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Economywide Assessment of CSA Interventions in Building Resilient Agri-food Systems in Rwanda

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ABSTRACT

Due to its structural features, the Rwanda's agri-food system is extremely vulnerable to the risks of climate variability. To accelerate and sustain growth in the food system, increase its resilience to shocks, and improve food security, the Rwandan government incorporated a list of climate-smart agricultural interventions into its updated Fifth Strategic Plan for Agricultural Transformation (PSTA-5) program, with ambitious, explicit targets. This paper assesses the impacts of these CSA interventions on Rwanda's agri-food system, both with and without climate change, using historical declines in yield within agriculture as a proxy. Results show that modeled CSA practices during the PSTA-5 period (2024/25-2028/29) increase agricultural and overall GDP growth by 4.2 and 1.3 percentage points by the end of the plan period, respectively, with a long-term growth impact that stretches well beyond the plan period mainly owing to the persistent effects of irrigation and terracing. Cumulative agricultural GDP (2024/25-2028/29) would be 2.7 percent higher than the baseline outcome of no such CSA investments. We also find stronger household level effects, mainly in rural areas. Furthermore, a recurrent 1-in-5-year magnitude of climatic shock in Rwanda can cause substantial reductions in agricultural (-7.6 percent) and overall (-2.7 percent) GDP during the PSTA-5 period. The CSA interventions are impactful in minimizing the effects of climate change on the Rwandan economy.

Keywords: Climate-smart agriculture, economic modeling, food systems, Rwanda

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1 INTRODUCTION

Rwanda's agri-food system involves a complex network of actors linked to each other through their roles in producing, distributing, processing, and consuming primary agricultural and agro-processed products. The country's agri-food system contributes over 36 percent of gross domestic product (GDP) and employs about 68 percent of the workforce (Diao et al., 2023). Primary agriculture is the engine of growth, accelerating by about 5 percent annually over the past decade (NISR, 2024), currently contributing to 26 percent of GDP (Diao et al., 2023). With appropriate policy reforms and targeted investments, the sector has tremendous potential to further accelerate and contribute its critical share to Rwanda's economic transition.

However, the agriculture sector is highly vulnerable to climate change induced risks. Rainfall variability has been the most significant climatic risk affecting the performance of the agrifood system in Rwanda (Twahirwa et al., 2023). Changes in temperature and precipitation and their distributions are the key drivers of climate and weather-related disasters that negatively affect Rwandans and the overall economy (MoE, 2020). With the changing climate, it is likely that these phenomena will increase both with intensity and duration.

To accelerate and sustain agricultural growth, improve food and nutritional security, and increase the resilience of the economies to climatic shocks, countries incorporate climate-smart agricultural (CSA) practices in their sector development programs. The Rwandan government also incorporates an extensive list of CSA interventions in the recently implemented the Fifth Strategic Plan for Agricultural Transformation (PSTA-5) program which covers the period 2024/25-2028/29 (MINAGRI, 2024). These include a bold move to expand access to farmers services such as climate information system, crops and livestock insurance, micro credit, and animal health services. PSTA-5 also includes plans to expand agricultural infrastructure by investing in various types of irrigation schemes (marshland, hillside, and small scale) and terracing (progressive and radical).

As a guiding document, PSTA-5 includes explicit targets to be achieved associated with each of the CSA interventions. For example, it aims to increase the hectares of land under hillside irrigation by 416 percent from 9,439 hectares (ha) in 2023/24 to 48,667 ha in 2028/29 (MINAGRI, 2024). Likewise, it aims at increasing the coverage of radical terracing by 18 percent from 142,318 ha during the same period. These increases demonstrate the Rwandan Government's CSA commitments set forth under PSTA-5. However, there is no adequate quantitative assessment of the benefits of a successful achievement of these targets on the Rwandan agri-food system both with and without climatic risks.

Under such a background and to support evidence-based policy making, this paper aims at assessing the impacts of selected CSA interventions identified in the PSTA-5 on the Rwandan economy, focusing on macroeconomic, sectoral, and household level outcomes. This is accomplished using IFPRI's Rural Investment and Policy Analysis (RIAPA) modeling system (IFPRI, 2023) which uniquely integrates an investment module that translates identified investment targets into changes in productivity at the subsector level and a household survey-based microsimulation module that estimates changes in poverty and undernourishment. The RIAPA modeling system has been widely applied to evaluate the economywide impacts of various public expenditure options across different contexts (Thurlow et al. 2007; Pauw and Thurlow 2015; Benfica et al., 2019; Aragie et al., 2019; Aragie et al., 2024), including in Rwanda.

2 SELECTED CSA INVESTMENTS IN RWANDA'S PSTA-5

Rwanda's PSTA-5 (2024/25–2028/29) is designed to build climate-resilient food systems focusing on scaling climate-smart agriculture across production, value-chains and services. PSTA-5 mixes national policy with zone-specific packages (agroecology, irrigation, climate services) to fit local risks, and constitutes an investment envelope to mobilize public and private funds for achieving the stated objectives.

The main CSA practices and interventions promoted under PSTA-5 fall into the following seven groups. Table 1 summarizes the specific CSA-related practices along with their baseline values and targets for the end of the plan period. Table A1 provides the projected annual progress toward these targets through 2028/29.

Climate information, digital advisory, and early warning: PSTA-5 explicitly pushes digital extension and climate-smart advisory services through scaling mobile/ICT extension, local weather forecasts, and agro-advisories so farmers time planting and inputs. The plan document sets a target of increasing the share of farmers accessing weather information from the current rate of close to 10 percent to 65 percent by 2028/29, signifying a 55-percentage point jump in coverage (Table 1).

Risk-management, finance, and insurance: In its investment plan, PSTA-5 emphasizes mechanisms to increase farmers' access to micro credit such that they are able to unlock some of their input constraints, and expand access to crop and livestock insurance, weather-index insurance and blended finance to reduce investment risk in climate-sensitive agriculture. In its results framework, PSTA-5 aims at doubling the share of farmers accessing credit to 32 percent by the end of the plan period. From a base of one percent, PSTA-5 targets to increase to seven and two percent of crop and livestock farmers with agricultural insurance, respectively.

Climate resilient livestock practices: Risks and vulnerabilities of the livestock sector increase with climate variability. In recognition of this, Rwanda identifies practices that can enhance the sectors performance and resilience in times of dry spells, including improving fodder systems, access to health services, and shifting the breed composition. In particular, it targets increasing feed production by 112 percent to 163,000 metric tons, expanding the coverage of artificial insemination for cows by 72 percent, and covering 25 percent more animals with vaccines by 2028/29 compared to 2024/25.

Conservation agriculture and pest management: Rwanda's PSTA-5 promotes soil-friendly practices (minimum/no-till, mulching, cover crops, contour farming, and organic matter buildup) and sets ambitions to expand those practices at scale. The plan targets an almost ten-fold increase in areas under conservative agriculture from 1,060 ha to 10,000 ha by the end of the period. PSTA-5 also emphasizes using more traditional control of pests and reducing indiscriminate use of pesticides by increasing the share of farmers using pest and disease surveillance tools from the current rate of 7 percent to 40 percent by 2028/29.

