Short-term impact of climate change on crop production and adaptation options in East Africa

Authored by

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Executive summary

Climate change presents an increasing threat to agriculture in East Africa, where rising temperatures, altered rainfall patterns, and more frequent extreme events are undermining smallholder livelihoods. As part of the Climate Resilient Agribusiness for Tomorrow (CRAFT) project[1], this study assesses the near-term impacts of climate change on key smallholder crops, common beans, maize, potatoes, sorghum, and soybeans, across selected districts in Kenya, Uganda, and Tanzania. Using an integrated approach that combines climate projections, crop suitability analysis, and yield modelling, the study examines how projected changes in temperature and precipitation during 2024–2033 are likely to affect crop performance. The analysis also evaluates the potential of low-cost adaptation strategies, specifically adjustments to planting dates and varietal selection, to mitigate climate-induced yield losses. The results highlight crop- and season-specific vulnerabilities, with legumes and tubers showing greater sensitivity to warming than cereals, while demonstrating that feasible management adaptations can substantially reduce near-term climate risks for smallholder farming systems.

The climate change impact report was carried out in the context of the Climate Resilient Agribusiness for Tomorrow (CRAFT) project (https://www.crafteastafrica.org/). The project is funded by the Ministry of Foreign Affairs of the Netherlands and aims to increase the availability of climate-smart foods for the growing population in Kenya, Tanzania, and Uganda. The CRAFT project is implemented by SNV (lead) in partnership with Wageningen University & Research (Climate Resilience) and Agriterra.

1. Introduction

The climate is changing rapidly worldwide. Rising temperatures, shifting rainfall patterns, and more frequent extreme weather events continue to increase climate risks, especially in East Africa. Kenya, Uganda, and Tanzania have experienced a significant increase in climate-related shocks, including droughts, floods, and heatwaves, over the past 20 years (World Bank, 2023; IPCC, 2023). These events have wide-ranging impacts on human health, biodiversity, economic stability, and migration, with rural communities bearing the heaviest burden. In Uganda, the April 2024 floods displaced over 4,000 families, damaged infrastructure, and destroyed thousands of hectares of crops (ReliefWeb, 2025). Earlier droughts in 2022 left more than 500,000 people food insecure, with over 200 deaths reported due to hunger in the Karamoja sub-region (UN OCHA, 2022). Kenya has also faced severe drought episodes, including the 2020–2023 drought, the worst in 40 years, which pushed more than 4.4 million people into acute food insecurity and caused widespread crop failures (FEWS NET, 2023). In Tanzania, recurrent dry spells in the southern and central regions have affected key staples such as maize and sunflower, while intense rainfall has caused flooding and erosion in highland areas (URT, 2021).

Climate-related disruptions can significantly affect the agricultural sector and have widespread economic impacts across the region (Bhanuwanti et al., 2024). Agriculture remains a key part of East Africa's economies and livelihoods, playing a significant role in reducing poverty and boosting rural development. In Uganda, about 70% of the population works in agriculture, which accounts for roughly 24% of GDP (Uganda Bureau of Statistics, 2022). In Kenya, the sector employs more than 40% of the population, accounts for nearly 65% of export earnings, and contributes between 20–30% to the country's GDP (Mose et al., 2025; Kenya National Bureau of Statistics, 2023). In Tanzania, agriculture accounts for 26-30% of GDP and employs 65% of the population (TICGL, 2024; Tanzania National Bureau of Statistics, 2022). Smallholder farmers primarily practice mixed farming, including livestock, food and cash crops, and fishing or aquaculture. Common food crops in the region include maize, rice, potatoes, bananas, cassava, beans, vegetables, sugarcane, wheat, sorghum, millet, and various pulses. Over 95% of cropland depends on rainfall, making farmers and the broader economy highly vulnerable to climate change (Bhanuwanti et al., 2024).

Despite the importance of these crops for food security and household income, yields still fall far short of their potential. For instance, cereal yields average about 2 t/ha, well below genetic potential and the global average of 10.8 t/ha (Bedasa et al., 2025). This productivity gap is caused by a mix of climate and non-climate factors, including ongoing soil degradation, low fertilizer use, limited access to improved seeds, and growing exposure to climate stressors. Nearly 40% of soils in East Africa are classified as degraded, and 25% of productive land suffers from nutrient loss and declining soil organic matter due to erosion, overgrazing, and continuous cropping without replenishment (AbdelRahman, 2023). With fertilizer use averaging only 18 kg/ha, compared to 150–300 kg/ha in Asia and North America (Otaiku et al., 2019), nutrient limitations significantly limit yields,

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especially amid more frequent droughts and rising temperatures. Additionally, climate projections suggest that further increases in temperature and reductions in precipitation may reduce East Africa's cereal output by

Most climate-impact assessments in East Africa have focused on long-term horizons such as 2050 or 2100. For example, temperatures are projected to rise by an additional 2–3°C by the end of the century (Verburg et al., 2018). While future rainfall patterns remain uncertain, many studies indicate a likelihood of higher precipitation during the short rains (October–December) and reduced rainfall during the long rains (March–April) (Bedasa et al., 2025; Ogega et al., 2020). These long-term climatic changes are expected to have profound implications for agricultural productivity across East Africa. Combined warming and altered precipitation patterns are projected to reduce cereal yields by 6–32% by mid-century, with tuber and root crops such as potato facing even greater losses. Across both the long and short rain seasons, yield potential is expected to decline markedly due to increased heat stress and growing water constraints (Kirina et al., 2025). Even when accounting for the potential benefits of elevated CO_2 concentrations, significant yield reductions persist. In parallel, climate change is projected to sharply reduce the suitability of agricultural land for key crops, with large areas becoming unsuitable by mid-century, particularly in regions already close to critical climatic thresholds.

While this information is helpful for strategic planning, these timelines are too distant for farmers, business champions, financial institutions, extension services, and regional development programs needing actionable intelligence within the next decade. Short-term, decade-scale assessments provide greater practical value by capturing near-term climate trends, aligning with agricultural planning cycles, and supporting realistic, locally relevant adaptation strategies. This study, therefore, focuses on the 2024–2033 period to evaluate emerging climate risks to crop suitability and yield. It also examines how low-cost interventions, such as adjusting planting dates and selecting different varieties, can lessen climate impacts on crop yields in several districts in Kenya, Uganda, and Tanzania.

2. Methodology

2.1. Description of study area

This study examined selected agricultural districts in Kenya, Uganda, and Tanzania that span diverse agroecological zones and typify smallholder-dominated farming systems in East Africa (Figure 1). These districts were selected for their importance in producing key food crops and their strong reliance on rainfed agriculture, making them particularly vulnerable to changes in temperature and rainfall patterns. Across all study areas, farming is predominantly smallholder-based, with households cultivating less than two hectares and producing primarily for household consumption and local markets. Collectively, the selected regions provide a representative snapshot of East African smallholder agriculture under current and emerging climate risks.

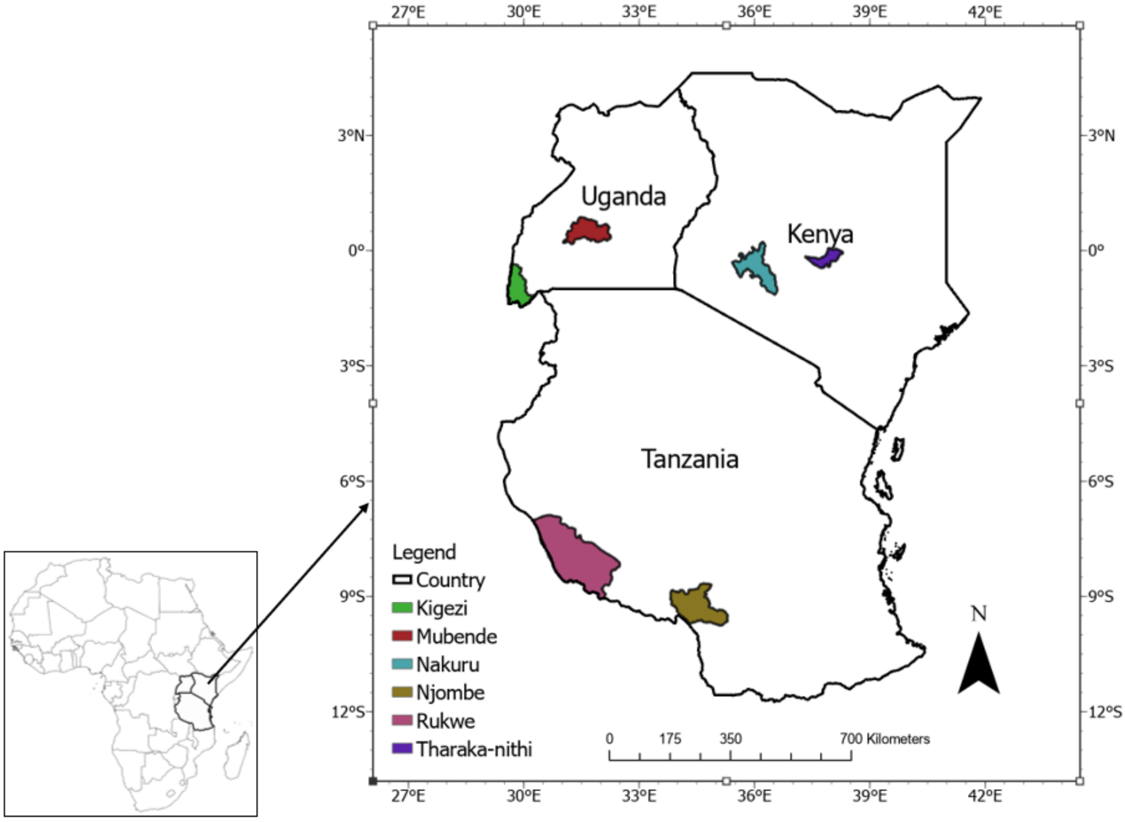


Figure 1: Map of East Africa highlighting the study areas in Kenya, Uganda, and Tanzania

In Kenya, the analysis was conducted in Tharaka-Nithi and Nakuru Counties. Tharaka-Nithi, located in eastern Kenya, experiences semi-arid to sub-humid conditions and depends heavily on sorghum–common bean intercropping as a main livelihood activity. Nakuru County, in the central Rift Valley, has a cooler highland climate and mainly practices intensive potato–common bean sequential cropping systems. In Uganda, the study focuses on Mubende District in the Central Region and the Kigezi sub-region in southwestern Uganda. Mubende features a mid-altitude farming system where maize and soybeans are commonly cultivated, often in mixed or rotational cropping. The Kigezi highlands are a key area for potato and climbing bean production, characterized by cooler temperatures, steep slopes, and high population density. In Tanzania, the analysis focused on the Njombe and Rukwa Regions, both in the Southern Highlands. Njombe supports potato–common bean systems under relatively cooler conditions, while Rukwa is an important maize–sunflower production area. The study regions in Tanzania have a unimodal rainfall pattern, with the main rainy season occurring from October to December (OND). In contrast, areas in Kenya and Uganda experience bimodal rainfall, with the long rains typically from March to May (MAM) and the short rains from September to November (SON).

