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Cost effective options for inclusive and sustainable development

Emerta Aragie, Josue Niyonsingiza, James Thurlow, James Warner and Valencia Wenqian Xu

This brief is part of IFPRI's series of country studies that utilize the RIAPA modeling system to systematically evaluate and rank agrifood system investment options based on their cost-effectiveness in achieving multiple development objectives. These country studies examine whether the rankings evolve over time and production shocks such as droughts influence their relative cost-effectiveness.

Abstract

In this policy brief, we present research findings of a systematic evaluation and ranking of investment options for Rwanda's agrifood system based on their cost-effectiveness in achieving multiple development outcomes, including agrifood gross domestic product (GDP) growth, agrifood job creation, poverty reduction, declining rates of undernourishment, and lowering diet deprivation. Additionally, the study assesses their environmental footprint, focusing on water consumption, land use, and emissions. Investments in small and medium enterprise (SME) processors are shown to be the most cost-effective at expanding agrifood GDP and employment, while extension and advisory services on livestock and climate emerge as the most efficient farmer-facing investments. However, crop extension services rank least in cost-effectiveness for economic and social outcomes. However, many cost-effective investments have relatively high environmental footprints, which highlights potential tradeoffs. The study further reveals shifts in the cost-effectiveness ranking of investment options overtime and when extreme production shocks occur.

Keywords: Investment priorities, agrifood system, economic, social, environment, Rwanda

Introduction

The agrifood system in Rwanda is the engine of growth, the main employer, and the source of livelihood for millions. However, its main constituent is low-productivity agriculture, which struggles to supply affordable high-quality food for the growing population. This juxtaposition underscores the urgent need for a sustainable transformation of the entire agrifood system. Providing technical and financial support to agriculture and allied sectors is crucial to achieving this transformation. As such, the country has been implementing a series of Strategic Plan for Agricultural Transformation (PSTA) programs for the past couple of decades (MINAGRI, 2018). However, the policy and investment choices, along with the growth patterns they drive, play a decisive role in shaping the magnitude and sustainability of the development gains (Christiaensen and Martin, 2018; Pham and Riedel, 2019). As such, policies and investments should be evaluated in terms of their impact on key economic outcomes, such as economic growth or job creation, as well as social outcomes, such as poverty, undernourishment, or diet deprivation. Understanding whether tradeoffs exist across these outcomes can help inform policymakers' decisions about resource allocations. Increasingly, policymakers and development partners are also incorporating environmental sustainability considerations into their assessments. This is based on an enhanced awareness that unsustainable production practices contribute to environmental degradation and to climate change, the burden of which will fall disproportionately on future generations of poor people (GLOPAN 2020).

The effectiveness of policies or investments may be affected by unanticipated shocks facing the economy. Rainfall variability has been the most significant climatic risk affecting the performance of agrifood systems 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). The main risks that adversely affect the population include droughts, floods, landslides and storms. With the changing climate, it is fair to assume that these phenomena will prevail both with intensity and duration. While there is little doubt these climatic shocks adversely affect the performance of the agri-food system and, therefore, the effectiveness of agrifood system policies and investments in general, it is not evident whether climatic shocks would also alter the prioritization of these policies and investments.

In this country brief we provide data- and model-driven insights to inform policy discussions on the design and prioritization of agrifood system interventions, considering both the current state of the system in Rwanda and the emerging risks that threaten its performance, sustainability, and resilience. We systematically evaluate a range of investment options and rank them based on their cost-effectiveness in delivering multiple development outcomes, including agrifood GDP growth, agrifood job creation, poverty reduction, undernourishment reduction, and improvements in diet deprivation. To assess the impacts of these investments on nature capital, we calculate the associated environmental footprints, focusing on water, emission, and land.

We also analyze how these investment rankings shift when the system is exposed to climatic shocks with varying adverse crop yield effects across the agricultural sub-sector (the design of these sensitivity scenarios is informed by observed historical climatic shocks). This additional layer of analysis ensures policy recommendations are not only effective under normal conditions but also resilient to external risks, providing a more robust framework for guiding agricultural investments in Rwanda.

Results are generated using IFPRI's Rural Investment and Policy Analysis (RIAPA) modeling system (IFPRI, 2023) which uniquely integrates an investment module that translates identified investments into changes in productivity at the subsector level; a household survey-based microsimulation module that estimates changes in poverty, undernourishment, and diet deprivation; and a newly incorporated environment module that computes environmental footprints, including water, emission, and land. As such, this integrated RIAPA framework provides a comprehensive assessment of investment impacts. 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).

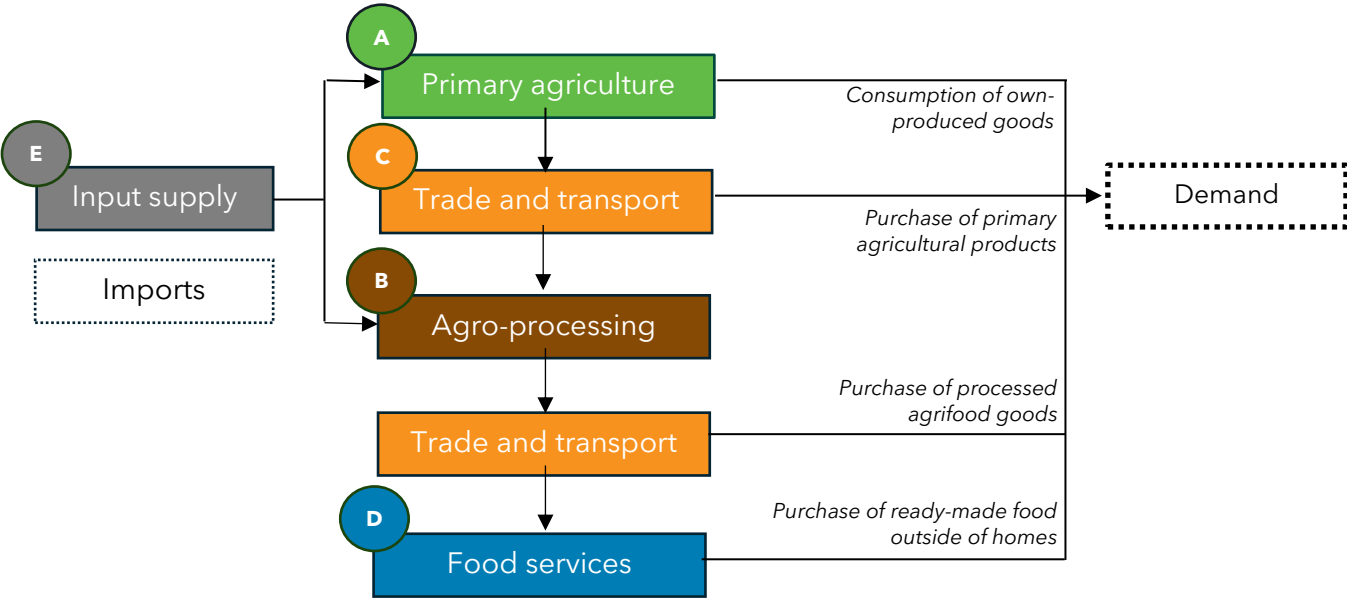
Country Context

Structure of Rwanda's agrifood system

A country's agrifood 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. We measure the agrifood system from a supply-side perspective, leveraging national accounts and employment statistics to directly simulate changes in growth and employment by investment scenarios and over time. By disaggregating the agrifood system into distinct value chain groups and mapping interventions that target improving some of their bottlenecks, this approach provides valuable insights into the key drivers of agrifood system growth and associated environmental impacts in Rwanda.

Figure 1 presents a simplified conceptual framework of the agrifood system, consisting of five key components, labeled **A** to **E** (see Diao et al., 2023). Primary agriculture (**A**) encompasses the supply and demand for all agricultural products, including crops, livestock, fisheries, and forestry products. Agro-processing (**B**) is part of the manufacturing sector and includes subsectors that process agriculture-related food and non-food products. Meanwhile, trade and transport (**C**) involve services related to the transportation, wholesaling, and retailing of agrifood products between farms, firms, and final points of sale. Food services, represented in (**D**), include services such as meals prepared in restaurants, food stalls, or hotels. Finally, input supply (**E**) represents the portion of domestically produced intermediate inputs used directly in agricultural and agro-processing production, such as fertilizers and financial services.

Figure 1: A simple conceptual framework of the agrifood system



Source: Diao et al. (2023)

The agrifood system in Rwanda contributes to over 36 percent of gross domestic product (GDP), employing 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), and currently contributing to 26 percent of GDP (Diao et al. 2023). With appropriate policy reforms and targeted investments, the sector has a huge potential to further accelerate and contribute its fair share to Rwanda’s economic transition.