Improved access to modern inputs: Farmers in Rwanda typically consume low levels of modern farm inputs including improved seed varieties and fertilizer, resulting in low productivity. PSTA-5 targets unlocking these input constraints by increasing the share of farmers using improved seeds and fertilizer over the coming five years by 14 and 12 percentage points, respectively.

Water and landscape management: Irrigation and terracing development has been central to agricultural development plans in Rwanda. With the changing climate, these have become urgent. Whereas water management reduces dependence on rainfall and supports intensification, terracing and agroforestry stabilize slopes and soil moisture context. PSTA-5 promotes irrigation and terracing schemes specific to the needs of each locality and topography. Overall, cropland under irrigation is planned to increase by about 85 percent from 71,585 ha to 132,171 ha. This expansion is mainly driven by extensive development in hillside irrigation. Likewise, Rwanda aims at boosting its terracing infrastructure by eight percent over the course of PSTA-5, with progressive terracing expansion providing most of these gains in ha.

Value-chain and post-harvest resilience: Post-harvest loss—implying inefficient use of human and natural resources—is a critical issue in Rwanda. As such, PSTA-5 aims at achieving productivity gains by cutting post-harvest handling and storage losses through better agro-logistics and value-chain investments. The sector development program targets at reducing the 14 percent post-harvest loss currently observed for most priority staple crops to eight percent by the end of the program, suggesting only a slightly ambitious plan compared to the 50 percent reduction in losses set forth under the global Sustainable Development Goals (SDGs) (Lipinski, 2024).

Table 1. List of CSA interventions and their corresponding PSTA-5 targets (cumulative)

CSA intervention	Code	Unit	2023/24 (Base year)	2028/29 (Target)	Increase (in % or p. points)
Climate information	climp	%	10.0	65.0	55.0
Farmers credit	cred	%	16.0	32.0	16.0
Crop insurance	cinsu	%	1.0	6.8	5.8
Livestock insurance	linsu	%	1.0	2.1	1.1
Conservation agriculture	cons	ha	1,055.7	10,000.0	847.2
Pest management	pstm	%	7.0	50.0	43.0
Livestock feed	afed	mt	77,023.0	163,000.0	111.6
Livestock breed (cattle)	abrdp	#	109,209.0	188,245.0	72.4
Livestock health (in TLU)*	ahth	#	38,560.0	48,236.7	25.1
Seeds - practice	seedsp	%	35.9	50.0	14.1
Fertilizer - practice	fertp	%	54.9	66.5	11.6
Marshland irrigation	mirri	ha	37,273.0	42,473.0	14.0
Hillside irrigation	hirri	ha	9,439.0	48,667.0	415.6
Small-scale irrigation	sirri	ha	24,873.0	41,031.0	65.0
Radical terraces	rterr	ha	142,318.0	167,268.0	17.5
Progressive terraces	pterr	ha	1,032,282.0	1,102,282.0	6.8
Food loss reduction	flwp	%	13.8	8.0	-5.8

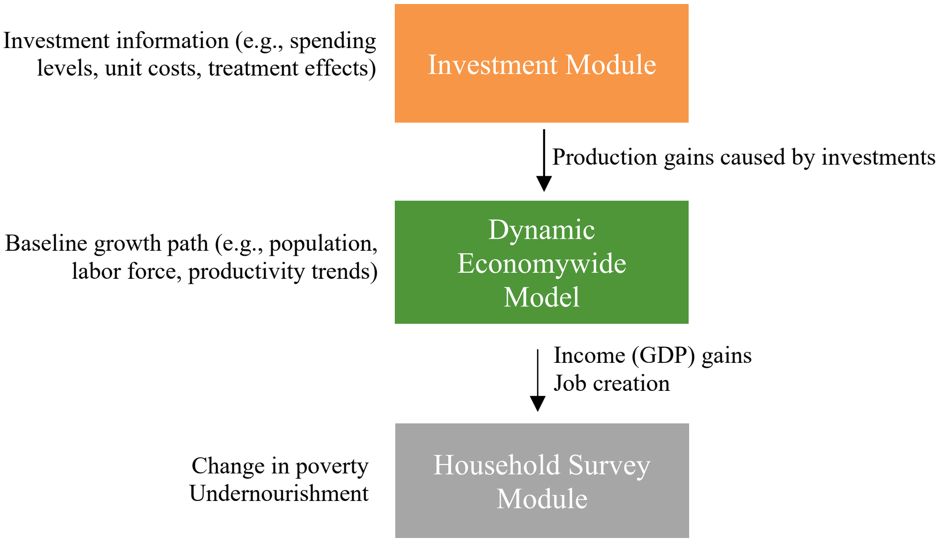
Note: *PSTA-5 set vaccination targets by animal type. Tropical livestock units of 1.0, 0.11, and 0.01 are used for cattle, small ruminants and poultry. In the simulations, separate animal health (vaccination) scenarios were designed for each animal type. Table A1 provides the annual targets for these interventions throughout the PSTA-5 period.
Source: MINAGRI (2024).

3 METHOD OF ANALYSIS

3.1 Modeling approach

This study estimates the impacts of a potential realization of planned targets for selected CSA interventions outlined in PSTA-5. The impacts are assessed across key outcome indicators, categorized into macroeconomic, sectoral, and household welfare dimensions. To do so, we apply IFPRI's RIAPA modeling system (IFPRI, 2023) which uniquely integrates an investment module that translates identified investments into changes in productivity at the subsector level and a household survey-based module that estimates changes in poverty (Figure 1).

Figure 1. A modeling framework for CSA investment and outcome analysis



Source: Authors' compilation

3.1.1 The economywide model

At the core of the integrated RIAPA framework is IFPRI's standard, recursive-dynamic computable general equilibrium (CGE) model. CGE models are widely utilized for economic policy formulation and analysis (Dixon and Parmenter, 1996; Devarajan and Robinson, 2010). They capture the interlinkages between sectors, households, and rural-urban economies, making them well-suited for assessing the economywide effects of public policies.

The Rwanda model used in this study is calibrated to a 2022 Social Accounting Matrix (SAM) for the country (IFPRI, 2024a). The model represents the economy through a set of disaggregated sectors, encompassing 33 agricultural sub-sectors, which include 24 individual crops or groups of crops, six livestock production sectors, as well as forestry and fisheries. The model also incorporates 36 industrial sectors—including 17 agro-processing activities—and 12 service sectors, which include food-related areas such as trade, transport, and restaurant services. This detailed representation of both the on-farm and off-farm components of the broader agrifood system permits detailed analysis of agrifood value chains, from primary producers to processors and traders to final consumers.

