be more vulnerable to climate change than maize, as they show greater yield losses in both regions, even in an optimistic climate scenario (Figure 6). In the Busoga region, bean yields are expected to decline by 9% in the optimistic scenario and by 14% in the most likely and worst-case scenarios of the 2040s. In the Busoga region, a decrease from ~2050 kg/ha in the current climate to ~1760 kg/ha in the most likely and worst-case scenarios can be expected, primarily due to increased temperatures and heat stress. Continued yield losses are also expected in the Lango region, with the worst-case scenario resulting in the sharpest decline of up to 15%, a decrease from ~1800 kg/ha to ~1500 kg/ha.

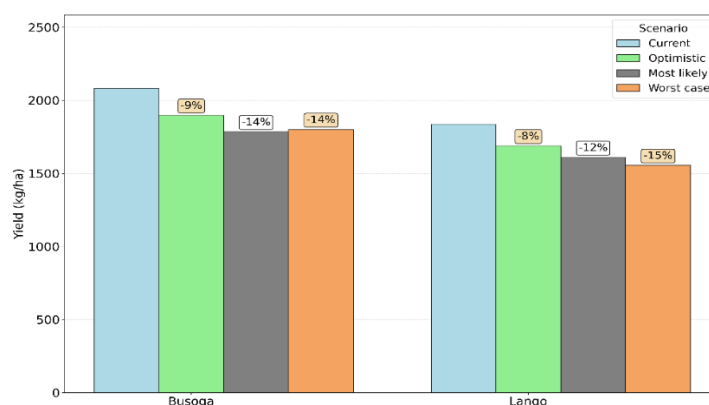


Figure 6: Current (2009s) and projected (2040s) bean yields under optimistic, most likely, and worst-case scenarios in Busoga and Lango

3.6 Effect of Planting Date on Bean Yield Under Different Climates

In the Busoga and Lango regions, beans are currently usually planted at the end of March and the beginning of April. However, the planting window can be extended to the beginning of March and the end of April, depending mainly on the onset of rainfall. Planting between mid-April and early May is likely to reduce yield losses due to climate change, with bean yields increasing steadily at later planting dates in all scenarios and regions (Figure 7). Planting in early March is likely to reduce bean yields in all scenarios and regions. From a climate change perspective, mid-April and early May are the optimal windows for planting beans in Busoga and Lango in the future. However, without adaptation measures, the yield is expected to decrease slightly compared to current climate conditions.

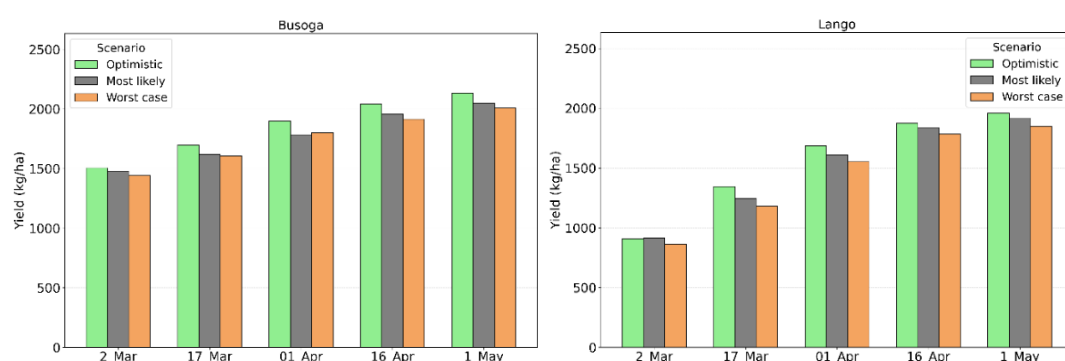


Figure 7: Effect of different planting dates on bean yield under different climate scenarios in Busoga (left) and Lango (right).

4. Conclusions and Recommendations

- Despite the increase in rainfall, maize and bean yields are projected to decline in the future, especially under the worst-case climate scenario, mainly due to the expected increase in temperature.
- Using the appropriate planting window will be critical in the future to reduce the climate-induced yield losses.
 - From a climate change perspective, for maize, the optimal planting window in the Busoga region is likely early to mid-March, while mid-March to early April may be the best planting window in the Lango region.
 - For beans, from a climate change perspective, mid-April and early May is the optimal window for planting beans in Busoga and Lango in the future. However, without adaptation measures, the yield is expected to decrease slightly compared to current climate conditions.
- Adapting the planting plan is one of the simplest and most cost-effective adaptation measures that smallholder farmers, in particular, can take to compensate for yield losses. Therefore, local agricultural advisors should support farmers in creating a region-specific and climate-informed planting calendar.
- There is a need to incorporate information on climate change and climate change adaptation measures into the agricultural extension or advisory services.
- Other climate-smart adaptation measures should be considered, including the use of early-maturing varieties, heat-tolerant varieties, mulching, and rain-harvesting techniques.

5. References

1. World Bank, 2020. [**Climate Risk Country Profile-Uganda.**](#)
2. Ntaate, I., 2024. [The escalating impact of Climate Change on Child Labour in Uganda.](#) 3 October 2024.
3. Global Climate Risks, 2023. [Uganda \(drought and flooding, July 2023\).](#) 31 July 2023.
4. Kakumba, M.R., 2022. [Climate change worsens life in Uganda; citizens want collective action to mitigate it.](#) 6 September 2022.
5. Kiyingi, I., Aliau, D.A., Lukwago, G., Ariong, R.M., Obongo, I., Adur, S., Angudubo, S., Ndhokero, J., Luzinda, H., Magala, D., and Mutonyi, S., 2024. Impact of Improved Maize and Bean Varieties on Household Income and Food Security in Uganda. *Uganda Journal of Agricultural Sciences*, 22(1), pp.1-13.
6. De Wit, A., Boogaard, H., Fumagalli, D., Janssen, S., Knapen, R., van Kraalingen, D., Supit, I., van der Wijngaart, R. and van Diepen, K., 2019. 25 years of the WOFOST cropping systems model. *Agricultural systems*, 168, pp.154-167. <https://doi.org/10.1016/j.agsy.2018.06.018>.
7. [CMIP6 climate data.](#)