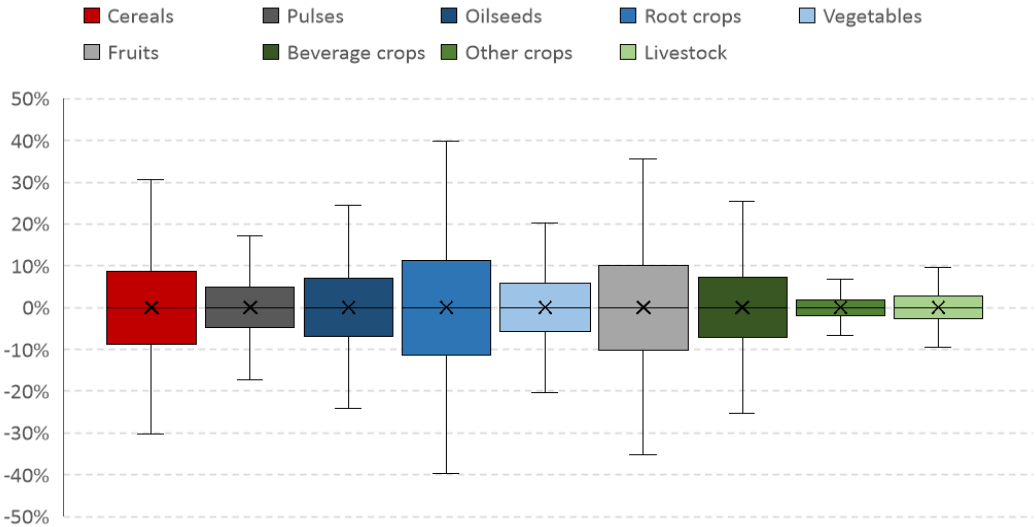
Accelerating growth and sustaining high employment levels have long been central development objectives in Rwanda. With a poverty headcount rate of 38 percent in 2016/17 (NISR, 2018) and notable deficiencies in dietary diversity, the Rwandan government recognizes the formidable challenge it faces—particularly as it strives to achieve inclusive growth through cleaner, more sustainable means (MoNR 2015). Consequently, there is an increasing policy imperative to assess investment and development strategies not only through traditional economic and social lenses but also in terms of their environmental and sustainability implications. In this regard, water, emission, and land footprints of activities are worth exploring.

Agricultural production variability in Rwanda

Given the predominance of rainfed production systems, Rwanda’s agricultural sector has historically been exposed to weather-related production shocks. These shocks adversely affect the efficacy of technologies; for example, several studies have shown that extreme events can lower the expected yield gains from using modern inputs such as fertilizer and seeds (Kumar and Maiti, 2024; Austin et al., 2020). Data show production risks in Rwanda vary across sectors where yields for root crops and tree fruits fluctuate more than yields of pulses and vegetables (see Figure 2). We find from historical data that production losses during a 1-in-25-year production shock event relative to baseline “normal” year could range between -12 and -15 percent in pulses and vegetables to -26.0 and -28.0 percent in fruits and

oilseeds. This variation in yield effect across sectors highlights different degrees of vulnerability of sectors to climatic shocks. Moreover, there is spatial variation both in the severity of drought conditions and sectors distribution in production, both contributing to the national level variation in yield impacts across products. In our modeling results, we will test the robustness of our investment ranking to climatic shocks using historical 1-in-25-year drought events as indicative of how such shocks will contribute to sectoral yield losses and alter the impacts of investments.

Figure 2: Historical production variability for crops and livestock



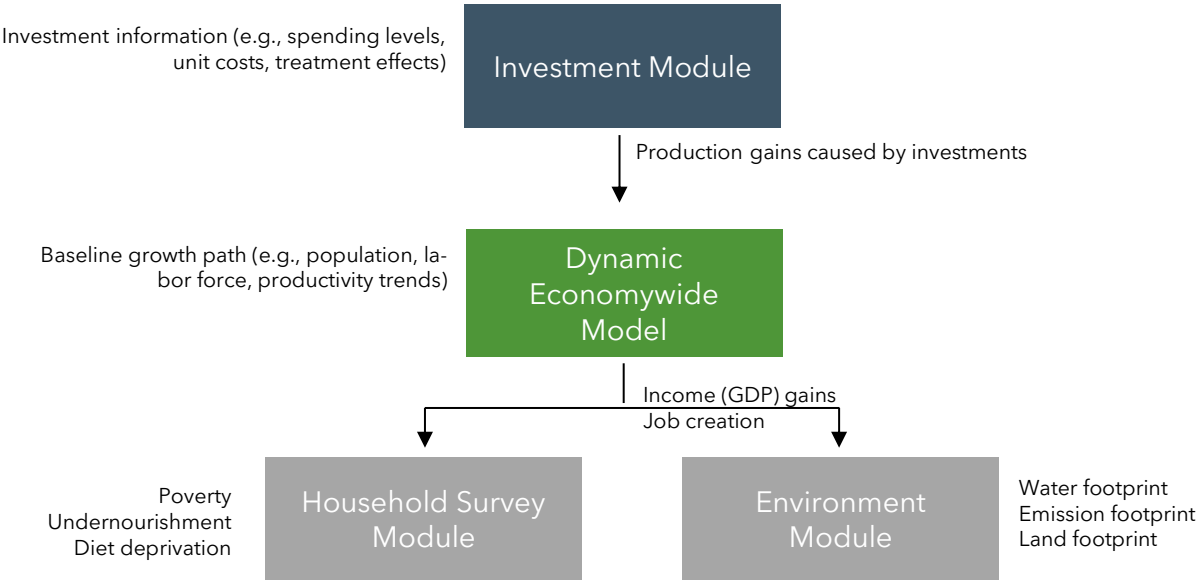
Note: The historical variability values are residual fluctuations from the determined production time series for 1990-2021. Fruits, root crops, and livestock are the three main contributors of agricultural GDP, with shares of 29, 24 and 12 percent, respectively. Beverage crops and pulses follow, contributing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

Method of Analysis

Modeling approach

This study estimates the impacts of alternative agrifood system investments on the Rwandan economy across key outcome indicators which are categorized as economic, social, and environmental/resource use. 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; a household survey-based microsimulation module that estimates changes in poverty, undernourishment, and diet deprivation; and a newly incorporated environment module that computes environmental footprints, including impact on water utilization, emission, and land use (Figure 3). This integrated RIAPA framework thus enables a comprehensive assessment of investment impacts.

Figure 3: An integrated model for agrifood system investment and outcomes analysis



The economywide model

At the core of the integrated RIAPA framework is IFPRI’s standard, recursive-dynamic computable general equilibrium (CGE) model. These 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 is calibrated to the 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. These households are categorized into rural and urban household groups, 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 2045. 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.

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 of expenditure on each of a range of agricultural transformation investments. The module used in this study is a newly updated version of the framework previously adopted in various contexts (Aragie et al., 2022; Pauw and Thurlow, 2015; Benfica et al., 2019). The previous version of the investment module was elaborated in Aragie et al. (2024). The updated framework separates agrifood system investments in layers depending on whether they are at the knowledge generation stage (up-stream: e.g., R&D) or innovation dissemination stage (midstream, e.g., seed system), or at the farmgate level (downstream: e.g., seed application at farmer level). In this study, the investment module tracks 18 individual interventions, with many targeting up to six distinct groups of agricultural sectors.

The investment module structures agrifood investments and processes data on the costs and impacts of interventions across targeted sectors. Specifically, it integrates investment details—such as spending levels, unit costs, changes in adoption rates, and impact coefficients (or marginal effects)—as inputs and generates corresponding productivity gains as outputs. Whereas unit costs measure costs per area of farmland or head of animal, adoption rates refer to the extent to which new technology is implemented, expressed as a percentage of the target area or number of animals. The productivity gains are then transmitted to the economywide model, which endogenously adjust 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.

Unit costs are usually obtained from the literature and are retrieved from project planning (such as irrigation master plans) or evaluation documents. Baseline adoption rates and coverage levels are obtained from farm household surveys such as the Rwanda's Agricultural Household Survey (AHS) 2020 (NISR, 2021) which reports the number of farmers with access to certain technologies and practices or the cropland covered by those technologies and practices. Likewise, impact coefficients—which measure the change in productivity resulting from the adoption of a specific technology or practice—can be estimated using these types of surveys or 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. Given these fundamental features of sector-investment combinations, the final productivity gains for each sector will be determined by the level of spending on each intervention. In this brief, an equal amount of hypothetical spending for each intervention area is considered for cost-benefit comparison. An actual budget allocation pattern can also be evaluated using spending data from ministries of agriculture or ministries of finance.

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.

The process for estimating changes in diet deprivation is similar to that for poverty in that survey households are linked to their respective representative household groups in the CGE model. In this instance, however, modeled changes in real food consumption across six food groups are used to compute changes in the Reference Diet Deprivation (ReDD) index (Pauw et al., 2023), which serves as a multidimensional indicator of a household's diet quality. ReDD index, which is a deprivation gap measure, quantifies shortfalls in consumption relative to a recommended consumption threshold. A decline in the deprivation gap indicates improvement in overall diet deprivation.

The environment module

The environment module uses information on water, emission, and land intensities of sectors to calculate changes in total water, emission, and land footprints of the economy. These footprints change as the structure or size of the economy changes over time. For instance, the expansion of a water-intensive sector, such as rice, can potentially increase the total water footprint of the cereal sector. However, this shift may also result in resource reallocation—such as the increased availability of cheaper animal feed—which could, in turn, accelerate growth in more emission-intensive sectors like livestock.