The Rwanda model also distinguishes 15 representative households, each of which is an aggregation of a group of households captured in the 2016/17 Fifth Integrated Household Living Conditions Survey (EICV5) (NISR, 2018). These households are categorized into rural and urban, with rural households further divided into farm and non-farm groups based on their reliance on agriculture as a primary source of income. Finally, each household group is further disaggregated by per capita expenditure quintiles. In the model, households earn labor income and receive returns on their assets, which include land and capital, as well as domestic or foreign transfers.

The CGE model is used to produce a baseline that follows historical levels of economic and sectoral growth, population and labor force growth, and levels of government spending. This "business-as-usual" scenario runs until 2038/39. All investment scenarios are compared against this baseline. As will be seen later, the temporal feature of the model allows us to examine how the effects of various interventions change over time.

3.1.2 The investment module

The investment module is used to synthesize data from several sources to measure at a detailed sectoral level the expected productivity gains that can be attributed to a unit expansion in access to agricultural inputs and infrastructures. The module used in this study is a newly updated version of the framework previously adopted in various contexts (Aragie et al., 2022; Benfica et al., 2019; Pauw and Thurlow, 2015). The previous version of the investment module was elaborated in Aragie et al. (2024). In this study, the investment module tracks 17 individual interventions, with some targeting up to six distinct groups of agricultural sectors.

The investment module used in this study structures agrifood investments and processes data on targeted gains in coverage across selected interventions across sectors. Specifically, it integrates investment details—such as targeted changes in adoption rates and impact coefficients (or marginal effects)—as inputs and generates corresponding productivity gains as outputs that in turn enter to the core dynamic economywide model as a shock to generate a new economic structure.[1] Adoption rates refer to the extent to which access to input is expanding, expressed as a percentage of the target area or number of animals. The productivity gains are then transmitted to the economywide model, which endogenously adjusts the targeted sector's productivity levels. Through direct and indirect economywide linkages, these adjustments drive changes in income, prices, employment levels, and other key economic indicators. While previous studies linked adoption rates to input unit costs and planned spending levels, here we focus directly on the coverage rates explicitly targeted during the PSTA-5 period.

Both baseline coverage levels and targeted rates for the investment areas considered in this study are obtained from the PSTA-5 document (MINAGRI, 2024) which reports the number of farmers with access to certain technologies and practices or the cropland covered by those technologies and practices. Meanwhile, impact coefficients—which measure the change in productivity resulting from the adoption of a specific technology or practice—can be estimated using farm household surveys or can otherwise be sourced from existing literature. Alternatively, crop models, which simulate how crops interact with their environment and respond to various factors, can provide usable impact estimates for many crops and interventions. Table A2 in the annex presents the impact coefficients obtained from IFPRI's crop model for Rwanda (IFPRI, 2024). Given these fundamental features of sector-investment combinations, the final productivity gains for each sector will be determined by the level of expansion in access to inputs.

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[1] The investment model adopted in this study does not include the costs of the interventions or the associated budget. In other words, this study estimates the benefits of the CSA investments without accounting for the costs involved.

Investment budgeting can also be incorporated into the modeling using realistic estimates of unit costs, which are often the most difficult pieces of information to obtain for each type of investment.

3.1.3 The household survey module

While major economic indicators – changes in economic growth and job creation – are directly calculated from the core economywide model, assessing changes in social and environmental indicators necessitates specialized modules. To this end, the CGE model is linked top-down with household survey-based microsimulation modules measuring changes in poverty, the prevalence of undernourishment, and diet deprivation. Real income changes for different household groups result in diverse effects on these social outcomes.

Changes in poverty are calculated by linking a poverty microsimulation module to the outcome variables of the CGE model—namely, household income, prices, and consumption—following the methodology of Arndt et al. (2012). The changes in real consumption across commodities, derived from the RIAPA model, are then applied to the corresponding households in the 2016/17 EICV5 (NISR, 2018), which are mapped to 15 representative household groups within the CGE model. The new poverty status is computed for all sampled households. Likewise, the undernourishment model uses the same set of households and measures the change in the share of the population below a minimum dietary energy requirement per capita per day.

3.2 Scenario design

This study considers four major groups of scenarios: (i) the Baseline scenario, (ii) the CSA scenario, (iii) the Climate scenario, and (iv) the CSA + Climate scenario.

Baseline scenario: This scenario predicts the Rwandan economy until 2038/39 considering the recent economic performance, current practices and rates of yield increases. This scenario considers no fundamental changes in key climate indicators and assumes away rapid onset changes such as drought and flooding during the simulation period. Further, in this scenario, we assume no adoption of climate smart agricultural practices as those identified in the PSTA-5. By doing so, the baseline scenario establishes an economic trajectory against which we compare outcomes under alternative shock and policy scenarios.

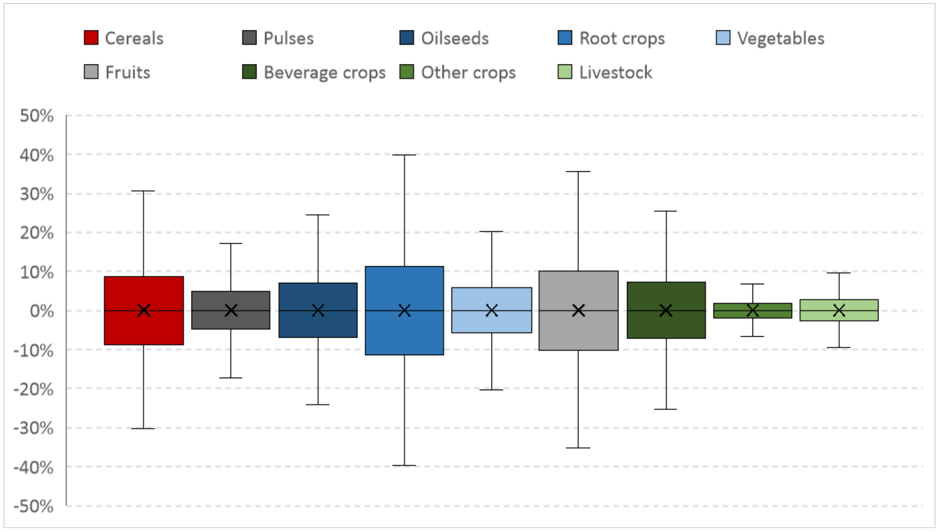
CSA scenario: In this scenario, we assume that the various CSA practices identified in PSTA-5 are implemented to the full extent. This scenario includes 17 main CSA scenarios, with some of them—such as seeds, fertilizer, irrigation, and terracing—further disaggregated by agricultural subsector. See Table A1 for the list of modeled CSA interventions and their corresponding targets under PSTA-5. In this scenario, these practices are not affected by climatic shocks during the course of the simulation period. This scenario aims at evaluating the economic and social impacts of the full implementation of those practices as planned in the absence of climate change.