2.2. Methodology

We adopted an integrated climate–crop impact assessment approach to evaluate the near-term (decadal) effects of climate change on crop suitability and yields, as well as the potential effectiveness of selected low-cost adaptation strategies. Unlike many climate-impact studies, including previous CRAFT assessments, that focused on mid- or end-century projections, this analysis emphasizes the 2024–2033 period, which aligns with agricultural planning cycles, development programming, and farmers' decision-making horizons.

2.2.1. Climate data and projections

Decadal climate predictions were obtained from the Decadal Climate Prediction Project (DCPP). Daily climate variables, including mean, minimum, and maximum temperature, and precipitation, were extracted from the EC-EARTH3 global climate model using the most recent forecast initialization, initialized in November 2023 (EC-Earth-Consortium, 2020). This forecast consists of 50 ensemble members and extends through October 2034, enabling assessment of near-term climate conditions for the study period (2024–2033). To establish a baseline climatology and evaluate historical forecast performance, hindcast simulations were retrieved for the 1991–2020 period. Hindcasts were initialized in November 1990, November 2000, and November 2010, with each run comprising 10 ensemble members. These data provide a consistent reference for comparing projected changes against recent historical climate conditions. In addition to temperature and precipitation, daily data on relative humidity, solar radiation, and wind speed were also obtained to support crop growth simulations using the WOFOST crop model. All climate data were globally gridded and spatially extracted for the study regions in Kenya, Uganda, and Tanzania. Projected changes in temperature and precipitation were quantified as anomalies relative to the 1991–2020 model climatology, enabling consistent comparisons across regions and seasons while accounting for model-specific biases.

2.2.2. Crop suitability assessment

Crop suitability analysis was conducted to identify areas where specific crops are most likely to perform well under current and projected climate conditions, and to support the targeting of climate-smart investments and adaptation strategies. The assessment followed a three-step approach.

First, the onset of the wet season was derived dynamically from rainfall time series for each grid cell using harmonic analysis (Dunning et al., 2016). The estimated onset was used as a proxy for the start of the growing season. In regions with bimodal rainfall regimes, the two wet seasons were identified, and the longer season was selected. The estimated onset of this season was then used as a proxy for the start of the growing season.

Second, the growing season was divided into three phenological stages; planting to emergence, emergence to flowering, and flowering to maturity—based on crop-specific heat unit requirements obtained from the WOFOST crop parameter database (De Wit et al., 2019). For each phenological stage, climate stress indicators were calculated, including dry spells (consecutive dry days), heat stress (number of days exceeding crop-specific optimal temperature thresholds), heavy rainfall events (number of days with rainfall greater than 20 mm), cumulative solar radiation, and aridity. These stage-specific climate variables were combined with static biophysical and accessibility indicators, including soil properties (rooting depth, bulk density, sand and clay content), elevation, protected area status, and travel time to cities as a proxy for access to inputs and markets.

Third, to model crop suitability and capture the complex, non-linear interactions among climatic, biophysical, and socioeconomic drivers of crop production, we applied a machine-learning classification approach. Predictor variables were compiled for the 2010–2020 period, which served as the baseline for model training. The model was trained to learn characteristic combinations of underlying factors associated with each suitability class, enabling robust discrimination between suitable and unsuitable areas and providing insight into the interactions among key drivers.

To assess changes in crop suitability in the near future, the climate stress indicators—dry spells, heat stress, and heavy rainfall events—were recalculated using projected climate data. All non-climatic factors, including soil properties, topography, land-use constraints, and socioeconomic indicators, were held constantly, such that only climate-related stressors varied between baseline and future analyses.

2.2.2. Crop yield modelling

Crop yield modelling complements suitability analysis by quantifying the effects of climate change and management adaptations on productivity within suitable areas, while suitability analysis provides a spatial perspective on where crops can be sustainably grown. Together, these approaches enable the assessment of climate impacts on crop productivity and the evaluation of adaptation strategies under changing conditions. In this study, the World Food Studies (WOFOST) crop growth model was used to assess the response of key smallholder crops to projected climate change and to evaluate the effects of adjusting planting dates and crop varieties as adaptation options. WOFOST is a widely used, process-based crop growth model that integrates knowledge of plant physiology, agronomy, and meteorology to simulate crop growth, biomass accumulation, and final yield under varying environmental conditions. The model accounts for key drivers of crop development, including temperature, solar radiation, precipitation, soil characteristics, and management practices. In this study, WOFOST was applied consistently across all study regions and crops to ensure comparability of results.

The model was used to simulate water-limited yields, representing the maximum attainable yield under rainfed conditions where water availability constrains crop growth. This approach captures the influence of climate variability and change on yield potential in smallholder systems that rely primarily on rainfall. However, the simulations do not explicitly account for other yield-limiting factors such as nutrient deficiencies, suboptimal management, weed pressure, pests, or diseases, and therefore represent potential rather than realised farm-level yields.

2.2.3. Cropping calendar and management practices

Information on cropping calendars and management practices was provided by local partners (SNV), drawing on extensive local knowledge and direct engagement with farmers in the study areas. These data reflect prevailing farmer practices and were used to define baseline planting windows for each crop and region

2.2.4. Soil data

Spatially explicit soil data for East Africa were incorporated into the WOFOST soil database using information from the World Soil Information (ISRIC) system. Key soil properties include field capacity, wilting point, saturated water content, and maximum rooting depth. The WOFOST soil database comprises six soil classes defined by sand, clay, and silt fractions, each characterized by parameters describing soil water retention, percolation, soil depth, and workability. To adapt this database to the East African context, the study area was first classified into six soil classes based on sand, clay, and silt content using ISRIC data, following the original WOFOST classification approach. Subsequently, for each grid cell, soil water retention and soil depth parameters were replaced with corresponding ISRIC-derived values to reflect local soil conditions better.

2.2.5. Crop growth parameters and model calibration

Crop growth parameters were derived from the generic tropical crop parameter sets available in the WOFOST database. Model calibration and validation were performed using historical climate data by comparing simulated yields with regional average yield statistics provided by INSPIRE. Due to the lack of spatially disaggregated observed yield data, this approach ensured that simulated yields remained within realistic and attainable ranges for each crop and study region. Crop simulations were conducted for the main growing seasons relevant to each country. In Kenya and Uganda, simulations were performed for both the March–April–May (MAM) long-rain season and the September–October–November (SON) short-rain season. In Tanzania, simulations focused on the October–November–December (OND) season, which represents the primary rainfall and cropping period in the study regions. This seasonal differentiation allowed the model to capture country-specific rainfall regimes and seasonal variations in crop response to climate change and management adaptations.

3. Results and Discussion

3.1. Projected near-term climate changes

Across all study areas in Kenya, Uganda, and Tanzania, climate projections indicate a consistent warming trend over the next decade (2024–2033), with mean temperatures increasing by approximately 0.5–1.0°C relative to the baseline (1991–2020) (Figure 2). This warming is evident in all months and regions, though its magnitude varies seasonally and spatially. A key feature across the three countries is that minimum temperatures, particularly at night, are projected to rise faster than maximum (daytime) temperatures, especially during the main growing seasons. This pattern is likely to increase heat stress, accelerate crop development, and reduce grain-filling duration, especially for temperature-sensitive crops such as beans and potatoes.

Projected changes in precipitation are more uncertain and spatially heterogeneous (Figure 3). In Kenya and Uganda, rainfall is generally expected to increase slightly during the short rains (SON), whereas during the long rains (MAM), changes range from marginal increases to slight decreases, depending on location. In contrast, large parts of Tanzania, particularly the southern highlands, are projected to experience modest declines in rainfall during much of the growing season, with longer dry spells. Although projected changes in monthly rainfall totals are relatively small in absolute terms, they represent meaningful departures from historical norms and may have significant impacts on planting dates, crop establishment, and water availability.

These findings align with earlier studies highlighting that temperature increases are more robust and consistent than rainfall changes in East Africa, but that even modest rainfall shifts can strongly influence rainfed agricultural systems.