The data used to calibrate the environment module come from various sources. Whereas the water footprint data for agricultural sectors come from the Water Footprint Network (Mekonnen and Hoekstra, 2010), this source only reports aggregate water footprints for industrial sectors and municipal water withdrawals. In the absence of sector-specific data, we assume water use is distributed across non-agricultural sectors in proportion to their sectoral output shares. Given our focus on agri-food system investments, this assumption, while crude, has little bearing on our results.

Sectors also differ in terms of their emissions intensities. We use total emission data (in tons of CO₂ equivalent) obtained from FAO (2025) and Climate Watch (2025). FAO (2025) reports total emissions generated in the rice sector, other cereals, and livestock sub-sectors, including milk and meat production. We complement this with global-level estimates of emission per kilogram (CO₂ equivalent) for a comprehensive list of commodities compiled by Poor and Nemecek (2018). Climate

Watch (2025) reports emissions generated by major manufacturing and service sectors. The resulting emission coefficients for all sectors included in the Rwanda SAM are then scaled using the corresponding sector's output to match total emissions in agriculture, industry, and services.

The land footprint calculation uses the FAO (2025) cropland allocation estimates to calibrate the Rwanda CGE model. Rwanda had 2.1 million hectares of land under crop cultivation in 2022, the model base year. In addition to this, we incorporate land use for livestock grazing into the land footprint calculation. FAO (2025) reports about 0.4 million hectares of grazing land in Rwanda in 2022. The country usually practices minimal open grazing livestock rearing. In our modeling analysis we assume total agricultural land expands by 0.4 percent per annum, demonstrating the limited rate of land expansion in the country. Land use by sector may, however, adjust in line with relative changes in land productivity and output.

Scenario design

This study assesses the impact of eighteen different investment areas. We assume a marginal increase of \$25 million in spending per year from 2025-2030 for each investment area. The relative effectiveness of each intervention is assessed based on its effect in driving different development outcomes by 2045. To bring future returns to their current equivalent for comparability reasons, we discount the future impacts using a discount rate of 4%. Investments are grouped into five broad types of interventions: (i) research and development (or R&D), (ii) extension and advisory services, (iii) markets and food systems, (iv) risk reduction and resilience, and (v) infrastructure. Annex Table 1 includes a detailed list of interventions considered. In short, the interventions include the following:

- R&D investments contribute to the development of improved seed varieties, productive agronomic practices, animal breeds, and animal husbandry.
- Extension and advisory services promote the adoption of improved seeds, agronomic practices, livestock inputs (e.g., feed and vaccines), and climate-smart agricultural practices.
- Markets and food system investments are designed to strengthen seed systems, enhance the productivity of small and medium enterprise (SME) processors and traders through access to finance and training, reduce food loss and waste, or improve access to credit.
- Risk reduction and resilience interventions support better decision-making by agrifood system actors by providing early warning information, climate forecasting, and productive safety nets.
- Infrastructure investments raise overall value chain productivity through expanding irrigation schemes or feeder roads that connect farmers to input and product markets.

Calibration of the investment module requires a range of data inputs for each of the eighteen investment areas. These include adoption rates (or coverage rates), which specify the number of farmers that use a specific technology or service, or the area of land on which technology is applied, as well as yield gains from utilizing those technologies or services. Baseline rates of technology adoption and service coverage rates were obtained from farm household surveys. Productivity impacts of the respective interventions across the targeted sectors are derived from impact evaluation documents and crop and livestock models. Rwanda's AHS 2020 (NISR, 2021) is specifically used to estimate adoption and coverage rates for the various practices and technologies modeled in this analysis. The

survey shows moderate fertilizer adoption in cereal production at about 49 percent of cropland, followed by roots and tubers at 36 percent. Coverage is the least among horticulture crops. Likewise, improved seed adoption is the highest for cereals (43 percent), while other crop groups have marginally lower application rates. On the other hand, IFPRI's crop model (IFPRI, 2024) is used to estimate yield gains from adopting different farm practices. For Rwanda, the model reveals stronger cereal yield effect from irrigation infrastructure, followed by information on planting window and the adoption of improved seeds. These investment module parameters, alongside measures such as value-added and output prices, are important determinants of the returns on investments in different technologies or services.

Investment unit costs measure the financial cost of expanding input coverage (e.g., increasing irrigated land by one hectare). These are primarily sourced from impact evaluation studies, sector development plans, and existing literature. A key enhancement in this version of the investment module, compared to its most recent predecessor described in Aragie et al. (2024), is its ability to track the time lag between investment spending and its eventual impact (e.g., for rural roads or irrigation projects that take a number of years to become operational) as well as the duration of that impact (this accounts for depreciation or time-bound interventions). This distinction is crucial, as some investments yield one-time effects while others generate sustained benefits over multiple years.

The agrifood system in Rwanda is historically exposed to production shocks that can reduce the efficiency of technologies and practices. An alternative situation of a permanent decline in yield gain from a 1-in-25-year drought is also considered to test how the rankings of interventions change by 2045 when the system is faced with large climatic shocks.

Cost-Effective Investment Options for Inclusive and Sustainable Transformation

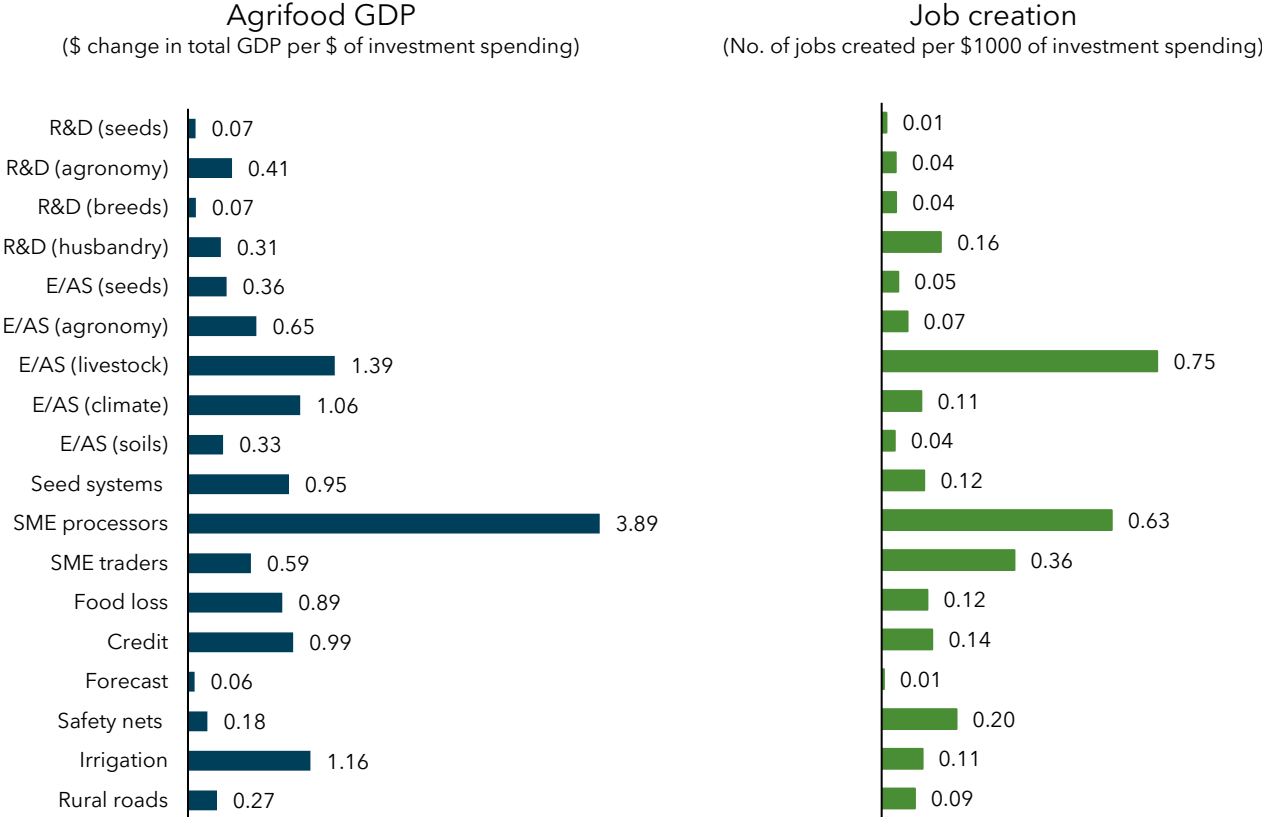
Comparing the impacts of investments

We start our comparison of investments based on their impact on two standard economic outcomes: agrifood growth and job creation. These outcome indicators are directly obtained from the economywide model (see Figure 3). Results are reported in Figure 4. These reveal relatively stronger growth effects from investments in SME processors, livestock advisory services, irrigation infrastructure, climate information system, and access to credit to agrifood system practitioners. Specifically, 1-dollar spending on SME processors could cause a \$3.89 gain in agrifood system GDP, whereas dollar investment on livestock extension and advisory services may generate \$1.39 in return (Figure 5). Spending on climate information system and irrigation infrastructure also yields economywide benefits slightly over the cost.

