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Leveraging Science, Technology and Innovation to Enhance Food Security in Rwanda

TECHNICAL REPORT FOR THE STI FOR SDGs ROADMAP

Elci, S., Galindo, M., Miedzinski, M.

2025

EUR 40248

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JRC140412

EUR 40248

Print ISBN 978-92-68-25277-2 ISSN 1018-5593 doi:10.2760/2516628 KJ-01-25-155-EN-C

PDF ISBN 978-92-68-25276-5 ISSN 1831-9424 doi:10.2760/1741010 KJ-01-25-155-EN-N

Luxembourg: Publications Office of the European Union, 2025

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How to cite this report: European Commission: Joint Research Centre, Elci, S., Galindo, M. and Miedzinski, M., *Leveraging Science, Technology and Innovation to Enhance Food Security in Rwanda*, Publications Office of the European Union, Luxembourg, 2025, <https://data.europa.eu/doi/10.2760/1741010>, JRC140412.

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ABSTRACT

Science, Technology, and Innovation (STI) play a key role in achieving the Sustainable Development Goals (SDGs). The Joint Research Centre (JRC) and the Directorate General for International Partnerships (DG INTPA) of the European Commission joined forces launching the project on STI for Sustainable Development Goals (SDGs) Roadmaps in Africa. The report lays the foundation for STI for SDGs roadmap in Rwanda with the focus on fostering food systems transformation to enhance food security of the country with the focus on leveraging emerging technologies to enhance food productivity. The report identifies areas for further investment in STI and proposes policy and governance mechanisms to increase impact of innovation in the challenge area. This report is based on stakeholder workshop and interviews and the desk study. The work was undertaken in collaboration between JRC and the National Council for Science and Technology (NCST) of Rwanda.

FOREWORD BY THE JOINT RESEARCH CENTRE OF THE EUROPEAN COMMISSION

It is with great pleasure that I present the report on the role of science, technology, and innovation (STI) for Sustainable Development Goals (SDGs) in Africa, with a spotlight on Rwanda. The report is a result of the collaboration of the Joint Research Centre (JRC) and the Directorate General for International Partnerships (DG INTPA) of the European Commission (EC). This project embodies the long-standing commitment of the EC to fostering STI as a cornerstone for achieving sustainable development, in line with the African Union-European Union Innovation Agenda and the Global Gateway initiative.

The challenge-oriented STI for SDGs roadmaps approach, pioneered by the JRC based on the collaboration with the UN, is an innovative framework designed to align STI policies with the ambitious goals set by the 2030 Agenda for Sustainable Development. Roadmaps are strategic policy and governance frameworks based on evidence and participatory deliberation. Their goal is to ensure that STI contribute effectively to addressing localised sustainability challenges.

The development of STI for SDGs roadmaps is a participatory process that brings together diverse stakeholders, including policymakers, researchers, industry leaders, international partners, and civil society. Roadmaps capture collective knowledge and experience of these actors to respond to the specific needs and localised challenges.

Rwanda's remarkable development journey serves as an inspiring example of what can be achieved through collaborative efforts engaging local and international actors. STI play a fundamental role in accelerating the transformation that creates benefits for all communities. Rwanda's roadmap, developed in close collaboration with colleagues from the National Council for Science and Technology (NCST), focuses on the role of STI in fostering the transformation of the food system to enhance food security.

We hope that the roadmap will become a useful framework for policy makers and stakeholders engaged in transforming Rwanda's food system and policy practitioners in other countries working on similar challenges.

I would like to express my sincere appreciation to the Rwandan partners at NCST and all contributors who have made this report possible. Your insights and expertise are invaluable as we continue to make collective efforts to mobilise STI for sustainable development.

The JRC is proud of having supported this initiative and remains committed to providing evidence-based scientific support to the policymaking process. We look forward to witnessing the positive impact of our joint efforts in Rwanda and the strengthened Africa-Europe collaboration.

Mikel Landabaso

Director – Fair and Sustainable Economy

Joint Research Centre, European Commission

FOREWORD BY THE NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY

The National Council for Science and Technology (NCST) is pleased to present the Science, Technology, and Innovation (STI) for Sustainable Development Goals (SDGs) Roadmap, with a specific focus on leveraging STI to enhance food security in Rwanda. This roadmap is the result of a collaborative effort between the Joint Research Centre (JRC) of the European Commission (EC), the Directorate General for International Partnerships (DG INTPA) of the European Commission (EC), and the NCST.

Food security remains one of the most pressing challenges of our time. In Rwanda, where agriculture plays a vital role in the economy and in sustaining livelihoods, the need for sustainable, innovative, and science-driven solutions has never been greater. The COVID-19 pandemic and other disease outbreaks, climate change, and global food supply chain disruptions have underscored the urgency of building a resilient food system that can adapt to current and future challenges.

This roadmap aims to harness the potential of STI as key enablers for achieving sustainable food security. By employing cutting-edge technologies such as precision agriculture, big data analytics, biotechnology, and renewable energy solutions, we envision a food system that is more productive, efficient, and environmentally friendly. This will not only ensure that Rwanda meets its food security needs but also aligns with the country's ambition to achieve the SDGs by 2030.

The collaboration with the European Commission's Joint Research Centre and DG INTPA has been instrumental in bringing global expertise and best practices to this process. Through this partnership, we have established a comprehensive strategy that prioritizes research, innovation, and technology transfer to tackle food security challenges. This roadmap is closely aligned with Rwanda's national development agenda, including Vision 2050 and the National Strategy for Transformation (NST-2), reinforcing the country's commitment to fostering an innovation-driven economy.

The STI for SDGs Roadmap provides actionable insights and policy recommendations that will guide our collective efforts in making food security a reality for all Rwandans. It underscores the pivotal role that both local and international partnerships play in driving the application of science and technology to address real-world challenges effectively. Looking ahead, NCST remains dedicated to collaborating with stakeholders across various sectors to implement this roadmap. By building a strong foundation of science,

technology, and innovation, we can achieve food security, drive inclusive growth, and build a prosperous and sustainable future for Rwanda.

Dr Eugene Mutimura

Executive Secretary

National Council for Science and Technology (NCST)

Republic of Rwanda

ACKNOWLEDGEMENTS

We would like to acknowledge the support from the Rwanda National Council for Science and Technology (NCST) that laid the ground for the successful implementation of the project. Our sincere gratitude goes to Dr Eugene Mutimura for his leadership and strategic support.

We would like to thank Dr Louis Sibomana, Head of Science, Technology Development and Outreach Department at NCST, for his strategic guidance and active engagement throughout the process. Special words of appreciation are due to Mr Felly Kalisa Migambi and Dr Marie Chantal Cyulinyana from NCST for their invaluable feedback and crucial role in preparing the national workshop and making it a success.

We would like to express our warmest thanks to colleagues at the Delegation of the European Union to Rwanda. We would like to thank Ms Belen Calvo Uyarra, the EU Ambassador to Rwanda, for supporting the project since the outset and Ms Michela Tomasella, Head of Cooperation, for contributing to the Kigali workshop. We are particularly grateful to Ms Natalija Waldhuber for her strategic advice and ongoing support and Ms Mugeni Kayitenkore for helpful feedback on the draft report.

We owe a debt of gratitude to all stakeholders who found time for an interview with us, contributed to the workshop and responded to the survey.

EXECUTIVE SUMMARY

PURPOSE AND APPROACH OF THE STI FOR SDGs ROADMAP

Science, Technology, and Innovation (STI) play a key role in achieving the Sustainable Development Goals (SDGs). In 2022, the Joint Research Centre (JRC) and the Directorate General for International Partnerships (DG INTPA) of the European Commission joined forces launching the project STI for Sustainable Development Goals (SDGs) Roadmaps in Africa. The objective of the project was to improve directionality and effectiveness of STI policies to contribute to the SDGs in line with the EU priorities for STI cooperation with Africa as expressed in the AU-EU Innovation Agenda.

To develop the roadmap in Rwanda the JRC partnered with the National Council for Science and Technology (NCST), a leading institution designing and implementing STI policy. Following stakeholder consultations, the recommendation was to focus the project on the role of STI in fostering food systems transformation to enhance food security with the focus on leveraging emerging technologies to enhance food productivity.

The project used a participatory and co-creation approach, involving stakeholders from the public and private sectors, NGOs, international partners and academia. The roadmap was informed by the stakeholder workshop held in Kigali on 4 March 2024, and a series of interviews with the local and international stakeholders involved in initiatives relevant for food system transformation in Rwanda.

CHALLENGES AND OPPORTUNITIES OF FOOD SYSTEM TRANSFORMATION

Rwanda has made notable progress in transforming its food system with improvements in agricultural transformation, food security and nutrition. However, the country faces significant challenges, including low agricultural productivity, malnutrition, post-harvest food waste, limited access to finance, and inadequate infrastructure.

Agriculture accounts for nearly a quarter of Rwanda's GDP and has grown at the rate of 4.5% annually from 2012 to 2022. However, the sector experiences low levels of productivity, with only 34% of total food produced reaching the market. The country loses three million tons of food annually, equivalent to 40% of its total production, impacting land use, greenhouse gas emissions, and economic stability. Rwanda's food system is characterised by a significant informal sector, encompassing small-scale vendors and local markets, which plays a key role in food access and affordability, especially for low-income populations.

There are several areas where STI can help boost system security in Rwanda:

- Enhancing agricultural productivity and resilience through localised innovation;
- Strengthening research and innovation capabilities to foster food system transformation;
- Promoting digital and precision agriculture in combination with agroecology for sustainable farming;
- Investing in agro-processing capabilities and facilities;
- Strengthening innovation-oriented public-private partnerships in the agri-food value chains.

The roadmap identified several specific STI investment areas, including climate-resilient agriculture, better diets and access to affordable nutritious foods, women and youth empowerment in agriculture, digital solutions for enhanced productivity, and soil conservation techniques.

EXISTING POLICIES MOBILISING STI FOR FOOD SYSTEM TRANSFORMATION

Rwanda has implemented a range of policy instruments aimed at leveraging STI to transform its food system. The National Strategy for Transformation (NST1) and Vision 2050 are overarching strategies that set goals for Rwanda to become an upper-middle-income country by 2035 and a high-income country by 2050. While NST1 does not explicitly refer to the transformation of food systems, it identifies priorities linked to this challenge, such as modernising agriculture, promoting sustainable management of the environment, eradicating malnutrition, and focusing on non-communicable diseases. The National Agriculture Policy (NAP) and the Strategic Plan for Agriculture Transformation 2018-24 (PSTA 4) provide a more detailed roadmap for achieving the vision laid out in the NAP.

The National Research and Innovation Agenda and national STI Policy identify 'food security and modern agriculture' as a national priority area, focusing on research topics such as crop research and protection, biotechnology, post-harvest handling and management, livestock, irrigation and mechanization, precision agriculture, and land husbandry. Rwanda's STI Policy aims to integrate and mainstream STI in national policies to address societal challenges and establish a globally competitive knowledge-based economy.

The STI policy addressing food system transformation faces several challenges:

- Limited policy coherence: There is a lack of a comprehensive STI strategy and governance mechanisms that integrate all dimensions of the food system transformation.
- Funding and resource allocation shortcomings: Research institutions in Rwanda face significant underinvestment in R&D staff and research.
- Limited support for sustainable agriculture and localised innovation:

There is insufficient support for context-specific sustainable agricultural innovation practices that respond to localised challenges.

- **Infrastructure and data integration gaps:** Rwanda faces challenges in establishing the infrastructure required to support strong research and innovation in transforming its food systems.
- **Capacity building and skills development gaps:** A considerable gap exists in the training of extension personnel, limiting their capacity to effectively transfer knowledge and engage with farmers.
- **Addressing behavioural challenges and regional disparities in food security and malnutrition:** There are significant regional disparities in Rwanda in malnutrition and food security, necessitating innovative non-technological solutions that focus on behavioural change and tailored interventions to meet the specific nutritional needs of different communities.

These challenges highlight the need for a more coordinated approach to STI policy to deliver on the ambition to address urgent societal challenges facing Rwanda.

PROPOSED POLICY ACTIONS FOR THE ROADMAP

To tackle the identified challenges and capitalise on emerging opportunities presented by the STI, we propose the following policy recommendations:

- **Strengthen governance and STI policy coherence in the area of food system** by establishing a high-level committee to coordinate policies and their implementation across various domains and sectors.
- **Develop a research and innovation agenda for food system transformation** to provide a systemic approach to developing and improving a robust evidence base for policy decisions and investments.
- **Support the adoption of innovative technologies** such as cold chain systems, digital tracking of food inventory, and recycling initiatives to convert food waste into value-added products such as fertilisers and bioenergy.
- **Revitalise innovation platforms** to address specific food system challenges and provide a collaborative space for stakeholders to exchange experience and co-create new ideas. Encourage collaboration between government, private sector, and civil society to develop integrated food waste management systems and share best practices across the food supply chain.
- **Build science and research capabilities for food system transformation** by establishing a research network to provide independent studies and advice/guidance to the government and other stakeholders.
- **Invest in modern storage, transportation, and processing facilities** to minimize post-harvest losses, particularly for perishable goods, while streamlining investments in STI to enhance productivity and resilience within the food system. This includes implementing an innovation scheme aimed at reducing food waste across the entire supply chain.

- Support social and frugal innovation in food system for resilient local communities by establishing Frugal Innovation Labs to develop cost-effective, scalable, and sustainable solutions specifically designed for the unique challenges of Rwanda's agri-food sector. Develop and enforce regulations that promote sustainable food waste management practices, including incentives for businesses and farmers to adopt post-harvest waste-reducing technologies and methods.
- Introduce integrated approach to advisory and extension services by developing a digital platform to provide a one-stop shop access to relevant services and information sources, including relevant local contacts, problem-based and place-relevant information and good practices in agricultural techniques, sustainable farm management practices, and management skills.

INTRODUCTION

Science, Technology, and Innovation (STI) play a key role in achieving the Sustainable Development Goals (SDGs). In 2022, the Joint Research Centre (JRC) and the Directorate General for International Partnerships (DG INTPA) of the European Commission joined forces launching the project science, technology and innovation (STI) for Sustainable Development Goals (SDGs) Roadmaps in Africa. The objective of the project is to improve directionality and effectiveness of STI policies to contribute to the SDGs in line with the EU priorities for STI cooperation with Africa. The roadmaps support the implementation of the AU-EU Innovation Agenda, a framework that fosters cooperation in research, science, and technology.

The STI for SDGs roadmaps are strategic policy frameworks mobilising STI to address key societal challenges and contribute to the SDGs. The roadmaps create complementarities and synergies between relevant public interventions supporting STI implemented across policy areas and sectors. JRC has adapted the methodology to collect evidence and stakeholder views on the future investments in research and innovation addressing country-specific sustainability challenges. The methodological approach builds on the experience of smart specialisation strategies (S3) in the European Union and beyond and the adaptation of S3 approach to the rationale of STI for SDGs roadmaps¹ as defined by United Nation's Inter-Agency Task Team (UN IATT) in cooperation with JRC. JRC and DG INTPA are working towards the design of STI roadmaps with a selection of six African countries, including the Gambia, Mauritius, Namibia, Malawi, Rwanda and Seychelles. STI for SDGs Roadmaps are the product of close collaborations between international experts and local stakeholders in a participatory and co-creation environment.

To develop the roadmap in Rwanda the JRC partnered with the National Council for Science and Technology (NCST). Following stakeholder consultations, the recommendation was to focus on the role of STI in fostering food systems transformation to enhance food security of the country with the focus on leveraging emerging technologies to enhance food productivity. Although a notable progress has been made in transforming food systems, with significant improvements in agricultural transformation, food security, and nutrition, considerable challenges remain in agricultural productivity, nutrition, and land distribution and use. The focus area is in line with national key priorities: 'Food security and modern agriculture' as per the STI policy and the National Research and Innovation Agenda (NRIA, 2021).

¹ See *Background paper: Overview of the existing STI for SDGs roadmapping methodologies* co-published by JRC and IATT.

The report is based on desk study, including literature review and data analysis, and empirical research comprising two interactive stakeholder workshops and in-depth interviews. More than 40 participants representing the public and private sectors, non-governmental organizations, international organisations, and academia took part in the final workshop in Kigali on 4 March 2024. Face-to-face interviews were conducted with 15 stakeholders to gain detailed insights from key stakeholders. In parallel, a comprehensive survey was administered, yielding responses from 9 stakeholders. The consulted stakeholders included representatives from the public sector (ministries and government agencies), research, businesses and non-governmental organisations.

The report first discusses the challenges related to food system transformation in Rwanda (*Chapter 1*). It then analyses fitness of the Rwandan innovation system and STI policies to address the challenge (*Chapter 2*). Based on this background diagnosis, gaps and areas of opportunity for STI are proposed (*Chapter 3*) which are then further elaborated and presented as possible areas of investment, based on the empirical evidence collected during the project (*Chapter 4*). The report concludes with key findings and main policy messages and a tentative list of policy actions proposed for the STI for SDGs roadmap (*Chapter 5*). The report is aimed as a consultative document presented for the consideration of the Rwandan policy makers as well as development partners investing in STI for food transformation in Rwanda.

1. THE CHALLENGE OF FOOD SYSTEM TRANSFORMATION IN RWANDA

1.1. DESCRIPTION OF THE CHALLENGE AREA

Rwanda is a small, landlocked country in Central and Eastern Africa, characterised by its hilly and fertile landscape. As of 2022, the population exceeded 13 million. Since the 1994 genocide against the Tutsi, Rwanda has maintained political stability and now aims to become a middle-income country by 2035 and a high-income country by 2050. These goals are pursued through a series of seven-year National Strategies for Transformation (NST), supported by sectoral strategies aligned with the Sustainable Development Goals (SDGs). Despite robust economic growth following the end of the pandemic, inclusive development remains a challenge, with a noticeable slowdown in poverty reduction. Particularly in rural areas, the poverty rate has stagnated at around 52% since 2016, after a decline from 75.2% in 2000 (*World Bank, n.d.-a*).

Agriculture is a cornerstone of Rwanda's economy, employing over 70% of the population and accounting for nearly a quarter of its GDP as of 2023 (NIS, 2023). While the country is advancing an agenda on economic and trade integration, climate ambition, and making efforts toward the SDGs in health, education, gender equality, and environmental sustainability, it faces significant challenges in the agricultural sector. These challenges include enhancing food productivity, safety, and security. Despite ongoing efforts, around 19% of Rwandan families remain food insecure. This persistent food insecurity is compounded by chronic malnutrition affecting 34.9% of children under five, contributing to

Rwanda's poor performance on the Human Capital Index (HCI) (EC, n.d.). Therefore, achieving food systems transformation is critical for the country's economic and social resilience, environmental sustainability, and alignment with global food security efforts.

Considering these persistent challenges and following stakeholder consultations, it was agreed to focus the STI for SDGs roadmap on food system transformation. The sustainably challenge to be addressed by the roadmap is to “mobilise STI for food systems transformation, with a focus on leveraging emerging technologies to enhance food productivity, safety, and security”.

Food system comprises “the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption and disposal of food products that originate from agriculture, forestry or fisheries, and parts of the broader economic, societal and natural environments in which they are embedded” (FAO, 2018). A food system is composed of sub-systems, such as farming system, waste management system, input supply system, and interacts with other key systems like science, technology and innovation (STI) systems, energy system, trade system or health system. Hence, a structural change in the food system might depend and be driven by a change in another system (FAO, 2018).

Another key concept addressed by the roadmap is food security. Food security is defined as the consistent availability and accessibility of food, along with its proper utilisation and the stability

of food resources (UNCTAD, 2017). However, the challenge extends beyond these immediate aspects, as food insecurity presents both short-term difficulties and long-term developmental issues. The immediate challenge is the loss of human lives and well-being, while the long-term issues lead to economic consequences: malnourished individuals are less productive, and hungry children often miss education, becoming less capable adults even if they overcome hunger. These challenges not only affect individual lives but also create a significant obstacle to economic growth (UNCTAD, 2017).

Rwanda has taken significant steps in transforming its food systems, achieving the highest score (7.43 out of 10) in the 2015-2021 assessment of progress on the Malabo Declaration for Agricultural Transformation in Africa (AU, 2022). Despite these efforts, improvements in food security have been modest. Since 2015, there has been little change in the overall share of food-insecure households. However, there was a slight decline of 1% in the percentage of severely food-insecure households between 2015 and 2018, and the 2.3% increase in the proportion of fully food-secure households. In addition, the prevalence of chronic malnutrition among children under five years decreased from 37% in 2015 to 35% in 2018 (WFP, 2018). Meanwhile, the agricultural sector, vital for advancing Rwanda's food security, achieved an average annual growth rate of 4.5% between 2012 and 2022 (World Bank, 2023).

Despite this progress, several challenges continue to have significant impact on the food system transformation and food security in Rwanda:

- **Agricultural productivity and added-value:** The country experiences low levels of productivity for both crops and livestock due to low input use, underdeveloped production techniques and inefficient farming practices. Between 1999 and 2008, the share of food crops processed was below 6.5%. Furthermore, of the total food produced in Rwanda, only 34% reaches the market (FAO, n.d.-a), while exports still make relatively minor contributions
- to the sector, accounting for just 6.4 percent of agricultural GDP between 2010 and 2019. Yet two-thirds of the country's working population rely either directly or indirectly on agriculture and the wider food systems for their livelihoods, often through diversified livelihood strategies that include non-farm rural enterprises and migration to urban areas to help cope with the risks inherent in Rwandan agriculture (Petronille et al., 2022). More specific barriers related to agricultural productivity and added value are low-quality farm inputs and the overuse of hazardous agrochemicals; scarcity and low quality of livestock feed; low genetic potential of indigenous livestock breeds; and high incident of livestock diseases (Adolph et al., 2021).
- **Land distribution and use:** Nearly 98% of Rwanda's territory is categorized as rural, with approximately 49% classified as arable (FAO, n.d.-a). Food and agricultural production are primarily done on small and fragmented parcels that average 0.4 ha per household and are concentrated in food staples. Land degradation and soil erosion, caused by unsustainable agricultural practices and pressures related to rising population, is a major concern. The increasing fragmentation of land holdings is also a cause for concern, as good livelihoods are harder to achieve with smaller farms. Limited land security has often led to less interest among farmers in investing in their land, for example, by planting trees, mulching, and taking other measures to reduce erosion or improving soil fertility (Wigboldus, S. et al., 2021).
- **Post-harvest food waste:** Rwanda loses 3 million tons of food annually, equivalent to 40% of its total production, impacting land use, greenhouse gas emissions, and economic stability. This waste utilises 21% of the country's land, contributes to 16% of its greenhouse gas emissions, and represents a financial burden estimated at 12% of its annual GDP. Addressing this issue requires collaborative efforts and innovative solutions across the entire food chain (BCG, 2021). There is a need to encourage collaboration between government, private

sector, and civil society to develop integrated food waste management systems and share best practices across the food supply chain.