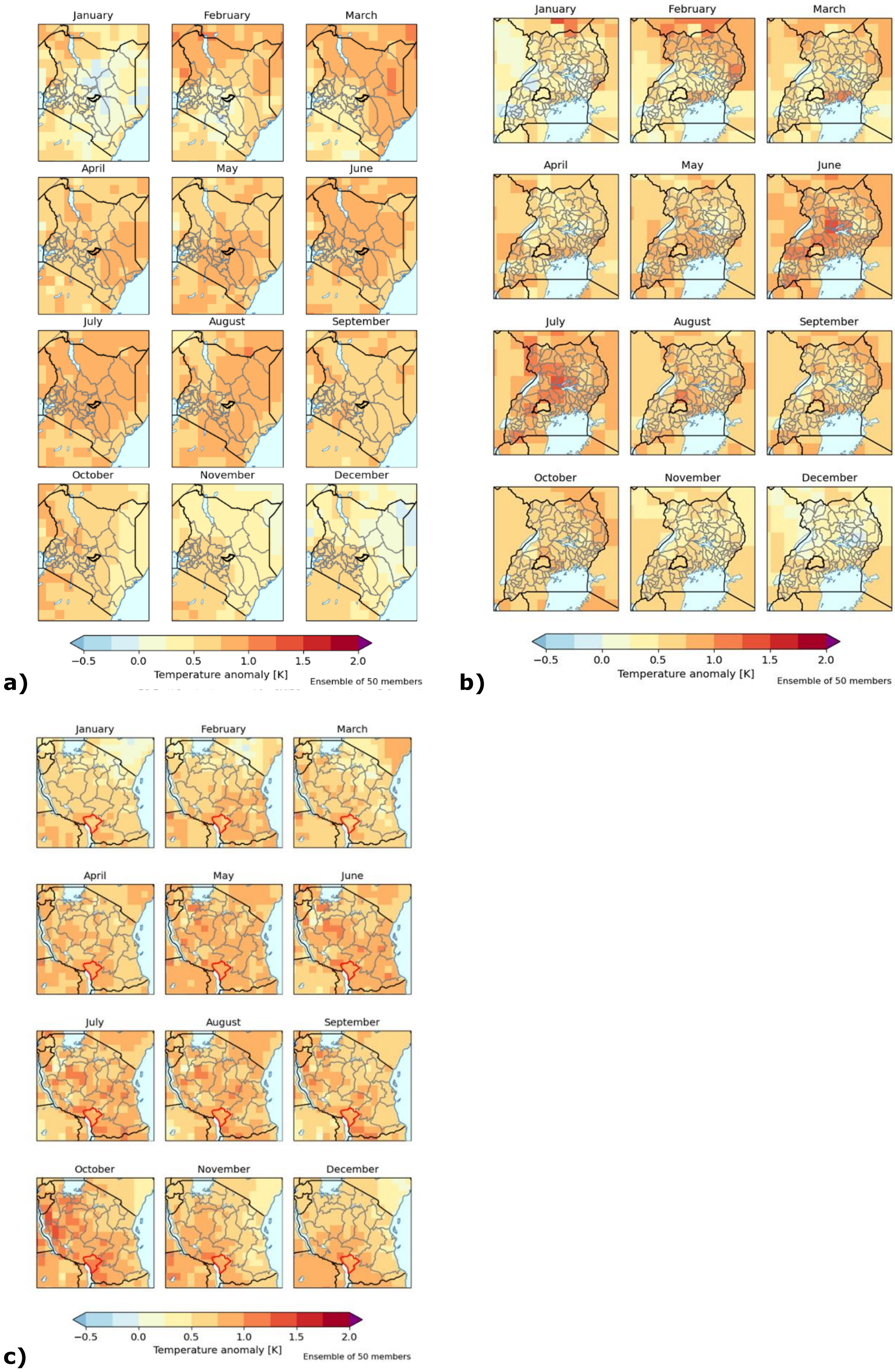
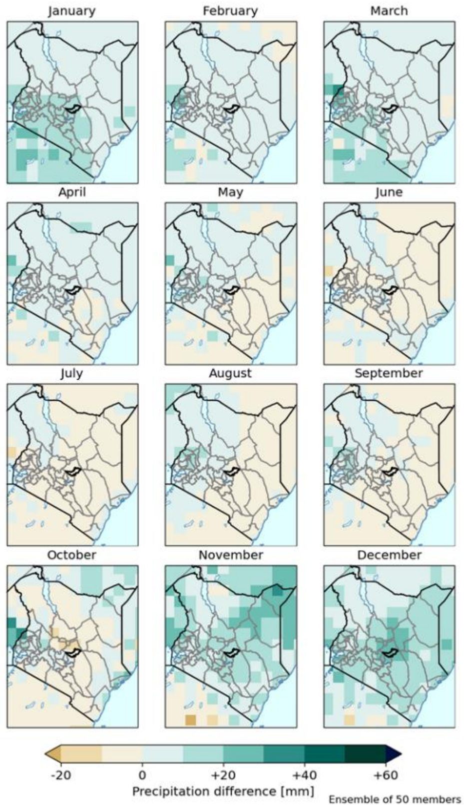


Figure 2: *Expected change in average temperature in Kenya (a), Uganda (b), and Tanzania (c) over the next decade. Darker orange and red colours indicate greater warming. Areas outlined in black and red represent selected focus regions. The projections show year-round warming across all three countries.*



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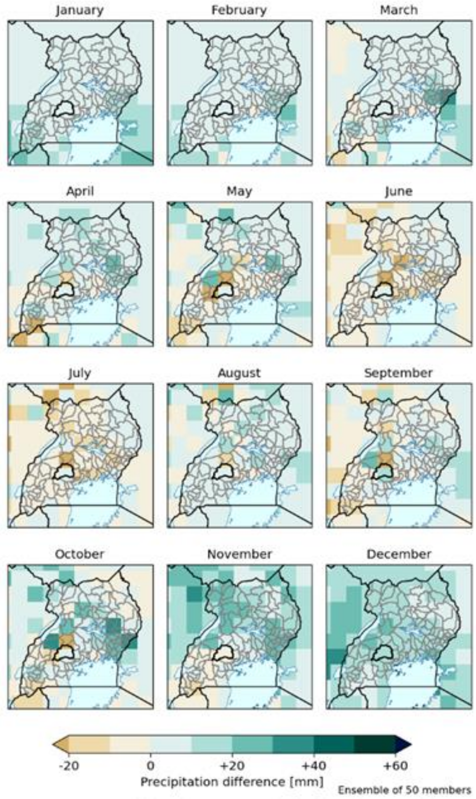

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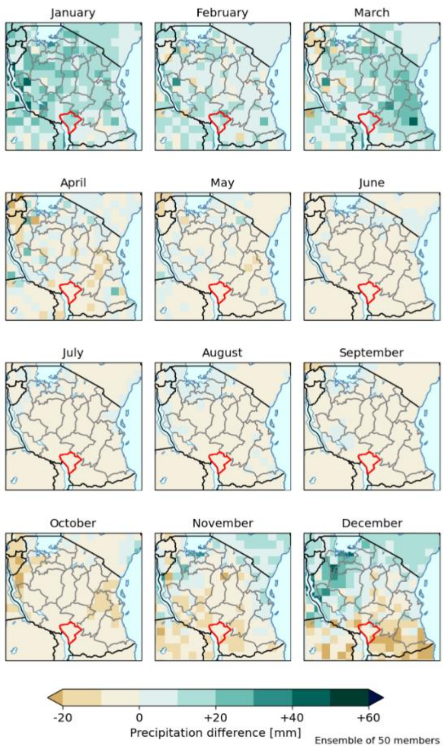

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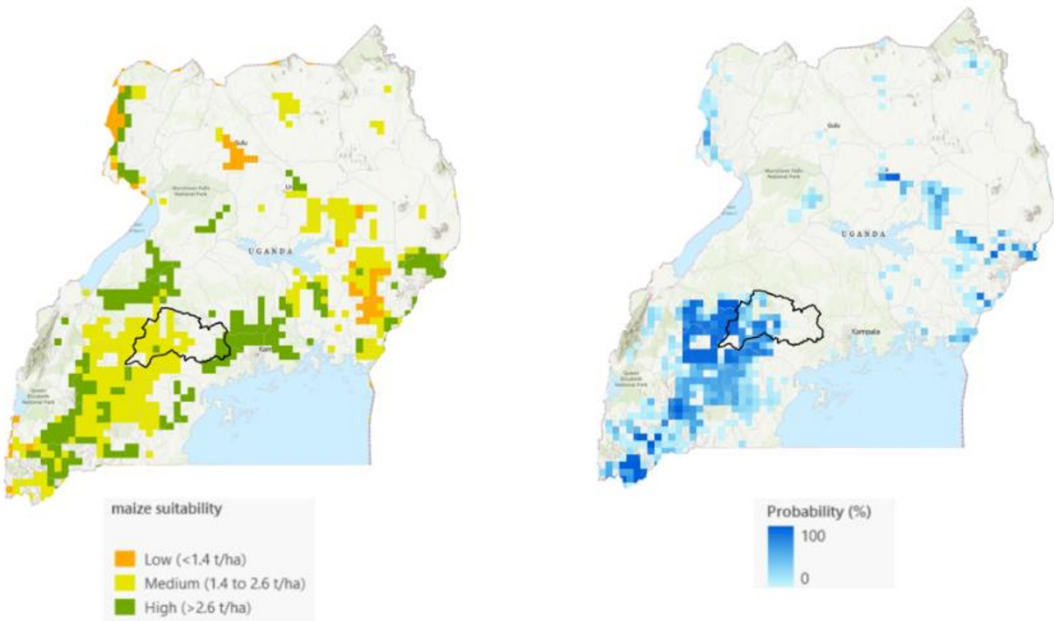
Figure 3: *Expected change in average monthly rainfall in Kenya (a), Uganda (b), and Tanzania (c) over the next decade. Darker blue–green colours indicate increases in rainfall, while brown colours indicate decreases. Areas outlined in black and red represent selected focus regions. Overall, projected changes in rainfall are modest and highly uncertain.*

3.2. Changes in crop suitability

Projected near-term climate change (2024–2033) is expected to alter the spatial distribution and probability of suitability for key crops across the study regions, although the magnitude and direction of change differ by crop and location.