Job creation remains an important development challenge for most developing countries, including Rwanda, especially given the continued rapid increase in the working-age population. Notably, model results highlight livestock and SME processor related interventions as the most effective, generating 0.63-0.78 additional jobs per dollar invested due to their stronger backward and forward linkages across the economy. Spendings such as on SME traders, R&D on animal husbandry, and

productive safety nets are among the top ranked interventions in terms of their employment impacts. By contrast, most crop specific interventions, such as advisory services on seeds, soils and agronomy practices, were found to have minor employment effects.

Figure 4: Comparison of investments based on their cost-effectiveness on economic outcomes



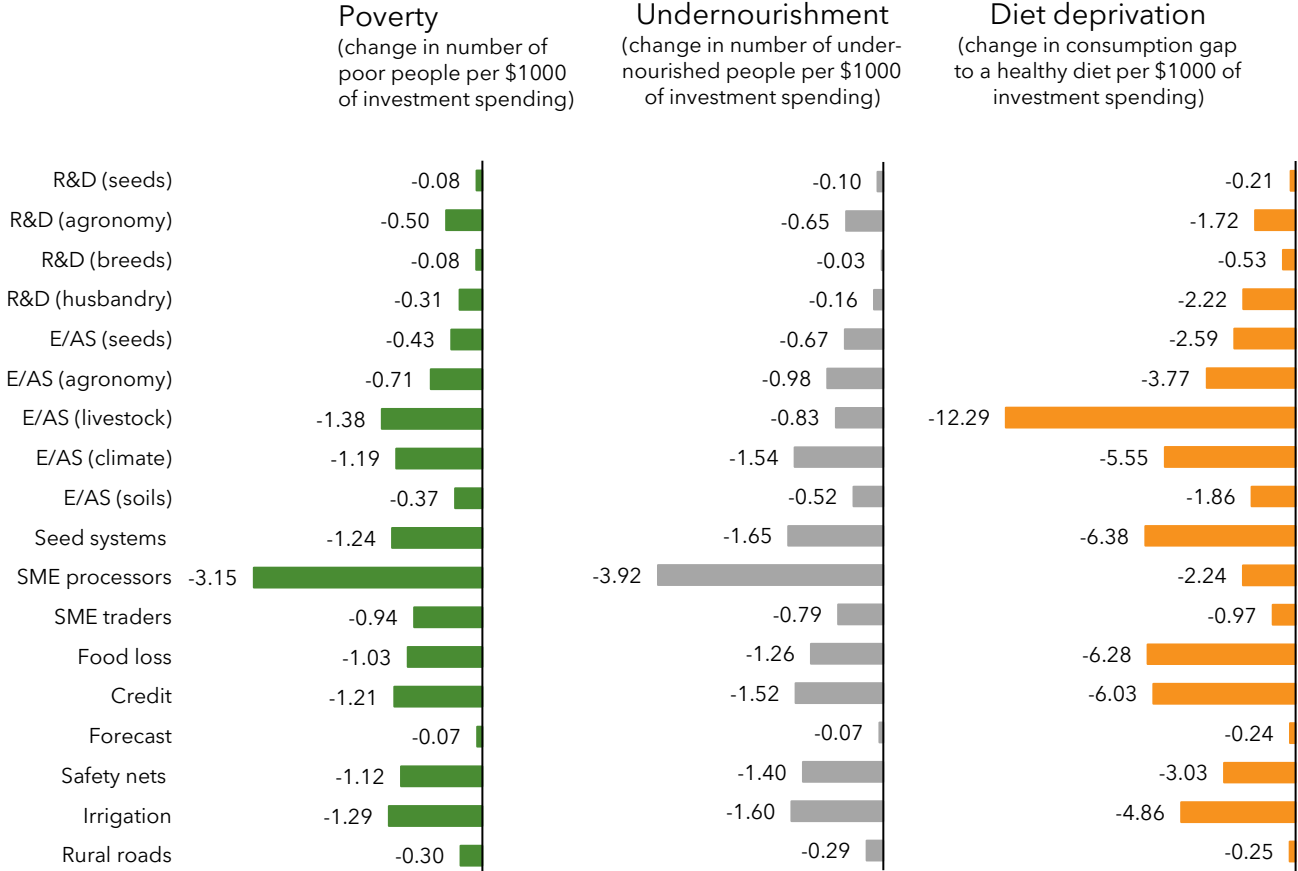
Source: RIAPA modeling system

The three social indicators considered in this study are the poverty headcount, prevalence of under-nourishment, and quality of household diets. These are obtained from the various household survey-based microsimulation models incorporated into the RIAPA framework. Results show that investment areas differ in terms of their effectiveness in driving these outcomes (Figure 5). Investing in SME processors stand at the top in its effect on poverty and undernourishment, partly explained by their strong GDP effects and underlying the fact that SMEs employ the lower income quintile households in the informal sector. Extension and advisory services to livestock producers, irrigation, and improved seed system are the three other top performing spending options for stronger poverty effect. Productive safety nets also have a moderate effect on poverty reduction.

Regarding effects on undernourishment, efficient seed system, irrigation infrastructure, climate information system and farmers access to credit emerge as the most cost-effective interventions, driving significant reductions. In contrast, livestock-related interventions appear to have marginal effects on undernourishment, as those engaged in the livestock sector tend to be relatively better-off, limiting the benefits flowing to the most vulnerable populations. However, unlike their impact on poverty

and undernourishment, livestock interventions have the strongest diet diversifying effect. Additionally, investments in seed systems, food loss and waste reduction, and access to credit contribute to greater improvements in diet deprivation by enhancing productivity and improving access to food products, particularly fruits and vegetables, which are often lacking in household diets.

Figure 5: Comparison of investments based on their cost-effectiveness on social outcomes



Source: RIAPA modeling system

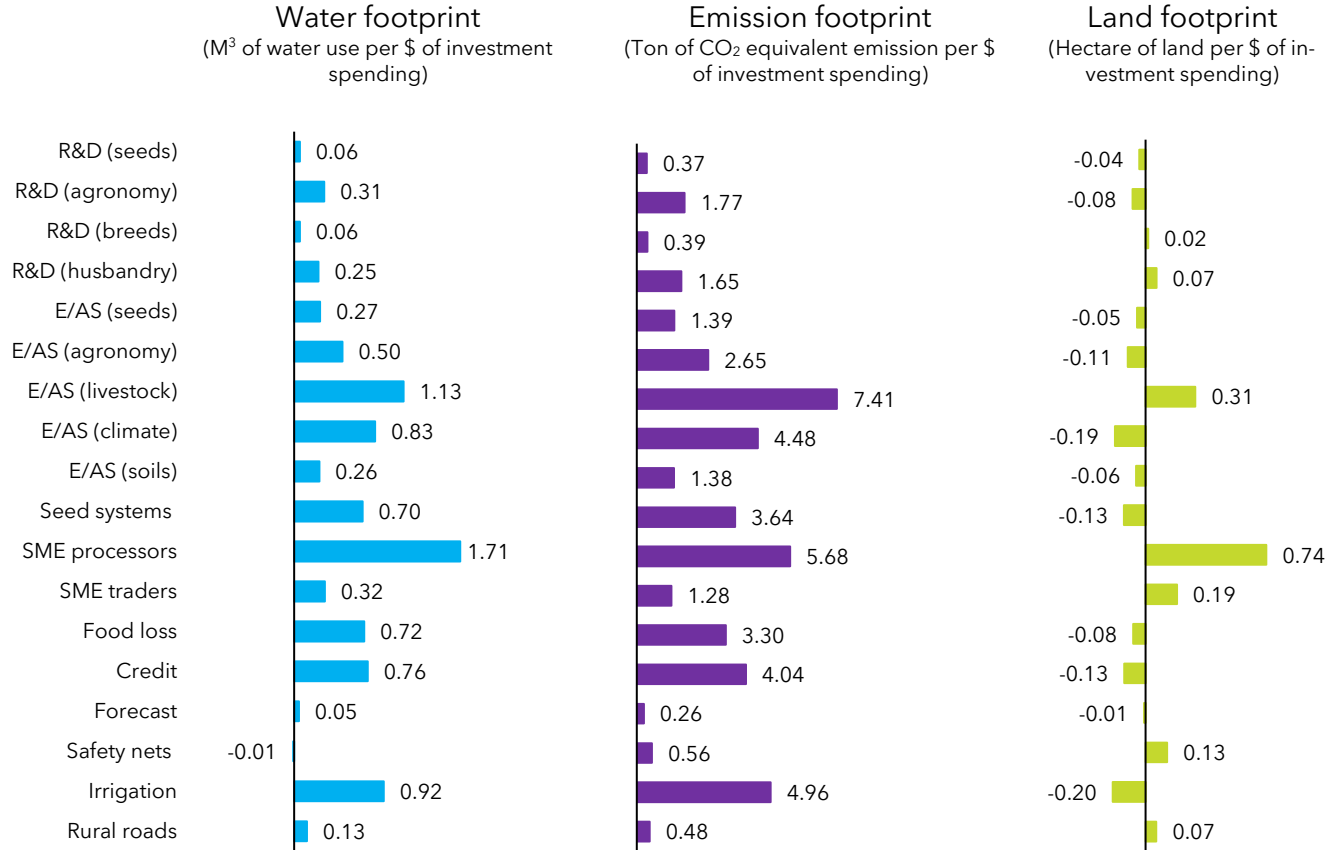
We also evaluated the various investments based on their resource use or environmental impacts, looking specifically at changes in the economywide water, emissions, and land footprints. The changes in environmental footprints associated with investments will depend on the initial resource intensity of sectors the interventions target, changes in sectoral activity as a result of the interventions, and any indirect adjustments in the economy outside the targeted sector due to economywide linkage effects and changes in resource reallocation. The basic principle here is that increases in environmental footprint per dollar of spending are undesirable.