- **Nutrition:** Rwanda experiences persistent malnutrition, particularly during early childhood (stunting). The nutritional value of food consumed by food insecure households is a concern and the consumption of protein-rich food and food containing heme iron is very low (WFP, 2018). Access to food is a major issue with around 40% of all households experienced one or more shocks that affected their ability to access food. These shocks were mainly weather-related, such as drought, prolonged dry periods, or irregular rain (WFP, 2018). Economic dimension of the issue is also important since it would cost a household about twice as much to purchase a diet that meets nutrient needs compared to a diet that meets only energy needs (WFP, 2019).

- **Informality:** Rwanda's food system is characterised by a significant informal sector, encompassing small-scale vendors, street food, and local markets. This informal network plays a key role in food access and affordability, especially for low-income populations. However, it often remains overlooked in policy discussions and interventions. The lack of recognition and support for informal food systems hinders their potential to contribute to food security and nutrition goals. Integrating this sector into the food system framework through improved infrastructure, access to resources, and capacity building is essential for ensuring inclusive and sustainable food system transformation in Rwanda (TBI, 2021).

STI can significantly contribute to transforming food systems and enhancing food security through a range of interventions from climate-resilient farming methods and sustainable practices in both agriculture and aquaculture to digital solutions to increase productivity across food systems and technologies that increase the availability of nutritious foods. In addition to technological solutions, non-technological innovations are also critical for food security, including social

innovations such as community programmes for nutritional education and food sovereignty, local and regional policies for enhancing local food systems resilience as well as new business models improving food supply chain by reducing post-harvest losses, among others.

Such efforts require robust policy support, community engagement, and governance innovations to ensure their successful implementation and to achieve significant advancements in food security and sustainability. In this regard, the government makes efforts by putting in place policies and strategies aimed at evolving agriculture from primarily a subsistence activity into a knowledge-driven, value-creating sector, emphasizing the need for innovation and investment in modern technologies to enhance productivity and sustainability, as elaborated in the following section.

1.2. FOOD SYSTEM TRANSFORMATION IN NATIONAL POLICIES, STRATEGIES AND PLANS

The **Vision 2050** sets the development objectives and targets for Rwanda (GoR, 2020b). The strategy sets the goal of joining the group of upper-middle-income countries by 2035 and the high-income countries by 2050. The country's growth target was set to an average of about 10% until 2050 (Porte, 2021). Reflecting this commitment, Rwanda has demonstrated significant economic progress, achieving an annual growth rate higher than 7.5% from 2012 to 2022, with the exception of a downturn in 2020 due to the COVID-19 pandemic (World Bank, 2023).

The Vision 2050 defines the following pillars for a sustainable and inclusive development (*GoR, 2020b*):

- Human development aiming at building a healthy, well-educated and highly skilled workforce;
- Competitiveness and integration targeting efforts focused on positioning Rwanda among

the top 10 countries for ease of doing business by 2035 and maintaining this status into the future;

- Agriculture for wealth creation aiming at achieving an agriculture transformation that is equally led by men and women professional farmers and commercialised value chains;
- Urbanisation and agglomeration aiming at 70% of the population living in urban areas by 2050;
- Accountable and capable institutions to consolidate the progress made through citizen-centred reforms. The focus is on integrating home-grown solutions into the next phase of long-term development.

This new strategy made a reference to a number of global commitments such as the Addis Ababa Action Agenda, Agenda 2030 for Sustainable Development, Paris Declaration on Climate Change, East Africa Community Vision 2050, and African Union Agenda 2063 (Uwizeyimana, 2019).

While the pillars of the Vision 2050 do not explicitly address the transformation of food systems, they link to related aspects through specific priorities such as supporting a healthy population, which requires efforts towards appropriate nutrition, creating a modern, market-oriented, productive and climate-resilient agriculture sector. Supporting all these aspects, the document emphasises a knowledge-intensive economy, underpinned by excellence in research and development (R&D), innovation, and education (GoR, 2020b).

The Vision 2050 is implemented through multi-annual programmes. In 2017, the government launched **the National Strategy for Transformation (NST1)** for 2017-2024 focused on (GoR, 2017a):

- Economic transformation by speeding up private sector-led economic growth;
- Social transformation to improve the quality of lives;

- Transformation of governance to consolidate and provide building blocks for equitable transformational and sustainable national development.

While NST1 does not explicitly refer to the transformation of food systems, many priorities identified for above focus areas are linked with this challenge. These, for example, include the following priorities: “modernise and increase the productivity of agriculture and livestock”, “promote sustainable management of the environment and natural resources to transition Rwanda towards a Green Economy”, “eradicate malnutrition through enhanced prevention and management of all forms of malnutrition”, and set a new focus on non-communicable diseases (NCDs), the leading causes of death globally, and are among the top public health challenges of the 21st century. NST1 defines “environment and climate change” as a cross-cutting area where it focuses on activities to support “environmental and social impact assessments, biodiversity and ecosystem management, pollution and waste management” (GoR, 2017a).

Building on this foundation, Rwanda’s decentralised governance structure plays a key role in localising these national strategies. Rwanda’s approach to governance highlights the importance of decentralisation and granting local entities their autonomy. The country is divided into provinces and further into 30 districts, each with the autonomy to develop medium-term development plans that address specific local needs. Each district is responsible for formulating a medium-term development plan. These plans play a key role in how Rwanda tackles its challenges.

As an example, the Nyabihu district aims to establish itself as a hub for agro-food processing (GoR, 2018b) and therefore the Nyabihu District Development Strategy acknowledges the district’s strong agricultural position with a focus on modernising and enhancing productivity in both crop and livestock farming. This entails encouraging the use of contemporary agricultural practices such as irrigation and the consolidation

of land usage, improving access to better-quality seeds and fertilisers, using IT tools, like “e-Soko”² for farmer training, building agro-processing facilities and reinforcing agricultural value chains to reduce post-harvest losses and promote value addition (GoR, 2018b).

The government’s vision of food systems transformation is set by **the National Agriculture Policy 2018 (NAP)** and **the Strategic Plan for Agriculture Transformation 2018-24 (PSTA 4)**. The NAP sets the overarching policy framework, while the PSTA 4 provides a more detailed and operational roadmap for achieving the vision laid out in the NAP.

The **NAP** outlines a comprehensive path to transform the Rwanda’s food systems and ensure food security and nutrition for all. Its first pillar focuses on creating an enabling environment by attracting private sector investment, improving access to finance, and promoting responsive institutions, while the second pillar prioritises technological upgrading and skills development. This involves research on high-yielding crop varieties, improved animal breeds, and sustainable farming practices. Furthermore, the policy emphasises knowledge dissemination and skills development through a strengthened extension system and targeted training programs for farmers, with a focus on women, and youth. The third pillar makes an emphasis on increasing productivity and sustainability by addressing land fragmentation, promoting irrigation and sustainable land management, and building resilience in farming communities. The last pillar aims to develop inclusive markets and off-farm opportunities by strengthening post-harvest handling to avoid food waste, promoting value addition, and expanding access to local, regional, and international markets.

The **PSTA 4** envisages a transformation of agriculture from a subsistence sector to a

knowledge-based value creating sector that contributes to the national economy and ensures food and nutrition security (MINAGRI, 2018). It outlines four key priorities to achieve agricultural transformation and inclusive growth:

- Innovation and extension to improve practices, technologies, and skills, creating job opportunities and enhancing food security through bio-fortification;
- Productivity and resilience by increasing yields, diversifying into high-value commodities, and promoting climate-resilient practices;
- Inclusive markets and value addition by reducing post-harvest losses, increasing trade, and job creation through value chain development;
- An enabling environment and responsive institutions through increased public investment, private sector engagement, and coordinated policy implementation.

A complementary plan to PSTA is **the Action Plan for Mainstreaming Nutrition Sensitive Agriculture** that aims to maximise positive impact of agriculture on nutrition outcomes while minimizing any negative consequences. The plan focuses on increasing the availability, access, and consumption of diverse, safe, and nutritious foods while promoting sustainable agricultural systems. Key objectives include integrating nutrition into agricultural policies and programmes, strengthening institutional capacity, empowering women, and enhancing resilience to climate change. The plan also emphasizes the importance of multi-sectoral coordination and collaboration among various stakeholders (GoR, 2019a).

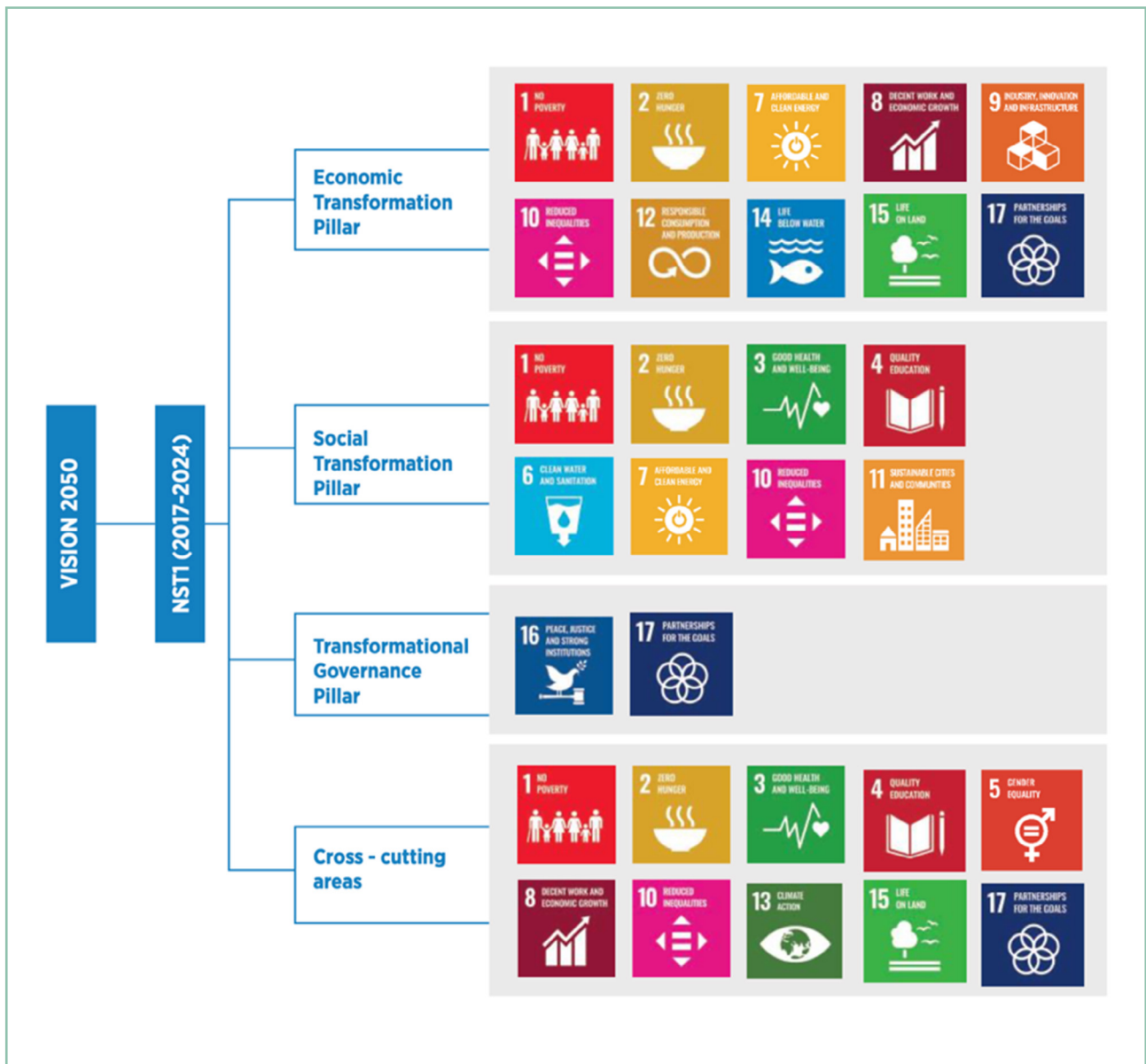
Expanding beyond its nutritional initiatives, Rwanda incorporates sustainable agricultural practices to enhance its commitment to environmental sustainability and climate resilience. As the key strategic document in this respect, **Green Growth and Climate Resilience Strategy (GGCRS)** aims at enhancing agro-ecology, develop climate-resilient crop varieties and animal breeds, and improving on-farm water and energy management.

² A project that seeks to empower farmers enabling them to make more informed market pricing decisions and ultimately more successful farming (e-soko, n.d.).

This includes promoting efficient irrigation systems, soil and water conservation techniques, and diversification of agricultural production. By investing in post-harvest infrastructure and agro-processing facilities, the GGCRS aspires to reduce losses and add value to agricultural products, increasing farmers' incomes and enhancing food security. The strategy also promotes sustainable land management practices such as agroforestry and reforestation, which contribute to climate change mitigation and improve ecosystem services that support agricultural productivity (GoR, 2023b).

Building on these strategies, Rwanda has further refined its approach to sustainable agriculture through the development of **the Green Taxonomy**. This classification system defines activities contributing to the country's environmental objectives, with a significant focus on transforming food systems. The taxonomy prioritises sustainable agriculture and livestock practices, outlining eligible activities and investments that promote climate resilience, resource efficiency, and biodiversity protection. It encourages practices like crop rotation, efficient

FIGURE 1.
LINK BETWEEN NST1 PRIORITY AREAS AND SDGs



Source: GoR, 2023

water management, organic fertilizer use, and integrated pest management. For livestock, the taxonomy promotes efficient water use, improved animal health, and methane reduction strategies. It also incentivises the adoption of agroforestry systems and the utilization of bio-digesters for energy generation (GoR, n.d.-d).

1.3. PROGRESS TOWARDS THE SDGs WITH RESPECT TO FOOD SYSTEM TRANSFORMATION

The SDGs form a key part of the national development agenda of Rwanda although there is no explicit SDG strategy or action plan (Sachs et al., 2023). They are deliberately embedded within Vision 2050, the NST1, and other sectoral or subnational plans, such as **Sector Strategic Plans and District Development Plans (Figure 1)**. PSTA 4 emphasises developing conducive environment for the agriculture sector to contribute to the achievement of several SDGs, particularly: SDG 1 (“end extreme poverty”), SDG 2 (“zero hunger, improved nutrition, and sustainable agriculture”), SDG 8 (“decent work and economic growth”), SDG 13 (“climate action”) and SDG 15 (“terrestrial ecosystems, forests, and land”) (MINAGRI, 2018).

Rwanda’s progress on the path of reconstruction can also be seen through the lens of the SDGs. In 2000, Rwanda began with an SDG Index score of 45.9, which had increased to a score of 60.2 by 2022. This represents a 30% improvement, ranking Rwanda as the fourth highest country in terms of rate of improvement globally (Sachs et al., 2023). However, gaps still remain; while the goal related to climate change (SDG13) has been achieved or is on track, the goal for responsible consumption and production (SDG12) continues to face issues, and significant challenges persist across the remaining goals.

Figure 2 illustrates the SDG Index performance of Rwanda compared to the Sub-Saharan region and the upper-middle-income countries targeted by Vision 2050. The chart reveals that Rwanda and

Sub-Saharan Africa exhibit similar patterns in their SDG achievements. While Rwanda outperforms the Sub-Saharan average in several areas, particularly in promoting gender equality (SDG 5), evidenced by a demand for family planning satisfied by modern methods at 72.1% of females aged 15 to 49 in 2023, and ensuring quality education (SDG 4), with a participation rate in pre-primary organized learning at 68.7% of children aged 4 to 6 in 2021, it slightly lags behind in eradicating poverty (SDG 1), where the poverty headcount ratio at US\$2.15/day is 38.55% in 2023, and reducing inequalities (SDG 10), as indicated by a Gini coefficient of 43.7 in 2020 (Sachs et al., 2023).

Although Rwanda generally does not reach the performance levels of upper-middle-income countries, there are notable exceptions. Rwanda performs well in addressing climate-related challenges (SDG 13), with CO₂ emissions from fossil fuel combustion and cement production at only 0.13 tons per capita in 2021. It also shows strong performance in protecting and sustainably managing terrestrial ecosystems (SDG 15), with 51.24% of terrestrial sites important to biodiversity being protected as of 2022. Furthermore, Rwanda advances peaceful and inclusive societies with accessible justice and accountable institutions (SDG 16), as reflected in a homicide rate of 3.59 per 100,000 population in 2021. This performance highlights Rwanda’s commitment to sustainable development and its potential to meet its Vision 2050 targets despite challenges in certain areas (Sachs et al., 2023).

Figure 3 offers an overview of performance in three key dimensions of Rwanda’s food system: food and nutrition security, environmental performance, and socio-economic and political performance.

Rwanda has made considerable progress towards global nutrition targets. However, significant challenges remain in the field of nutrition, especially considering children. The environmental performance is mixed with strong actions protecting ecosystem and biodiversity but much room for improvement in other areas,

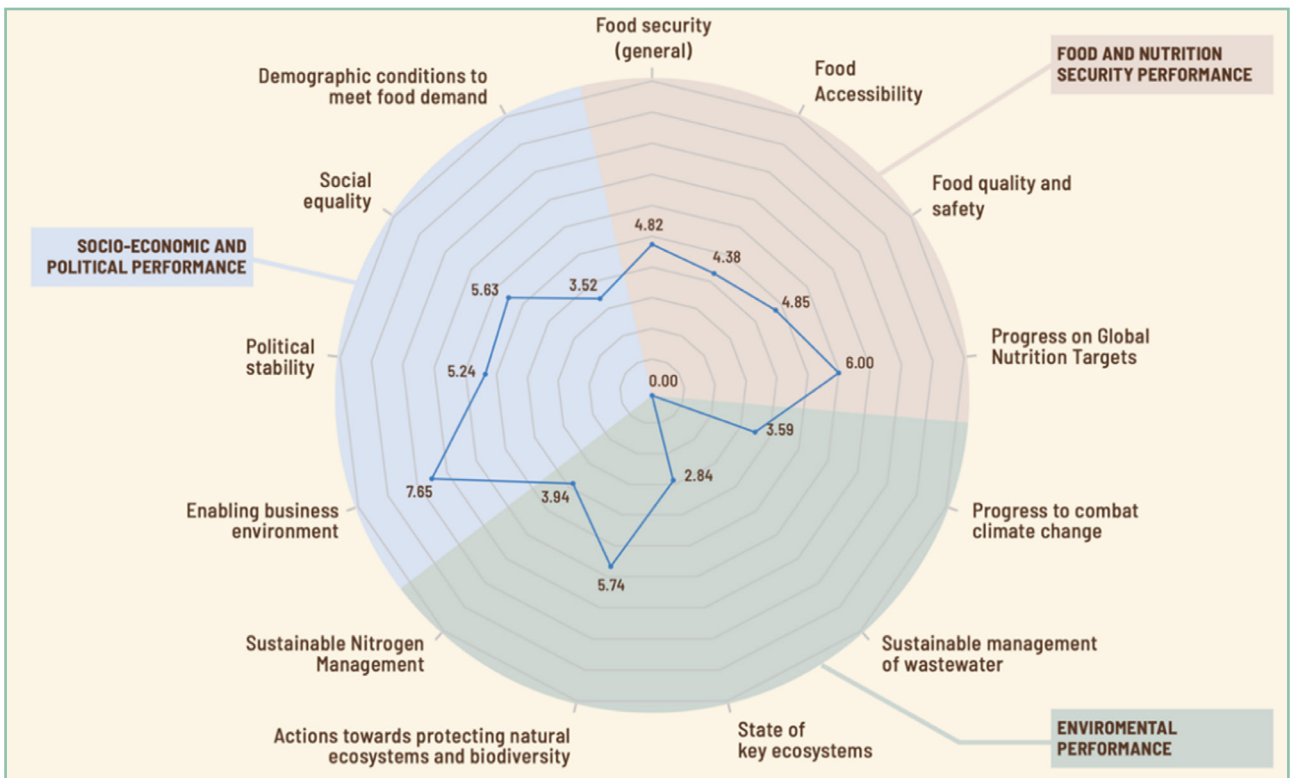
e.g. waste water management and state of ecosystems. Significant advances have been made in addressing land degradation and erosion, yet these issues continue to create vulnerabilities for the food system. Rwanda has a favourable business environment which is promising for the development of agri-food sector. However, the combined pressures of a growing population and rapid urbanisation are increasing demographic pressure on the food system, potentially complicating efforts to meet future food demand (Wigboldus, S. et al., 2021).