Cereals

For maize, suitability remains generally moderate across most districts, especially in Mubende, where most maize-growing regions are expected to stay moderately suitable. However, the chances of maintaining current suitability levels are decreasing. This signals increased production risk rather than outright crop failure. In Kenya and Uganda, maize suitability remains relatively steady compared to other crops, reflecting maize's broader climatic adaptability. In the semi-arid production system of Tharaka-Nithi County (Kenya), sorghum-growing areas were mainly classified as moderately suitable during the recent period (2010–2020). Over the next decade, these areas are projected to stay moderately suitable, but with lower certainty, indicating rising production risk and a tendency for some zones to shift toward lower suitability classes. This pattern suggests that sorghum will probably remain a viable crop option under near-term climate change, but with a greater need for risk management and adaptation to seasonal variability.



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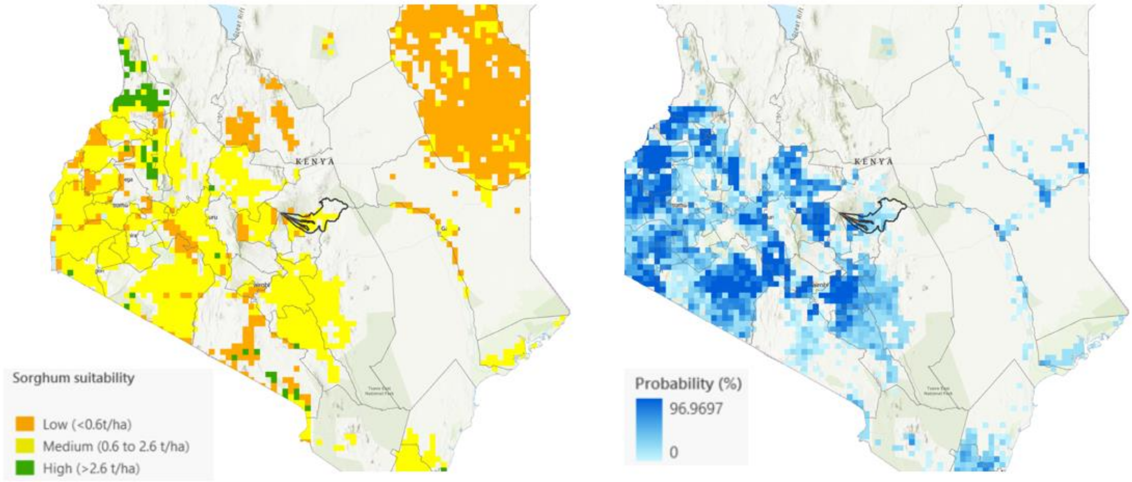
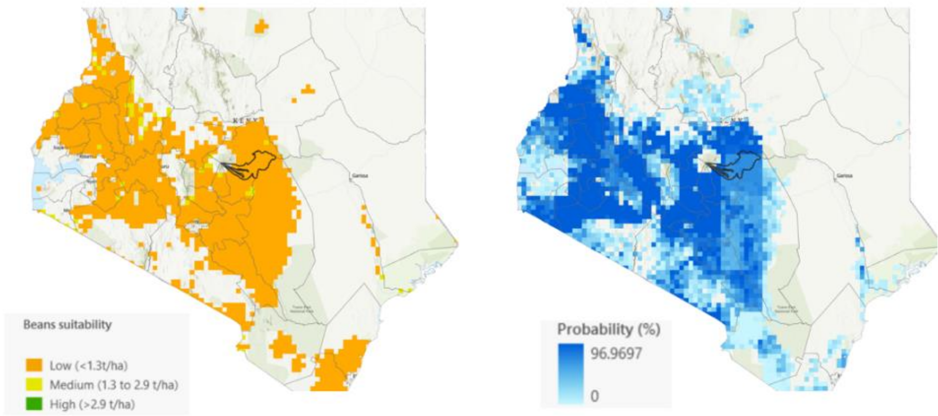


b)

Figure 4: *Current crop suitability (left) and projected probability of medium suitability (right) for maize in Mubende District (a) and sorghum in Tharaka-Nithi County (b) for the baseline period (2010–2020) and the next decade (2025–2034). Areas outlined in black indicate the study focus regions. While overall suitability patterns remain broadly stable, the probability of maintaining medium suitability declines across key production areas, indicating increasing production risk rather than abrupt spatial shifts.*

Legumes

Suitability for beans shows stronger vulnerability and a more pronounced decline. In Tharaka-Nithi and Nakuru, common bean production areas are projected to remain in low suitability classes, with limited likelihood of improvement under future climate conditions. In Kigezi, climbing bean suitability is projected to remain largely moderate, but with declining probability and increased likelihood of shifts toward lower suitability categories. Together, these patterns reflect beans' high sensitivity to heat stress and moisture deficits and indicate that beans, particularly in warmer or more variable environments, may face increasing climate constraints relative to cereals. In contrast, the main soybean-growing areas in Mubende are projected to remain highly suitable; however, the probability is again lower than in the recent period. This suggests that soybeans may be relatively resilient in the near term compared to other legumes, although yield impacts still warrant attention.



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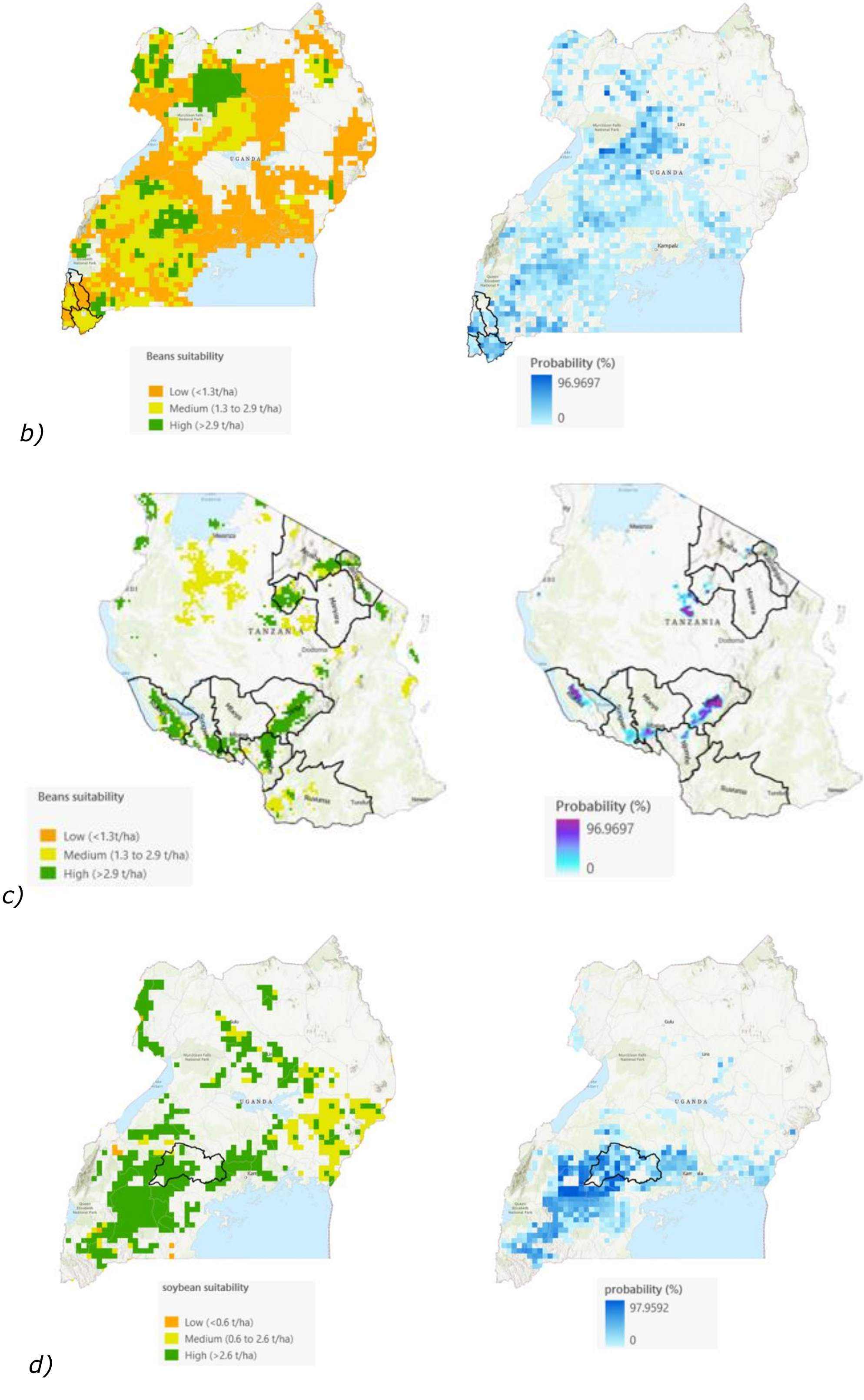
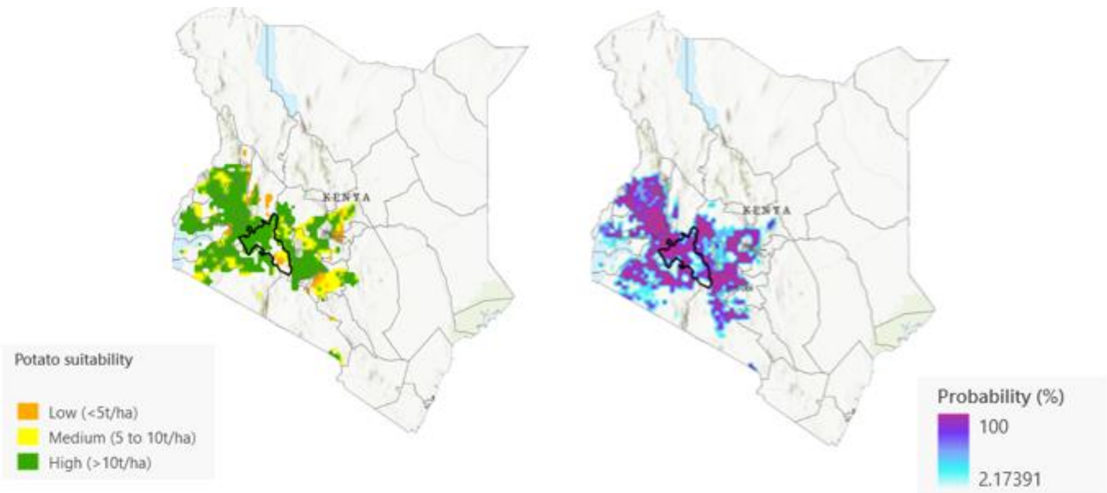