Results from the environment module show investments in extension services to livestock producers and SME processors consistently rank among the highest across the three environmental indicators, underscoring the resource intensity of sectors that show significant expansion due to these interventions (Figure 6). On-farm investments including irrigation and farmer facing spending including extension and advisory services in agronomy and climate information have strong emission effects. Investments in food loss and waste reduction, and access to credit together with seed systems result in a stronger increase in

emissions since these interventions specifically promote the production of sectors with higher emission footprints. Figure 6 also highlights a stronger economywide water use effect from interventions on micro credit, food loss and waste reduction, and extension services on agronomy and climate. Investment in irrigation infrastructure is arguably one of the interventions with a stronger water footprint effect, specifically through increased surface and groundwater withdrawal.

Whereas all interventions cause increases in water and emission footprints at economywide level, land footprints show movements in both directions depending on the change in economywide demand for land due to these investments. Land footprint increases (i.e., more land put under cultivation) when investments in SME processors and traders and on livestock advisory are considered. These increases in land footprints are likely due to additional opportunities for land-intensive sectors to grow as the economic opportunity changes. By contrast, irrigation infrastructure, R&D in agronomy, extension services in climate information systems, food loss reduction and irrigation help release agricultural land, creating a possibility for environmental regeneration. For example, irrigation infrastructure enhances land productivity, enabling more output from a smaller area and potentially allowing some land to be taken out of agricultural production.

Figure 6: Comparison of investments based on their cost-effectiveness on environmental footprint



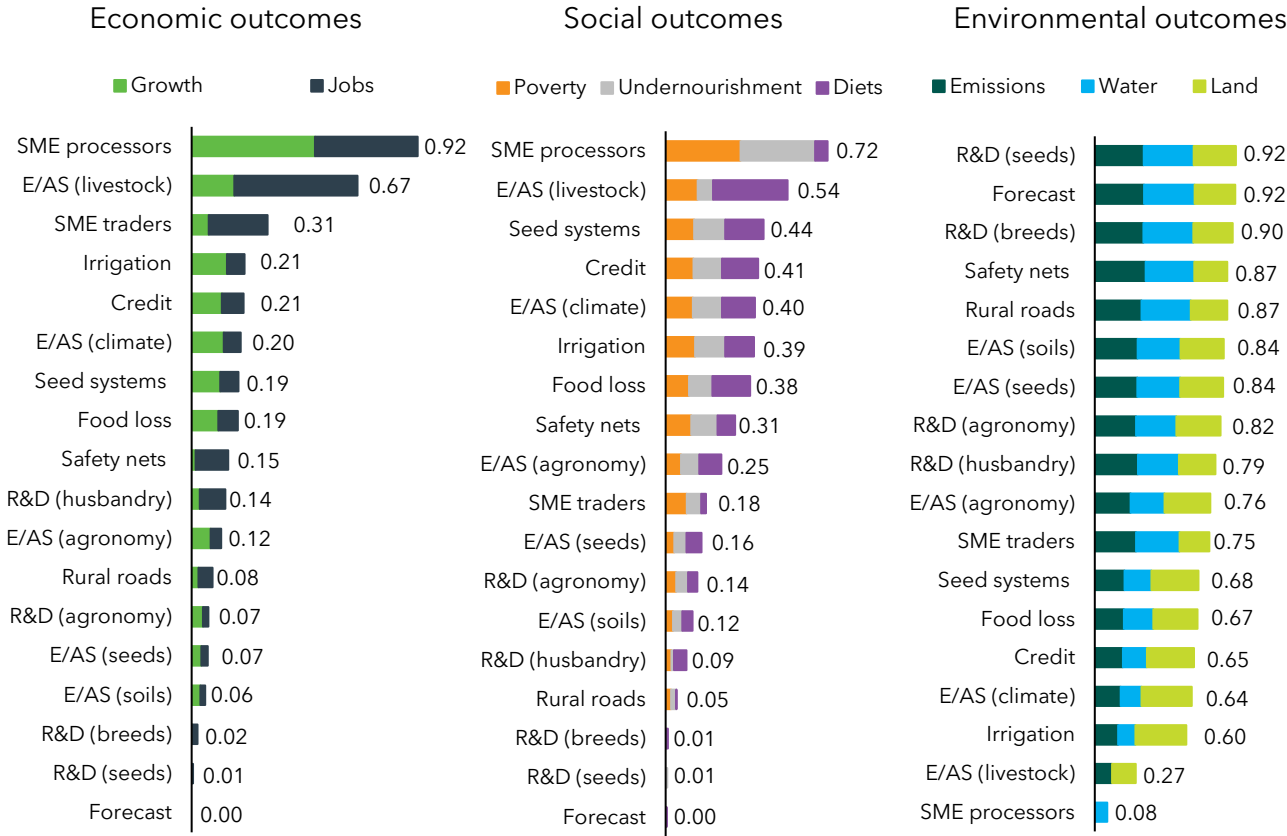
Source: RIAPA modeling system

Composite score of investments by their impact on selected outcome indicators

As presented in the preceding section, investments were ranked by their impacts on a long list of outcomes, grouped into economic, social, and environmental dimensions. We noted from the results that no single intervention was ranked top across all outcomes and that we witnessed potential tradeoffs across these indicators. In this section, we construct composite scores of the interventions by their impact on each group of outcomes. This is done in steps. First, we normalize the intervention scores for each outcome, attaching a value of 1 to the most cost-effective and 0 to the least cost-effective. Second, we then attach equal weights to each outcome in a group. Third, we sum up the weighted scores of the outcomes for each intervention to use it for ranking the interventions based on their overall impact. For example, when creating the composite score for the interventions based on their overall economic outcome, an equal weight - 50 percent each - is attached to growth and job creation, assuming equal preference by policymakers for these outcomes. Finally, for each intervention, we sum the weighted scores for growth and job creation to produce an overall score, which is then used to rank all interventions.

Figure 7 ranks investing in SME processors as the most cost-effective option for expanding the agrifood system's GDP and employment. This effect of investment in SME processors was greatly contributed to by stronger growth in agrifood GDP. Livestock extension/advisory services and irrigation infrastructure are among the most cost-effective investments, mainly driven by faster growth in agrifood system employment. Among R&D investments, animal husbandry has the strongest impact but is ranked below average in the list. Improving access to credit and climate information, facilitating the seed system, and reducing food loss and waste are among the more cost-effective resilience investments.

Figure 7: Composite scores on economic, social, and environmental outcomes by investment area



Source: RIRPA modeling system

Figure 7 further reports composite scores of interventions based on their overall impacts on social outcomes, summarizing their effects on poverty, undernourishment, and diet. The overall impact is constructed by summing together each indicator’s normalized score assuming equal weights. Similar to the economic outcome scores, investing in SME processors ranks as the most cost-effective option for achieving greater progress in poverty reduction, improvement in the rate of undernourishment, and diversity of diets. Providing extension services to the livestock sector and climate information can cost-effectively promote greater social outcomes. Investing in irrigation, reducing food loss and waste, extending farmers credit and functioning safety nets are among the cross-cutting interventions with stronger effects, mainly on undernourishment and diet deprivation.