FIGURE 2.
SDG INDEX SCORE (2023)



Source: Sachs et al., 2023

FIGURE 3.
PERFORMANCE OF THE RWANDAN FOOD SYSTEM ACROSS THREE DIMENSIONS



Source: Wigboldus, S., Guijt, J., Garcia-Campos P, 2021

2. FITNESS OF INNOVATION SYSTEM TO FOSTER FOOD SYSTEM TRANSFORMATION

2.1. STI POTENTIAL AND PERFORMANCE WITH A FOCUS ON FOOD SYSTEM TRANSFORMATION

The R&D intensity has been gradually increasing since 2016. The gross expenditures on R&D (GERD) as a percentage of GDP has risen to 0.79% in 2023 from 0.69% in 2019 (NCST, 2024). This is still below the 1% target of the African Union (AU, 2014). Higher education sector was the highest R&D performer with nearly half of GERD (49.9% of GERD) followed by the Government sector – 37.1%. Higher education R&D expenditure has increased threefold since 2019. The business sector (BERD) and private non-profit R&D expenditure (PNP) were 6.9 and 5.9% of GERD respectively. Despite a low value, BERD increased since 2019 in absolute terms by 38.5%.

The two main sources of R&D are the Government with 51.9% in 2023 and foreign sources with 25.5% in the same period. The foreign funding has increased threefold since 2019 in absolute value (NCST, 2024). The foreign sources are highly relevant for R&D in the country. For example, the Institute of Policy Analysis and Research (IPAR), a flagship independent think tank in Rwanda, relies exclusively on international financial support (Fosci et al., 2019).

There has been a considerable growth in R&D personnel in Rwanda since 2016. Between 2016 and 2023, the number of researchers increased more than tenfold from 162 FTEs in 2016 to 1,837 FTEs in 2023. Rwanda reached 130 researchers per million inhabitants. This growth in the number of researchers over years was likely supported by

the enrolment of students in Ph.D. programmes which peaked in 2016 with 377 students (UNESCO Institute for Statistics, 2024). The overall increase in the number of researchers has not translated into improvement of gender equality in research. In 2019 women comprised 30.4% of all researchers in the country and in 2023 the share fell to 26.1% (by head count).

The statistics on STI performance in the agri-food sector are scarce. Agriculture and veterinary sciences research constituted 14% of GERD in 2019. However, the data by research field have not been reported since 2019. The 2023 statistics report R&D by multidisciplinary areas which did not include food system or agri-food sector explicitly. According to International Food Policy Institute in 2016 the country invested 0.44% of its agricultural GDP in R&D within the agri-food sector (ASTI, n.d.).

RAB, the main funding body for agricultural R&D, relies on external sources of funding for its research activities and has been successful in attracting diverse funding from regional and international organisations. Donor funding, however, is mostly ad-hoc and project-based, and does not always align with national priorities. Donor funding to RAB has declined since 2014, leading to a decline on RAB's R&D spending.

Although during 2011–2013, the country experienced growth in its total number of agricultural researchers, starting from 2014 there was a sharp decline due to a restructuring of the RAB researcher classifications. A Master's degree is now the minimum requirement for scientists to qualify as researchers, leading to the reclassification of many junior researchers

TABLE 1.
KEY R&D INDICATORS FOR RWANDA

Indicator	2016	2019	2023
GERD as share of GDP	0.65%	0.76%	0.79%
Share of R&D expenditure performed by Business Enterprise (BERD)	0.73%	7.93%	5.97%
Share of R&D expenditure performed by Government (GOVERD)	82.8%	63.59%	37.16%
Share of R&D expenditure performed by Higher Education (HERD)	8.40%	22.97%	49.87%
Share of R&D expenditure performed by Private non-profit (PNP)	8.02%	5.51%	7.00%
Total researchers (FTE)	233.9	1,333	3,655
Researchers per million inhabitants (FTE)	14	59	130
Share of female researchers (FTE)	25.05%	41.93%	31.49%

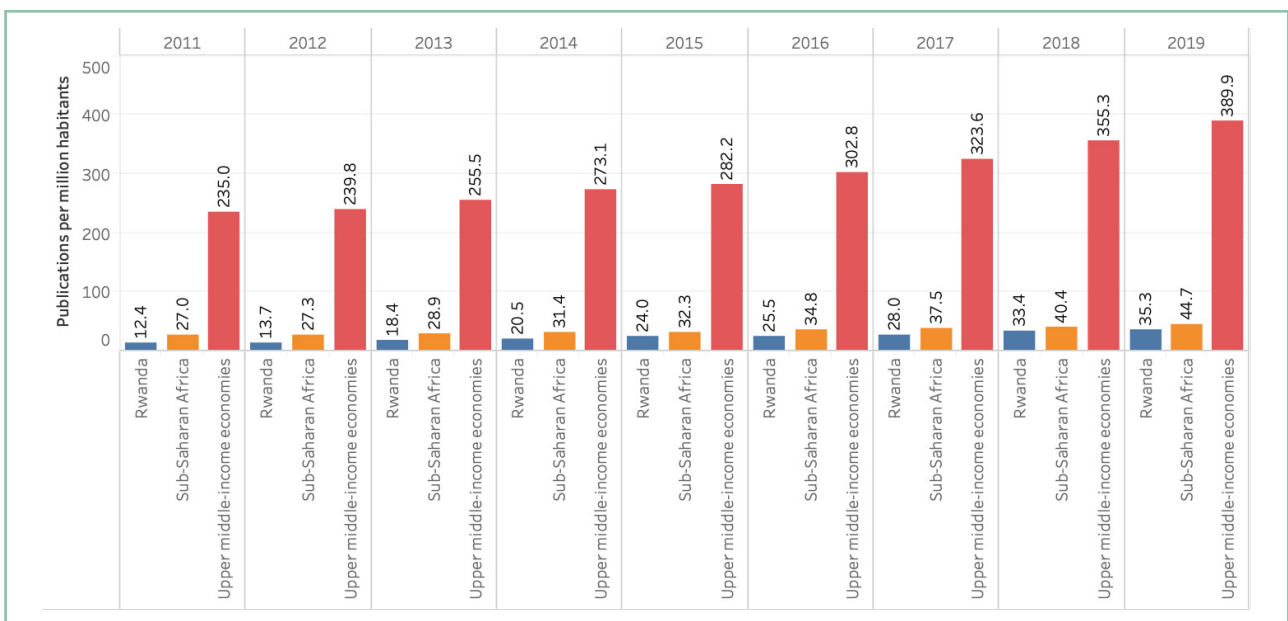
Source: (NCST, 2024)

as research technicians. Moreover, the number of researchers with PhD degrees remains low. (ASTI, n.d.). On the upside, Rwanda has one of the youngest pools of agricultural researchers in Africa.

In addition to the previously described challenges in human resources for research, Rwanda also faces obstacles in the production of knowledge and technological outputs. This situation is evident

from bibliometric indicators, which are crucial for assessing the R&D output and specialisation of a country's R&D performers. As shown in *Figure 4*, the volume of scientific publications in Rwanda has nearly tripled between 2011 and 2019, surpassing the growth rate of Sub-Saharan Africa and narrowing the gap with the region. However, despite this progress, the country still lags behind in absolute numbers. When compared to upper-

FIGURE 4.
PUBLICATIONS PER MILLION HABITANTS



Source: UNESCO, 2021

middle-income countries - a status Rwanda aspires to achieve by 2050 - the gap in research output becomes even more pronounced.

Research culture is a factor affecting the scientific production of the country. The University of Rwanda is the primary higher education institution with research capacity, while the wider higher education sector lacks the resources, reputation or recognition to undertake impactful research. Private universities appear to prioritise their vocational education function over research, and they struggle to recruit enough PhD students (Fosci et al., 2019).

A bibliometric study conducted for the UNESCO Science Report, which grouped scientific publications under specific SDGs (UNESCO, 2021), illustrates the distribution of Rwanda's scientific publications according to their respective SDGs (*Figure 5*). Rwanda's publications are predominantly concentrated in fields related to SDG 3 (good health and wellbeing), representing about three-quarters of the total papers during 2014-2016 and around two-thirds in 2017-2019. Another significant focus area has been SDG 15 (life on land), especially during 2017-2019. Over time, emphasis on SDG 2 (zero hunger) has increased, surpassing that of Sub-Saharan Africa. While Rwanda's focus on SDG 3 was notable, Sub-Saharan Africa experienced a slightly lower share of publications under this goal. In contrast, upper-middle-income economies showed a significantly lesser concentration in this area, with more diversified publication patterns, particularly in SDG 7 (affordable and clean energy) and SDG 9 (industry, innovation, and infrastructure), which are identified as challenges in Rwanda. In terms of SDG 15, both Sub-Saharan Africa and upper-middle-income economies had similar percentages, especially in the 2017-2019 period.

The 2024 JRC report on STI in Sub-Saharan Africa provides additional insight into Rwanda's research achievements (Daniels, et al., 2023). Analysing Horizon 2020 data, which includes metrics such as the number of funded projects, total funding, and institutions that received support, Rwanda achieved a score of 4 out of 5, indicating notable success.

However, in terms of involvement with the Marie Skłodowska-Curie Actions, Rwanda scored only 1 out of 5, highlighting significant room for improvement. The report also identifies Uganda, Kenya, Tanzania, Zambia, and Ethiopia as potential research collaborators due to their strong and compatible networking activities with other African Union countries within the Horizon 2020 framework.

Regarding intellectual property (IP), the data indicate Rwanda is a service-led economy where trademarks are critical asset (*Table 2*). The prominence of trademark applications shows that branding is important within the competitive retail and service sectors. On the other hand, the modest number of patent applications contrasts with a relatively higher interest in industrial designs, suggesting that Rwandan businesses are more inclined to enhance product design and functionality to address local preferences rather than invest in R&D.

Global Competitiveness Index (GII), another important data source regarding Rwanda's STI performance indicates that the country ranks first among the 12 low-income group economies and ninth among the 27 economies in Sub-Saharan Africa in 2022. However, as seen in *Figure 6*, shows a decline in Rwanda's performance since 2014, which can primarily be attributed to a decrease in its score rather than changes in the performance of other countries. Despite these fluctuations, Rwanda's relative ranking has remained between 83rd and 105th from 2014 to 2022 (WIPO, 2022).

As shown in *Figure 7*, some of Rwanda's strengths are reflected in the institutional dimension of the GII. The leading indicator is policies for doing business, where Rwanda ranks 11th in the world. This ranking is derived from the World Economic Forum's Executive Opinion Survey 2021, which measures the perception of the government's ability to ensure a stable policy environment conducive to business. Another strength highlighted by the GII is the country's political and operational stability, securing a rank of 33rd. This metric evaluates the likelihood and implications of political, legal, operational, or security risks

impacting business undertakings. The dimension of market sophistication has shown some positive signs, especially due to the availability of capital, as evidenced by Rwanda’s 17th rank in the number of venture capital deals. However, the decline in

performance seen in this dimension in 2022 was attributed to the limited access to credit for the private sector, which constituted only 24% of the GDP (WIPO, 2022).

FIGURE 5.
SHARE OF SCIENTIFIC PUBLICATIONS BY SDG

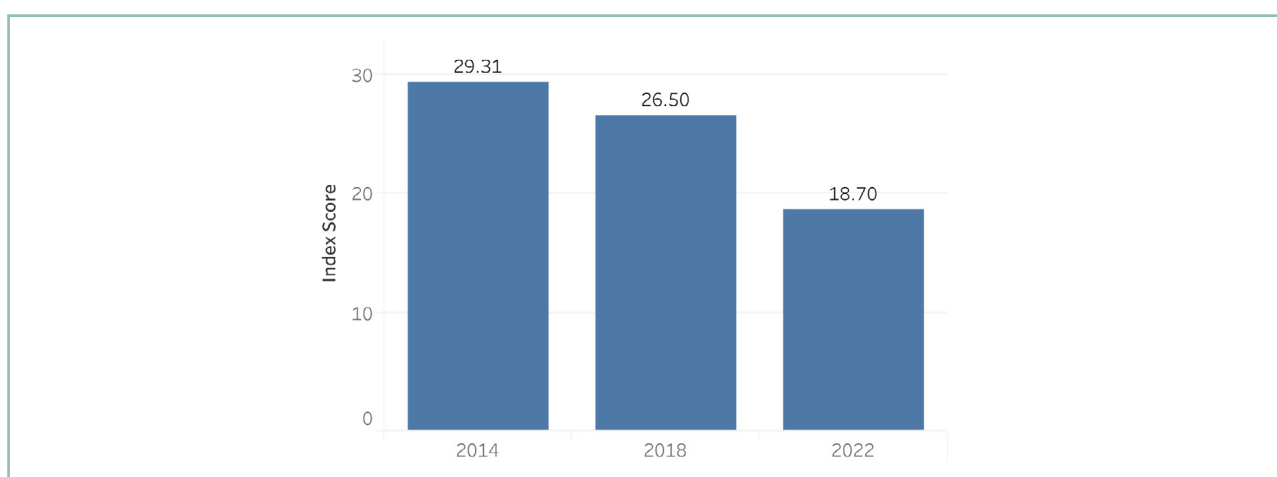


Source: UNESCO, 2021

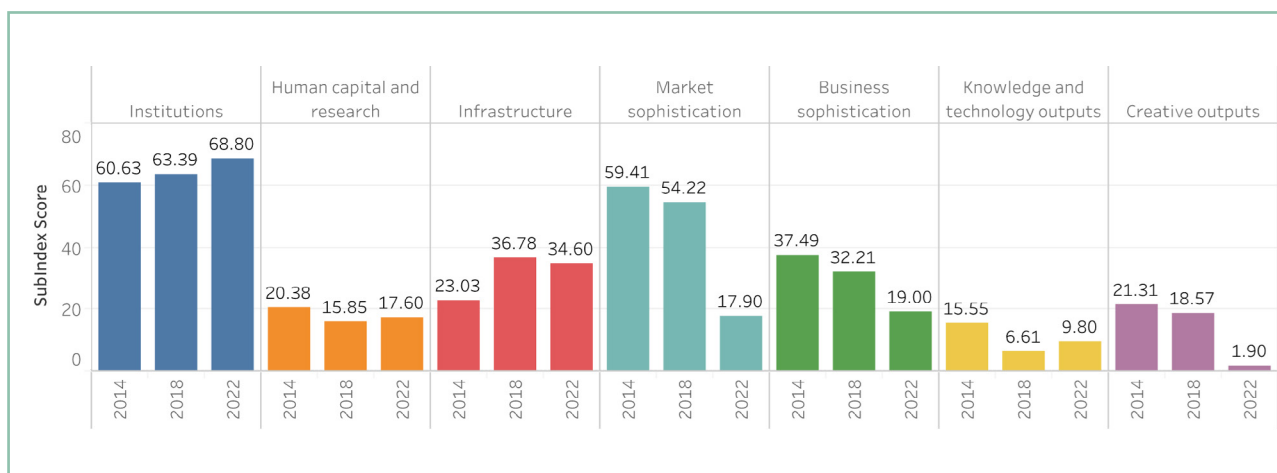
TABLE 2.
IP IN RWANDA

Year	Patents applications		Trademark applications		Industrial design applications	
	Non-resident	Resident	Non-resident	Resident	Non-resident	Resident
2018	1	6	32	318	27	5
2019	-	-	187	316	41	4
2020	-	16	62	396	46	6
2021	2	14	34	462	31	5
2022	5	7	6	383	43	3

Source: WIPO

FIGURE 6.
PERFORMANCE OF RWANDA IN THE GLOBAL INNOVATION INDEX

Source: WIPO, 2022

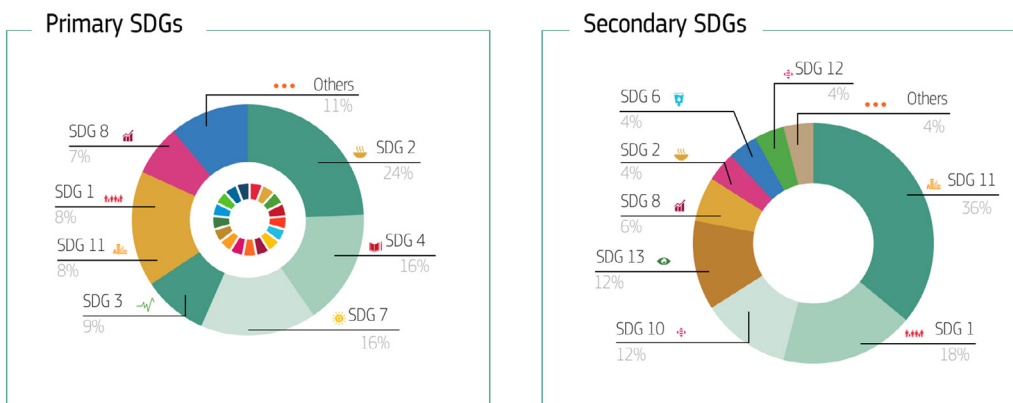
FIGURE 7.
BREAKDOWN OF RWANDA'S SCORES IN THE GLOBAL INNOVATION SUB-INDICES

Source: WIPO, 2022a

Rwanda’s entrepreneurial ecosystem, while still young, is demonstrating notable growth and a strong commitment to addressing global challenges. With over 300 active start-ups, hubs, and investors, the country is in the process of developing a vibrant environment for entrepreneurship and innovation. Rwandan start-ups focusing on SDG-related issues have collectively attracted over \$476 million in funding across 21 deals, with the health and mobility sectors taking the lead. As shown in **Figure 8**, a significant portion of these start-ups directly target SDG 2, SDG 4, and SDG 7, showcasing their dedication to creating a more sustainable and equitable future (Daniels, et al., 2023).

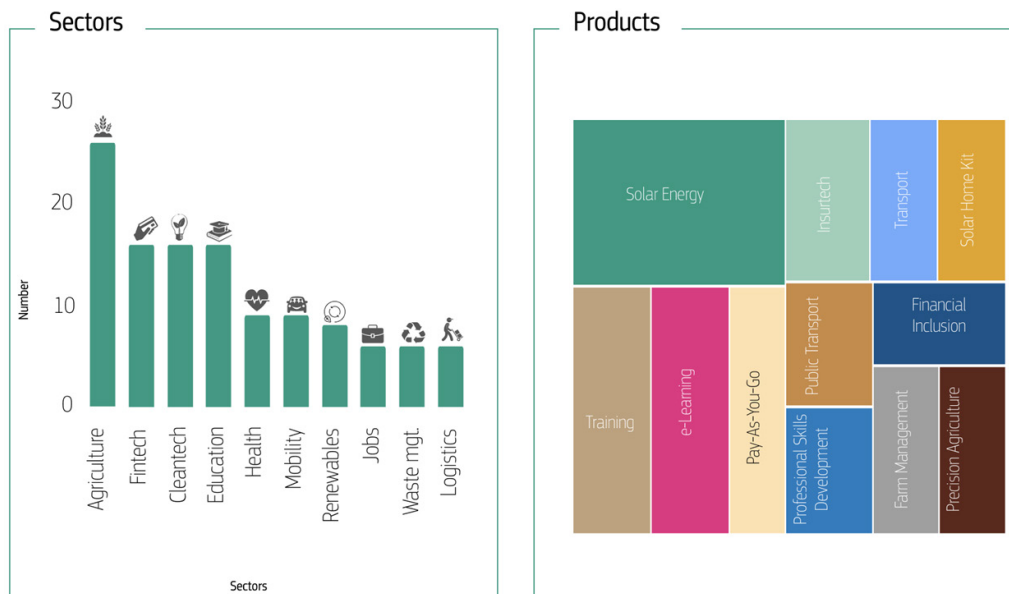
Start-ups in Rwanda are concentrating on several key sectors. Among them, the agri-food sector is witnessing a rise in the number of companies focused on improving farming practices, increasing yields, and enhancing food security, as shown in **Figure 9**. Similarly, the fintech sector is flourishing, with start-ups developing accessible and inclusive financial services for individuals and businesses. Moreover, cleantech start-ups, especially those specialising in solar energy solutions, are making significant contributions to sustainable energy development. Furthermore, the proliferation of training and e-learning products offered by Rwandan start-ups highlight a commitment to skills development and knowledge dissemination across various sectors (JRC, 2024).

FIGURE 8. PRIMARY AND SECONDARY SDGs TARGETED BY COMPANIES OPERATING IN RWANDA



Source: JRC, 2024

FIGURE 9. DISTRIBUTION OF COMPANIES IN RWANDA BY SECTOR AND PRODUCT



Source: JRC, 2024.

2.2. MAIN STI ACTORS AND INNOVATION COLLABORATIONS

The STI system in Rwanda is in the process of development with a range of stakeholders undertaking different roles (*Figure 10*). NCST plays a central policy role in setting the STI agenda and coordinating initiatives. The system involves ministries and other public bodies, relevant private sector companies, non-governmental organisations (NGOs), higher education institutes and research performers. International organisations are significant actors within the system, acting as funders and catalysts of STI through their projects and programmes. *Figure 10* illustrates the overall framework of the system with a categorisation of the stakeholders according to the roles they play.

STI AND FOOD POLICY ACTORS

The NCST plays a key role in stimulating STI policy for socio-economic development. It advises the government on policies, legislation, and regulation related to STI, sets national priorities, identifies and monitors the implementation of these policies (NCST, n.d.-b). The NCST influences policy implementation and financing through the management of the National Research and Innovation Fund (NRIF), while the Treasury funds university research (through the Ministry of Education) and public institutions.

The Rwanda Green Fund (FONERWA) is a cross-sectoral financing mechanism through which environment and climate change finance is channelled, programmed, disbursed, and monitored. The fund has administrative and legal autonomy and is overseen by the Prime Minister. The responsibilities of the organisation include mobilising and managing resources for environmental protection, preservation of natural resources, and addressing climate change (GoR, 2017b). FONERWA is a national basket fund financed through external aid and domestic finance. Access to the fund is open to line ministries and districts, charitable and private entities, including businesses, civil society and research institutions (UNESCO, n.d.). FONERWA

also contribute to funding university research and environmental projects.

The Ministry of Agriculture and Animal Resources (MINAGRI) is the main institution responsible for the policies and programs that seek to improve food security, agricultural productivity, diversification, and growth (MINAGRI, 2018). National Agricultural Export Development Board (NAEB) as a public institution stimulates exports through production, value addition, marketing and policy interventions (NAEB, n.d.).