Figure 5: *Current crop suitability (left) and projected probability of medium suitability (right) for common beans in Tharaka-Nithi and Nakuru (a) as well as in Njombe (c), climbing beans in Kigezi (b), and soybean in Mubende district (d) for the baseline period (2010-2020) and the next decade (2025-2034). Areas outlined in black indicate the study focus regions. Legumes are more vulnerable than cereals, with common and climbing beans showing declining suitability and increased climate risk, whereas soybeans remain relatively resilient in the near term despite a reduced probability of maintaining high suitability.*

Tubers

Potato suitability shows pronounced spatial variation across the study regions. In highland areas such as Nakuru and parts of Tanzania's Northern Highlands, suitability is projected to remain high or remain relatively stable over the next decade. In contrast, in traditionally cooler production zones such as Njombe and parts of Kigezi, the probability of maintaining current medium suitability is expected to decline, indicating increasing vulnerability of established highland systems. While potato suitability in Kigezi is projected to remain largely within the medium range, localized improvements are possible, reflecting the complex interactions between rising temperatures, particularly at night, and local agroecological conditions. Overall, these patterns suggest a gradual upslope or latitudinal shift in potato suitability, consistent with longer-term climate change projections.

Overall, the suitability analysis indicates that near-term climate change is more likely to reduce the reliability of existing production zones than to cause sudden spatial shifts, underscoring the importance of local risk management strategies.



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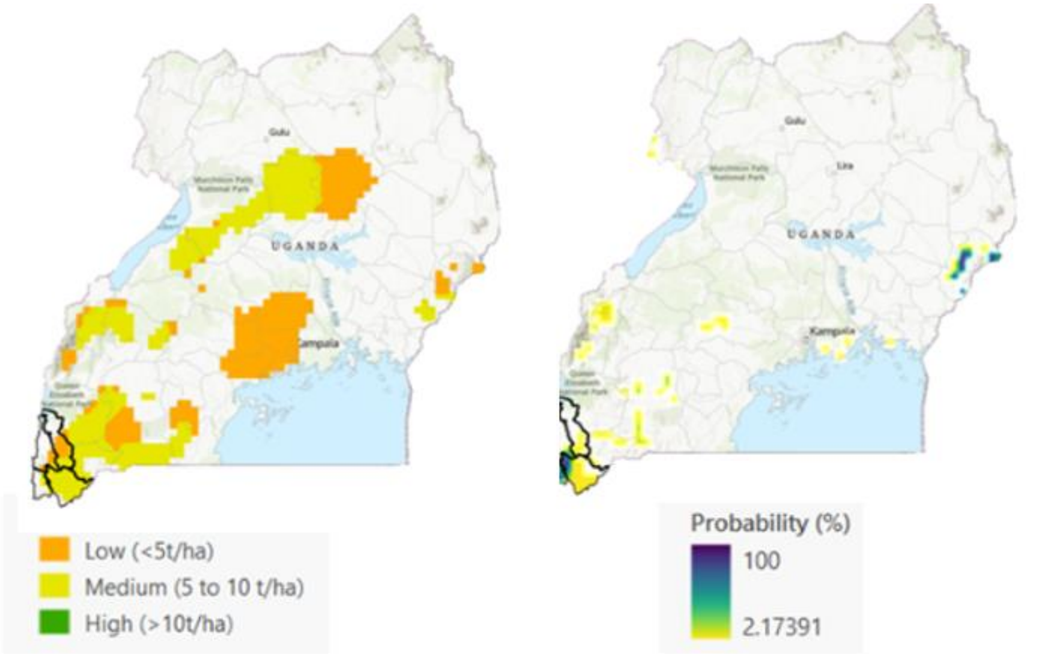

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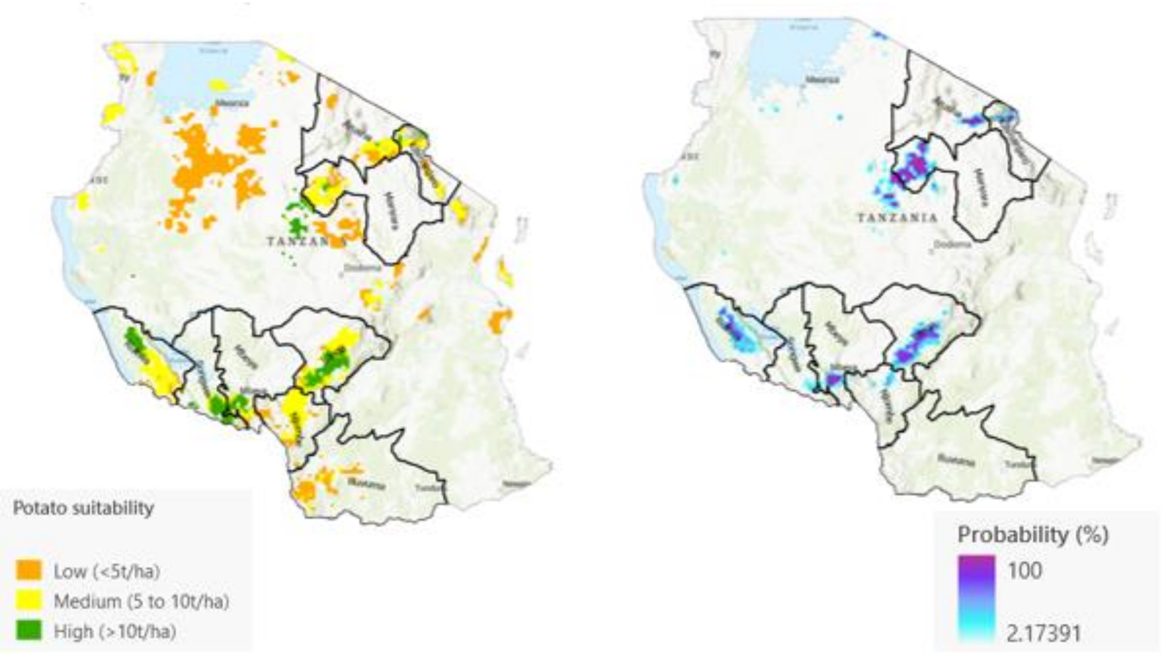


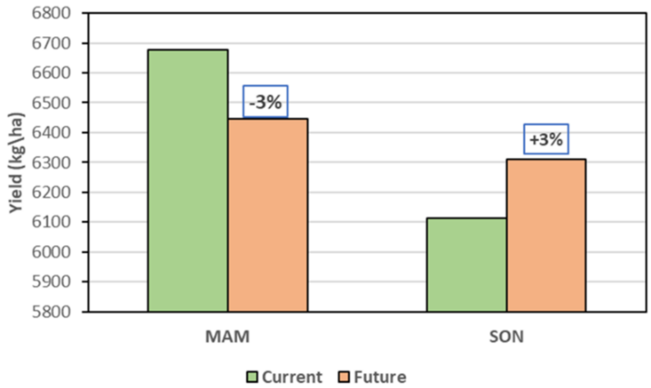
Figure 4: *Current crop suitability (left) and projected probability of high suitability (right) for potatoes in Nakuru (a), Kigezi (b), and Njombe (c) for the baseline period (2010-2020) and the next decade (2025-2034). Areas outlined in black indicate the study focus regions. Potato suitability remains relatively stable in Nakuru but shows declining probabilities of medium suitability in traditionally cooler highland regions such as Kigezi and Njombe, indicating increasing climate-related risk.*

3.3. Impacts on crop yields

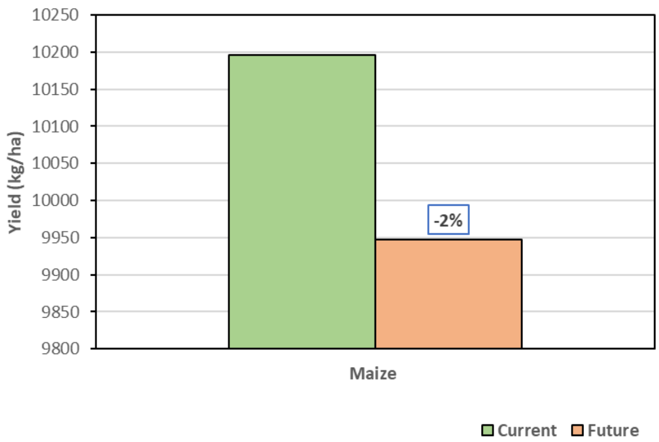
Projected yield responses to near-term climate change vary across crop groups, seasons, and locations, reflecting differences in crop physiology, sensitivity to heat and water stress, and prevailing agroecological conditions.