Climate scenario: Based on climate impact projections and historical evidence of yield fluctuations, we assume that agricultural subsectors experience recurrent yield shocks or climatic risks every five years. These shocks are modeled as equivalent to the magnitude of a 1-in-5-year climate-related yield decline observed over the 1990–2021period. Specifically, we assume such shocks occur at the end of the PSTA-5 plan periods: 2028/29, 2033/34, and 2038/39. This climatic risk analysis follows the sectoral pattern reported in Figure 2. The figure shows that, historically, cereals, fruits, and root crops experience the highest yield shocks in the range of 10.8–14.1 percent every five years, whereas cash crops, other than beverages and livestock, experience the least, suggesting interventions that focus on the most vulnerable sectors may face volatility in impacts. In this scenario analysis, the timing and frequency of these climatic shocks are critical, as they strongly influence the extent to which CSA practices can mitigate their adverse impacts.

CSA + Climate scenario: In this scenario, we aim at assessing the contribution of CSA in mitigating some of the impacts of climate change as proxied by the decline in yield defined in the Climate scenario.

Unlike previous agri-food investment studies using the RIAPA modeling system (Aragie et al., 2024; Aragie et al., 2022, Pauw and Thurlow, 2015), we focus here on assessing the benefits of these investments without providing a detailed accounting of costs due to further challenges on accessing reliable unit cost data of expanding coverage of some of the investments considered in this analysis.

Figure 2. Historical production shocks for crops and livestock in Rwanda (in %)



Production losses during 1-in-5-year event

Cereals	-10.8%
Pulses	-6.1%
Oilseeds	-8.7%
Root crops	-14.1%
Vegetables	-7.2%
Fruits	-12.6%
Beverage crops	-9.1%
Other crops	-2.4%
Livestock	-3.4%

Note: The historical variability values are residual fluctuations from the determined production time series for 1990-2021. Fruits, root crops, and livestock are the three main contributors of agricultural GDP, with shares of 29, 24 and 12 percent, respectively. Beverage crops and pulses follow, contributing 11 and 9 percent.

Source: IFPRI (2024)

4 MODEL RESULTS

4.1 Macroeconomic effects

Table 1 reports the changes in selected macroeconomic indicators under the alternative scenarios compared to the Baseline scenario during selected years across the simulation period. Under the baseline growth trajectory, the Rwandan economy is predicted to expand to 15.6 billion USD by 2028/29 from the current 13.5 billion USD (Table 2). Most of this growth is due to an expansion in exports and private consumption. Thanks to the CSA interventions incorporated in the PSTA-5, the economy could increase an additional 1.3 percent by the end of the plan period than without these interventions. This growth is contributed by a 1.1 percent higher domestic absorption—a measure of final demand by households, the government, and gross investment—owing mainly to a 1.7 percent increase in private consumption. Meanwhile, export performance accelerates by 0.8 percent relative to the state without the CSA interventions, ultimately contributing to a slight currency appreciation. Infrastructural investments, such as irrigation and terracing, persist over the medium term reflected in the macroeconomic indicators and prevail until 2038/39, albeit with declining magnitudes over time.

By contrast, the simulated climatic risks - i.e., a recurrent 1-in-5-year yield shocks—can noticeably deviate the economy from its trend performance, causing a 2.7 percent decline in GDP from the baseline level during the years where the climatic simulated shocks are observed (i.e., 2028/29, 2033/34, and 2038/39). These effects are more pronounced on private consumption for a couple of reasons. Firstly, most households in Rwanda base their livelihoods on the agricultural sector which has historically been vulnerable to the effects of climatic shocks. Secondly, agri-food consumption constitutes a substantial share of spending by these households—climatic shocks make food products scarce and unaffordable for many. Further, as the export base of the economy—agriculture—is hit hard by the climate shocks, export performance declines, limiting foreign exchange inflows and depreciating the local currency during the respective shock years.

Under CSA + Climate scenario, we overlay climate risk scenarios onto the CSA scenarios to see the net effects of investing on the identified interventions. We observed from Table 2 that the magnitude of the historically observed 1-in-5-years yield shock in agriculture is strong enough that the CSA interventions do not fully compensate for the effects of climate on the macroeconomy. For example, GDP in 2028/29 remains 1.3 percent lower during the same year than its level under the Baseline scenario. Nevertheless, these interventions moderate the effect of climatic shock by 1.4 percent compared to the outcome under the Climate scenario. Importantly, the effects of climatic shocks on the economy, the CSA + Climate scenario, increase over time as short term or recurrent CSA interventions such as seeds, fertilizer, and credit cease their moderating effect and infrastructural investments such as irrigation gradually depreciate over time and become less efficient.

Table 3 reports the cumulative effect on selected macroeconomic variables under the alternative scenarios. For the cumulative impact analysis, we group the time periods into 2024/25-2028/29 to cover the entire PSTA-5 period, 2029/30–2034/35 to assess the medium-term impacts over the next five years, and the 2034/35–2038/39 period to assess the longer time effects. We observe from the table that the CSA interventions, under the CSA scenario, increases Rwanda's GDP by 0.9 percent points when compared to the cumulative GDP without the interventions. This reduced cumulative GDP effect compared to the effect reported in Table 2 for year 2028/29 suggests a smaller effect from some interventions in the earlier period and a more pronounced effect later. This is also supported by the slightly higher (1.1 percent) cumulative GDP effect during the 2029/30–2033/34 period. The cumulative effect on macroeconomic variables further shows the persistence effect of some of the interventions which goes beyond the PSTA-5 period.

Meanwhile, the Climate scenario shows that a one-time shock in the order of 1-in-5-years yield shock magnitude on the country's agriculture makes the Rwandan economy 0.6 percent lower on average over a five-year period. However, the CSA interventions identified in the PSTA-5 help the economy recover well from the impacts of the climate shocks throughout the simulation period as depicted under the CSA + Climate scenario.

Table 2. Macroeconomic effect of alternative scenarios during selected years (in %)

	GDP in bil. USD				Change in macroeconomic variables from the Baseline scenario (%)								
	Baseline				CSA			Climate			CSA + Climate		
	2023/24	2028/29	2033/34	2038/39	2028/29	2033/34	2038/39	2028/29	2033/34	2038/39	2028/29	2033/34	2038/39
Absorption	16.8	19.2	22.0	25.1	1.1	0.9	0.6	-2.3	-2.3	-2.3	-1.1	-1.4	-1.7
Private consumption	10.7	12.2	14.0	16.0	1.7	1.3	0.9	-3.2	-3.2	-3.2	-1.5	-1.9	-2.3
Investment demand	3.7	4.2	4.8	5.4	0.3	0.2	0.2	-1.1	-1.1	-1.1	-0.7	-0.8	-0.9
Export	3.3	3.9	4.6	5.4	0.8	0.6	0.4	-2.5	-2.4	-2.3	-1.6	-1.8	-1.9
Import	-5.6	-6.4	-7.3	-8.3	0.5	0.4	0.3	-1.5	-1.5	-1.5	-1.0	-1.2	-1.3
GDP at factor cost	13.5	15.6	17.9	20.6	1.3	1.1	0.7	-2.7	-2.7	-2.7	-1.3	-1.6	-1.9
Exchange rate	1.0	1.0	1.0	1.0	0.2	0.2	0.2	-2.0	-2.1	-2.2	-1.6	-1.8	-1.9