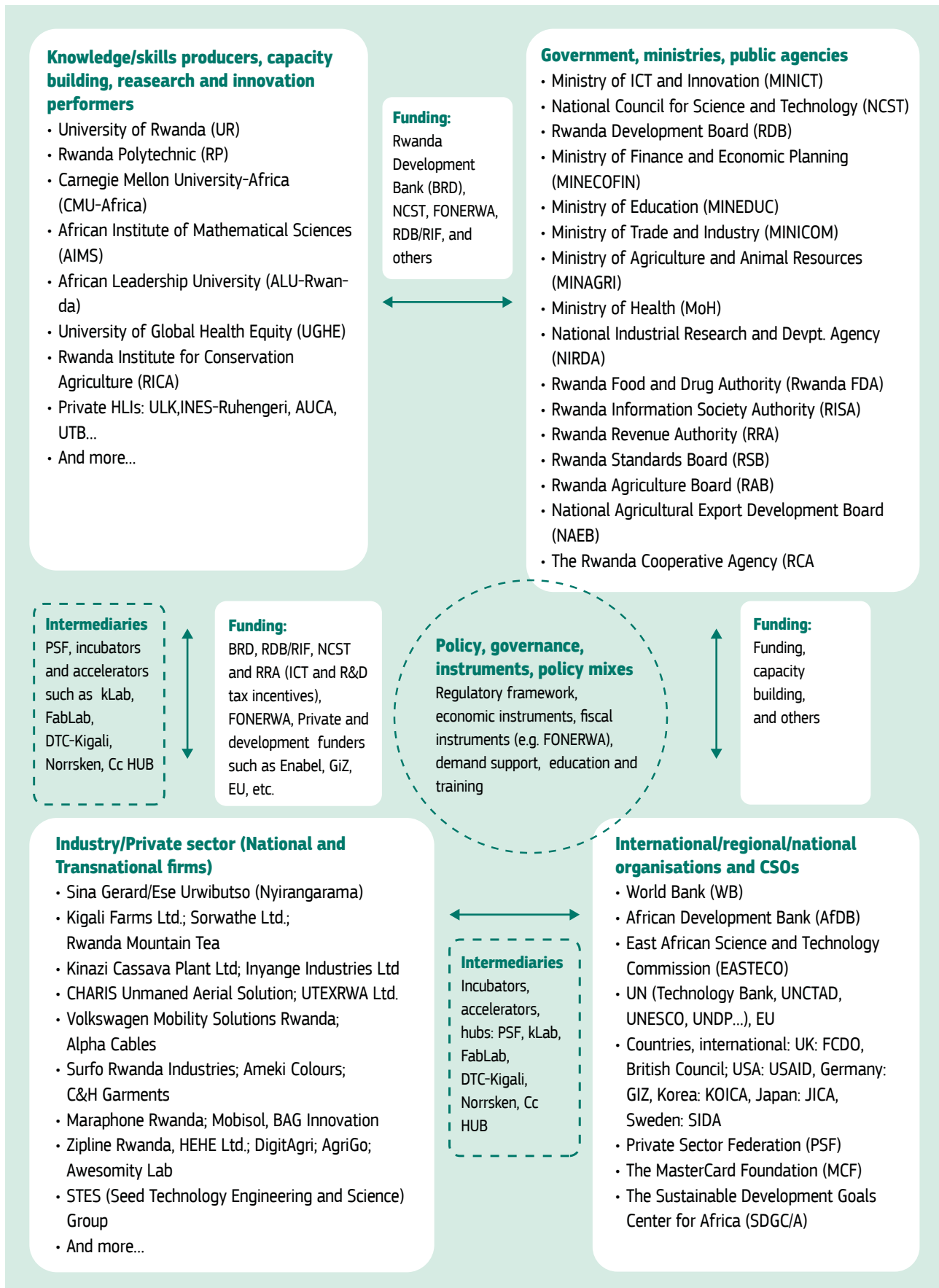
Rwanda Finance Limited promotes and develops Rwanda as a leading financial destination for international investment and cross-border transactions in Africa (KIFC, n.d.), while the Development Bank provides development finance for socio-economic impact, offering lending products as well as complementary financial instruments such as guarantees and advisory services (BRD, n.d.).

Standardisation and quality control in Rwanda are managed by several agencies. The Rwanda Cooperative Agency (RCA) is a regulatory public institution responsible for registration, regulation, promotion and capacity building of cooperatives (RCA, n.d.). The Rwanda Food and Drugs Authority (RFDA) regulates human and veterinary medicines, vaccines, processed foods, cosmetics, medical devices, and related products to protect public health (FDA, n.d.). The Rwanda Standards Board (RSB) develops national standards, provides certifications, and offers metrology services across various sectors (RSB, n.d.). The Rwanda Inspectorate, Competition and Consumer Protection Authority (RICA), carries out inspection of quality and standards conformity, promotes fair competition, and ensures consumer protection (RICA, n.d.-b).

RESEARCH, DEVELOPMENT AND EDUCATION ACTORS

Rwanda Agriculture Board (RAB) is an autonomous body tasked to develop agriculture and animal resources through research, agricultural and animal resources extension with the aim of

FIGURE 10.
ACTORS AND STAKEHOLDERS IN RWANDA'S STI SYSTEM



increasing agricultural and animal resources productivity and quality, as well as their derived products (RAB, n.d.). RAB has been able to leverage significant funding from international and regional organizations, such as FAO, CGIAR and many development partners. Its research outputs include releasing new varieties of beans, cassava, rice, wheat, sweet potato varieties and soybean.

National Industrial and Research Development Agency (NIRDA) supports the industry through technology monitoring, acquisition, development and transfer as well as applied research (NIRDA, 2017). It provides services for improving the competitiveness of existing industries to increase their export potential or import substitution; as well as identifying new sub-sectors or value chains where investment by the private sector would likely lead to export growth or import substitution (NIRDA, n.d.-a).

Formal education and technical capacity building are conducted by the University of Rwanda, Institute of Legal Practice and Development, and Rwanda Polytechnic, along with 27 private higher learning institutions offering undergraduate and postgraduate's level programs in various STI-related fields. The University of Rwanda is the primary higher learning institute with the capacity to conduct research in the country. The University hosts multiple centres of excellence, including the ones on Biodiversity and Natural Resource Management, Sustainable Cooling and Cold Chain, and Geographic Information System and Remote Sensing (Fosci et al., 2019), Regional Centre of Excellence in Biomedical Engineering and e-Health (CEBE), and Regional Centre of Excellence for Vaccines, Immunization and Health Supply Chain (RCESCM). The African Centre of Excellence in Data Sciences (ACE-DS), African Centre of Excellence in Internet of Things (ACE-IoT), African Centre of Excellence in Energy and Sustainable Development (ACE-ESD) and African Centre of Excellence for Innovative Teaching and Learning Mathematics and Science (ACEITLMS) are also run by the University of Rwanda (ACEDS, n.d.) with support from the World Bank (MINEDUC, n.d.). Rwanda Institute for Conservation Agriculture (RICA) combines research,

education, and extension services to train students and farmers, while supporting national priorities for agricultural development (RICA, n.d.-a). In addition, Rwanda supports renowned Universities and R&D institutions, such as Carnegie Mellon University Africa (CMU-Africa, Rwanda), African Institute for Mathematical Sciences (AIMS-Rwanda), University of Global Health Equity (UGHE, Rwanda).

STI INTERMEDIARIES

Intermediaries and facilitators, such as the Rwanda Development Board, Chamber of Commerce and Services, and the Industry and Entrepreneurship Promotion Department, under the Ministry of Trade and Industry, provide essential support for business and investment for the growth of the agri-food sector.

The Rwanda Development Board operates as a one-stop-shop for business and investments with its mandate to accelerate Rwanda's economic development by enabling private sector growth. It provides support throughout the entire investment journey (RDB, n.d.).

The Industry and Entrepreneurship Promotion Department supports entrepreneurship development institutions with access finance to develop SMEs. It ensures the effective development of industrial zones and SME parks (MoTI, n.d.). Incubators like Simcubator and Envisage Incubator, along with accelerators such as MEST and Accelerate2030, foster early-stage start-ups and growth-stage ventures (Liman, 2023).

Key fora, such as the Agricultural Sector Working Group (ASWG), facilitate dialogue and coordination on agricultural development issues, involving stakeholders from development partners to government agencies. Its members include development partners, NGOs, the private sector, civil society, farmer organizations, financial institutions and government agencies (MINAGRI, 2018).

The Rwanda Forum for Agricultural Advisory Services (FAAS-R), established in 2012, is an umbrella organisation of agricultural Extension and Advisory Services (AEAS) providers, actors and stakeholders in Rwanda. The forum is affiliated to

the Africa Forum for Agricultural Advisory Services (AFAAS) which is an umbrella network organisation for AEAS in Africa. FAAS-R was set up to advise the MINAGRI and RAB on agricultural extension and advisory services activities and aimed to act as a link between research and extension especially between public and private AEAS providers.³ The forum has been recently “revived” in collaboration with the Global Forum for Rural Advisory Services (GFRAS).

STI GOVERNANCE AND COLLABORATION PATTERNS

The government has established various mechanisms to facilitate collaboration and enhance coordination among the system’s actors. For example, sector working groups gather stakeholders from diverse areas, such as agriculture, health, and ICT, to discuss challenges, exchange best practices, and collaborate on projects that advance STI within their respective fields. The Joint Action Development Forum (JADF) serves as a platform for gathering government institution, development partners, civil society organisations, and the private sector to coordinate development efforts at the district level, ensuring that STI initiatives are incorporated into local development plans. In addition, Rwanda hosts various research and innovation (R&I) forums providing STI actors with opportunities for networking, presenting their activities, and seeking collaboration opportunities.

To enhance the alignment and efficacy of research initiatives, the Research Coordination Committee (RCC), formed by research and university institutions, supports coordination through mutual planning, implementation and monitoring and evaluation of R&D (NCST, 2021a).

The Innovation Platforms (IPs) are an important collaboration mechanism in Rwanda that enhances cooperation within the agricultural sector by aligning it with national policies, such as the Rwanda Agricultural Policy and Vision 2020.

They have been instrumental in creating market linkages, connecting producers to consumers and processing units, improving market accessibility, raising income levels, and promoting food security. Nevertheless, IPs have faced challenges such as over-reliance on donor funding and the necessity for a legal framework to support sustainability (Stakeholder interviews, 2024). Agole et al. (2021) report the presence of 47 IPs in sectors including potatoes, beans, maize, and milk, among others, in Rwanda between 2008 and 2018. Out of these, 15 initiatives were classified as successful or slightly successful, while 16 were not successful. The remaining IPs were either lacking information, non-functional, or still in progress at the time of the study. Institutionalising IPs is seen as critical for achieving long-term agricultural development goals, requiring coordinated support and a dedicated budget from the government and development partners (Agole et al., 2021).

Collaboration between academia and the private sector is facilitated by NIRDA and NCST. NIRDA publishes Open call programme serves a competitive forum that enables SMEs to receive technical assistance and technology advancements to increase productivity and competitiveness. NIRDA also works with international partners to finance local innovations. Furthermore, many universities and research institutions in Rwanda have established Knowledge and Technology Transfer Offices (KTTOs) to help with the dissemination of knowledge and technology from academia to industry. In addition, NCST manages the national research and innovation fund (NRIF), and has established a number of grant schemes including industry-academia collaboration grant scheme to foster collaboration between private sector and academia.

Regarding the coordination of support from development partners, the Ministry of Finance and Economic Planning has a leading role in aligning foreign assistance with the development agenda of the country. The European Union (EU) engages in policy dialogues with the Rwandan government to define priorities and support sectors with a combined strategy defined in the Multiannual

³ See <https://www.afaas-africa.org/rwanda/>

Indicative Programme (MIP), currently covering the 2021–2027 period.⁴ Under the Team Europe approach⁵, the EU and EU Member States strive for opportunities for joint implementation but also for opportunities for joint policy engagement with the authorities. However, according to interviewed stakeholders, the overall coordination of programmes funded by development partners is insufficient. Despite the overall strong coordination from the Government, donors work directly with individual ministries or NGOs without an overarching coordination mechanism which leads to project fragmentation and weak financial sustainability of many initiatives.

Stakeholders consulted for this study highlighted insufficient coordination among various organisations, including government ministries and agencies, which can lead to duplication of efforts and untapped potential for synergies. For example, the responsibilities of the Ministry of Environment and the Ministry of Agriculture overlap in areas like agroforestry. Similarly, organisations such as RAB and NIRDA experience weak linkages with industrial entities, according to stakeholders. Furthermore, some stakeholders observed a systemic gap that impedes the transfer of knowledge and innovation from academia to industry. For example, while the African Centre of Excellence in Data Sciences (ACE-DS) conducts pioneering research, including projects that predict agricultural yields and detect potential crop diseases through big data analytics, transforming its research outcomes into commercial products

or services usable by farmers and agribusinesses proves challenging. While the centre makes efforts to incubate student-led projects and develop applications addressing real-world agricultural problems, the lack of a structured partnership approach continues to be a barrier.

In addition, the challenge of communication and information sharing among STI actors in Rwanda, including the area of food system transformation, creates a significant barrier to effective collaboration and coordination. Stakeholders highlight a pressing need for more robust and dedicated platforms to facilitate the exchange of information, dissemination of research findings, and fostering of joint initiatives, also between STI actors active in various districts.

2.3. STI POLICY AND GOVERNANCE IN RELATION TO THE CHALLENGE AREA

The current STI Policy was developed in 2020 with the objective of supporting the implementation of the medium-term national development plan for the period 2017–2024, which explicitly calls for support to R&D as a mechanism to fast-track Rwanda's socioeconomic transformation (GoR, 2017a). As such, the STI policy intends to integrate and mainstream STI in national policies and strategies through effective and efficient application of knowledge, tools, scientific research and technological innovation towards addressing societal challenges, exploring opportunities, and ultimately establishing a globally competitive knowledge-based economy (IPAR, n.d.).

The general objectives of the STI policy are the following (NCST, 2020):

- **Effective governance:** With this objective, the policy aims to create a conducive environment for STI by integrating relevant laws, policies, incentives, and standards both horizontally and vertically. Key strategies include establishing an STI governance framework that identifies and addresses gaps within the STI system by strengthening policy-making capacity, and implementing a robust monitoring

4 See https://international-partnerships.ec.europa.eu/document/download/a5efa21a-0d4e-4976-993e-487fffdd157f_en

5 *Team Europe Initiatives ('TEIs') focus on identifying critical priorities that constrain development in a given country or region, where a coordinated and coherent effort by 'Team Europe' would ensure results with a transformative impact. Team Europe consists of the European Union, EU Member States — including their implementing agencies and public development banks — as well as the European Investment Bank (EIB) and the European Bank for Reconstruction and Development (EBRD). See https://international-partnerships.ec.europa.eu/policies/team-europe-initiatives_en*

and evaluation system. It also underlines the importance of adopting regulatory frameworks for global competitiveness, prioritising environmentally-friendly technologies, and aligning STI agendas with national goals of NST1 and Vision 2050. In addition, it aims to strengthen Rwanda's intellectual property system to attract global innovators, and advocate for strategic and cost-effective STI investments, ensuring optimal resource utilisation through measures such as foresight studies.

■ **Increased scientific and technological output:** This objective aims to enhance the performance of the STI system through strategies such as “Technology Innovation Support Mechanism” aiming to create a supportive environment for technologies all technology readiness levels. It includes establishing knowledge and technology nodes, fostering technology transfer, promoting commercialisation of innovative products, and strengthening R&D departments in academia and private sector. Moreover, it aims at supporting technology import and adaptation highlighting the need to achieve a balance between importing technologies and leveraging local expertise. This involves creating a framework for importing and adapting foreign technologies, promoting export of local solutions, and adopting open-source technologies. The policy also aims at encouraging research in areas such as AI, space, and biotechnology. Furthermore, it highlights the importance of engaging the Rwandan diaspora and international scientists to leverage their expertise. Lastly, it recognises the value of indigenous knowledge and homegrown solutions.

■ **Increased R&D and innovation financing:** The policy recognises the need for more robust and diverse financing mechanisms for STI. Strategies for increasing investments from both public and private sectors include managing and operationalising the National Research and Innovation Fund (NRIF), supporting national development targets, and mobilising resources from various sectors. For example, there is a target to raise R&D expenditures to at least 1%

of GDP by 2024, including contributions from the private sector. Incentive schemes are planned to be established to promote private sector investment in research activities. The policy acknowledges the need to support women in STI fields and proposes strategies to strengthen their participation, potentially through quotas and dedicated funding schemes. Infrastructure development, particularly in R&D, is also considered important to foster an innovative economy and attracting foreign investment. Finally, to strengthen academia-industry collaboration, the policy aims at establishing funding schemes that require participation from both sectors.

■ **Improved STI capacity and knowledge networks development:** The policy highlights the importance of human capacity in strengthening STI systems and the objective aims at developing a critical mass of skilled Rwandans to lead the country's transformation. To achieve this goal, the government plans to align skills development with market demands, and enhance the calibre and quantity of STI professionals. Relevant strategies include assessing human capital needs to design roadmaps, promoting innovative STEM pedagogy, and ensuring the availability of competent researchers, especially at the PhD level. The policy emphasises developing a research and innovation culture from early education stages and designing national research promotion programmes. It also identifies challenges in the research careers and aims to establish a framework to elevate research as an attractive career choice. To strengthen STI outreach, the policy highlights the importance of the popularisation of science amongst society and suggests programmes to relate science to everyday life and mechanisms for disseminating scientific findings amongst society.

■ **Enhanced international STI collaboration:** This objective is to integrate Rwandan scientists, researchers, and innovators into the global community while supporting international STI initiatives aligned with the

county's financial capabilities and strategic interests. One strategy is to encourage strategic STI partnerships and collaborations with regional and international entities through a conducive research environment that attracts domestic and foreign support and a mechanism to open national research-innovation infrastructure to foreign researchers and innovators. Another objective is to attract foreign R&D and innovation firms with mechanisms and incentives that facilitate cross-border collaborative, multi-disciplinary research in universities, research institutions and private sector.

The STI policy addresses the **food systems transformation** area through most of its STI priority sectors, namely 'Food Security and Modern Agriculture'; 'Local Production and Value Addition'; and 'Resilient Environment and Climate Change', as elaborated below:

- The **'Food Security and Modern Agriculture'** priority aims at using STI to promote adequate and safe production of food, including how to reduce waste and increase the shelf life of food so that everyone has access to safe and nutritious food. The policy in this context identifies some research and innovation areas such as unmanned aerial vehicles, satellite imagery, Internet of Things, irrigation techniques, mechanisation of agriculture and research on climate-resilient crop varieties (NCST, 2020).
- The **'Local Production and Value Addition'** priority aims at using STI in enhancing local production and facilitating access to export markets. In the context of food systems, the policy aims at supporting the development of local food technology (Foodtech) that is applied to food production, supply chain and distribution models (NCST, 2020).
- The **'Resilient Environment and Climate Change'** priority connects to Rwanda's food systems, offering solutions to the country's land and environmental challenges. The policy seeks to tackle these issues through focused research and innovation in areas such as clean technology, green production methods, and biodiversity

conservation. Furthermore, it emphasises the use of technology-enabled atmospheric and climate science, which harnesses the power of big data and emerging technologies to enhance understanding and forecasting of climate change and its various consequences (NCST, 2020).

To support the implementation of the STI Policy, the **National Research and Innovation Agenda** (NCST, 2021b) was issued by the government in 2021 that identified 'food security and modern agriculture' as one of the national priority areas. The key research topics identified include the following:

- **Crop research and protection:** Research and innovations aimed at improving crop productivity, crop varieties and reduce crop losses.
- **Biotechnology:** Cutting-edge research and solutions in plant genotyping using molecular biology techniques and modern diseases diagnostics.
- **Post-harvest handling and management:** Solutions to broaden the utilisation base of primary agricultural products through food processing and other value addition techniques and reduce post-harvest losses through improving food handling and storage.
- **Livestock:** Solutions to develop high-yielding livestock genotypes for meat and milk production.
- **Irrigation and mechanisation:** Solutions to modernise agriculture to reduce dependence on rain and manual labour.
- **Precision agriculture:** Monitoring and control of real time information in agriculture to improve productivity and profitability.
- **Land husbandry:** Increasing the productivity and commercialisation of hillside agriculture.

Rwanda has implemented further supportive policies to enhance its research environment. This includes the National Research Incentives and Support Policy aimed at increasing research productivity by empowering scientists and

institutions to develop new knowledge, techniques, and technologies. In addition, the Tech Enabled Innovation Policy (TEIP) is designed to drive economic growth, stimulate high-growth firms, and accelerate domestic innovation. Efforts also extend to regulatory frameworks that enhance research capabilities, such as the biosafety law that facilitates GMO research and the potential advantages of biotechnology in crop genetics, and a draft law promoting formal collaboration between the University of Rwanda College of Agriculture, Animal science and Veterinary Medicine (UR-CAVM) and the MINAGRI, enabling university students to use RAB's stations for research and internships.

NCST plays a key role in governing these initiatives through its monitoring and evaluation responsibilities. Within this framework, NCST is responsible for producing an annual Science and Technology Outlook report, which includes national R&D and STI survey reports. These reports are crucial for assessing the progress and impact of STI investments and promoting accountability within Rwanda's scientific community.

Rwanda employs distinctive accountability systems including public performance reviews, led by the Ministry of Finance and Economic Planning, and involving the cabinet. These reviews are broadcasted on television, enabling the public to directly interact with political leaders and senior officials and even the President, fostering a culture of accountability and transparency, encouraging government officials to meet targets and generate positive outcomes. However, the focus on public scrutiny and the high-pressure environment may also curtail the willingness to engage in new policy-making and risk-taking, potentially limiting innovation efforts in more untested areas.