Cereals

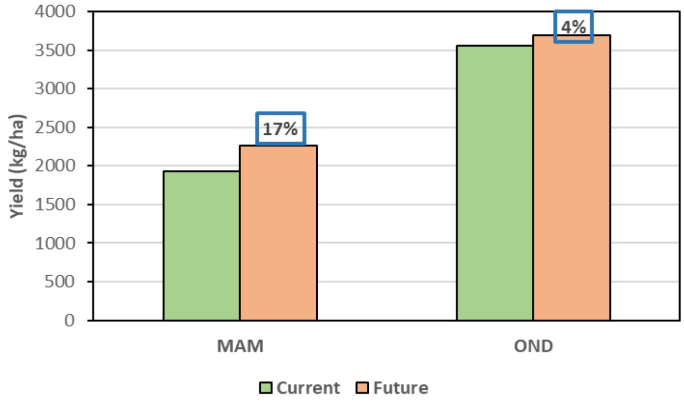
Cereal crops show relatively greater resilience to near-term climate change compared to other crop groups (Figure 5). For maize, yield changes over the next decade are generally modest and season-dependent. In Mubende, maize yields are projected to decline slightly during the main MAM season but to increase marginally during the SON season, suggesting a redistribution of productivity across seasons rather than a uniform decline. In Rukwa, maize yields are projected to decline, driven primarily by rising temperatures and longer dry spells. Overall, maize demonstrates moderate near-term resilience, but increasing exposure to heat stress raises concerns for longer-term productivity. In contrast, sorghum exhibits a positive yield response to projected climate conditions in semi-arid systems such as the Tharaka-Nithi region. Yield increases are projected for both the MAM and OND seasons, with more substantial gains during MAM. This reflects sorghum's high tolerance to heat and intermittent water stress, reinforcing its role as a climate-resilient cereal under warming conditions.



a) Maize, Mubende



b) Maize, Rukwe

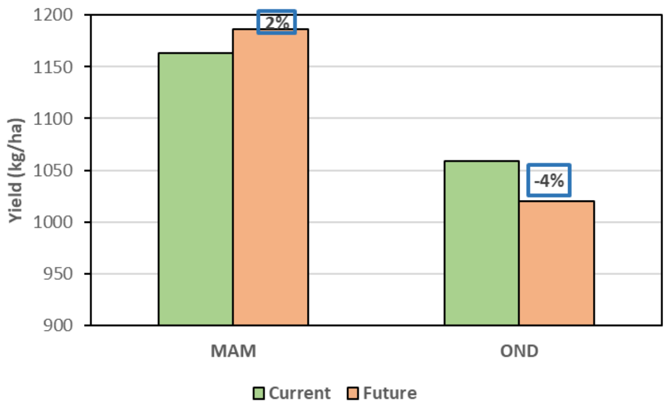


c) Sorghum, Tharaka-Nithi

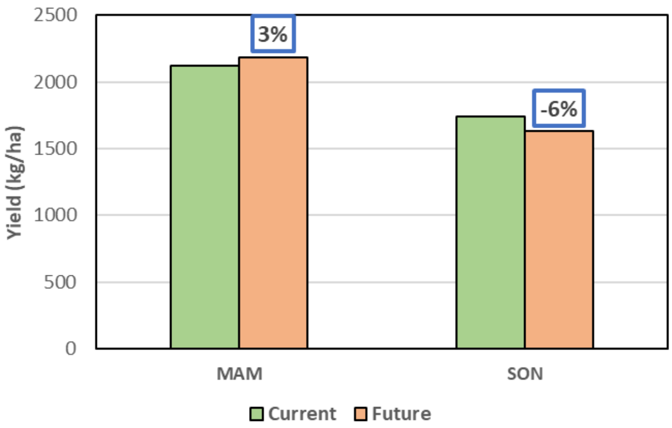
Figure 5: Impact of climate change on maize yield (a) Mubende (MAM and SON) and (b) Rukwe (OND) as well as sorghum yields (c) for (MAM and OND) seasons under the current (2011-2020) and future (2024-2033) decade.

Legumes

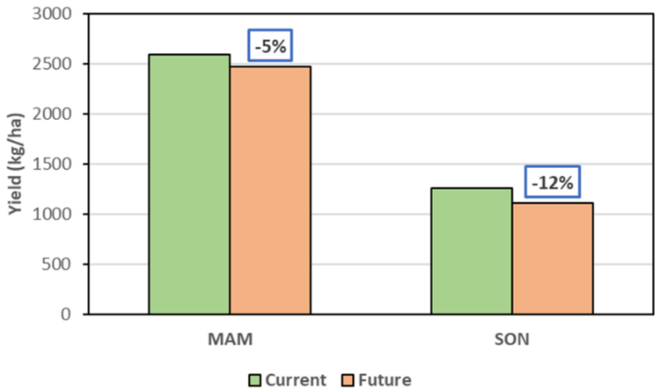
Legume crops are generally more vulnerable to near-term climate change, particularly as temperatures rise. Both common and climbing beans exhibit consistent yield declines across most regions and seasons. Yield reductions are more pronounced during short rainfall seasons (SON and OND) than during the main MAM season. In Tharaka-Nithi and Nakuru, common bean yields are projected to decline, particularly during the SON seasons. Similarly, in Kigezi, climbing bean yields are expected to decline, with larger reductions in the SON season. These patterns reflect the high sensitivity of bean crops to heat stress and rainfall variability.



a) Tharaka-Nithi



b) Nakuru



c) Kigezi

Figure 6: Impact of climate change on common beans yield for the MAM, SON, and OND seasons under the current (2011-2020) and future (2024-2033) decades for Tharaka-Nithi (a), Nakuru (b), and Kigezi (c).

Soybeans, assessed in Mubende, show comparatively greater resilience than other legumes (Figure 7). Soybean yields are projected to decline slightly across both growing seasons, with somewhat larger reductions during the SON season. This relative resilience may be linked to soybeans' nitrogen-fixing capacity and broader tolerance to temperature variability. Nonetheless, continued warming and drought stress are likely to erode this advantage without adaptive management.

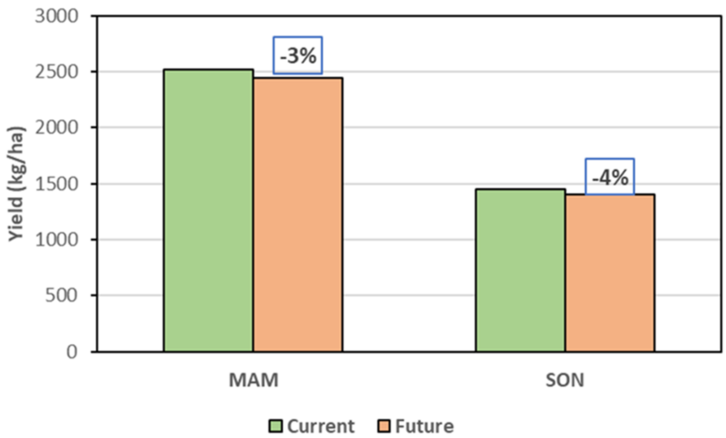
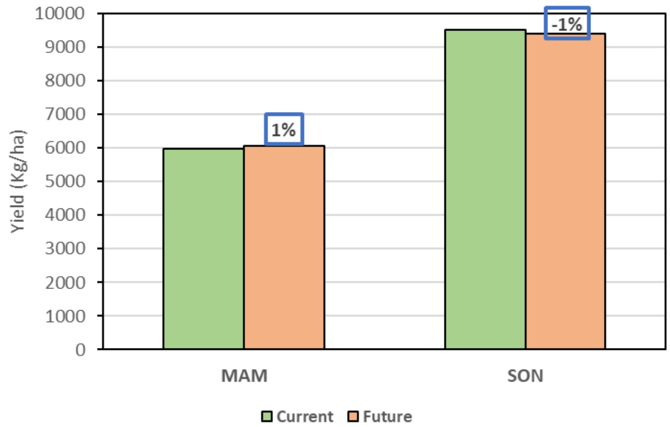


Figure 7: Impact of climate change on soybean yield for the MAM and SON seasons in the next ten years, Mubende district

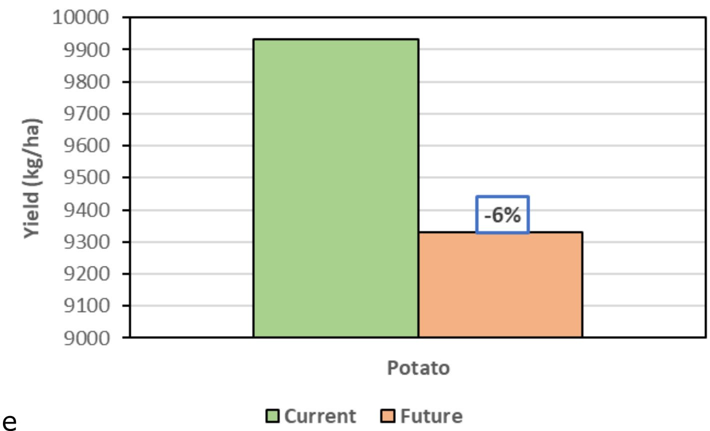
Tubers

Potato yields vary with elevation and local climate (Figure 8). In Nakuru, yields are expected to stay fairly stable over the next decade, with only small seasonal changes. Conversely, in Njombe and Kigezi, potato yields are likely to decline, especially during SON-growing seasons, due to increased heat stress in areas that are usually cooler. Despite these declines, yields remain higher during the main rainy season, underscoring the importance of season-specific management practices.



a) Nakuru

b) Kigezi



c) Njombe

Figure 8: Projected potato yield under the current baseline period (2011-2020) and future climate (2024-2033) in Nakuru (a), Kigezi (b), and Njombe (c).