Table 3. Macroeconomic effect of alternative scenarios, cumulative (in %)

	GDP in bil. USD			Change in macroeconomic variables from the Baseline scenario (%)								
	Baseline			CSA			Climate			CSA + Climate		
	2024/25-2028/29	2029/30-2033/34	2034/35-2038/39	2024/25-2028/29	2029/30-2033/34	2034/35-2038/39	2024/25-2028/29	2029/30-2033/34	2034/35-2038/39	2024/25-2028/29	2029/30-2033/34	2034/35-2038/39
Absorption	91.1	104.2	119.1	0.7	0.9	0.8	-0.5	-0.5	-0.5	0.2	0.4	0.3
Private consumption	57.8	66.3	75.8	1.1	1.4	1.2	-0.7	-0.7	-0.7	0.4	0.7	0.5
Investment demand	20.0	22.6	25.6	0.2	0.2	0.2	-0.2	-0.2	-0.2	0.0	0.0	0.0
Export	18.4	21.7	25.5	0.6	0.6	0.5	-0.5	-0.5	-0.5	0.0	0.1	0.0
Import	-30.3	-34.5	-39.4	0.3	0.4	0.3	-0.3	-0.3	-0.3	0.0	0.0	0.0
GDP at factor cost	73.5	84.8	97.7	0.9	1.1	0.9	-0.6	-0.6	-0.6	0.3	0.5	0.4
Exchange rate	1.00	1.01	1.03	0.0	0.1	0.0	0.0	-0.3	0.0	0.0	0.0	0.0

4.2 Sectoral effects

In this section, we discuss the impacts of various scenarios on detailed sub-sectors of the economy. Table 5 reports changes in sectoral GDP during selected years across alternative scenarios compared to the Baseline outcome. As illustrated in the table, the agricultural sector experiences the most gain in growth under the CSA scenario when compared to the baseline outcome. In particular, agricultural GDP is 4.2 percent higher in 2028/29 compared to its level during the same year under the Baseline scenario. Roots and horticulture grow faster, showing stronger impacts on these sectors from the interventions considered. As the agricultural sector expands, ago-processing accelerates—resulting in a 1.6 percent greater than baseline outcome—due to a cheaper supply of intermediate inputs. Together with linkage effects elsewhere in the manufacturing sector, this expansion in agro-processing contributes to a 0.9 percent higher growth in the sector in 2028/29 under the CSA scenario compared to the Baseline scenario. Although we simulate the CSA interventions for the 2024/25–2028/29 period, their effect on the economy persists for several more years due to lagged effects of some of the interventions. Specifically, the agricultural sector expands by 3.3 during the intervention period and 2.2 percent over the 2033/34 to 2038/39 time period when compared to the Baseline scenario. In addition, the agro-processing sector continued to perform robustly over this period.

Meanwhile, the simulated climate shocks significantly alter the performance of the agricultural sector. The difference in impact on agricultural GDP is approximately 4.7 percentage points less decline with the CSA interventions as opposed to the Baseline scenario during the three shock years (2028/28, 2033/34, and 2038/39). This decline is mainly contributed by the poor performances in the horticulture and pulses sectors as these sectors face the brunt of the 1-in-5-year climate-induced productivity shocks (Figure 2). Following the growth effect in the agricultural sector, the performance of the manufacturing sector—particularly agro-processing—contracts as well, as inputs become scarce and costly, while demand from agriculture for intermediate manufactured goods declines.

Table 5 further reports the contribution of the CSA interventions in reducing the negative impacts of climate risks (CSA + Climate scenario) during climate shocks. We observe from the results that, despite strong mediating effect of CSA practices identified in PSTA-5, Rwanda's agriculture can decline by up to 3.2 percent during a shock, possibly increasing to a 5.2 percent decline as a result of a similar magnitude of shock beyond the PSTA-5 period if such investments are not sustained.

Table 6 reports the cumulative effects under the alternative scenarios at the sectoral level. In contrast to Table 5, which reports effects in selected years (i.e., period end effects), Table 6 reports the period-wide average sectoral effects. We note from the CSA scenario in the table that the cumulative agricultural GDP during the PSTA-5 period becomes 2.7 percent higher than the level under the Baseline scenario, signifying a noticeable effect of the interventions throughout the plan period. This growth in agriculture is complemented by a modest growth in cumulative manufacturing GDP.

Further, the Climate scenario shows that a 1-in-5-years climatic shock can cause the five-year cumulative agricultural sector GDP to decline by 1.6 percent due to the one-time strong effect on the sector and the time it takes for it to recover. Against what is reported in Table 5 under the CSA + Climate scenario which shows a strong decline in sectoral GDP when the CSA and Climate scenarios are jointly considered, Table 6 shows net increase in cumulative sectoral GDP over five years as the economic acceleration during non-climatic shock years over-compensate for the economic contractions during the climate shock years. We observe from the results that cumulative agricultural GDP increases by 1.1 percent during the PSTA-5 period, with persistent positive effects in the succeeding periods. However, the cumulative gain in agricultural GDP does not translate into a noticeable increase in manufacturing GDP, as the adverse effects of climate shocks on the manufacturing sector outweigh the positive impacts of CSA interventions.

This study evaluates the impacts of 17 CSA interventions incorporated within Rwanda's PSTA-5 on various economic outcomes. Results reported so far relate to the aggregate or composite effects of these interventions.[2] Table 4 reports the contribution of each group of interventions to total gains in overall and agricultural cumulative GDP over a course of years. The table ranks the interventions based on their impacts in total GDP over the first five-year period. Results show significant differences in the contribution of each intervention and overtime. Infrastructural investments including irrigation (mainly hillside irrigation) and terracing (mainly progressive terracing) jointly contribute over half (56 percent) of the gain in overall and agricultural sector GDP during the PSTA-5 period. Climate information system (close to 16 percent) and pest management (12 percent) follow due to a significant targeted shift in the share of farmers having access to these services (from as low as 7 percent of farmers to over 50 percent by 2028/29). We also observe temporal differences in impacts across the interventions. While the contributions of irrigation and terracing increased gradually to 93 and 97 percent during the 2029/30–2033/34 and 2034/35–2038/39 period, respectively, most recurrent type spendings quickly lose impact as the gain in productivity disappears when the spendings cease.