2.4. POLICY IMPLEMENTATION AND SUPPORT PROGRAMMES

The Government supports the food system transformation through a number of instruments and initiatives:

- The National Research & Innovation Fund implemented by NCST has the objective is to stimulate societal and economic growth in accordance with the national development agenda. The fund operates with various grant schemes such as the Academia Industry Collaboration, Sector Strategic Research Grant, Rwanda Innovation Challenge, Excellent Research Grant, Women in Science Research and Innovation Grant, Research and Innovation Mobility Grant and Rwanda Innovation Challenges for Academia-Industry R&D, and Grand Challenges Rwanda (NCST, n.d.-c).
- FONERWA (the Rwanda Green Fund) offers grants for public institutions and NGOs; innovation grants, a performance-based investment to the private sector for research and development; proof-of-concept and demonstration; and a credit line available to the private companies that obtain a matching loan from Rwanda's Development Bank (RGF, n.d.).
- The Rwanda Innovation Fund (RIF), implemented by the Rwanda Development Bank, is a USD30 million fund launched in 2018 (Fosci et al., 2019) aiming to promote national R&I capacity, performance and productivity through funding research and innovation. The fund is used by incubators and accelerators for capacity building among entrepreneurs. Furthermore, it aims to support companies at various stages and early growth-stage opportunities. It aims to create more than 2,000 direct jobs and over 6,000 indirect jobs over its 10-year life cycle (GoR, n.d.-c).
- The Grand Challenges Rwanda is a scheme established following the model of the global Grand Challenge championed by Bill and Melinda Gates Foundation. Grand Challenges Rwanda aims at global and African partners not only to mobilise resources but also to conduct high impact research related to the priority areas defined in the Rwanda National Research and Innovation Agenda. The programme's budget is USD1.6 million for 5 years (NCST, 2023). The Innovative Frontier Technologies for Climate Resilient Agriculture, Food Security and Safety

in Africa is a grant scheme under Grand Challenges Rwanda, with main goal to support scientists in Rwanda to implement research that fosters innovation and promotes collaboration in solving the critical development challenges of intersection of climate change and resilient agriculture in the country and in the region (NCST, n.d.-a).

- NIRDA Open Calls stimulate the introduction of firm-level innovations aimed at improving productive capabilities and capacities to produce competitive products for domestic and international markets. NIRDA's support offered to selected firms include the acquisition and adaptation of specific technologies needed to improve industrial competitiveness (e.g. equipment, software, or related investments); technical support and expertise necessary to maximise the use of equipment, processes or systems for technologies to improve their competitiveness; and staff training to enhance productivity through the use of new or the adaptation of existing technologies to improve their competitiveness (NIRDA, n.d.-b).

- Capacity building and support to farmers is delivered through the Twigire Muhinzi National Extension System. Twigire Muhinzi is based on Farmer Field School and the farmer promoter approach. The approach means “self-reliance in farming” and focuses on capacity building, on- and off-field training and experimentation (demo plots). The system, established in 2014, is overseen by MINAGRI and implemented by RAB (Department of Crop Research and Technology Transfer) and the National Agricultural Export Development Board (NAEB). At district level, extension services are implemented by the Ministry of Local Government (MINALOC) closer to field level. 13 RAB stations play an important role in capacity building. According to MINAGRI, in 2023 there were 21,620 extension agents in Rwanda, including 19.4 thousand public and 2.2 private agents. There were more than 14 thousand farmer promoters and nearly two thousand farmer field school facilitators that reached nearly 1.4m farmers in 2022-2023 (MINAGRI, 2023).

- Smart Nkunganire System (SNS)⁶ is an application that enables farmers to register and access subsidised agriculture inputs. SNS was developed by Rwandan start-up, BK TechHouse in 2017. It is a joint effort to digitise Rwanda's national agri-inputs subsidy management under a public-private-partnership (PPP) agreement between BK TechHouse (a business subsidiary of Bank of Kigali Plc.) and the Rwanda Agricultural and Animal Resources Development Board (RAB). SNS is based on a software designed as a service (SaaS) and data as a service (Daas) models. The system is available offline and online via smart and regular mobile phones and computers. The system targets all actors involved in the supply chain of the agriculture sector. According to MINAGRI, there were more than 1.3m farmers and 1059 agro-dealers, importers and distributors registered in SNS in 2023 (MINAGRI, 2023).

Stakeholders highlighted that the high level of trust Rwandans have in their government significantly facilitates the execution of these programmes. The emphasis on good governance practices, including the separation of roles to minimise corruption, is deemed essential for the successful implementation of policies.

Rwanda has successfully attracted numerous international and national development partners and NGOs to support the transformation of its food system. Many of these initiatives directly supports implementation of national policies (e.g. agricultural capacity building). Notable organisations, programmes and projects in this area are summarised below:

- The World Food Programme (WFP) is integral to national efforts in Rwanda aimed at transforming food system and enhancing food security, particularly in regions vulnerable to chronic poverty, food insecurity, and malnutrition. WFP supports resilience building against climate-related shocks through projects such as land terracing, marshland

⁶ See <https://smartnkunganire.rw/>

restoration, and strengthening national social protection programmes. In collaboration with the government, WFP is developing a National School Feeding Strategy, providing nutritious meals to 117,000 students and involving local smallholder farmers in supply chains to boost the local economy. It assists smallholder farmers, especially women, by improving access to markets and finance, reducing post-harvest losses, and enhancing the quality of agricultural products. This support helps link farmers to commercial buyers and government-led nutritional programmes. WFP's efforts in emergency preparedness and response supports Rwanda's capacity to handle natural disasters (WFP, 2024).

- One Acre Fund is a social enterprise dedicated to supporting smallholder farmers in East Africa which is funded by multiple international foundations such as Bill & Melinda Gates Foundation, USAID and others (OAF, n.d.). Its model is built around offering smallholder farmers an asset-based loan that encompasses distribution of seeds and fertilizer, financing for farm inputs, training on agricultural techniques, and market support to maximise profits. The Fund's activities support the implementation of the Twigire Muhinzi National Extension System.
- Circular Food Systems for Rwanda Programme of the World Resources Institute aims to implement circular economy principles in Rwanda's food system. It operates through two channels: The SME Development Fund offers technical assistance to SMEs, enabling them to adopt circular business models, while the Policy and Stakeholder Engagement focuses on fostering a supportive environment for food system transformation through policy development and stakeholder collaboration (WRI, n.d.).
- CGIAR is an important actor for food system transformation in Rwanda. Its Research Initiative Seed Equal initiative aims to support delivery of quality seed of improved varieties that are climate-resilient, market-preferred, and nutritious, providing farmers with a high rate of genetic gain while ensuring equitable access for

women and other disadvantaged groups (CGIAR, n.d.-b). CGIAR Initiative on Foresight aims at combining state-of-the-art analytics, innovative use of data, and close engagement with national, regional and global partners to offer better insights into alternative transformation pathways that can inform choices and sharpen decision-making today, leading to more productive, sustainable and inclusive food, land and water systems in the future (CGIAR, n.d.-a).

- Tropical Agriculture Platform - Agricultural Innovation Systems (TAP-AIS) is an EU-funded project coordinated by MINAGRI and managed by FAO in Rwanda. It supports the country's policies to increase rural household income and food security through diversified and intensified agricultural production and a transition from subsistence to market-oriented systems (FAO, n.d.-b).
- Capacity Development for Agricultural Innovation Systems (CDAIS) is an EU-funded project aimed at enhancing the capacity for agricultural innovation in various countries, including Rwanda, to improve food security. Its main focus is on "functional capacities", such as collaboration and strategic engagement, which are essential for effective innovation in agriculture. The project facilitates continuous learning and improvements at national and global levels, contributing to a common framework for agricultural innovation systems (CDAIS, n.d.).

The ongoing initiatives and programmes are relevant and have significant outreach to local communities but they face many challenges, including funding limitations, systemic fragmentation (project-based approach) and weak financial sustainability. These challenges are discussed in the following section.

3. GAPS AND OPPORTUNITIES TO FOSTER FOOD SYSTEM TRANSFORMATION

The chapter prepares the ground for identifying concrete STI areas with a potential to transform Rwandan food system. We first map gaps and persisting shortcomings in the STI system that need policy attention. We then identify broad areas of opportunity where STI can drive food system transformation.

3.1. GAPS AND SHORTCOMINGS IN THE STI SYSTEM

There are several shortcomings in the policy and regulatory framework that prevent Rwanda from tapping in benefits of STI for food systems transformation. Many of these gaps are common for nascent STI systems with limited research and innovation capacities and still developing STI governance and policy. The issues highlighted by stakeholders include, among others, policy misalignment, limited research funding, insufficient coordination of development partners activities, inadequate focus on localised innovation, difficulties in scaling successful innovations, shortcomings in extension services, skills and training deficiencies, and insufficient environmental considerations. The chapter builds on evidence collected during hybrid and in-person workshops, face-to-face and virtual interviews, and an online survey.

LIMITED POLICY INTEGRATION AND COHERENCE

A significant challenge in Rwanda's policy framework for food system transformation is the lack of a comprehensive STI strategy and governance mechanisms that integrate all

dimensions of the food system transformation. The government's sectoral setup leads to fragmented efforts across different departments and sectors that fail to adequately address the interconnected nature of food systems. There is no systemic view on the role of STI in transforming food systems and food value chain. The current policies often focus too narrowly on sectors or issues. This narrow focus misses the opportunity to leverage STI for addressing broader challenges such as climate resilience, food security, health, circular economy and sustainable agricultural practices, thus limiting the potential for systemic change.

Although the need for food transformation is recognised and given high priority in many policy documents, the policies, strategies, action plans and studies conducted by national and international actors often overlap and lack coordination that limit the possibility to seek complementarities and synergies between implemented initiatives. This results in duplicated efforts and creates a confusing landscape for stakeholders navigating the policy environment.

The landscape of donor assistance in Rwanda is crowded and fragmented. The lack of a cohesive strategy among donors frequently burdens Rwanda's ability to manage and coordinate effectively, resulting in suboptimal resource utilisation, further complicating the implementation of programmes that require a unified and streamlined funding mechanism.

To improve strategic integration, Rwanda needs an overarching framework that not only aligns national priorities and policies but

integrates diverse inputs from non-governmental stakeholders and development partners. This framework should facilitate the effective use of STI across the entire food system, enhance synergy among various initiatives, and maximise the impact of government and donor investments.

FUNDING AND RESOURCE ALLOCATION SHORTCOMINGS

Stakeholders point out that research institutions receive government support primarily for basic operational costs (e.g. salaries). This results in a significant underinvestment of R&D staff and research.

Funding constraints critically hamper the operational effectiveness of key institutions like the RAB and the NIRDA important in agricultural research and innovation. Despite their significant roles, these institutions are underfunded which limits their ability to undertake or support impactful research and innovation activities. The staff often has to seek additional funding for their core R&D activities through donor support and competitive grants which are not consistently available and may not fully align with their competences and capabilities. The dependence on competitive grants and donor funding not only adds uncertainty and interrupts the continuity of long-term research projects. Furthermore, access to finance creates a substantial barrier, particularly hindering youth engagement in agri-food sector related innovative ventures. This funding shortfall impedes not only the introduction of new technologies but also their adoption and effective application, which are critical for transforming Rwanda's food systems.

The issue of inconsistent funding is further compounded by the lack of sustained or multi-year research and innovation budgets, leading to pilot projects that often conclude without clear prospects for scaling. This results in a repetitive cycle of pilots that often fail to achieve long-term impact. There is a pressing need for a strategic framework and consensus among local and international stakeholders to not only experiment and demonstrate innovation but also ensure their diffusion, scalability and integration into the

national and regional food systems. The complexity is heightened by the crowded and fragmented landscape of donor activities in the agri-food sector, characterised by limited coordination, which leads to inefficiencies and redundant efforts. This influx of donor initiatives often exceeds the country's capacity to effectively manage and deliver lasting tangible impacts in food system transformation.

LIMITED SUPPORT FOR SUSTAINABLE AGRICULTURE AND LOCALISED APPROACHES

Stakeholders indicate that supporting innovative sustainable agricultural practices would not only improve soil health, like soil acidification and eutrophication, and mitigate other environmental issues, but also enhance the overall sustainability of food production. The transition to sustainable agricultural practices in Rwanda is, however, hindered by insufficient policy support.

A significant barrier to achieving these outcomes is the heavy reliance on funding that originate from external sources, which often fail to align with local needs and conditions. This external dependency results in solutions that are neither sustainable nor effective in the local context, impeding the development of a resilient and self-sufficient food system. Furthermore, the transfer and adoption of technologies, especially in areas like agro-processing, is slow. This impedes the enhancement of food production capabilities and the support of sustainable agricultural practices. Moreover, while the Rwanda Environment Management Authority (REMA) regulates and monitors environmental standards, its active involvement in the national dialogue on food systems transformation has been limited. This may lead to missed opportunities to thoroughly integrate environmental considerations into relevant policies and practices, which is essential for addressing broader issues such as climate change and biodiversity loss.

The wider governance challenges in the area of food system include improving the overall coordination of the implementation of existing STI initiatives, regional articulation of the support to consider territorial specificities and

bottom-up place-based STI initiatives as well as collaboration spaces focused on food system transformation engaging multiple stakeholders, including local stakeholders, development partners, and representatives of Government from across governance levels.

INFRASTRUCTURE AND DATA INTEGRATION GAPS

Rwanda confronts challenges with the infrastructure necessary to support robust research and innovation in the area of food system transformation. This includes, among others, insufficient laboratory facilities and equipment for agri-food research and development, including processing and preservation research. Such deficiencies not only restrict the scope and quality of research that can be conducted but also negatively impact the development and scaling of innovative solutions critical for enhancing food security and agricultural productivity across the country.

Compounding these infrastructure issues are shortcomings in the collection, availability, and utilisation of data on food systems. Current data collection mechanisms and data infrastructure are not adequate to capture detailed and continuous data, creating knowledge gaps that severely hinder the strategic application of research and innovation in the agriculture and food sectors.

CAPACITY BUILDING AND SKILLS DEVELOPMENT GAPS

Capacity building in the agricultural sector is delivered jointly by the governmental and non-governmental actors. MINAGRI and RAB plays a key role in capacity building through its 13 field stations undertaking research and the extension services. The Government's activities are supported by many NGOs working directly with farmers, including among others One Acre Fund (operating in Rwanda under the brand Tubura) or the World Food Programme.

There is evidence that the Twigire Muhinzi model has proven beneficial to local farmers and communities, including providing spaces and mechanisms for peer-to-peer training,

communication in local languages and high sensitivity to local culture, farming practices and farmers' needs (Neza, 2021). Importantly, the model relies on farmers as trainers which allows a degree of informality and allows the trainers to operate formal hierarchical structures (ibid.).

There are, however, many challenges impeding a more effective capacity building processes, some specifically related to a better use of STI. Kazungu et al. (2015) point to shortcomings in delivering knowledge and innovative technologies to rural areas due to lack of coordination, delays of providing key inputs to farmers, fragmented policy mandates, lack of funding, aging and low competencies of extension agents, and the lack of mobility and interactions of agents with key actors (Kazungu, Munezero, & Dushimana, 2015). Stakeholders consulted for the STI for SDGs roadmap highlighted similar concerns and challenges. Many pointed that the RAB stations lack the capacity to effectively combine research and extension services. Although the station's research activities are adapted to their geographical context, their capacities to effectively deliver extension services are not sufficient to effectively respond to urgent local needs, especially those faced by smallholder farmers.

There is also a significant gap in specialised training for extension personnel, which limits their ability to effectively transfer knowledge and engage with farmers. Linked with these issues are gaps in skills and capacities among smallholder farmers and local entrepreneurs, particularly in advanced agricultural techniques and technology. Stakeholders attribute these deficiencies to insufficient educational programmes and limited targeted capacity building initiatives based on the state-of-the-art knowledge on agricultural practices and designed to respond to the local needs and market realities. Several stakeholders pointed to the need in further develop critical thinking, entrepreneurship, and project development skills among the educated youth, essential for fostering a generation capable of making significant advancements in food systems through innovation.

In addition to challenges in extension services and training deficiencies, Rwanda's food system could benefit from a more robust entrepreneurial ecosystem. There is a deficiency in entrepreneurial knowledge and skills, particularly in the agricultural sector, exacerbated by limited access to finance and practical support for start-ups. This gap hinders the private sector's ability to contribute effectively to food system transformation through STI, resulting in missed opportunities for leveraging local entrepreneurship to enhance food systems.

Stakeholders emphasised that the agricultural sector does not appear attractive to the younger generation. They argue, however, that this trend could be reversed if young people are provided with opportunities and support to adopt smart, innovation-driven agricultural practices. By integrating innovative technologies and business models, agriculture can become more appealing to the youth, potentially transforming it into a dynamic and profitable sector.

ADDRESSING BEHAVIOURAL CHALLENGES AND REGIONAL DISPARITIES IN FOOD SECURITY AND MALNUTRITION

There are significant regional disparities in Rwanda in malnutrition and food security. Notably, 38% of children under five years are stunted nationally, but this rate varies significantly by region, peaking at 49% in the Western Province, which is considerably higher than in Kigali at 23% (USAID, 2018). These disparities extend to acute malnutrition levels, which are higher in rural areas compared to urban settings. The prevalence of stunting is inversely related to a mother's education level and household wealth, highlighting a clear socioeconomic dimension to nutritional deficiencies.

Furthermore, geographical variations affect food security, with the Western and Northern parts of the country facing higher risks. This regional imbalance necessitates innovative non-technological solutions that focus on behavioural change. Initiatives should aim to transform local dietary habits and cultural beliefs, tailoring interventions to meet the specific nutritional

needs of different communities. By strengthening social innovation strategies, such as community-led educational programs, culturally sensitive behaviour change campaigns, and localised food security initiatives, Rwanda can address these disparities more effectively. Such approaches should integrate cross-sectoral collaboration, leveraging insights from education, health, and agriculture to foster a comprehensive understanding of nutrition and encourage healthier eating practices.

3.2. OPPORTUNITY AREAS TO MOBILISE STI TO IMPROVE FOOD SECURITY

Investment in STI is an enormous opportunity for Rwanda to accelerate food system transformation. There are many technological and non-technological innovation areas with a potential to benefit local businesses and communities. The section introduces the main opportunities identified through field and desk research.

ENHANCING AGRICULTURAL PRODUCTIVITY AND RESILIENCE THROUGH LOCAL INNOVATION

Enhancing local seed technology, especially in developing new crop varieties resistant to climate change, is critical for Rwanda's food security. Introducing high-quality, climate-resilient seeds developed through local initiatives could reduce reliance on imported seeds, promote self-sufficiency, and enhance agricultural resilience. Furthermore, high costs of agricultural inputs like greenhouses are a barrier due to the need to import most materials. Developing local manufacturing capabilities for inputs like greenhouse materials and fertilizers could reduce costs, make technology more accessible to farmers, and stimulate local economies.

In response to the challenges of climate change, there is a pressing need to embed climate resilience into agricultural practices. Stakeholders suggest expanding climate resilience funding to cover essential areas such as water management,

soil conservation, and the development of drought-resistant crops. Implementing policies and programmes that support these practices will ensure that Rwanda's agriculture remains viable in the face of climate variability, thereby protecting livelihoods and enhancing food security.

STRENGTHENING RESEARCH AND INNOVATION CAPABILITIES

Rwanda's agri-food sector requires significant enhancements in research capabilities, technological infrastructure, and innovative capacity to effectively address local challenges. Stakeholders underline the need for upgraded research and experimental development facilities and recommend improving infrastructure at disposal of RAB stations and higher education institutions. They also emphasise the importance of building strategic partnerships with international institutions to develop local research and innovation capabilities. Investing in essential infrastructure such as laboratories, processing plants, and energy solutions is needed to facilitate the adoption of new technologies and innovations across the food value chain, enhancing efficiency and sustainability.

Furthermore, expanding innovation hubs and incubators is important to provide students and entrepreneurs with the necessary resources and support, and encourage the development of innovative ideas in the agri-food sector, fostering new solutions and technologies that address specific challenges within Rwanda's food systems. These efforts could also be supported by initiatives for engaging youth in the sector, for instance by launching agri-tech competitions, internships, and entrepreneurship opportunities. Creating such opportunities for young people would not only address the aging farmer problem but also infuse the sector with new ideas and innovations.

Another critical step under this opportunity is to strengthen intellectual property (IP) protection and technology transfer mechanisms in Rwanda. A robust framework for IP protection is essential since currently weakness in the system discourages collaboration, knowledge sharing and

dissemination for innovative ideas and solutions. At the same time, strengthening technology transfer mechanisms is needed to enhance the flow of technologies, knowledge and skills from research institutions to farmers and entrepreneurs.

PROMOTING DIGITAL AND PRECISION AGRICULTURE

Digital technologies and precision agriculture have the potential to transform Rwanda's agricultural practices for increased food security. Stakeholders consider, for example, ongoing projects that utilise drones for precision farming and satellite imagery for regenerative agriculture practices. Expanding the use of these and emerging technologies (such as Artificial Intelligence, Internet of Things, Robotics, etc.), could lead to more efficient resource utilisation, superior pest and disease management, and more accurate yield forecasts. Such a technological shift could empower farmers with the information needed to make better decisions, minimise environmental impact, and enhance productivity, contributing to the sustainability and resilience of Rwanda's food systems. Furthermore, it is important to enhance extension services and farmer education on sustainable and smart agriculture optimising and improving sustainability in agricultural production. These initiatives could also help in bridging the gap between research and practical application, ensuring that scientific advancements reach the grassroots level and contribute to overall agricultural productivity.