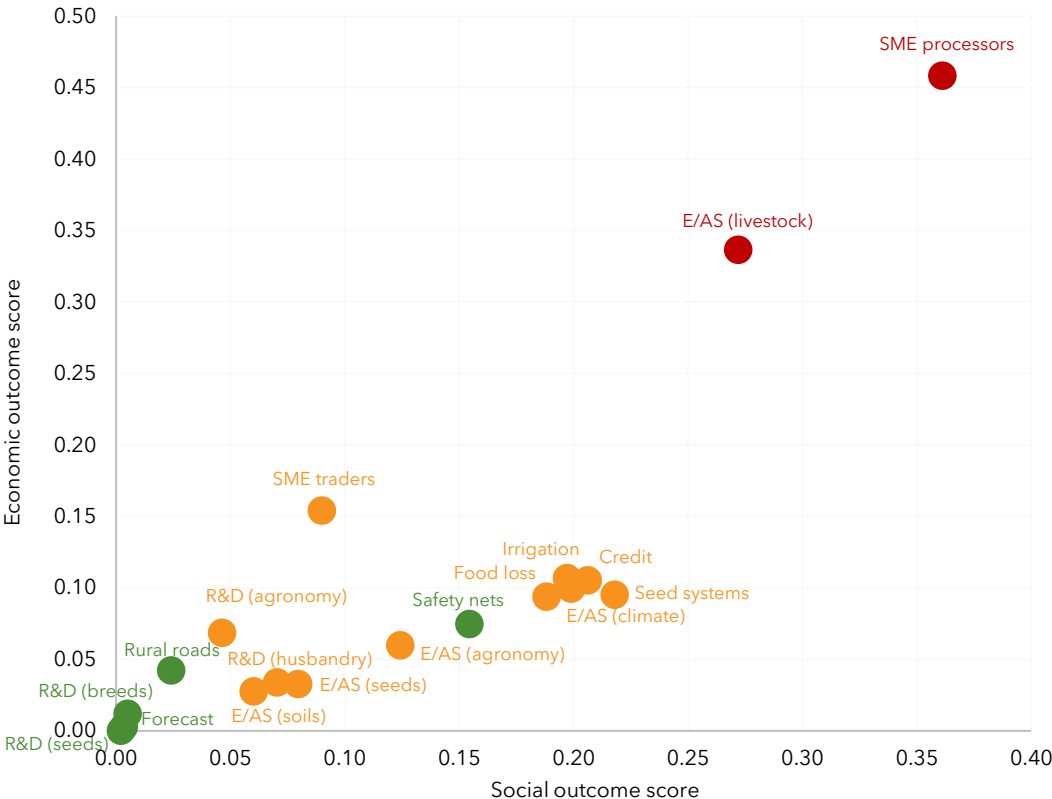
The last panel in Figure 7 reports the composite score of the interventions based on their overall effects on the three environmental indicators, namely water, emission, and land footprint, each receiving equal weight. Interventions with greater GDP effects tend to have undesirable environmental outcomes, demonstrating tradeoffs. Livestock-related investments such as farmer-facing extension services appear the most resource-intensive, mainly due to their high water use and emission per output. Market and food system investments such as spending on SME traders and processors, seed systems, and credit packages are among the most resource-demanding spending options. Irrigation expansion also contributes highly to the environmental footprint, mainly due to increased water use. By contrast,

most farmer-facing interventions such as extension and advisory services on seed, agronomy, and soil management have the least environmental footprint effect due to their limited effect on the economy (see Figure 4 above).

Traditionally, policymakers would have based policy decisions primarily on economic and social dimensions. To create a composite ranking of the investments, these two dimensions are combined attaching 50 percent weight to each and reported in Figure 8. This clearly illustrates the synergies and tradeoffs across investments as far as these two outcomes are concerned. The composite score puts investing in SME processors and livestock advisory services at the top, mainly because of their impact on economic and social outcomes although they are among the most resource-using, implying some tradeoffs. Systemic interventions such as those targeting credit access, seed systems, food loss, and safety nets rank as cost-effective in generating overall gains within the agrifood system. However, interventions with greater economic and social outcomes tend to be most resource-using, implying some tradeoffs. In Figure 8, interventions with red markers have a high environmental footprint, those with orange markers have a medium level environmental footprint, and those in green have a lower footprint. This grouping of interventions by their environmental impact is determined by first calculating their Z-scores and then identifying those with the highest and lowest impacts as outliers from the data using a specified standard deviation threshold. The tradeoff between economic and social impacts, on one hand, and environmental impact, on the other, highlights the need to improve the resource-use efficiency of interventions that yield strong economic and social benefits.

These two dimensions - economic and social - remain important, and may still dominate decision-making in many countries. However, a broader agrifood systems approach requires policymakers also to consider the environmental footprint of their policy or investment choices. Figure 8 shows most farmer-facing interventions such as extension and advisory services on inputs rank as the least cost-effective although they generate the least environmental footprint principally because of overall weaker impacts on production, revealing stronger tradeoffs between the previous two outcomes and the environmental footprint indicator.

Figure 8: Composite scores on economic and social outcomes by investment area



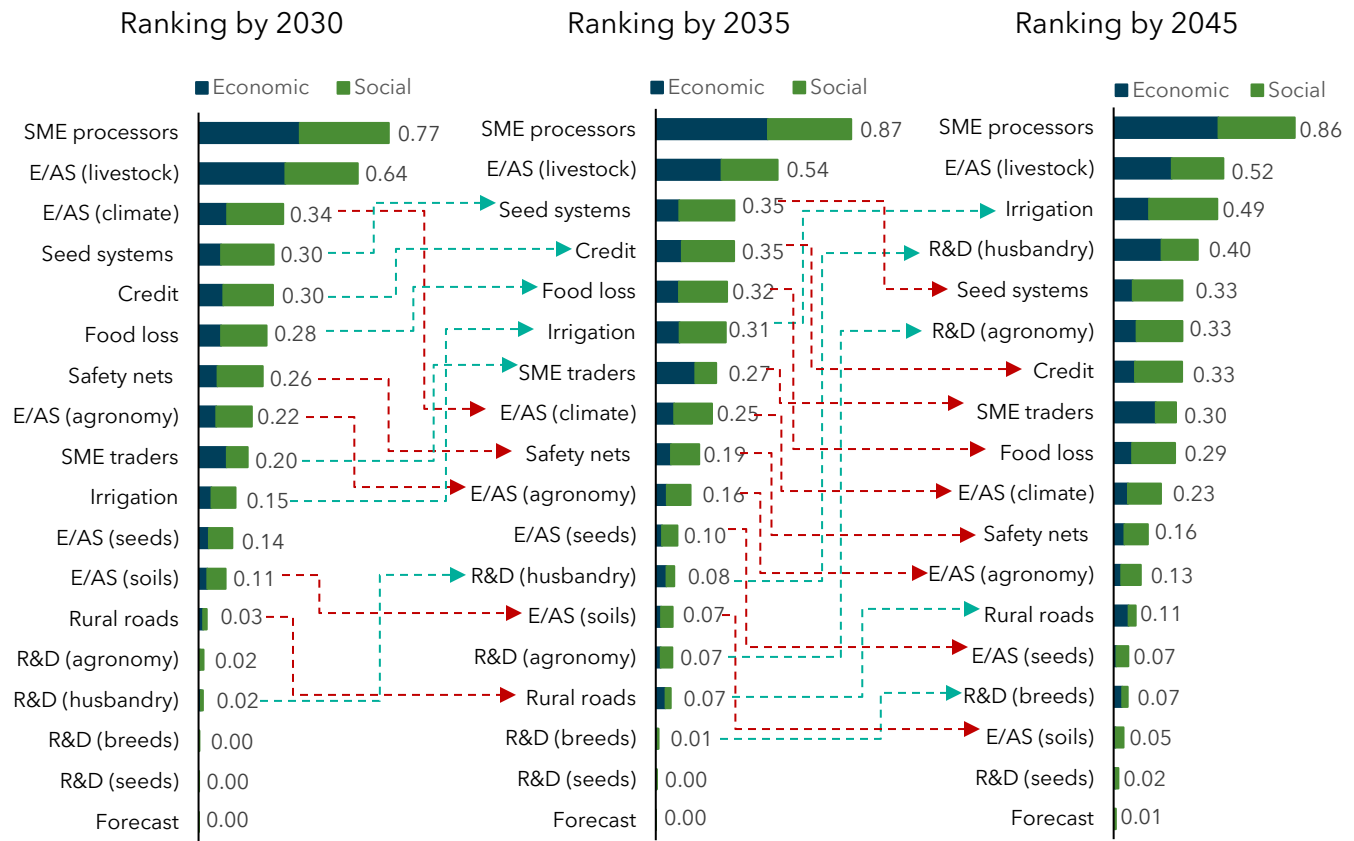
Source: RIAPA modeling system

Do the rankings change over time?

The previous section compares the investments by the end of the simulation period, i.e., 2045. Given differences in the lag time between when a particular investment is made and when it starts having an impact on economic and social outcomes, it is of interest to consider whether investment priorities change depending on the time horizon of the policymaker. Notably, most politicians or line ministries in governments may have a shorter time horizon (i.e., matching the typical 4-5 years of the political cycle). In contrast, national planners may have much longer planning horizons (often several decades). The modeling framework adopted in this study accounts for these time delays between when an investment is made and its effect materializes. This section assesses the magnitude of changes in composite scores by investment area over time. We specifically compared the rankings by 2030, 2035 and 2045 (Figure 9).

Model results indicate that R&D-related investments in agronomy, and husbandry become increasingly cost-effective over time as their lagged but long-term impacts materialize. In contrast, market and food system-related investments, such as farmers credit and food loss and waste reduction, show a rise in effectiveness by 2035 compared to 2030 but a decline in impact in later periods. Meanwhile, farmer-facing and recurrent investments—such as extension and advisory services on seeds, agronomy, and soils—gradually lose relative effectiveness as long-term, high-impact investments take over their role in driving economic and social outcomes.