Overall, the results indicate that cereals, particularly sorghum, are more resilient to near-term climate change, while legumes and tubers are more sensitive, especially to rising temperatures. Seasonal differences play a critical role, with secondary or short rainfall seasons generally resulting in greater yield reductions. These findings underscore the importance of aligning crop selection, planting season, and adaptation strategies with evolving climate conditions to reduce production risks in East African smallholder systems.

4.4 Adaptation measures and their effectiveness

The assessment of adaptation options indicates that low-cost, management-focused strategies can significantly reduce climate-related yield losses across crops and regions. Adjusting planting dates is one of the most effective adaptation measures. Sowing in line with expected rainfall and avoiding peak heat periods consistently boost yields across cropping systems. Early planting benefits sorghum and potatoes in several areas, while delaying planting increases bean yields in others, highlighting the need for crop- and season-specific advice rather than general recommendations (Figures 9 and 10).

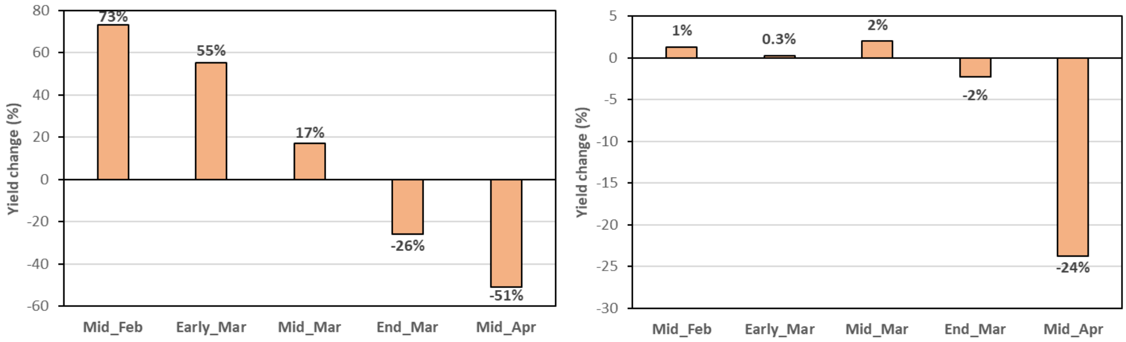


Figure 9: Sorghum (left) and common beans (right) yield changes in the future at different sowing dates in Tharaka-Nithi during the MAM season.

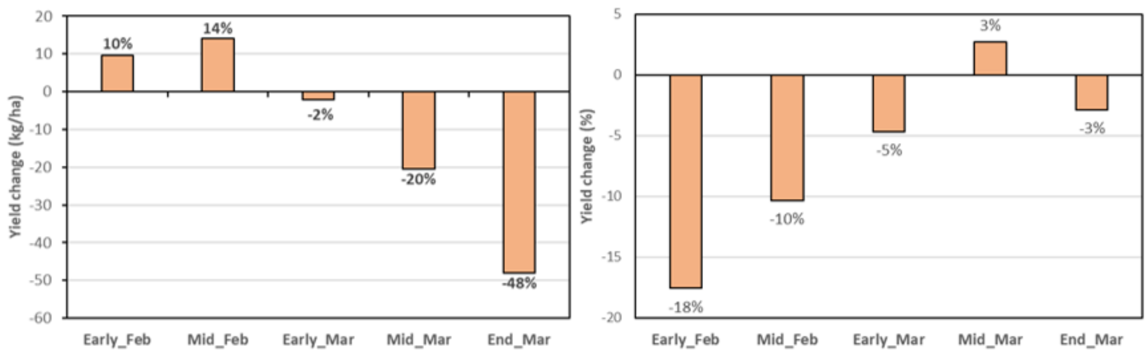


Figure 10: Potatoes (left) and climbing beans (right) yield changes in the future at different sowing dates in Kigezi during the MAM season.

Using improved crop varieties with suitable growing cycles also shows strong potential (Figures 11-14). Shorter-cycle varieties perform better for sorghum and potatoes in warming environments, while longer-cycle varieties increase yields for beans and soybeans by enabling extended vegetative growth and better grain filling. However, the benefits of improved varieties vary by context and would require cost–benefit assessments to evaluate their economic feasibility for smallholders.

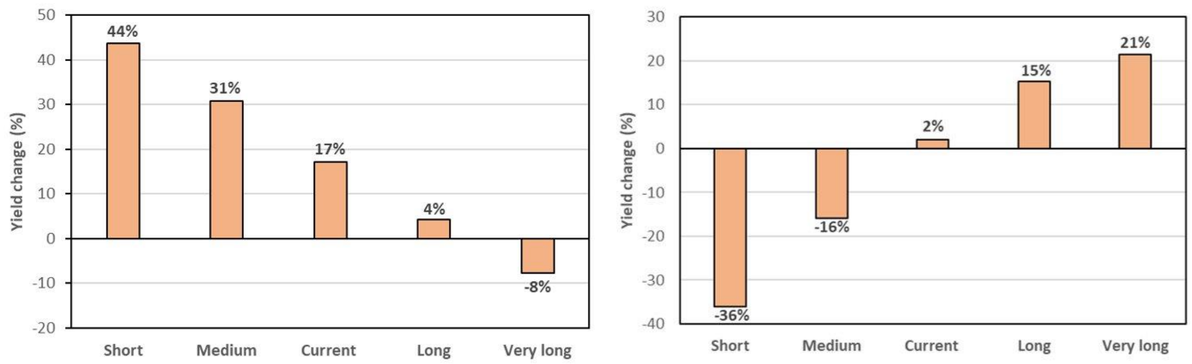


Figure 11: Effect of changing sorghum (left) and common bean (right) varieties on yield in Tharaka-Nithi during the MAM season.

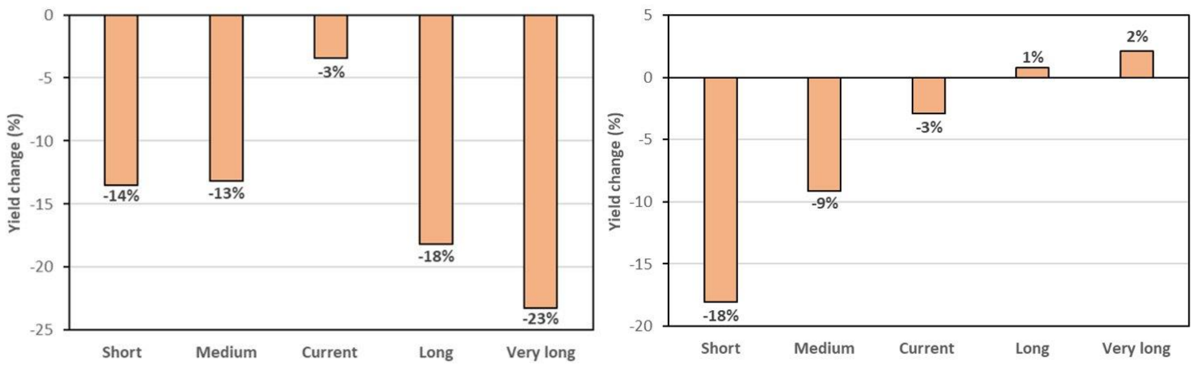


Figure 12: Effect of changing maize (left) and soybean (right) varieties on yield in Mubende during the MAM season.

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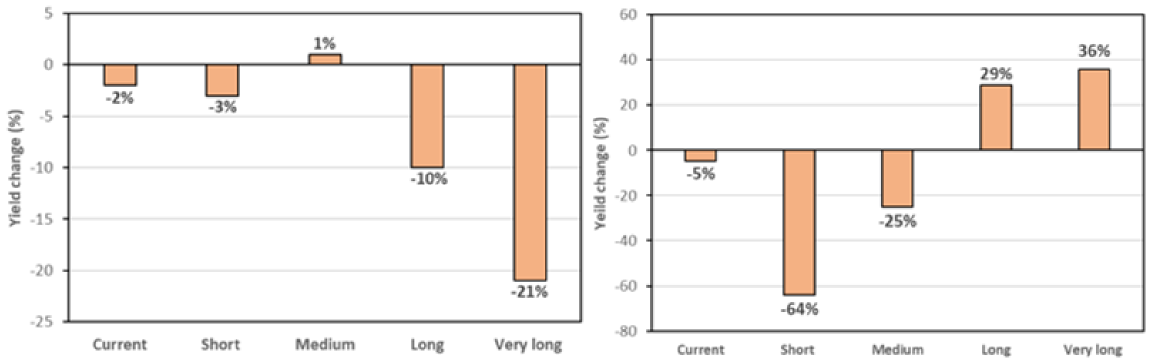

Figure 13: Effect of changing potatoes (left) and common bean (right) varieties on yield in Kigezi during the MAM season.

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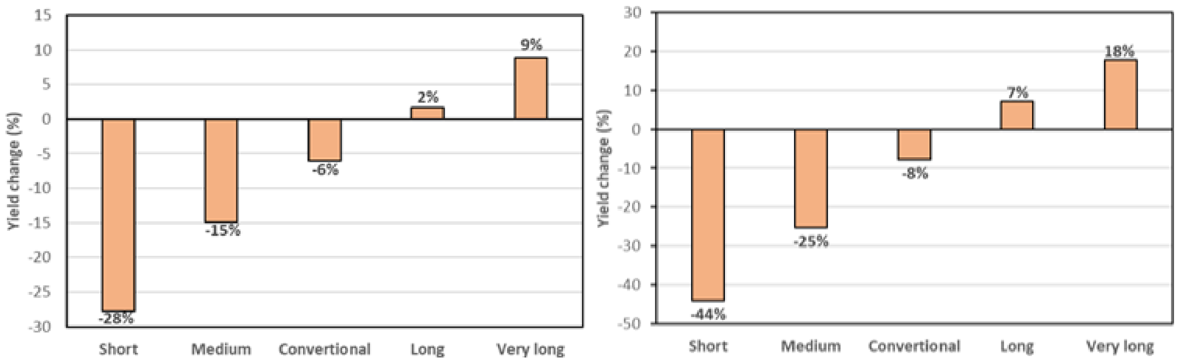

Figure 14: Effect of changing potatoes (left) and common bean (right) varieties on yield in Njombe during the MAM season.