INVESTMENT IN AGRO-PROCESSING FACILITIES

Rwanda faces significant limitations in local food preservation and processing capabilities, including the absence of a local food freezing system. Stakeholders suggest investing in agro-processing infrastructure, such as freezing and canning plants, to extend the shelf life of produce, minimize post-harvest losses, and reduce the importation of frozen products. Implementing these facilities would not only secure the food supply but also add value to local agricultural products, potentially opening up new markets and increasing farmers' incomes. Moreover, the establishment of such

infrastructure could drive economic growth in rural communities and ensure that the value generated remains within the country. Enhancing local processing capabilities would also address the post-harvest food waste issue, further optimising resource use and improving food security.

CAPITALISING ON PUBLIC-PRIVATE PARTNERSHIPS IN THE AGRI-FOOD VALUE CHAIN

The private sector plays a key role in addressing local needs and expanding innovative solutions across Rwanda's agri-food value chain. Establishing public-private partnerships is essential for developing dynamic systems that seamlessly integrate innovation, effectively responding to market demands while addressing societal challenges such as malnutrition and food insecurity. Such partnerships could facilitate technology transfer to the sector, enhance market access for smallholder farmers and small businesses, and mobilise investments. By leveraging the strengths of both public and private sectors, these collaborations can significantly advance Rwanda's objectives for food security, economic growth, and the achievement of SDGs.

LEVERAGING VERTICAL FINANCING MODELS FOR AGRICULTURE

Inspired by the success in the health sector, some stakeholders see a significant opportunity to apply vertical financing models to the agricultural sector. This approach involves dedicated funding streams that target specific initiatives, such as climate-smart agriculture, seed development, and food processing technologies. By drawing lessons from the use of vertical financing in health sector, the agricultural sector could attract targeted funding that could provide the necessary capital to scale up successful agricultural innovations and support the development of infrastructure needed to increase productivity and sustainability. It could also facilitate more efficient allocation of resources, ensuring that funds directly support the most impactful projects.

USING INNOVATION TO PROMOTE NUTRITIOUS AND SUSTAINABLE FOOD CHOICES

Stakeholders believe that the lack of consumer awareness regarding the environmental and health benefits of sustainable and nutritious food choices reduces the demand for such products, discourages farmers from adopting sustainable practices, and hinders market growth for these foods. To address this situation, stakeholders suggest the use of focused consumer education campaigns, awareness programmes, and clear labelling. These initiatives should be tailored to address regional dietary habits and cultural beliefs, particularly in areas with high rates of malnutrition and food insecurity. By promoting non-technological innovation in campaigns aimed at encouraging nutritious and sustainable eating practices, these efforts can significantly enhance consumer understanding and appreciation of both the health benefits and environmental importance of sustainable food production. This targeted approach not only raises awareness but also supports the broader goal of creating a resilient and equitable food system by encouraging demand across diverse regions, thus motivating farmers to adopt sustainable practices and expand the market for nutritious, environmentally friendly food products (TBI, 2021).

4. PARTICIPATORY DELIBERATION OF CHALLENGE-ORIENTED STI AREAS

The chapter introduces STI areas considered most impactful in driving food system transformation in Rwanda. The following descriptions of the STI areas are based on stakeholder consultations (interviews, workshops and an online survey) and information available to the team at the time of conducting the study (February–May 2024). The areas should not be considered an exhaustive list of investment opportunities.

4.1. KEY CHALLENGE-ORIENTED STI AREAS

CLIMATE-RESILIENT AGRICULTURE

Due to the pressing threat of climate change on agricultural productivity and food security, Rwanda invests in developing capacities to adopt climate-resilient agriculture technologies. The country's approach focuses on research, innovation, and integrated strategies to enhance the sustainability and resilience of its agricultural sector. Key policy frameworks supporting these initiatives include the Vision 2050, the Strategic Plan for Agriculture Transformation 2018–24 as well as the Green Growth and Climate Resilience Strategy that offers detailed guidance on implementing green growth initiatives and developing climate-resilient agricultural practices (GoR, 2023b).

Building on this foundation, the country has invested in agricultural research and innovation to develop and disseminate climate-resilient crop varieties and farming practices. Key institutions, notably RAB and NAEB focus on R&D new technologies and practices that can withstand climate variability (World Bank, 2015). In addition, the Climate-Resilient Post-harvest and Agribusiness Support Project, supported by the

International Fund for Agricultural Development (IFAD), exemplifies efforts to introduce climate-resilient post-harvest technologies in response to increasing climatic uncertainty (IFAD, n.d.).

The UNDP and FAO-led joint initiative - “Joint Programme on Enhancing Climate Resilience and Integrated Agriculture in Disaster-Prone Areas of Rwanda” - bridges the gaps between agriculture and disaster management sectors (UN, n.d.). This integrated approach ensures that climate-resilient technologies not only increase productivity but also play a critical role in mitigating risks associated with climate-induced disasters.

Rwanda has adopted climate-smart agriculture, which includes a spectrum of practices aimed at increasing productivity, enhancing resilience, and reducing greenhouse gas emissions. Promoting climate-resilient crop varieties and effective management practices involves a collaborative effort between agricultural research institutions and extension services (World Bank, 2015). For instance, the Rwanda Climate Services for Agriculture project, supported by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), exemplifies how Rwanda is transforming agriculture through the integration of climate information and historical climate data (CGIAR, 2018).

Incorporating specialised technologies, such as deep placement fertiliser pellets and biogas production, aligns closely with Rwanda's strategic initiatives to enhance agricultural efficiency and sustainability. Specifically, the use of slow-release nitrogen pellets for deep placement could significantly benefit farmers by increasing the output of nitrogen-dependent crops such as maize, which are essential to the country's food security

and economic stability. Similarly, leveraging biogas production from livestock droppings can substantially enhance Rwanda's renewable energy resources, reducing the environmental impact of traditional farming practices. These technologies offer practical solutions that can be broadly implemented across the country serving the dual purpose of increasing crop yields and managing agricultural waste effectively within the overarching framework of climate-smart agriculture (World Bank, 2015).

Considering the importance of widespread adoption of climate-resilient technologies, capacity building and knowledge sharing are essential. In this respect, programs such as the Participatory Integrated Climate Services for Agriculture (PICSA) are proven to be successful, as they equip farmers with the skills and insights needed to make informed decisions based on climate data (CGIAR, 2018).

Furthermore, Rwanda recognises the critical role of the private sector in enhancing climate resilience. The Innovative Frontier Technologies for Climate Resilient Agriculture initiative highlights the potential of emerging technologies such as drone technology, artificial intelligence, and big data in increasing agricultural productivity and resilience (NCST, n.d.-a). Similarly, the Rwanda Climate Finance Partnership seeks to stimulate public-private partnerships to increase climate finance for innovative climate actions (IMF, n.d.).

To ensure sustained progress and adaptability to future challenges, it is imperative to continue investing in research and innovation in this area, as these efforts will pave the way for more effective climate resilience strategies and technologies.

BETTER DIETS AND ACCESS TO AFFORDABLE NUTRITIOUS FOODS

Rwanda's approach to technology adoption in the agri-food sector is strategically focused on increasing the availability of nutritious foods to address food security and nutritional challenges through a multifaceted strategy that includes government initiatives, partnerships, and innovative solutions.

The government actively invests in creating an environment conducive to the adoption of agricultural technologies. For example, the \$2 million Hanga Agritech Innovation Challenge Fund, a collaborative effort between the Ministry of Agriculture and Animal Resources and the World Bank (World Bank, 2022) shows Rwanda's commitment to supporting local start-ups that develop technological solutions to enhance agricultural productivity and natural resource management (Afrik 21, n.d.). This initiative, part of a broader strategy to integrate digital innovations in farming, introduces advanced technologies such as sensors for soil moisture and agricultural robots for weeding and harvesting, focusing on improving food security and the nutritional quality of food products.

Rwanda has witnessed the introduction of various innovative solutions aimed at increasing the availability of nutritious foods. Technologies such as the Internet of Things (IoT) are being used to transform food waste into organic fertiliser, demonstrating the potential for new technologies to contribute to sustainable agriculture and improved food security. Similarly, the adoption of drone technology for precision agriculture, through projects like the Nitrogen fertilization of wheat crops in Musanze, shows the country's capacity to leverage advanced technologies for enhancing crop health and productivity (AATF-Africa, 2022).

The process is also supported by the investment in infrastructure and human capital in Rwanda. The government's focus on ICT development, as part of the National Information and Communication Infrastructure (NICI) plans, promotes the digital transformation of the agricultural sector (GoR, 2016). There have also been efforts for equipping local communities and farmers with the necessary knowledge and skills to adopt and use agricultural technologies effectively (GoR, 2016).

Addressing the nutritional aspect of food security, there efforts have been made to use biofortification as a strategy to improve the nutritional quality of staple crops. The assessment of the coverage of biofortified foods in Musanze

district highlights the potential of biofortification to increase nutrient intakes and improve health outcomes (Petry et al., 2020).

The food processing sector is underdeveloped. Food processing is an area of strategic importance for adding value to Rwanda's agricultural outputs and enhancing food security. The government has prioritised this sector for investment, promoting the production of value-added products such as fruit juice, jam, canned fruits, coffee, tea, and dairy products. The establishment of modern processing facilities and the support for the dairy sector, including the development of milk collection centres and processing plants, are notable steps toward improving the availability of nutritious foods. These initiatives not only enhance the food processing industry but also aim to increase Rwanda's export potential. However, to fully realise these benefits, challenges such as access to financing, inadequate infrastructure, and limited technical expertise need to be addressed through supportive policies and targeted investments in the sector (Kigali Business Network, n.d.).

Despite significant initiatives and investments aimed at eradicating hunger, challenges persist. According to stakeholders, key among these are the accessibility and affordability of technologies and the ongoing need for various types of innovation. In addition, access to finance remains a critical barrier, hindering farmers and companies from investing in novel technologies and innovations. To effectively overcome these challenges, a sustained commitment from the government is essential, coupled with increased investment in research and innovation. It is also important to promote the development of an ecosystem that encourages experimentation and innovation in the agri-food sector, and provides an enabling environment for grass-root and frugal innovation. In this respect, potential strategies could include expanding digital literacy programmes for farmers, developing more affordable and localised technological solutions, promoting social innovation and strengthening public-private partnerships to fight against hunger.

WOMEN AND YOUTH EMPOWERMENT IN AGRICULTURE

Rwanda has made significant progress in promoting gender equality and youth empowerment within its agricultural sector. Despite these efforts, substantial challenges hinder the full participation of women and youth in farming communities. Notably, farms managed by women are approximately 12% less productive than those managed by men, primarily due to unequal access to essential resources such as land and agricultural inputs (GoR, 2019b). The Women's Empowerment in Agriculture Index (WEAI) survey conducted in Rwanda reveals that while women demonstrate high levels of empowerment in several agricultural domains, they encounter considerable challenges in participating in lucrative agricultural value chains and securing the necessary financial resources to advance their farming practices (Rosenbach et al., 2023).

Stakeholders further emphasise that financial inclusion remains a critical challenge for women and youth in agriculture. Despite some women accessing credit, they encounter disproportionate barriers relative to men, including issues like lack of collateral and higher interest rates, as evidenced by the WEAI findings. For youth, the situation is even more challenging as financial exclusion is notably high, significantly limiting their potential for agricultural entrepreneurship (Rosenbach et al., 2023). Therefore, enhancing financial inclusion through tailored products and services is needed to empower these disadvantaged groups to invest more effectively in agricultural technologies and innovation.

Further exacerbating the challenges in financial inclusion, access to agricultural inputs and technology is uneven, disproportionately affecting women and youth. The WEAI survey underscores this disparity, revealing that women are less likely than men to access extension services, which are critical for adopting new agricultural technologies. This issue is supported by additional findings highlighting that women have significantly lower access to improved seeds and fertilizers (GoR,

2019b). Furthermore, there is limited participation of women and youth in profitable agricultural value chains. According to Rosenbach et al. (2023), women's involvement in value chains like coffee and meat is significantly lower than that of men, and they often have less control over the income generated from these activities.

Stakeholders recognise the significant benefits of the customised agricultural extension services recently introduced in Rwanda, particularly for women and youth as they services offer targeted support tailored to their specific challenges and opportunities. Furthermore, the promotion of digital technologies such as drones for precision farming and mobile apps for market access is particularly appealing to youth, helping to attract them to agriculture. Efforts are also underway to advocate for the rights of women and youth, ensuring they have equal access to land, resources, and decision-making processes. Both governmental and non-governmental organisations play a crucial role in promoting policy changes and providing the necessary support to these vulnerable groups.

DIGITAL SOLUTIONS FOR ENHANCED PRODUCTIVITY

Rwanda has been actively working towards the digitalisation of its agriculture sector to enhance food system productivity. The country's capacities to adopt digital solutions are shaped by several factors, including government initiatives, infrastructure development, private sector engagement, and international support. The government has placed a strong emphasis on digitalisation as a key driver for transforming the sector. Initiatives such as the Rwanda Economy Digitalisation Programme aim to leverage data insights to improve policymaking and catalyse innovation (GoR, n.d.-b). The government has also developed digital platforms for farmers, such as Smart Nkunganire or e-Soko. Moreover, RAB's strategic plans aim to make agriculture high-tech and market-led by 2024, with a focus on professionalising livestock farmers and increasing outputs (GoR, 2020a).

In parallel, digital infrastructure in the country has seen improvement with 93% of the population gaining access to 3G network (UN, 2019). With a financing approved in 2021, the World Bank has provided \$100 million to accelerate Rwanda's digital transformation, which includes expanding digital access and adoption, enhancing digital public service delivery, and promoting digitally enabled innovation (World Bank, n.d.-b).

Rwanda invests in developing and implementing various digital platforms to facilitate the dissemination of information and services that are critical for farmers. For instance, the deployment of digital tools and crowdsourcing approaches has been used to generate high-frequency data for monitoring diet quality at the population scale, which indirectly supports agricultural productivity by providing insights into food consumption patterns (Manners et al., 2022). Moreover, the use of data analytics is becoming increasingly important for the country for data-driven decision-making in optimising farming practices, predicting crop yields, and managing resources more efficiently.

The private sector plays a key role in the digitalisation of Rwanda's agriculture. Stakeholders commend the government for creating a conducive policy environment that encourages private sector investment in digital technologies. This support includes developing public-private partnership models that facilitate private investment in essential infrastructure and value addition, crucial for adopting digital solutions. Digital platforms can play a pivotal role by providing farm management support and connecting farmers to advisory services and markets (UN, 2019). Moreover, initiatives like the Smart Rwanda Master Plan, which focuses on digital transformation across key sectors including agriculture, depend on private sector collaboration (GoR, n.d.-a).

Despite these developments, notable challenges such as the digital divide between rural and urban areas, high data costs, and limited access to electricity in rural areas persist. The government is making efforts to close infrastructure gaps in rural areas and to develop sustainable business models

for digital service providers (Benfica et al., 2023). While addressing infrastructure is a critical part of the solution, more comprehensive measures are needed to ensure that disadvantaged regions benefit from digital solutions to contribute effectively to food systems transformation.

SOIL CONSERVATION TECHNIQUES

Soil erosion presents a severe problem in Rwanda, with estimates indicating annual soil losses of about 1.4 million tons. This significant erosion leads to economic setbacks and reduced agricultural productivity (Karamage et al., 2016; Rizinjirabake et al., 2023). Recognising this, the National Agriculture Policy and various strategic plans underscore the importance of sustainable land management and soil conservation as essential for achieving food security and promoting economic growth (GoR, 2018a).

The government has implemented a range of soil conservation measures, including bench terraces, trenches, progressive terraces, contour cropping, grass strips, and agronomic management practices. Key agencies like the Rwanda Environment Management Authority (REMA) and the Rwanda Water Resources Board (RWB) play key roles in these initiatives. REMA coordinates the protection, conservation, and management of the environment, while RWB oversees the sustainable management of water resources.

The effectiveness of these soil conservation practices is influenced by factors such as land ownership, awareness of soil erosion, and resource availability. Research in Northern Rwanda indicates that landowners are more inclined to implement conservation techniques than those who rent or borrow land, due to the security and long-term benefits ownership provides (Nahayo et al., 2016). Furthermore, awareness on the issue as well as understanding the causes and consequences of soil erosion is important; for example about half of the farmers in the study area were not aware of the causes of soil erosion, such as cultivation on steep slopes and inadequate erosion control practices (Nahayo et al., 2016).

Agroforestry systems are promoted within Rwanda to improve soil health, ameliorate microclimates, and increase productivity. These systems, which integrate trees into farming landscapes, help control erosion, enhance water absorption, and maintain soil organic matter levels. Alongside, reforestation efforts increase forest cover, reducing the risk of landslides and other soil degradation processes (Fahad et al., 2022; Mukuralinda et al., 2016).

Community-centred approaches to soil conservation engage local communities in both identifying problems and implementing solutions, creating a sense of ownership and commitment to soil health. Projects like the Alliance for Restoration of Forest Ecosystems in Africa (AREECA), supported by the International Union for Conservation of Nature (IUCN), aim to restore over 100,000 hectares of degraded forest landscapes, involving multiple African countries, including Rwanda and targeting significant land areas by 2025 (IUCN, n.d.).

Despite the adoption of various soil conservation techniques, challenges remain in effectively mitigating soil erosion and enhancing soil fertility. The persistence of soil erosion issues indicates that these techniques alone are insufficient since factors such as over-cultivation on small, steep farmlands, limited financial capacity, and inadequate practical training hinder the effectiveness of the implemented conservation solutions (Nahayo et al., 2016).

4.2. STI INVESTMENT AREAS PROPOSED BY CONSULTED STAKEHOLDERS – AN OVERVIEW

STI area	STI gaps and needs	Enabling developments	Possible STI investments	Relevant stakeholders	Selected relevant initiatives
Climate-resilient agriculture	<ul style="list-style-type: none"> ■ Need for comprehensive climate-resilient technologies ■ Lack of capacity building and knowledge sharing ■ Insufficient public-private partnerships ■ Need for increased climate finance 	<ul style="list-style-type: none"> ■ Developing and disseminating climate-resilient crop varieties ■ Adopting climate-smart agriculture practices ■ Utilising emerging technologies (drones, AI, big data) ■ Enhancing biogas production from livestock droppings ■ Promoting integrated strategies to link agriculture and disaster management 	<ul style="list-style-type: none"> ■ Research and innovation in agricultural technologies ■ Development of climate-resilient crop varieties ■ Implementation of climate-smart agriculture practices ■ Utilization of deep placement fertilizer pellets ■ Biogas production technology ■ Application of drone technology, AI, and big data in agriculture ■ Transformation of food waste into organic fertiliser 	<ul style="list-style-type: none"> ■ Rwanda Agriculture and Animal Resources Development Board (RAB) ■ National Agricultural Export Development Board (NAEB) ■ International Fund for Agricultural Development (IFAD) ■ Food and Agriculture Organization (FAO) ■ CGIAR Research Program on Climate Change ■ Agriculture and Food Security (CCAFS) ■ Private sector entities 	<ul style="list-style-type: none"> ■ Vision 2050 and Strategic Plan for Agriculture Transformation 2018-24 ■ Green Growth and Climate Resilience Strategy ■ Climate-Resilient Post-harvest and Agribusiness Support Project ■ UN Rwanda's Joint Programme on Enhancing Climate Resilience and Integrated Agriculture ■ Rwanda Climate Services for Agriculture project ■ Participatory Integrated Climate Services for Agriculture (PICSA) ■ Innovative Frontier Technologies for Climate Resilient Agriculture ■ Rwanda Climate Finance Partnership
Soil conservation techniques	<ul style="list-style-type: none"> ■ Significant annual soil losses (1.4m tons) causing economic setbacks and reduced agricultural productivity. ■ Limited awareness among farmers about the causes of soil erosion, such as cultivation on steep slopes and inadequate erosion control practices. ■ Challenges in the effectiveness of soil conservation techniques due to over-cultivation on small, steep farmlands. ■ Limited financial capacity and inadequate training for farmers. 	<ul style="list-style-type: none"> ■ Strong policy support for sustainable land management and soil conservation ■ Promotion of agroforestry systems to improve soil health, microclimate, and productivity. ■ Reforestation efforts to increase forest cover and reduce soil degradation. ■ Community-centred approaches to engage local communities in soil conservation efforts. ■ International support and collaboration 	<ul style="list-style-type: none"> ■ R&D of soil conservation techniques (e.g., bench terraces, trenches, progressive terraces, contour cropping, grass strips). ■ Enhancing farmer education and awareness programs on soil erosion and prevention methods. ■ Promoting and integrating agroforestry systems to improve soil health and productivity. ■ Strengthening reforestation efforts to mitigate soil degradation. ■ Community-centred approaches for soil conservation to ensure local engagement and ownership. 	<ul style="list-style-type: none"> ■ Rwanda Environment Management Authority (REMA) ■ Rwanda Water Resources Board (RWB) ■ International Union for Conservation of Nature (IUCN) ■ Alliance for Restoration of Forest Ecosystems in Africa (AREECA) 	<ul style="list-style-type: none"> ■ National Agriculture Policy ■ National Forest Policy ■ National Land Use and Management Master Plan ■ Alliance for Restoration of Forest Ecosystems in Africa (AREECA) supported by IUCN, aiming to restore over 100,000 ha of forest landscapes by 2025. ■ Projects involving local communities in identifying and implementing soil conservation solutions.