Figure 9: Changes in rankings over time



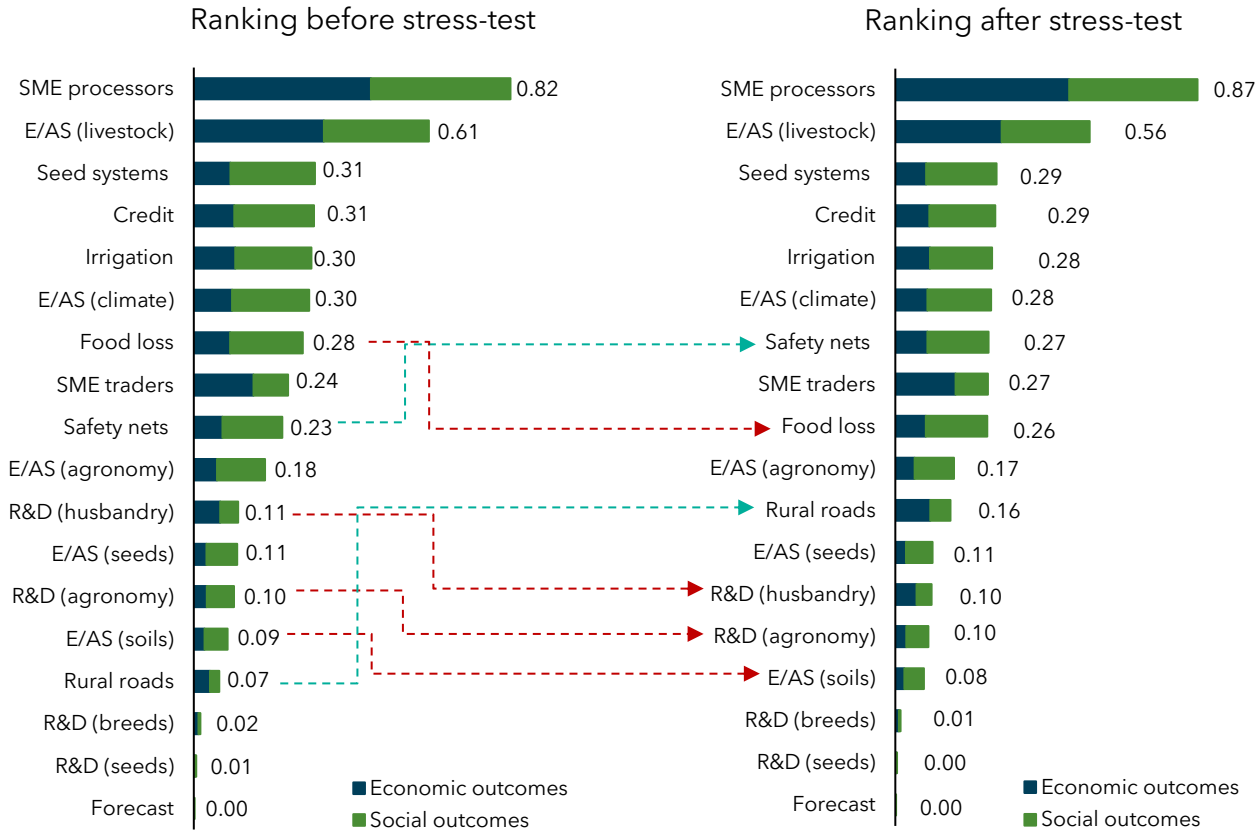
Source: RIAPA modeling system

Stress-testing of investments

This section reports on how investment rankings might change when a 1-in-25-year drought shock permanently slashes the yield gains throughout the simulation period (2025-2045). Of course, climatic shocks are unanticipated events, and so these simulations should not necessarily influence policymakers' decisions, but they do shed light on the robustness of the ranking results. The Rwandan case demonstrates a few changes in rankings (Figure 10). The top half cost-effective investments maintain their benefit-cost ranks even after accounting for the production risks discussed earlier, mainly because these investments target market and downstream food system actors that are not directly affected by the production shock.

However, the cost-effectiveness of R&D investments in agronomy and animal husbandry interventions fall slightly, especially when accounting for the environmental dimension in the assessment of ranks. The relative cost-effectiveness of food loss and waste reduction investments also decline moderately due to the direct and disproportional effect of the simulated 1-in-25-year production shock on targeted sectors. By contrast, safety nets directly impact households, demonstrating a strong improvement in relative impact when extreme shocks are likely. Investments on rural roads also show an improvement in ranking since this intervention improves the performance of the wider rural economy by enhancing productivity and intersectoral linkages.

Figure 10: Rankings of interventions after stress-testing



Source: RIAPA modeling system

Unpacking priorities by sub-sector

In the previous sub-sections, we present the cost-benefit rankings of interventions that also target various sub-sectors. For example, food loss reduction measures can focus on cereals, cash crops, or root crops. In this section, we consider a dual approach and provide a much deeper analysis of the ranking of interventions based on the sectors they target. The investment-sector combinations are compared using their normalized composite scores using their effects on economic and social indicators (Table 1).

The blue-shaded cells in Table 1 identify value chains or sectors where the impacts of a given intervention exceed the overall average impact score of the cross-cutting investment. For instance, the composite score for R&D in agronomy is relatively low - at 0.08 - when the intervention’s impact is evaluated across all targeted sectors. However, its impact on root crops is well above this cross-cutting average for cereals, at 0.17. Meanwhile, the green-shaded cells denote sector-investment combinations ranked among the top five in terms of potential impact. These indicate priority areas where targeted investment could substantially enhance the overall performance of the cross-cutting intervention. As such, although R&D in agronomy for root crops shows above-average impact relative to the cross-sector score, it does not fall within the top five intervention areas. Conversely, extension and advisory services horticulture and cash crops not only exceed the average impact score but also includes such investments in cash crops among the top five investment priorities. Furthermore, Table 1 suggests that concentrating food loss and waste reduction efforts on horticulture and cash

crops—as well as expanding irrigation access for horticultural and cash crop producers—would significantly improve the effectiveness of agrifood system investments. Supporting SME processors also remains one of the top cross-cutting interventions in terms of its impact on social and economic outcomes.

Table 1: Composite scores by investment area and crop sector

			Cross-cutting	Cereals	Root crops	Pulses and oilseeds	Horticulture	Other cash crops
R&D	1	R&D (improved seeds)	0.02	0.02	0.01	0.01	0.02	0.04
	2	R&D (agronomy)	0.08	0.04	0.17	0.14	0.09	0.09
	3	R&D (animal breeds)	0.02					
	4	R&D (animal husbandry)	0.06					
Extension / advisory services	5	E/AS (improved seeds)	0.08	0.04	0.08	0.09	0.12	0.26
	6	E/AS (agronomic practices)	0.12	0.06	0.15	0.08	0.22	0.47
	7	E/AS (livestock)	0.27					
	8	E/AS (climate information)	0.19					
	9	E/AS (climate smart agriculture)	0.07	0.04	0.08	0.04	0.12	0.27
Markets and food systems	10	Seed systems	0.20					
	11	SME processors (finance, training)	0.49					
	12	SME traders (finance, training)	0.13					
	13	Food loss and waste	0.17	0.06	0.15	0.15	0.36	0.75
	14	Credit access (financial inclusion)	0.19					
Risk reduction and resilience	15	Seasonal forecast (early warning)	0.02					
	16	Productive safety nets	0.15					
Infrastructure	17	Irrigation infrastructure	0.20	0.11	0.29	0.06	0.39	0.87
	18	Rural roads	0.05					

Source: RIAPA modeling system

Summary

The Rwandan economy relies heavily on its agrifood system as a major source of livelihood, an engine of growth, and source of employment. Despite encouraging progress thanks to the Plan for Structural Transformation in Agriculture (PSTA) programs, Rwanda has an urgent need to transform its agrifood system in a sustainable manner, requiring increased technical and financial support to agriculture and allied sectors. This calls for evaluating a long list of agrifood system investments against their simulated impacts across economic, social, and environmental outcomes. These impacts should also be scrutinized against history-grounded potential production shocks to affirm if investments’ relative cost-effectiveness is maintained under such unprecedented shocks.

This policy brief reported a research output that systematically evaluates a range of investment options, ranking them based on their cost-effectiveness in delivering multiple development outcomes,

including economic growth, job creation, poverty reduction, undernourishment reduction, and improvements in diet diversity. These investments are also evaluated based on their impacts on key sustainability and nature capital indicators, focusing on water, emissions, and land footprints.

We observe from the results that investing in SME processors and traders as the most cost-effective option for expanding the agrifood GDP and employment. Livestock extension/advisory services are the most cost-effective farmer-facing investments, mainly driven by faster growth in agrifood system employment. Similar to the economic outcome scores, investing in SME processors and advisory services to livestock producers rank as the most cost-effective option for achieving greater progress in poverty reduction, improvement in the rate of undernourishment, and diversity of diets. Improved seed systems and credit access are among the interventions that promote greater social outcomes. However, most farmer-facing interventions such as extension and advisory services on crops rank as the least cost-effective in relation to their effects on economic and social outcomes although they generate the least environmental footprint principally because of overall weaker impacts on production. Overall, interventions with greater GDP effects tend to have undesirable environmental outcomes, demonstrating tradeoffs. This analysis also reveals modest changes in the relative cost-effectiveness of interventions when the system is exposed to extreme production shocks.