Table 4. The contribution of each group of investments to cumulative GDP gain under CSA scenario (in %)

	Total GDP			Agricultural GDP		
	2024/25-2028/29	2029/30-2033/34	2034/35-2038/39	2024/25-2028/29	2029/30-2033/34	2034/35-2038/39
Progressive terraces	25.4	40.9	42.1	25.3	40.6	41.5
Climate information	16.3	0.0	0.0	16.6	0.2	0.1
Hillside irrigation	13.8	25.5	27.4	13.7	25.3	27.0
Pest management	11.7	0.0	0.0	12.1	0.1	0.1
Radical terraces	8.9	14.7	15.2	8.8	14.5	14.9
Small-scale irrigation	7.5	12.0	12.2	7.6	12.4	13.0
Crop insurance	4.2	0.4	0.0	4.4	0.4	0.0
Food loss reduction	3.4	1.6	0.0	3.5	1.8	0.1
Seeds - practice	2.5	0.0	0.0	2.6	0.0	0.0
Fertilizer - practice	1.4	0.0	0.0	1.5	0.0	0.0
Marshland irrigation	1.3	2.8	3.0	1.2	2.8	3.1
Livestock breed (cattle)	1.2	0.6	0.1	0.7	0.4	0.0
Farmers credit	1.0	0.9	0.0	0.9	0.9	0.0
Livestock health (in TLU)	0.7	0.0	0.0	0.6	0.0	0.0
Conservation agriculture	0.4	0.5	0.0	0.4	0.5	0.0
Livestock feed	0.1	0.0	0.0	0.1	0.0	0.0
Livestock insurance	0.1	0.0	0.0	0.0	0.0	0.0

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[2] We also examined whether the rankings of these interventions by total impact change significantly once climatic risks are considered. Overall, the rankings remain largely unchanged, with only a slight improvement for animal health interventions and a minor decline for conservation agriculture since livestock is typically one of the least affected sectors by climate variability.

Table 5. Sectoral effect of alternative scenarios during selected years (in %)

	GDP in bil. USD				Change in GDP from the Baseline scenario (%)								
	Baseline				CSA			Climate			CSA + Climate		
	2023/24	2028/29	2033/34	2038/39	2028/29	2033/34	2038/39	2028/29	2033/34	2038/39	2028/29	2033/34	2038/39
Total GDP	13.5	15.6	17.9	20.6	1.3	1.1	0.7	-2.7	-2.7	-2.7	-1.3	-1.6	-1.9
Agricultural GDP	3.6	4.2	4.8	5.4	4.2	3.3	2.2	-7.4	-7.4	-7.4	-3.2	-4.1	-5.2
Cereals	0.2	0.2	0.2	0.3	5.5	4.7	3.1	-7.1	-7.2	-7.2	-1.3	-2.2	-4.0
Pulses	0.3	0.3	0.4	0.4	3.6	2.2	1.5	-9.8	-9.8	-9.8	-6.3	-7.6	-8.3
Roots	0.6	0.8	0.9	1.0	8.2	6.9	4.5	-6.7	-6.8	-6.8	1.5	0.1	-2.3
Horticulture	0.9	1.0	1.2	1.3	6.8	5.7	3.7	-11.2	-11.2	-11.3	-4.5	-5.5	-7.6
Others crop	0.3	0.4	0.4	0.5	3.2	1.6	1.1	-9.0	-9.1	-9.2	-5.7	-7.5	-8.0
Livestock	0.4	0.5	0.5	0.6	0.8	0.3	0.2	-10.7	-10.7	-10.7	-9.8	-10.4	-10.5
Mining	0.4	0.5	0.6	0.6	0.0	0.1	0.1	0.0	0.0	-0.1	0.1	0.1	0.0
Manufacturing	1.4	1.7	2.0	2.3	0.9	0.7	0.5	-2.7	-2.7	-2.7	-1.7	-1.9	-2.1
Agro-processing	0.9	1.1	1.2	1.4	1.6	1.3	1.0	-4.7	-4.9	-5.0	-2.9	-3.4	-3.9
Services	6.5	7.5	8.7	10.0	0.2	0.2	0.1	-0.6	-0.6	-0.6	-0.4	-0.4	-0.5

Table 6. Sectoral effect of alternative scenarios, cumulative (in %)

	GDP in bil. USD			Change in GDP from the Baseline scenario (%)								
	Baseline			CSA			Climate			CSA + Climate		
	2024/25-2028/29	2029/30-2033/34	2034/35-2038/39	2024/25-2028/29	2029/30-2033/34	2034/35-2038/39	2024/25-2028/29	2029/30-2033/34	2034/35-2038/39	2024/25-2028/29	2029/30-2033/34	2034/35-2038/39
Total GDP	73.5	84.8	97.7	0.9	1.1	0.9	-0.6	-0.6	-0.6	0.3	0.5	0.4
Agricultural GDP	19.7	22.6	25.8	2.7	3.5	2.9	-1.6	-1.6	-1.6	1.1	1.9	1.3
Cereals	1.0	1.1	1.3	3.5	4.8	4.1	-1.5	-1.5	-1.5	2.0	3.4	2.6
Pulses	1.6	1.8	2.0	2.5	2.4	1.9	-2.1	-2.1	-2.1	0.4	0.3	-0.2
Roots	3.5	4.1	4.8	5.2	7.1	6.0	-1.4	-1.5	-1.5	3.8	5.6	4.5
Horticulture	5.0	5.6	6.2	4.2	5.9	5.0	-2.4	-2.3	-2.3	1.8	3.6	2.7
Other crops	1.9	2.1	2.3	2.4	1.8	1.4	-1.9	-2.2	-2.2	0.5	-0.4	-0.8
Livestock	2.2	2.5	2.9	0.5	0.4	0.3	-2.3	-2.3	-2.3	-1.8	-1.9	-2.1
Mining	2.3	2.6	3.0	-0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.1	0.1
Manufacturing	8.0	9.4	11.0	0.5	0.7	0.6	-0.6	-0.6	-0.6	0.0	0.2	0.1
Agro-processing	5.0	5.8	6.6	1.0	1.3	1.2	-1.0	-1.1	-1.2	0.1	0.2	0.0
Services	35.7	41.2	47.5	0.1	0.2	0.2	-0.1	-0.1	-0.1	0.0	0.0	0.0

4.3 Household welfare effects

In this section, we discuss changes in household consumption, poverty, and undernourishment due to the simulated changes in the economy. Table 7 reports changes in cumulative household consumption spending under alternative scenarios. Cumulative spending at the national level over the five-year period under the CSA scenario increases by over 1 percent compared to the Baseline scenario. Note that the gains in household consumption are noticeably stronger in the second five-year period due to strong but lagged impacts of infrastructural spendings made during the PSTA-5 period. This finding is in line with the sectoral impact reported in Table 6. Most of the gains flow to poorer households - both in rural and urban areas - as these households heavily rely on the domestic agricultural sector as a source of income and consumption. Arguably, the gain in consumption spending is stronger in rural areas due to the strong income effect on residents in these parts of the country as agriculture growth accelerates.

As expected, the Climate scenario presents an opposite consumption effect when compared with the CSA scenario. We noted from Table 7 that the modeled climatic shocks cause a 0.7 percent decline in cumulative household consumption over each of the five-year periods considered from the 1-in-5-year historical climatic shock. Rural households and the poor in both rural and urban areas suffer the brunt of the climatic shocks.

We also compare CSA + Climate scenario consumption spending when the climatic shocks are experienced, against consumption spending observed under the Baseline scenario. Results show a modest increase in cumulative consumption spending across all household groups owing to the strong cumulative effect of PSTA-5 interventions. The same pattern of gain in consumption spending across household groups discussed above is observed under the CSA + Climate scenario.