Overall, adaptation benefits are generally greater than the projected near-term yield losses, indicating that proactive management changes can substantially buffer climate impacts over the next decade. However, adaptation effectiveness varies by crop, season, and location, underscoring the importance of context-specific recommendations rather than uniform prescriptions. Other adaptation measures are further illustrated in Figure 15, which summarizes responses to key climate hazards, such as heat stress, drought, rainfall variability, soil fertility constraints, and pest and disease pressure, and links these hazards to their impacts on crop production and practical measures that reduce associated risks. Most of the measures presented are already practiced by farmers and/or actively promoted by CRAFT project staff, underscoring their feasibility and relevance for smallholder systems. Collectively, these measures contribute to enhanced climate resilience by reducing the risk of crop failure, improving yield stability, strengthening soil water retention, and increasing the reliability of farm income. Together, these findings highlight the critical role of extension services, timely climate information, and access to improved seed in translating adaptation potential into realized yield gains for smallholder farmers.

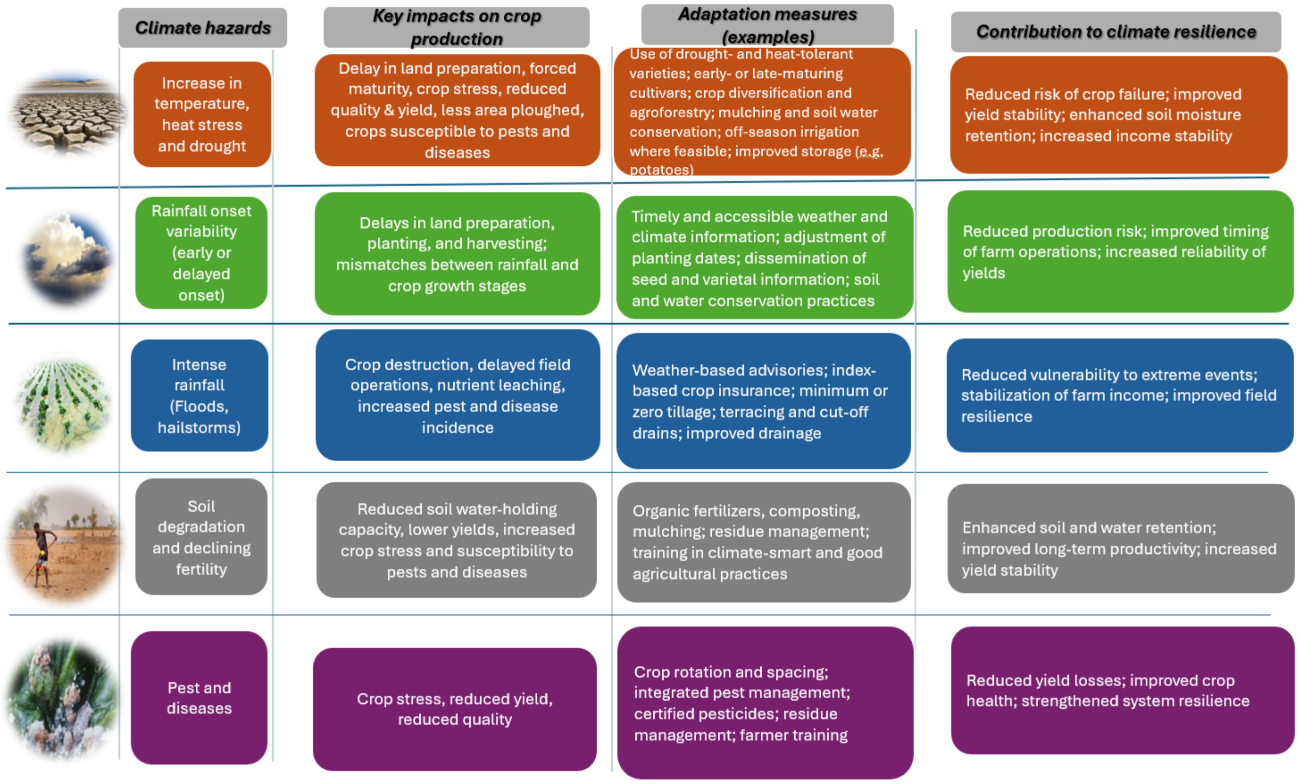

Figure 15: Examples of adaptation measures for addressing key climate hazards and their contributions to climate resilience across the studied cropping systems

4. Recommendations

The results of this study indicate that near-term climate risks to agriculture, especially smallholder farming, in East Africa, can be substantially reduced through targeted, low-cost adaptation measures. Given projected warming and increasing rainfall variability over the next decade, adaptation strategies within existing farming systems should be prioritised.

Farm level

At the farm level, adjustments to planting dates are among the most effective and feasible adaptation options across crop groups. Aligning planting with shifts in rainfall onset and avoiding peak heat-stress periods can significantly reduce yield losses, particularly for maize, beans, and potatoes. In addition, crop and varietal selection should increasingly reflect emerging climate conditions. The findings suggest that sorghum offers a more resilient alternative to maize in semi-arid environments, while longer-cycle legume varieties and early- to medium-maturing potato varieties can help sustain productivity under warmer conditions. Farmers are also likely to benefit from concentrating the production of more climate-sensitive crops during the main rainfall seasons, when climatic conditions are more favourable, and complementing these measures with climate-smart practices such as mulching, crop rotation, and improved soil fertility management.

Extension services and advisory systems level

Effective implementation of these measures relies heavily on robust extension and advisory systems. Extension services should update agronomic recommendations to reflect near-term climate projections, rather than relying solely on historical calendars. Crop- and season-specific guidance is increasingly necessary, as uniform recommendations are less effective under variable climate conditions. Strengthening the integration of agro-weather information, seasonal forecasts, and early warning systems into extension services can improve the timeliness and relevance of farmers' decision-making. Training programmes should focus on practical, locally appropriate adaptation options and highlight their benefits through demonstration and participatory learning approaches.

Policy level

At the policy level, the findings underscore the need to integrate decadal climate risk assessments into agricultural planning and investment strategies. Near-term projections are particularly valuable because they align with policy cycles, development programmes, and farmers' planning horizons. Public investment in seed systems is essential to ensure access to climate-adapted varieties, especially for legumes and potatoes, which are more sensitive to warming. Strengthening collaboration between agricultural and meteorological institutions can further enhance the delivery of usable climate information. Additionally, policies that encourage diversification towards more climate-resilient crops can reduce systemic vulnerability in food systems.

Private sector and financial institutions level

The private sector and financial institutions also have a crucial role in supporting adaptation. Including climate risk in agricultural finance and value chain investments can help stabilize production amid increasing climate variability. Business models that encourage climate-smart inputs, contract farming, and aggregation can strengthen resilience throughout value chains. Financial products designed for adaptation, such as climate-smart credit or insurance mechanisms, can further help farmers adopt recommended practices without adding financial risk.

Implications for research and development

The study also emphasizes key priorities for future research and development. Ongoing local-scale, decadal assessments of climate impacts, ideally based on multi-model climate forecasts (as opposed to the current study) and updated annually as new forecasts become available, are necessary to capture spatial differences and offer practical insights for farmers and policymakers. Analyzing the economic viability of adaptation options through cost–benefit reviews will be crucial to ensure that proposed strategies are affordable and scalable for smallholders. Increased integration of climate and non-climate factors, such as soil fertility and input use, will further enhance the relevance of future climate impact studies.

5. Conclusions

This study presents a decadal-scale assessment of climate change impacts on key smallholder cropping systems across selected regions in Kenya, Uganda, and Tanzania, addressing a significant gap in climate–agriculture research, which has traditionally focused on mid- and end-century projections. The results show that near-term climate change in East Africa will be characterised by consistent warming and increasingly variable rainfall, with temperature increases emerging as the dominant driver of changes in crop suitability and yields during 2024–2033. Across crop groups, the impacts of climate change are uneven. Cereals, particularly sorghum, exhibit comparatively greater resilience to near-term warming, while legumes and tuber crops (potatoes) are more vulnerable, especially in warmer and more variable environments. Yield impacts vary by season, with short rainfall seasons generally experiencing larger declines. Rather than causing abrupt spatial shifts in production, near-term climate change is more likely to reduce the reliability and suitability of existing production zones, thereby increasing production risk for smallholder farmers. Importantly, the study shows that feasible, low-cost adaptation measures can substantially buffer climate-induced yield losses in the near term. Adjustments in planting dates and the use of appropriately selected crop varieties consistently reduce vulnerability across crops and regions, often offsetting projected yield declines. These findings highlight the critical role of timely management decisions, access to climate information, and effective extension services in strengthening resilience**.**

Overall, the results show that although climate change poses increasing risks to smallholder agriculture in East Africa, proactive, context-specific adaptation can help maintain productivity and livelihoods in the short term. Additionally, these near-term assessments enhance longer-term climate projections by translating insights into actionable steps today. The findings emphasize the importance of localized, crop-specific analyses to guide adaptation strategies and policy decisions. Expanding these adaptation efforts, supported by extension services, policy frameworks, and climate-informed investments, will be crucial for building resilient agricultural systems amid a changing climate.

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