Several general policy messages can be drawn from this analysis. Firstly, not only have we demonstrated that integrating data- and model-driven insights into policy and investment prioritization decisions is feasible, but it is also important to do so given synergies and tradeoffs across of these investments on development outcomes. Secondly, considering the environmental implications of policy and investment decisions is critical to ensure that the adverse effects of climate change or environmental degradation do not fall disproportionately on future generations of poor people. Our analysis highlights the importance of designing appropriate climate adaptation and mitigation policies to help increase the productivity and resource use efficiency of sectors identified as drivers of socioeconomic progress.

About the Authors

Emerta Aragie is a Research Fellow, **James Thurlow** is the Director, and **Valencia Wenqian Xu** is a Research Analyst in IFPRI's Foresight and Policy Modeling Unit, all based in Washington, DC. **James Warner** is a Research Fellow and Rwanda Program Leader, and **Josue Niyonsingiza** is Senior Research Analyst in IFPRI's Development and Strategic Governance Unit, based in Kigali.

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References

- Aragie, E., Benfica, R., Pauw, K., Randriamamonjy, J. and Thurlow, J. 2024. Assessing Investment Priorities for Driving Inclusive Agricultural Transformation: An Application to Tanzania. *Development Policy Review*, 42(6): e12812.
- Aragie, E., Artavia, M., and Pauw, K. 2019. Strategic public spending: Scenarios and lessons for Ghana. IFPRI Discussion Paper 1852. Washington, DC: International Food Policy Research Institute (IFPRI). <https://doi.org/10.2499/p15738coll2.133332>
- Aragie, E., Diao, X., Spielman, D.J., Thurlow, J., Mugabo, S., Rosenbach, G. and Benimana, G. 2022. Public investment prioritization for Rwanda's inclusive agricultural transformation: Evidence from rural investment and policy analysis modeling. Rwanda Strategy Support Program. Working Paper 03.
- Arndt, C., M. Hussain, E. Jones, V. Nhate, F. Tarp, and J. Thurlow. 2012. Explaining the evolution of poverty: The case of Mozambique. *American Journal of Agricultural Economics*, 9 (94): 854-872.
- Austin, K.G., Beach, R.H., Lapidus, D., Salem, M.E., Taylor, N.J., Knudsen, M. and Ujeneza, N. 2020. Impacts of Climate Change on the Potential Productivity of Eleven Staple Crops in Rwanda. *Sustainability* 2020, 12(10), 4116; <https://doi.org/10.3390/su12104116>
- Benfica, R., Cunguara, B. and Thurlow, J. 2019. Linking agricultural investments to growth and poverty: An economywide approach applied to Mozambique. *Agricultural Systems*, 172, 91-100.
- Christiaensen, L., and W. Martin. 2018. Agriculture, structural transformation and poverty reduction: Eight new insights. *World Development*, 109: 413-416.
- Climate Watch. 2025. Historical GHG Emissions. https://www.climatewatchdata.org/ghg-emissions?end_year=2021&start_year=1990
- Devarajan, S. and Robinson, S. Contribution of Computable General Equilibrium Modeling to Policy Formulation in Developing Countries. In *Handbook of Computable General Equilibrium Modeling*, Peter B. Dixon, Dale W. Jorgenson (ed), 1: 277-301.
- Diao, X., Ellis, M., Pauw, K., Rosenbach, G., Mugabo, S., Spielman, D. and Thurlow, J. 2023. Transformation of Rwanda's Agrifood System Structure and Drivers. Country Series. IFPRI
- Dixon, P. and Parmenter, B.R. 1996. Computable general equilibrium modelling for policy analysis and forecasting. Chapter 01 in *Handbook of Computational Economics*, 1: 3-85.
- FAO. 2025. FAOSTAT. Food and Agricultural Organization of the United Nations. <https://www.fao.org/faostat/en/#data>
- GLOPAN (Global Panel on Agriculture and Food Systems for Nutrition) 2020. Future food systems: for people, our planet, and prosperity. London, UK. https://www.glopan.org/wp-content/uploads/2020/09/Foresight-2.0_Future-Food-Systems_For-people-our-planet-and-prosperity.pdf.
- IFPRI (International Food Policy Research Institute). 2023. RIAPA Data and Modeling System. Washington, DC. <https://www.ifpri.org/project/riapa-model>
- IFPRI (International Food Policy Research Institute). 2024. Global Spatially-Disaggregated Crop Production Statistics Data for 2020 Version 1.0.0. https://doi.org/10.7910/DVN/SWPENT_Harvard_Dataverse_Version_3.
- IFPRI (International Food Policy Research Institute). 2024a. 2022 Social Accounting Matrix for Rwanda: A Nexus Project SAM. Data Paper. Washington, DC: International Food Policy Research Institute. handle: 10568/155102.
- Kumar, N. and Maiti, D. 2024. Long-run macroeconomic impact of climate change on total factor productivity – Evidence from emerging economies. *Structural Change and Economic Dynamics*, 68: 204-223.
- MINAGRI (Ministry of Agriculture and Animal Resources). 2018. Strategic Plan for Agriculture Transformation 2018-24. Kigali: Ministry of Agriculture and Animal Resources (MINAGRI).
- Mekonnen, M.M. and Hoekstra, A.Y. (2010) The green, blue and grey water footprint of farm animals and animal products. Value of Water Research Report Series No. 48, UNESCO-IHE, Delft, the Netherlands. <http://www.waterfootprint.org/Reports/Report47-WaterFootprintCrops-Vol1.pdf>
- MoE (Ministry of Environment). 2020. Updated Nationally Determined Contribution. Ministry of Environment (MoE), Kigali. <https://www.environment.gov.rw/index.php?eID=dumpFile&t=f&f=40508&token=1ddacaf88d8399373776ecdc3d990479c1c9e181>
- MoNR. 2015. Intended Nationally Determined Contributions (INDCs) of Rwanda. Ministry of Natural Resource (MoNR), Kigali.
- NISR (National Institute of Statistics of Rwanda). 2024. GDP National Accounts 2023. Kigali: National Institute of Statistics of Rwanda (NISR). <https://www.statistics.gov.rw/publication/2114>
- NISR (National Institute of Statistics of Rwanda). 2018. The Fifth Integrated Household Living Conditions Survey (EICV5): 2016/17 Rwanda Poverty Profile Report. Kigali: National Institute of Statistics of Rwanda (NISR).
- Pauw, K., O. Ecker, J. Thurlow, and A.R. Comstock. 2023. Measuring changes in diet deprivation: New indicators and methods. *Food Policy*, 117, Article #102471.
- Pauw, K., J. Thurlow. 2015. Prioritizing Rural Investments in Africa: A Hybrid Evaluation Approach Applied to Uganda. *European Journal of Development Research*. 27(3): 407-424. Special Issue on Public Investments in and for Agriculture. <https://doi.org/10.1057/ejdr.2015.24>.
- Pham, T. H., and J. Riedel. 2019. Impacts of the sectoral composition of growth on poverty reduction in Vietnam. *Journal of Economics and Development*, 21 (2): 213-222.
- Poore, J. and Nemecek, T. 2018. Reducing food's environmental impacts through producers and consumers. *Science*, 360:987-992.

- Thurlow, J., J. Kiringai, M. Gautam. 2007. Rural Investments to Accelerate Growth and Poverty Reduction in Kenya. IFPRI Discussion Paper 00723 (October 2007). Washington DC: International Food Policy Research Institute.
<https://ebrary.ifpri.org/utils/getfile/collection/p15738coll2/id/40627/filename/40628.pdf>.
- Twahirwa, A., Oludhe, C., Omondi, P., Rwanyiziri, G. and Ndakize, J.S. 2023. Assessing Variability and Trends of Rainfall and Temperature for the District of Musanze in Rwanda. *Advances in Meteorology*, <https://doi.org/10.1155/2023/717776>

Annex Table 1: List of investment scenarios considered

Broad category	Number	Scenario	Description
Research and development (R&D)	1	R&D (improved seeds)	R&D into improved seed development
	2	R&D (agronomic practices)	R&D into improved agronomic practices
	3	R&D (animal breeds)	R&D into improving breeds
	4	R&D (animal husbandry)	R&D into improved husbandry practices
Extension / advisory services	5	E/AS (improved seeds)	Advising improved seed use
	6	E/AS (agronomic practices)	Advising improved agronomic practices
	7	E/AS (livestock)	Advising improved livestock handling
	8	E/AS (climate information)	Providing climate information system
	9	E/AS (climate smart agriculture)	Advising on climate smart practices
Markets and food systems	10	Seed systems	Extended seed system
	11	SME processors (finance + training)	Finance and training for SME processors
	12	SME traders (finance + training)	Finance and farming for SME traders
	13	Food loss and waste	Food storage and transport
	14	Credit access (financial inclusion)	Micro-credit access for farmers
Risk reduction and resilience	15	Seasonal forecast (early warning)	Seasonal weather forecast
	16	Safety nets	Productive safety nets for the poor
Infrastructure	17	Irrigation infrastructure	Small and medium scale irrigation
	18	Rural roads	Unpaved feeder roads

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