Table 8 reports changes in poverty and undernourishment as two related social outcome indicators. The table shows a poverty rate of about 55 percent in Rwanda, using the percentage of people below the $1.9/day/person poverty line. Under the current trajectory, national poverty would decline by 2.6 percentage points by the end of the PSTA-5 period. However, this rate can fluctuate due to targeted investments such as those planned under PSTA-5 or because of climate variability. In fact, CSA interventions modeled in this study could reduce the national poverty rate by over 2.0 percentage points by 2028/29 as the economy, particularly agriculture, accelerates. While poverty in urban areas declines noticeably, most of the decline in poverty occurs in rural areas since rural households benefit the most from the investments in the form of higher incomes and consumption spending derived from agriculture. We also note from the results that the poverty reduction effect of the CSA interventions could go beyond the PSTA-5 period, resulting in 1.6 and 1.0 percentage point lower rates of poverty by 2033/34 and 2038/39, respectively, even if spending on the interventions is not sustained beyond the plan period. This further suggests that sustaining and accelerating CSA interventions beyond PSTA-5 can contribute to a rapid reduction in poverty over the medium- and long-run.

In contrast to the positive impacts of CSA interventions on the rate of poverty, climatic risks that cause yield declines equivalent to the historically observed 1-in-5-year shock can add to poverty as a development challenge by increasing the poverty rate by over 3.4 percentage points during the specific years that such shocks occur. As the benefits of CSA interventions are pronounced in rural areas, the cost of climatic shocks in the form of poverty is also stronger in rural areas due to direct impact on the agricultural sector. The poverty impact in urban areas is also not negligible as urban households in developing countries such as Rwanda rely on agri-food systems for their livelihoods and spend most of their incomes on agri-food products.

The CSA + Climate scenario combines the effects of both CSA interventions and climatic shocks. Overall, although the poverty impact of a one-time climate shock diminishes over time, say the PSTA-5 period, the immediate effect during the shock year remains poverty-increasing, even under the simulated levels of CSA interventions.

Table 8 also reports the effects of the different scenarios on undernourishment, which measures the change in people with access below a certain minimum dietary energy requirement. We find a somewhat stronger impact on undernourishment compared to poverty. Unlike the poverty effects, however, CSA interventions have a slightly greater impact on reducing undernourishment in urban areas, reflecting improved access to nutrition as food becomes relatively more affordable. By contrast, climate shocks under the Climate scenario lead to a larger increase in undernourishment in rural areas, where farm households experience income losses alongside reduced market purchases and own consumption of food. Under the CSA + Climate scenario, undernourishment temporarily rises in Rwanda during the shock years, although CSA interventions contribute to improved food access in the post-shock period.

Table 7. Household consumption effect of alternative scenarios, cumulative effect (in %)

	Consumption spending in bil. USD			Change in consumption spending from the Baseline scenario (%)								
	Baseline			CSA			Climate			CSA + Climate		
	2024/25-2028/29	2029/30-2033/34	2034/35-2038/39	2024/25-2028/29	2029/30-2033/34	2034/35-2038/39	2024/25-2028/29	2029/30-2033/34	2034/35-2038/39	2024/25-2028/29	2029/30-2033/34	2034/35-2038/39
National	57.8	66.3	75.9	1.1	1.4	1.2	-0.7	-0.7	-0.7	0.4	0.7	0.5
Poor	7.9	9.1	10.5	1.6	2.1	1.8	-0.8	-0.8	-0.9	0.8	1.3	0.9
Non-poor	49.9	57.1	65.4	1.0	1.3	1.1	-0.7	-0.7	-0.7	0.3	0.6	0.4
Rural	31.0	35.6	40.8	1.3	1.8	1.5	-0.7	-0.8	-0.8	0.6	1.0	0.7
Poor	7.2	8.3	9.5	1.6	2.1	1.8	-0.8	-0.8	-0.8	0.8	1.3	0.9
Non-poor	23.8	27.3	31.2	1.2	1.7	1.4	-0.7	-0.7	-0.8	0.6	0.9	0.7
Urban	26.8	30.7	35.1	0.8	0.9	0.8	-0.6	-0.6	-0.6	0.1	0.3	0.2
Poor	0.7	0.8	1.0	1.7	2.1	1.7	-1.1	-1.0	-1.0	0.6	1.1	0.7
Non-poor	26.1	29.9	34.1	0.7	0.9	0.8	-0.6	-0.6	-0.6	0.1	0.3	0.2

Table 8. Poverty and undernourishment effects of alternative scenarios during selected years

	Poverty and undernourishment rates (%)				Change in poverty and undernourishment rates (p. point)								
	Baseline				CSA			Climate			CSA + Climate		
	2023/24	2028/29	2033/34	2038/39	2028/29	2033/34	2038/39	2028/29	2033/34	2038/39	2028/29	2033/34	2038/39
Poverty													
National	54.6	52.0	49.2	46.5	-2.1	-1.6	-1.0	3.4	3.6	3.8	1.4	2.1	2.7
Rural	60.9	58.1	55.2	52.1	-2.2	-1.7	-1.1	3.7	3.9	4.2	1.5	2.3	3.0
Urban	25.4	24.0	21.9	20.6	-1.7	-0.7	-0.5	1.9	2.6	1.9	0.9	1.2	1.1
Undernourishment													
National	34.5	32.5	30.6	28.6	-2.3	-2.0	-1.1	3.6	3.5	3.8	1.1	1.6	2.5
Rural	37.1	34.9	33.0	30.9	-2.3	-2.1	-1.3	3.8	3.6	3.8	1.2	1.5	2.5
Urban	22.8	21.4	19.7	17.9	-2.4	-1.8	-0.3	2.7	3.1	3.6	1.0	1.7	2.4

5 CONCLUDING REMARKS

Rwanda's agri-food system contributes over 36 percent of gross domestic product (GDP) and employs about 68 percent of the workforce, yet it remains highly vulnerable to climate variability. To accelerate and sustain growth, strengthen resilience to shocks, and enhance food security, the government has integrated a set of climate-smart agricultural (CSA) interventions into its updated Fifth Strategic Plan for Agricultural Transformation (PSTA-5), with ambitious and explicit targets. However, there has been no comprehensive quantitative assessment of the potential benefits of achieving these targets for Rwanda's agri-food system, either with or without the presence of climate risks.

This study assesses the impacts of selected climate-smart agricultural (CSA) interventions outlined in PSTA-5 on the Rwandan economy, focusing on macroeconomic, sectoral, and household-level outcomes. It also evaluates the moderating role of these interventions when the economy is exposed to historically observed 1-in-5-year climatic shocks affecting agricultural performance. In order to achieve these results this analysis employs IFPRI's Rural Investment and Policy Analysis (RIAPA) modeling system (IFPRI 2023), which integrates (i) an investment module that translates intervention targets into subsector-level productivity changes and (ii) a household survey–based microsimulation module that estimates effects on poverty and undernourishment.