STI area	STI gaps and needs	Enabling developments	Possible STI investments	Relevant stakeholders	Selected relevant initiatives
<p>Digital solutions for enhanced productivity</p>	<ul style="list-style-type: none"> ■ Digital divide between rural and urban areas ■ High data costs ■ Limited access to electricity in rural areas 	<ul style="list-style-type: none"> ■ Strong government emphasis on digitalisation as a key driver for sector transformation ■ Improved digital infrastructure with 93% of the population having access to a 3G network ■ International support, e.g. US\$100m funding for digital transformation from the WB ■ Development and implementation of digital platforms for information and service dissemination ■ Private sector investment facilitated by a conducive policy environment ■ Use of data analytics for optimized farming practices and resource management 	<ul style="list-style-type: none"> ■ Leveraging data insights for improved policymaking and innovation ■ Deployment of digital tools and crowdsourcing approaches for monitoring diet quality ■ Data analytics for data-driven decision-making in optimizing farming practices ■ Sustainable business models for digital service providers ■ Expanding digital access and adoption and enhancing digital public service delivery ■ Promoting digitally enabled innovation ■ Public-private partnership for infrastructure development and value addition 	<ul style="list-style-type: none"> ■ Ministry of ICT and Innovation ■ Private telecommunication companies ■ Agricultural technology companies ■ Research institutions and universities ■ Farmer cooperatives and associations 	<ul style="list-style-type: none"> ■ Smart Rwanda Master Plan ■ ICT4RAG strategy and development of Rwanda National Digital Agriculture Strategy-NDAS ■ RAB's strategic plans for high-tech and market-led agriculture ■ National Information and Communication Infrastructure (NICI) plans ■ Rwanda Economy Digitalisation Programme ■ Agriculture Management Information System (MIS) ■ Satellite Crop Monitoring ■ Agriculture Common Data Warehouse ■ Smart Nkunganire System ■ E-Soko ■ Donor support (e.g. FAO, WB)
<p>Better diets and access to affordable nutritious foods</p>	<ul style="list-style-type: none"> ■ Accessibility and affordability of technologies for farmers and companies. ■ Access to finance for investing in novel technologies and innovations. ■ Inadequate infrastructure and limited technical expertise. ■ Underdeveloped food processing sector. 	<ul style="list-style-type: none"> ■ Government commitment to supporting local start-ups and creating a conducive environment for agricultural technology adoption. ■ Strategic focus on increasing the availability of nutritious foods. ■ Introduction of advanced technologies and digital innovations in farming. ■ Investment in infrastructure and human capital. ■ Efforts to promote food processing and value-added products. 	<ul style="list-style-type: none"> ■ Support to R&D and innovative businesses promoting nutritious diets based on the local produce ■ Development of biofortified foods to improve nutrient intakes and health outcomes ■ Evaluation of impact of digital innovations on farming practices and food security. ■ Introduction of advanced technologies such as sensors for soil moisture and agricultural robots for weeding and harvesting ■ Use of drones for precision agriculture, including inclusive business models accessible to smallholders 	<ul style="list-style-type: none"> ■ Ministry of Agriculture and Animal Resources ■ Ministry of Trade and Industry ■ Ministry of ICT and Innovation ■ NGOs working on food security, nutrition, and agricultural development ■ Financial institutions ■ Agricultural extension services providers ■ Research institutions and universities ■ Private sector actors, including ICT 	<ul style="list-style-type: none"> ■ Strategic Plan for Agriculture Transformation 2018-24 ■ National Biofortification Strategy ■ Hanga Agritech Innovation Challenge Fund ■ Financial Inclusion for Agricultural Transformation (FIAT) project ■ One Acre Fund ■ World Food Programme (WFP) programs in Rwanda

STI area	STI gaps and needs	Enabling developments	Possible STI investments	Relevant stakeholders	Selected relevant initiatives
Women and youth empowerment in agriculture	<ul style="list-style-type: none"> ■ Farms managed by women are approximately 12% less productive than those managed by men due to unequal access to resources such as land and agricultural inputs. ■ Women face barriers to financial inclusion, e.g. lack of collateral and higher interest rates. ■ Youth face high levels of financial exclusion, limiting their potential for agricultural entrepreneurship. ■ Uneven access to agricultural inputs and technology disproportionately affects women and youth. ■ Women have lower access to extension services, improved seeds, and fertilizers. ■ Limited participation and control by women and youth in lucrative agricultural value chains like coffee and meat. 	<ul style="list-style-type: none"> ■ Customised agricultural extension services tailored to women and youth's specific challenges and opportunities. ■ Promotion of digital technologies such as drones for precision farming and mobile apps for market access, which are particularly appealing to youth. ■ Advocacy for equal access to land, resources, and decision-making processes for women and youth. ■ Efforts by both governmental and non-governmental organizations to support policy changes and provide necessary resources. 	<ul style="list-style-type: none"> ■ Development and promotion of tailored financial products and services for women and youth in agriculture. ■ Enhancement of agricultural extension services tailored to the specific challenges faced by women and youth. ■ Promotion and adoption of digital technologies such as drones and mobile apps for market access. ■ Support for advocacy efforts to ensure equal access to land, resources, and decision-making processes for women and youth. 	<ul style="list-style-type: none"> ■ Government of Rwanda ■ Non-governmental organizations ■ Financial institutions ■ Agricultural extension services providers ■ Digital technology companies 	<ul style="list-style-type: none"> ■ National Gender Policy ■ National Youth Policy ■ Land Tenure Regularization Program ■ Women's Empowerment in Agriculture Index (WEAI) ■ Gender in Agriculture Partnership (GAP) ■ IFAD-funded projects promoting women's economic empowerment in agriculture

5. CONCLUSIONS AND ACTION PLAN FOR THE STI FOR SDGs ROADMAP

5.1. KEY CONCLUSIONS AND POLICY MESSAGES

Food system transformation is among the high-level political and policy goals of Rwanda. There are many strategic documents, policy instruments and programmes focused on strengthening the resilience and productivity of the Rwandan food system. Science, technology and innovation are considered important drivers of the transformation. Key national strategic plans, such as “Strategic plan for agriculture transformation” (PSTA 4), include research and innovation among its priority areas. The strong political support and policy focus on agricultural transformation contributes to a favourable environment for initiatives focused on food system transformation in the country.

The recognition of food system transformation among nation’s development priorities is also reflected in the STI policy, adopted in 2020. The policy includes priorities directly targeting good system, including mobilising STI for food security, improving productivity and value added of local production and developing climate-resilient food system through clean technologies, green production methods, and biodiversity conservation. Similarly, the National Research and Innovation Agenda (2021) identifies “food security and modern agriculture’ as one of the national priority areas.

The wider policy mix focused on food system spans many policy areas. The most notable is agriculture policy with a strong focus on research, innovation and capacity building. Local communities have enjoyed benefits of the continuous development of national extension services reaching out to farmers around the country (e.g. through the Twigire Muhinzi system). The government, in collaboration with international partners, has promoted

innovative digital platforms developed to support farmers and other actors in the agri-food supply chain (e.g. Smart Nkunganire System).

Rwanda has achieved considerable progress on its transformation path enjoying benefits of science and innovation. This report argues are many untapped STI opportunities the country can exploit to accelerate the transformation towards a more resilient and sustainable food system. This chapter highlights key STI policy and governance actions to unlock STI investment in Rwanda. These areas are further elaborated in a proposed action plan for the STI for SDGs roadmap introduced in the following section. The action plan is designed to channel STI investments towards areas identified in [Chapter 4](#).

STRENGTHEN GOVERNANCE AND POLICY INTEGRATION TO FOSTER STI FOR FOOD SYSTEM TRANSFORMATION

STI policy is actively contributing to the food system transformation but it is rarely considered among key policy areas addressing. Few stakeholders consider STI policy a central element of policy mix supporting food system transformation. There are many instruments supporting R&I implemented by many governmental institutions (e.g. MINAGRI, RAB, NCST) and non-governmental actors (e.g. NGOs, cooperatives, donors).

There is, however, insufficient coordination across policy mix ensuring the overall directionality and coherence of instruments supporting STI for food system transformation. The Government has well developed coordination mechanisms focused on sectoral policies (e.g. agriculture) but – in the absence of an overarching policy for food system transformation – these mechanisms fall short of

providing a governance framework embracing a food system perspective and bringing together all relevant actors and initiatives. The absence of “big picture” leads to the lack of awareness of “who is doing what” and results in duplications and missed opportunities to benefit from synergies between STI policy and other policy areas (e.g. NCST and MINAGRI or NCST and MOH). The limited - and often lack of - collaboration between donors involved in numerous initiatives in the food system exacerbates the situation.

There is a need to develop appropriate governance mechanisms and “policy spaces” supporting research and innovation collaborations (e.g. innovation platforms) that systematically embrace food system perspective and ensure complementarities and synergies between STI investments.

Many stakeholders recognised the importance to adapt public policies and governance supporting STI to specific geographic contexts, local capabilities and needs in the area of food system transformation. The current STI policy does not sufficiently elaborate on the territorial dimension of science, technology and innovation. There is a need to ensure that the “policy spaces” support developing place-based strategies that address local needs and challenges based on local capabilities and market opportunities (e.g. place-based approaches to balance diversification and specialisation in choosing specific crops or crop rotations). The governance processes should include diverse stakeholders, including business, research, NGOs and policy makers, as well as actors less represented in policy processes such as small farmers, local cooperatives, women and youth.

STRENGTHEN EVIDENCE BASE AND BUILD RESEARCH CAPABILITIES FOR THE SOUND POLICY FOR FOOD SYSTEM TRANSFORMATION

There is very limited evidence and data available on STI performance in the area of food system in Rwanda. Many basic indicators on R&D and innovation are missing, too old or cannot be disaggregated to provide robust evidence base for public interventions mobilising STI for food system transformation. There are no dedicated policy

evaluations focus on STI and food system. There is, however, a growing body of knowledge on food system in general, focused mainly on agriculture and health. There is a wealth of empirical data collected by individual NGOs, researchers and donors which are, however, not aligned and often not publically accessible.

There is an urgent need to improve the evidence base for policies and programmes by funding dedicated empirical studies focused on STI in general and with a focus on food system transformation. This should be a continuous activity rather than one-off studies. We propose developing a dedicated research agenda with the focus on food system transformation. The agenda should lay out short- and longer-term research activities to strengthen research capacity, foster national and international research collaboration and gradually build an integrated digital platform with data on food systems available for researchers and public. The agenda would propose how to build research capacities for monitoring and evaluation (M&E).

There is a need to establish and strengthen “science for policy” collaboration processes focused on food system transformation. We propose establishing a research network that brings together Rwandan research institutes, universities, research-oriented NGOs, development partners, and research officers from relevant ministries and the national statistical office. This network could function as an independent think tank, tasked with commissioning evaluations, impact assessments, and foresight studies on research and innovation activities critical to the food system.

The evaluation and monitoring system in Rwanda is in its nascent phase. There is an urgent need to strengthen monitoring and evaluation capacity in Rwanda. This includes engaging universities and research institutes in developing M&E system focused on outcomes and impacts of STI, building M&E capacity as well as collecting data and commissioning evaluations focused on STI in the food system. There is also a need to develop processes and ensure sufficient funds for conducting ad-hoc thematic evaluations and integrated impact assessments of policies

addressing urgent issues linked with food system transformation, e.g. support to specific dietary habits and food products, specific products and technologies (e.g. impact of new seeds, fortified foods, fertilisers) and processes (e.g. extension services or advisory business services).

LEVERAGE AND STREAMLINE INVESTMENTS IN STI TO IMPROVE PRODUCTIVITY AND RESILIENCE OF FOOD SYSTEM

There are many relevant policy instruments addressing food system transformation in Rwanda but the funding available for research and innovation is limited. There is a need to dedicate more resources to support STI for food system transformation, design instruments to leverage more dedicated STI funding from development partners, as well as strengthen governance mechanisms to streamline funding from development partners and align it with food system challenges faced by Rwanda.

The following section proposes several dedicated initiatives focused on mobilising STI for specific food system challenges, including actions focused on climate-smart agriculture, minimising post-harvest food waste (e.g. post-harvest management and circular economy), and supporting social and frugal innovation. These are illustrative examples based on the stakeholder consultations and evidence analysed for this study.

SUPPORT SOCIAL AND FRUGAL INNOVATION IN FOOD SYSTEM FOR RESILIENT LOCAL COMMUNITIES

There are many examples of successful social innovations in the area of food system in Rwanda. They are often championed by cooperatives and NGOs. Government programmes have limited focus on support different forms of social innovation in the area of food system. Social innovation offers a great opportunity to create synergies between formal knowledge and technologies and local knowledge, including indigenous knowledge. Support to social innovation opens a possibility for local communities and companies to deliver products and services recognising local context, needs and capacities. It can also be a powerful tool

to adapt and diffuse technologies and business models that deliver value for local communities. We propose to introduce a dedicated programme supporting social innovation, including development and scaling of social and community business models. Social innovations can be promoted through the network of extension advisory services (e.g. FFS facilitators, FPs and Twigire groups).

INTRODUCE INTEGRATED APPROACH TO ADVISORY AND EXTENSION SERVICES

There is plethora of programmes and projects supporting STI in the area of food system transformation in Rwanda. The landscape is difficult to navigate for farmers and companies in the agri-food sector, let alone cooperatives or subsistence farmers. There is a need to for an integrated approach in providing relevant information and advisory services to various actors operating in food system.

We propose co-developing a digital platform bringing together in one place (one-stop shop) information on existing digital tools and services relevant for farmers and other actors in the supply chain, consumers as well as funders. The platform provide access to available tools and information sources on farming techniques, available inputs, market developments or funding opportunities. The platform could be used to disseminate good practices in agricultural techniques, sustainable farm management practices, and management skills with a focus to support farmers and agri-food business in taking strategic decision (e.g. crop selection).

The platform would be underpinned by regional hubs designed in a close collaboration with local actors (user-led design) to focus on place-based challenges and market demand relevant for different localities and regions. Collaborations with international organisations working in this area, notably FAO and CGIAR, could facilitate the design and uptake of the programme with regional and global experience and digital tools, such as AI-based solutions for processing farmer feedback, interactive radio programmes of CGIAR for a wider dissemination and FAO's guide on using smart phone applications.

5.2. PROPOSED POLICY ACTIONS FOR THE STI FOR SDGs ROADMAP

This section presents an action plan that outlines proposed governance and policy instruments mobilising STI for food systems transformation.

The actions identified are based on inputs from stakeholders, gathered through workshops, interviews, and survey, and desk research. The table introduces these actions by outlining specifying responsibilities, expected outputs, and timing.

Rationale	Actions	Lead	Partners	Output and outcomes	Timing for initiation*
Strengthen governance and STI policy integration in the area of food system	<p>1. High-level Committee for Food System Transformation</p> <p>Establish a high-level committee led by Office of the Prime Minister to coordinate policies and their implementation across various domains and sectors related to food system transformation, including a dedicated focus on the role of STI.</p> <p>The committee should comprise representatives of different stakeholder groups and relevant sectors to encompass diverse policies and actions covering all aspects of food systems and security. The Committee should be a platform to map and seek complementarities and synergies between international projects and programmes implemented with national and external funding; enable cohesive, evidence-based policymaking; streamline monitoring and evaluation of policies and instruments; foster effective inter-sectoral collaboration; promote food system innovation considering local, regional, and national levels, by prioritising disadvantaged regions and groups</p> <p>The committee can establish a specialized working groups to focus on various aspects of food system transformation, draw insights from international best practices, and forge long-term global partnerships for knowledge exchange.. One of the working groups could focus on mapping and streamlining policy activities supporting STI in the area of food system.</p>	<p>Office of Prime Minister</p> <p>MINAGRI</p> <p>RAB</p> <p>NCST</p> <p><i>(MINAGRI to act as the Secretariat of the Committee</i></p> <p><i>NCST and RAB as technical leads)</i></p>	<p>MINICT, MoH, MINEDUC, MoE, MINICOM, NAEB,</p> <p>HLIs, Private sector, NGOS, Development partners</p>	<p>An effective platform for developing, improving, overseeing, and aligning policies, policy instruments, and international projects and programmes</p> <p>The Committee to adopt a STI roadmap for Food System Transformation in Rwanda, with an explicit focus on research and innovation.</p>	<p>Short term</p>
<p>Strengthen governance and STI policy integration in the area of food system</p> <p>Insufficient STI governance and policy coordination</p> <p>Strengthening place-based research and innovation</p> <p>Shortcomings in capacity building and skills development</p>	<p>2. Food Systems Innovation Platforms</p> <p>Revitalise the concept of Innovation Platforms (IPs) to address specific (country-wide and place-based) food system challenges.</p> <p>The IPs will provide a collaborative space for stakeholders from across food value-chain to exchange experience on existing good practices, co-create new ideas and scale proven innovative solutions. They may first be initiated in districts where RAB stations exist and then expanded. The platforms will aim to create shared understanding of challenges, deliberate possible innovative ways to address them (pathways) and create challenge-oriented partnerships.</p> <p>Key activities can include regular stakeholder meetings, task forces, joint projects, capacity building workshops (linked to farmer field schools), and the development of pilot projects to test and refine innovative approaches. To ensure effectiveness and sustainability, the platforms will integrate robust monitoring and evaluation, secure national and international funding sources, and establish clear governance structures.</p>	<p>MINAGRI, MINICT, RAB, NAEB, NCST, NIRDA and MINALOC</p> <p>Regional facilitation through RAB, local government and other local actors (e.g. NGOs)</p>	<p>MINEDUC, Relevant line ministries, local government, research and education institutes, extension actors (including FAAS-R), NGOs, farmers and cooperatives, private sector representatives, technology providers, development partners</p>	<p>Effective collaboration and knowledge exchange among stakeholders, successful scaling and adoption of innovative practices within the agri-food sector, enhanced capacity of stakeholders to innovate and respond to food system challenges.</p>	<p>Short term</p>

*Short term is defined as within two years; medium term spans from year two to five and long term refers to the period beyond year five.

Rationale	Actions		Lead	Partners	Output and outcomes	Timing for initiation* <i>*Short term is defined as within two years; medium term spans from year two to five and long term refers to the period beyond year five.</i>
<p>Build science and research capabilities for food system transformation</p> <p>Capacity building and skills development gaps</p> <p>Infrastructure and data integration gaps</p>	<p>3. Food System Science for Policy Network</p> <p>Establish a research network grouping scientists and experts specialised in food system issues in Rwanda and wider region. The network can act as a think tank and advisory body to the Committee and the Food Systems Innovation Platforms. The network should act as a policy learning space and sounding board for ongoing and planned initiatives.</p>		NCST, MINEDUC, MINAGRI	RAB, NAEB, NISR, Research institutes and higher education; Representatives of private research organisations, Intermediaries (e.g. FAAS-R), relevant experts and NGOs	The network will provide independent studies to for the Government, the Committee and Innovation platforms (see above). The network will be a space for debates on the research and innovation agenda (see below). It may become an independent think-tank.	<p>Short term (network)</p> <p>Medium- to long-term (think-tank)</p>
<p>Strengthen governance and STI improve policy integration in the area of food system</p> <p>Build science and research capabilities for food system transformation</p> <p>Infrastructure and data integration gaps</p>	<p>4. Food System Research and Innovation Agenda to consolidate and develop scientific evidence for policies and STI investments</p> <p>Develop a dedicated cross-disciplinary research and innovation agenda for the food system transformation in Rwanda.</p> <p>The agenda should be co-developed with key STI stakeholders and draw on systematic literature and data review focused on the role of STI for food transformation. The agenda would provide a systemic approach to developing and improving a robust evidence base for policy decisions and investments implementing key strategic policy documents.</p>		MINAGRI, MINICT and NCST	<p>Relevant line ministries, RAB, NAEB, NIRDA, research entities, higher education institutes, private sector NGOs</p> <p>International investors and organisations (FAO, CGIAR, WB)</p>	<p>Study laying foundation for the research and innovation agenda on food system transformation</p> <p>Research and innovation agenda for food system transformation.</p>	Short term

Rationale	Actions		Lead	Partners	Output and outcomes	Timing for initiation*
<p>Capacity Building and Skills Development Gaps</p> <p>Promoting Digital and Precision Agriculture</p>	<p>5. Integrated Digital Platform and Regional Hubs for Advisory and Extension Services on Food System Transformation</p> <p>Exposed to plethora of new initiatives and information sources, food system actors find it difficult to identify relevant services or knowledge sources they need. The proposed Platform will have a holistic focus on food system and integrate information sources and services relevant for enhancing agricultural productivity and community resilience.</p> <p>The platform could provide a one-stop shop access to relevant services and information source, including relevant local contacts, problem-based and place-relevant information and good practices in agricultural techniques, sustainable farm management practices, and management skills with a focus to support farmers and agri-food business in taking strategic decision (e.g. crop selection).</p> <p>The Regional Hubs would be a “first-contact” advisory body for farmers, agri-food businesses and other actors active in the food system, tailored to reflect local specificities and needs relevant for their region or local markets. They could offer a mix of face-to-face advisory services and provide an expert interface for the digital platform.</p> <p>The hubs will be designed in a close collaboration with local actors (user-led design) to focus on place-based challenges and market demand relevant for different localities and regions. Collaborations with international organisations working in this area, notably FAO and CGIAR⁷, could facilitate the design and uptake of the programme with regional and global experience and digital tools, such as AI-based solutions for processing farmer feedback, interactive radio programmes of CGIAR for a wider dissemination and FAO’s guide on using smart phone applications.⁸</p> <p>⁷ https://www.cgiar.org/initiative-result/artificial-intelligence-enables-extension-services-reaching-12-million-farmers-in-sub-saharan-africa-to-respond-to-farmers-voices/</p> <p>⁸ https://openknowledge.fao.org/server/api/core/bitstreams/f188cc38-d16e-4da6-adc5-45e1dc0ac96d/content</p>		<p>MINAGRI, MINALOC, MINICT, NAEB and RAB</p>	<p>FAAS-R, local authorities, education institutes, NGOs, farmers and cooperatives, private sector representatives, technology providers, development partners (FAO, CGIAR)</p>	<p>Operational digital extension services equipped with integrated digital technologies, providing comprehensive agricultural training, real-time advisory services, and enhanced digital literacy among rural communities.</p>	<p>Medium term</p> <p><i>*Short term is defined as within two years; medium term spans from year two to five and long term refers to the period beyond year five.</i></p>

Rationale	Actions		Lead	Partners	Output and outcomes	Timing for initiation*
<p>Untapped opportunities in the area of food waste prevention and management</p> <p>Insufficient investment in agro-processing facilities</p>	<p>6. Innovation Scheme for Sustainable Food Value Chains and Circular Economy to minimise food waste</p> <p>Develop and implement an innovation scheme aimed at improving productivity and reducing food waste across the supply chain, including smallholder farmers and – when relevant - households. This initiative will support post-harvest management and preservation technologies, enhance food processing techniques, and optimise supply chain logistics to minimise waste along the food value chain.</p> <p>The scheme would cover innovative use of established solutions (e.g. solar powered refrigeration), circular economy models to transform food by-products from production, transport, storage, consumption, and food waste into valuable products, as well as testing and developing novel approaches such as hydroponic vertical farming systems to reduce waste, solar-powered dryers for transforming spoiled crops into non-perishable ingredients, or the development and use of microbial stickers with natural formulations to extend fruit shelf-life. The scheme will integrate consumer education to promote sustainable consumption.</p>		MINAGRI and NIRDA	RAB, NAEB, relevant line ministries, local governments, education institutes, NGOs, farmers and cooperatives, private sector representatives, technology providers	Deployment of innovative technologies and practices that significantly improve post-harvest management and reduce food waste, enhanced efficiency in food production and distribution, and increased public awareness about sustainable food consumption.	Short term
<p>Enhancing agricultural productivity through local innovation</p>	<p>7. Implementation of Site-Specific and Sustainable Fertilisation Techniques</p> <p>Develop and promote the use of advanced, site-specific fertilisation techniques based on soil nutrient mapping and analysis. This approach will optimise fertiliser use, enhance soil health, increase crop yield while minimising negative environmental impacts of fertilisers.</p>		MINAGRI and RAB	NAEB, NIRDA, MoE, IFDC, Local Agricultural Cooperatives	Customised fertilization plans for different regions, leading to efficient fertilizer use, improved soil health, and enhanced crop productivity.	Short term
<p>Enhancing agricultural productivity through local innovation</p> <p>Strengthening research and innovation</p>	<p>8. Development and Certification of Climate-Resilient and High-Yielding Seed Varieties</p> <p>Conduct comprehensive research comparing existing local (traditional) seed varieties and new seed varieties that are not only high-yielding but also resilient to climate change, pests, and diseases. The comparison should include not only biological and ecosystem dimension but also social-ecological and socio-economic impact of seed varieties in line with agro-ecological approaches.</p> <p>New seeds should be specifically tailored to Rwanda's diverse agro-ecological zones and embedded in sustainable farming practices.</p>		RAB	MINAGRI, MoE, NCST, IITA	Availability and distribution of robust, high-yield, climate-resilient seed varieties to farmers, resulting in improved crop yields and resilience.	Medium term

*Short term is defined as within two years; medium term spans from year two to five and long term refers to the period beyond year five.