Results indicate that CSA interventions can accelerate overall GDP growth by 1.3 percent and agricultural GDP growth by 4.2 percent by the end of the PSTA-5 period. Roots and horticulture experience the fastest growth, reflecting stronger intervention impacts. As agriculture expands, agro-processing also accelerates, reaching 1.6 percent above baseline due to cheaper intermediate inputs. Importantly, CSA effects persist beyond the plan period: agricultural GDP is projected to remain 3.3 percent and 2.2 percent higher than baseline by 2033/34 and 2038/39, respectively. Cumulative period analyses (2024/25–2028/29, 2029/30–2034/35, and 2034/35–2038/39) reveal similar patterns, while highlighting differences between short-run and medium- to long-run impacts across interventions.

By contrast, recurrent climate shocks—modeled as 1-in-5-year yield losses—significantly disrupt economic performance, reducing overall GDP by 2.7 percent and agricultural GDP by 7.4 percent in the simulated shock years (2028/29, 2033/34, and 2038/39). The magnitude of the historically observed 1-in-5-years yield shock in the economy is strong enough to negate the positive CSA interventions of climate on the macroeconomy. However, period long performance indicates positive net effects from these interventions. Infrastructure-focused interventions, particularly irrigation and terracing, emerge as the most impactful, with their relative contribution increasing over time.

At the household level, CSA practices boost consumption and reduce poverty and undernourishment. Gains in consumption become more pronounced in the second five-year period after PSTA-5, reflecting lagged effects of infrastructure investments. Poor and rural households benefit the most, given their heavy reliance on domestic agriculture. In contrast, under the climate shock scenario, consumption falls sharply, with rural households and the poor in both rural and urban areas most adversely affected. CSA interventions mitigate these risks, reducing poverty and undernourishment across rural and urban areas, while climatic shocks threaten to reverse development gains achieved through agricultural growth.

Overall, the study demonstrates significant economic and welfare gains from fully implementing CSA interventions under PSTA-5. Realizing these benefits, however, will depend on Rwanda's ability to mobilize sufficient financing, strengthen implementation capacity, and effectively target interventions. Given the persistent risks posed by climate variability, increased investment in early warning systems and resilience-building infrastructure will be essential to safeguard and sustain development gains.

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7 APPENDIX

Table A1. List of CSA interventions and their corresponding PSTA-5 targets (cumulative) modeled

CSA intervention	Code	Unit	2023/24 (Base year)	2024/25	2025/26	2026/27	2027/28	2028/29	PSTA-5 description
Climate information	climp	%	10.0	20.0	30.0	45.0	55.0	65.0	Farmers accessing weather information
Farmers credit	cred	%	16.0	16.0	19.0	22.0	27.0	32.0	Farmers accessing credit
Crop insurance	cinsu	%	1.0	5.7	6.0	6.2	6.5	6.8	Crop farmers with agriculture insurance
Livestock insurance	linsu	%	1.0	1.5	1.7	1.8	1.9	2.1	Animal farmers with agriculture insurance
Conservation agriculture	cons	ha	1,055.7	1,173.0	2,000.0	3,500.0	5,000.0	10,000.0	Area under conservation agriculture
Pest management	pstm	%	7.0	10.0	20.0	30.0	40.0	50.0	Farmers using pest & disease surveillance tools
Livestock feed	afed	mt	77,023.0	89,481.0	103,955.0	120,770.0	140,305.0	163,000.0	Local animal feeds production
Livestock breed (cattle)	abrdp	#	109,209.0	115,277.0	130,313.0	147,311.0	166,525.0	188,245.0	Cows inseminated
Livestock health (in TLU)*	ahth	#	38,560.0	39,328.1	40,101.0	42,664.2	45,063.7	48,236.7	Animals vaccinated (in TLU)*
Seeds - practice	seedsp	%	35.9	40.0	45.0	47.0	48.0	50.0	Farmers using improved seeds (Small scale)
Fertilizer - practice	fertp	%	54.9	57.5	60.3	62.8	64.5	66.5	Farmers using inorganic fertilizer (Small scale)
Marshland irrigation	mirri	ha	37,273.0	37,573.0	37,873.0	39,311.0	40,311.0	42,473.0	Marshland
Hillside irrigation	hirri	ha	9,439.0	13,640.0	17,490.0	27,275.0	39,735.0	48,667.0	Hillside irrigation
Small-scale irrigation	sirri	ha	24,873.0	25,473.0	30,406.0	35,298.0	38,183.0	41,031.0	Small-Scale Irrigation Technology
Radical terraces	rterr	ha	142,318.0	146,518.0	150,768.0	155,768.0	161,268.0	167,268.0	Area under Radical terraces
Progressive terraces	pterr	ha	1,032,282.0	1,044,282.0	1,057,282.0	1,071,282.0	1,086,282.0	1,102,282.0	Area under Progressive terraces
Food loss reduction	flwp	%	13.8	12.0	11.0	10.0	9.0	8.0	Reduction of post-harvest losses in priority crops

Note: *PSTA-5 set vaccination targets by animal type. Tropical livestock units of 1.0, 0.11, and 0.01 are used for cattle, small ruminants and poultry, respectively. In the simulations, separate animal health (vaccination) scenarios were designed for each animal type.

Source: MINAGRI (2024).

Table A2. Productivity gains by practice and sector (in %)

CSA practices	Cereals	Roots	Pulses and oilseeds	Horticulture	Other crops	Cattle	Small ruminants	Poultry	Source
Improved seeds	38.7	32.8	37.7	19.3	19.3				IFPRI (2024)
Chemical fertilizers	25.6	21.7	7.1	12.8	12.8				IFPRI (2024)
Marsh irrigation	163.7	138.7	28.2	81.9	81.9				IFPRI (2024)
Hillside irrigation	163.7	138.7	28.2	81.9	81.9				IFPRI (2024)
Small irrigation	163.7	138.7	28.2	81.9	81.9				IFPRI (2024)
Radical terraces	163.7	138.7	28.2	81.9	81.9				IFPRI (2024)
Progressive terraces	163.7	138.7	28.2	81.9	81.9				IFPRI (2024)
Planting window	48.2	40.8	12.2	24.1	24.1				IFPRI (2024)
Planting density	9.7	8.2	6.6	4.8	4.8				IFPRI (2024)
Manure use	9.6	8.1	6.4	4.8	4.8				IFPRI (2024)
Residue management	23.6	20.0	8.8	11.8	11.8				IFPRI (2024)
Vaccines for animals						18.0	18.0	18.0	Aragie et al. (2022)
Artificial insemination						41.5			Aragie et al. (2022)
Improved feed for animals						42.2	42.2	42.2	Aragie et al. (2022)
Reduced food loss and waste	4.4	4.4	4.4	4.4	4.4				Aragie et al. (2023)

Source: IFPRI (2024), Aragie et al. (2022), and Aragie et al. (2023).

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