Rationale	Actions		Lead	Partners	Output and outcomes	Timing for initiation* <i>*Short term is defined as within two years; medium term spans from year two to five and long term refers to the period beyond year five.</i>
<p>Strengthening research and innovation</p> <p>Infrastructure and data integration gaps</p>	<p>9. NIRDA Incubation and Lab Enhancement for Food System Transformation</p> <p>Strengthen NIRDA's Applied Research and Development & Foresight Incubation department and Life Sciences Laboratory by modernising and upgrading facilities and research infrastructure, developing R&D staff capabilities to enhance applied research skills; and developing effective systems and capacities for knowledge and technology transfer (KTT) in alignment with Rwanda's food systems transformation goals.</p> <p>In addition, NIRDA could expand its technology incubation and mentoring services, offering state-of-the-art workspace, mentorship, business support, among others.</p> <p>Collaboration with academia will be intensified to develop young innovative entrepreneurs for the sector and provide essential skill sets for the development of new ideas and joint research initiatives.</p>		MINICOM and NIRDA	NCST, NISR, relevant line ministries, higher education institutes, private sector entities, NGOs	Upgraded and modernized facilities at NIRDA equipped to support advanced research and innovation; a skilled R&D workforce capable of leading applied research and KTT; enhanced collaboration with academic institutions and industry; increased number of marketable innovations in food systems.	Medium term
<p>Addressing low awareness and behavioural challenges in malnutrition and food security</p> <p>Tackling regional disparities in malnutrition</p> <p>Enhancing agricultural productivity through local innovation</p>	<p>10. National Initiative for Social Innovation for Food System Resilience</p> <p>Design and implement a programme to enhance food security and nutrition, with a focus on sustainable, inclusive agricultural practices. This initiative will support community-driven and cooperative models such as Community-Supported Agriculture (CSA), agroecology and agroforestry, and cooperative farming, using innovation to transform these sectors. It will promote the identification and integration of traditional knowledge with modern technologies, fostering the development of innovative solutions tailored to local and regional challenges.</p> <p>The programme will engage vulnerable communities, particularly women and youth, by empowering them to lead and participate in innovative agri-food projects that increase self-sufficiency and improve livelihoods.</p>		MINAGRI and RAB	MINECOFIN, MOE, MINICT and other relevant line ministries, local governments, NGOs, farmer cooperatives, technology providers	Increased adoption of innovative and sustainable farming techniques, improved food security and nutritional outcomes, and stronger community engagement in the agri-food sector.	Medium term

Rationale	Actions		Lead	Partners	Output and outcomes	Timing for initiation*
<p>Strengthening entrepreneurship and innovation system</p> <p>Enhancing inclusiveness of STI system</p> <p>Enhancing agricultural productivity through local innovation</p>	<p>11. Frugal Innovation Labs</p> <p>Establish Frugal Innovation Labs to develop cost-effective, scalable, and sustainable solutions specifically designed for the unique challenges of Rwanda's agri-food sector considering place-based factors. They will focus on creating innovations that require minimal resources and are easily adoptable by local communities, including smallholder farmers and rural entrepreneurs.</p> <p>The labs will leverage local materials and indigenous knowledge to design tools and processes that improve agricultural productivity, food preservation, and resource management. Key activities will involve, among others, collaborative workshops, prototype development, field testing, and community training sessions. The labs should be equipped with essential technological infrastructure such as 3D printers, basic electronics toolkits, and software for design and simulation, enabling rapid prototyping and iterative development of agricultural tools and solutions. The labs will also serve as incubation centres for young innovators and start-ups, providing them with the necessary support to develop and scale their ideas.</p>		<p>MINAGRI, NIRDA and University of Rwanda</p>	<p>MINICOM, Relevant line ministries, RAB stations, higher education institutes, NGOs, private sector entities</p>	<p>Development and dissemination of low-cost, high-impact agricultural innovations, enhanced local innovation capabilities, increased adoption of sustainable practices among small-scale farmers, and greater involvement of youth in the agricultural sector.</p>	<p>Medium term</p>
<p>Funding and Resource Allocation Shortcomings</p> <p>Leveraging Vertical Financing Models for Agriculture</p>	<p>12. Piloting and Scaling Vertical Financing Models for Sustainable Agriculture</p> <p>Implement targeted funding streams inspired by successful models from the health sector to support specific agricultural initiatives such as climate-smart agriculture, seed development, and food processing technologies. This approach can involve dedicated funds providing necessary capital to scale up proven agricultural innovations and support the development of essential infrastructure. The objective will be to ensure that investments are directed towards initiatives that offer the greatest potential for enhancing productivity, sustainability, and food security. This action will include clear funding criteria, involving stakeholders in priority setting, and developing mechanisms for monitoring and evaluating the impact of funded projects.</p>		<p>MINAGRI and RAB</p>	<p>MINECOFIN, international donors, private sector investors, research institutions</p>	<p>Dedicated funds established for priority agricultural initiatives, increased investment in high-impact projects, improved agricultural productivity and sustainability.</p>	<p>Medium to long term</p>

Acronyms: Ministry of Agriculture and Animal Resources (MINAGRI), Ministry of Environment (MoE), Ministry of Finance and Economic Planning (MINECOFIN), Ministry of Education (MINEDUC), Ministry of ICT and Innovation (MINICT), Ministry of Health (MoH), Ministry of Local Government (MINALOC), Ministry of Foreign Affairs and International Cooperation (MINAFFET), Ministry of Gender and Family Promotion (MIGEPROF), Ministry of Infrastructure (MINIFRA), Ministry of Trade and Industry (MINICOM), Ministry of Youth and Arts (MOYA)

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LIST OF ABBREVIATIONS

ACE-DS	African Centre of Excellence in Data Sciences
ACE-ESD	African Centre of Excellence in Energy and Sustainable Development
ACE-IoT	African Centre of Excellence in Internet of Things
ACE-ITLMS	African Centre of Excellence for Innovative Teaching and Learning Mathematics and Science
AFAAS	Africa Forum for Agricultural Advisory Services
AIMS	African Institute for Mathematical Sciences
AREECA	Alliance for Restoration of Forest Ecosystems in Africa
ASWG	Agricultural Sector Working Group
ASTI	Agricultural Science and Technology Indicators
BRD	Development Bank of Rwanda
CDAIS	Capacity Development for Agricultural Innovation Systems
CEBE	Regional Centre of Excellence in Biomedical Engineering and e-Health
CGIAR	Consultative Group on International Agricultural Research
CMU-Africa	Carnegie Mellon University Africa
DG INTPA	Directorate General for International Partnerships
EC	European Commission
EU	European Union
FAAS-R	Rwanda Forum for Agricultural Advisory Services
FAO	Food and Agriculture Organization
FONERWA	Rwanda Green Fund
GFRAS	Global Forum for Rural Advisory Services
GII	Global Innovation Index
HLIs	Higher Learning Institutions
ICT	Information and Communication Technology
IFAD	International Fund for Agricultural Development
IITA	International Institute of Tropical Agriculture
IUCN	International Union for Conservation of Nature
JRC	Joint Research Centre
KIFC	Kigali International Financial Centre
MINAGRI	Ministry of Agriculture and Animal Resources
MINALOC	Ministry of Local Government

MINCOM	Ministry of Trade and Industry
MINEDUC	Ministry of Education
MINECOFIN	Ministry of Finance and Economic Planning
MINICT	Ministry of ICT and Innovation
MINICOM	Ministry of Trade and Industry
MoE	Ministry of Environment
MOH	Ministry of Health
MoTI	Ministry of Trade and Industry
NAEB	National Agricultural Export Development Board
NCST	National Council for Science and Technology
NISR	National Institute of Statistics of Rwanda
NIRDA	National Industrial and Research Development Agency
NRIA	National Research and Innovation Agenda
NRIF	National Research and Innovation Fund
NST	National Strategy for Transformation
PSTA	Strategic Plan for Agriculture Transformation
RAB	Rwanda Agriculture Board
RCA	Rwanda Cooperative Agency
RDB	Rwanda Development Board
RCESCM	Regional Centre of Excellence for Vaccines, Immunization and Health Supply Chain
RICA	Rwanda Institute for Conservation Agriculture
RSB	Rwanda Standards Board
SDGs	Sustainable Development Goals
SNS	Smart Nkunganire System
STI	Science, Technology, and Innovation
TAP-AIS	Tropical Agriculture Platform - Agricultural Innovation Systems
UGHE	University of Global Health Equity
UNESCO	United Nations Educational, Scientific and Cultural Organization
UN IATT	United Nation's Inter-Agency Task Team
USAID	United States Agency for International Development
WEAI	Women's Empowerment in Agriculture Index
WIPO	World Intellectual Property Organization
WFP	World Food Programme
WRI	World Resources Institute

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ANNEXES

ANNEX 1. METHODOLOGY

1.1. OVERALL METHODOLOGICAL APPROACH

The STI for SDGs roadmap methodology is based on a challenge-oriented research design based on desk research and participatory methods to identify STI areas relevant for addressing selected sustainability challenges. The approach uses quantitative and qualitative data and participatory deliberation methods.

The methodology consists of three interconnected components laying the ground for the roadmap:

- Situational analysis;
- Selection and scoping of sustainability challenge;
- Deliberation of key STI areas to address the challenge.

The approach follows the underlying logic of roadmap in a sense that it addresses three lead questions: Where are we? Where do we want to go? How do we get there? The challenge-oriented approach allows to identify STI gaps and opportunities based on comparing the current and emerging needs related to the sustainability challenges in focus and to analyse the fitness of STI system and policy to address those needs. The approach is by design iterative and interactive. For example, situational analysis prepares the ground for the selection of the key challenge addressed by roadmaps but then dives into the selected challenges (see *Figure 11*).

The overall approach relies on a close collaboration between JRC and the country team. The process is designed to encourage and enable country team to take ownership and influence the process by selecting and scoping the challenge area and by co-organising the fieldwork and consultations.

FIGURE 11.
KEY COMPONENTS OF STI FOR SDGs ROADMAP

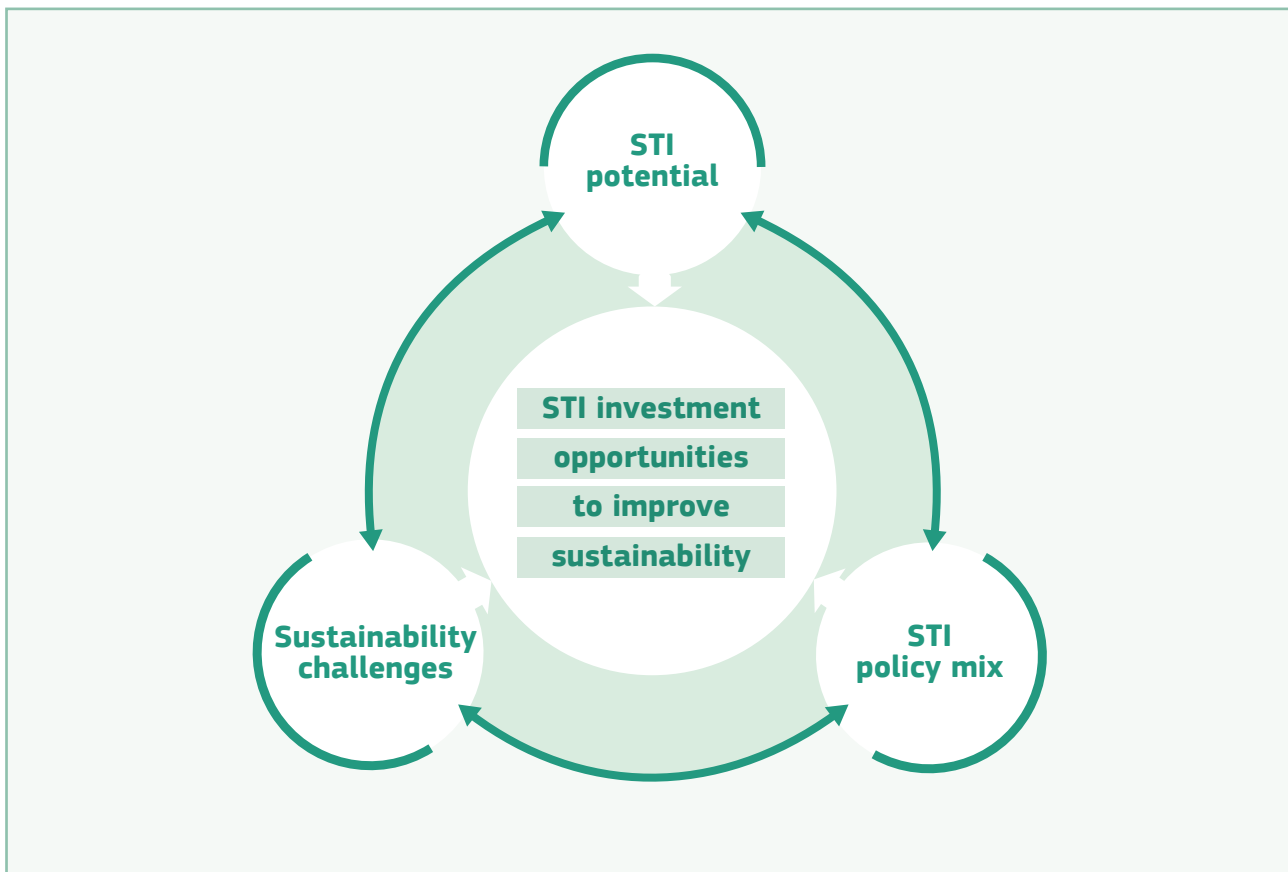


TABLE 3.
KEY COMPONENTS OF STI FOR SDGs ROADMAP

Elements of analysis	Quantitative analysis	Qualitative analysis
Sustainability challenges	<ul style="list-style-type: none"> • Socio-economic indicators • SDG indicators (targets) • Quantitative evidence used in diagnostic documents underpinning NDP and policy documents 	<p>Primary data</p> <ul style="list-style-type: none"> • Face-to-face and online stakeholder interviews • Web-based stakeholder survey • In-person and hybrid stakeholder workshop <p>Secondary data</p> <ul style="list-style-type: none"> • Qualitative evidence used in diagnostic documents underpinning NDP and policy documents • Literature review (academic and grey literature)
STI potential	<ul style="list-style-type: none"> • Scientific performance (e.g., bibliometric data on publications and citations; R&D personnel) • Technology and innovation indicators (e.g. R&D expenditures; patent data, Global Innovation Index (GII)) 	<p>Primary data</p> <ul style="list-style-type: none"> • Face-to-face and online stakeholder interviews • Web-based stakeholder survey • In-person and hybrid stakeholder workshop <p>Secondary data</p> <ul style="list-style-type: none"> • Literature review (including academic and grey literature)
STI policy mix		<p>Primary data</p> <ul style="list-style-type: none"> • Face-to-face and online stakeholder interviews • Web-based stakeholder survey • In-person and hybrid stakeholder workshop <p>Secondary data</p> <ul style="list-style-type: none"> • innovation ecosystem actor mapping • Document analysis (strategies and plans, instruments, and investment programmes)

SITUATIONAL ANALYSIS

The situational analysis of the STI for SDGs roadmaps prepares the evidence base for the roadmap. It focuses on three key areas:

- Sustainability challenges faced by the country;
- STI potential to tackle sustainability challenges;

- Policy mix and governance mechanisms focused on STI.

The analysis enables to identify gaps and opportunities in the STI ecosystem to address sustainability challenges at the country level. The initial desk research enables to identify key sustainability challenges faced by the country and the existing STI capacity to address these challenges. The in-depth analysis allows to co-

define areas for STI investments with high social and environmental impact. The analysis of each pillar relies on quantitative and qualitative data. **Table 3** introduces a non-exhaustive list of the data collected for the STI for SDGs roadmaps.

SELECTION AND SCOPING OF SUSTAINABILITY CHALLENGE

Based on the initial diagnosis and preliminary stakeholder consultations, the country teams proposed a challenges area for the roadmap. The initial diagnosis was conducted by JRC and independent experts and shared with country team for feedback. JRC and independent experts engaged in a series of meetings with country team to discuss alternatives and scope the roadmap. An online workshop was conducted to consult the choice and scope the focus.

Considering the resources and time available for the STI for SDGs project, the decision was to focus roadmaps on one challenge in order to demonstrate and to further co-develop the overall approach. The selected challenges were to be among challenges recognised in strategic national policy documents and should be framed to highlight the potential role of STI in addressing specific localised sustainability challenges. The areas were not selected based on their relative importance (e.g. they did not have to be of the highest political priority).

DELIBERATION OF STI INVESTMENT AREAS

To identify promising STI areas where mobilising research and innovation could help respond to the selected challenges, JRC in collaboration with the country teams conducted country visits including a multi-stakeholder workshop (20-50 participants) and a series of stakeholder interviews (10-20 interviews). The situational analysis provided essential material for the workshops designed to identify STI challenges and opportunities, and highlight potential investment opportunities. Based on these consultations and a close collaboration between the experts and the country teams, the reports propose tailor-made action plans to leverage variety of policy and governance tools

to mobilise STI for the selected sustainability challenges.

I.2. COUNTRY-SPECIFIC OBSERVATIONS: RWANDA

SUSTAINABILITY CHALLENGE

The country team proposed to focus the roadmaps on the role of science, technology and innovation (STI) to foster food systems transformation to enhance food security in Rwanda with the focus on leveraging emerging technologies to enhance food productivity.

SITUATIONAL ANALYSIS

The country report is based on the evidence sourced, see **Table 4**.

The sources of quantitative data included the recent edition of the Rwanda R&D Survey (August 2024) and international sources such as UNESCO, World Bank, WIPO and other referenced publications.

DELIBERATION OF STI INVESTMENT AREAS

The respondents to survey and workshop participants were asked to identify areas for investment based on the comprehensive list of areas prepared based on desk research. Both survey and workshop included open questions allowing stakeholder to formulate their own areas. The stakeholders were asked to share their assessment of the impact of the areas and the existing level capacity in the country to mobilise STI in these areas. Based on the workshop materials, interviews and the desk research, the authors highlighted STI areas for investment and further development.

TABLE 4.
SOURCES OF THE QUALITATIVE DATA SUPPORTING THIS STI FOR SDGs ROADMAP

Method	Quantitative analysis
Stakeholder interviews	<ul style="list-style-type: none"> • 18 interviews: 17 face-to-face interviews (conducted on 5 and 6 March 2024 in Kigali) and one online interview (March 2024) • Interviewed stakeholder profiles (7 representatives of ministries and government agencies, 7 stakeholders from research organisations and independent experts, 3 NGOs and one local cooperative)
Online stakeholder survey	<ul style="list-style-type: none"> • 7 responses (survey ran from 23 February until 31 March 2024)
Stakeholder workshops	<ul style="list-style-type: none"> • Hybrid workshop (23 February 2024) <ul style="list-style-type: none"> • 32 participants from Rwandan government, research, IOs and JRC team. • In-person stakeholder workshop (Kigali, 4 March 2024) <ul style="list-style-type: none"> • 29 participants (9 government, 4 business, 8 research organisations and independent experts, 2 IOs and international donors, 1 NGOs, 5 EU delegation and JRC team)
Literature review	<ul style="list-style-type: none"> • Academic literature, technical reports and publicly available datasets

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