REPUBLIC OF RWANDA

MINISTRY OF ENVIRONMENT

Rwanda's Climate Adaptation Monitoring, Evaluation and Learning (MEL) System in the Agriculture Sector:

Case studies on the capacity of storage constructed, utilization of surveillance tools, and area of land under erosion control measures and used optimally

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Rwanda's Climate Adaptation Monitoring, Evaluation, and Learning System in the Agriculture Sector (Phase 2): Case studies on the capacity of storage constructed, utilization of surveillance tools, and area of land under erosion control measures and used optimally

Briefing Note

Ministry of Environment, Department of Environmental and Climate Change, Kigali, Rwanda

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List of Abbreviations

BXW	banana Xanthomonas wilt
FAO	Food and Agriculture Organization of the United Nations
FAW	fall armyworm
MEL	monitoring, evaluation, and learning
MINAGRI	Ministry of Agriculture and Animal Resources
MINALOC	Ministry of Local Government
MINECOFIN	Ministry of Finance and Economic Planning
MoE	Ministry of Environment
NDC	nationally determined contribution
NISR	National Institute of Statistics Rwanda
RAB	Rwanda Agriculture and Animal Resources Development Board

1. Introduction

The Ministry of Environment (MoE) in Rwanda implemented its first work program on the operationalization of a monitoring, evaluation, and learning (MEL) framework for adaptation, focusing on the agriculture sector as a pilot test. The fifth national census showed that agricultural employment was by far the most frequent branch of economic activity (accounting for 53.4% of total employment) (National Institute of Statistics Rwanda [NISR], 2022a). Considering employment under the aggregated broad branches of economic activity, agriculture accounts for 46.8% of GDP (NISR, 2022b). The agricultural production system, being mainly rainfed, is highly prone to climate vulnerability, resulting in low yields and income for farmers. The impact of climate shock is more severe for smallholder farmers, who are less equipped with proper technologies to deal with extreme weather events, such as droughts and floods, leading to crop failure and livestock losses.

The work program took place from April 2022 to February 2023 and was implemented with technical and financial support from the National Adaptation Plan Global Network and the International Institute for Sustainable Development. The overall objective of the MEL work program was to pilot test the adaptation component of the MEL framework for Rwanda’s updated nationally determined contribution (NDC) in the agriculture sector.

A significant outcome of the initial work program was a report of three case studies that investigated the enhancement of adaptive capacity through the promotion of drought-resistant seeds, irrigation practices, and crop and livestock insurance. The studies that focused on these three areas systematically assessed both the achievements and obstacles associated with anticipated outcomes, through interviews with experts from non-governmental organizations and agro-cooperatives, as well as on-site visits, for comprehensive insights.

The evidence gathered from the studies on these three areas (improved seeds, irrigation, and crop and livestock insurance) helped to confirm that the implementation of various adaptation actions is leading to the expected outcome set out in Rwanda’s NDC Implementation framework: achievement of “an increased productivity, nutritional value and resilience through sustainable, diversified, and integrated crop, livestock, and fish production systems in a gender-responsive and climate-resilient manner” (Government of Rwanda [GoR] & NDC Partnership, 2021).

As an illustration, the adoption of improved seeds has increased the climate resilience of local communities. Beyond increasing agricultural yields and household revenues, these improved seeds include drought-resistant varieties. Consequently, production can now take place throughout the year for Irish potatoes, during the off-season for maize, and even during the hot season for soybeans (MoE, 2023, p. 31). These seeds have been reported to generate higher yields and are less sensitive to pests, diseases, and climate hazards. Similarly, the utilization of solar irrigation systems has proven to be instrumental in enhancing crop yields, diminishing susceptibility to droughts and shifting rainfall patterns, and facilitating the adoption of multiple cropping practices (MoE, 2023, p. 31). In some contexts, farmers using irrigation achieved a 50% average yield increase in seasons A and B and were able to produce in season C because they could grow crops in the dry season[1] (MoE, 2023, p. 31).

In September 2023, the National Adaptation Plan Global Network continued to support the GoR with a focus on new activities, such as assessing the outcomes of adaptation for the three NDC actions in agriculture that were not covered in the first work plan: (i) storage capacity constructed (in tonnes), (ii) number of farmers utilizing surveillance tools like the fall armyworm (FAW) database and the banana Xanthomonas wilt (BXW) application (app), and (iii) total land area that is under erosion control measures and being optimally utilized. Evaluating the effectiveness of these strategies is vital for informing future actions, allocate resources efficiently, and promote sustainable agricultural practices.

[1] In Rwanda, the agricultural calendar is divided into two primary cultivation seasons: the initial season, spanning from September to January (Season A), and the subsequent season, which extends from February to June (Season B). Further, in marshland areas characterized by plentiful water supply, a third agricultural season is observed (Season 3), which is dedicated primarily to the cultivation of rice and vegetables.

2. Assessment of Adaptation Outcomes

Rwanda's updated NDC identifies six priority adaptation actions in the agriculture sector that are expected to lead to the outcome identified above.

A systematic literature review was conducted to understand how the progress achieved on three adaptation actions (*storage capacity [in tonnes], the utilization of surveillance tools [FAW database and BXW app], and the optimal utilization of erosion control measures*) is leading to the expected outcome above. Based on the evidence available in the literature, the assessment of adaptation outcomes focuses on the following areas:

- **Storage capacity:** Assessing the successes and challenges related to increased storage capacity as a means of enhancing resilience to crop losses and food insecurity.
- **Utilization of surveillance tools:** Evaluating the effectiveness and limitations of the FAW database and BXW app in monitoring and controlling pest and disease outbreaks and analyzing the outcomes of surveillance tools on crop yields and farmers' income.
- **Erosion control measures:** Assessing the effectiveness of—and gaps in—erosion control measures in preventing soil erosion and maintaining soil fertility, assessing the adoption rate among farmers, and determining whether these measures are being optimally utilized.

This section reviews the successes and benefits that have resulted from the implementation of these three NDC adaptation actions in the agriculture sector and provides a discussion of the challenges encountered and recommendations. Table 1 provides a summary of the three indicators, targets, and progress made so far.

Table 1. NDC adaptation indicators in the agricultural sector: Baseline values, targets, and actual status in 2021/22

NDC indicators (Rwanda's 2020 NDC)	Baseline values for 2019/20 (various sources listed in table)	Targets (NDC implementation framework)	Actual status 2020/21 (various sources listed in table)
Capacity of storage constructed (tonnes)	263,000 tonnes (Ministry of Agriculture and Animal Resources [MINAGRI], 2019)	Agro-processing facilities increase storage capacity to 1.2 million tonnes by 2030.	• 296,770 tonnes (MINAGRI, 2020) • 316,420 tonnes (MINAGRI, 2021)
Number of farmers using surveillance tools such as the FAW database and BXW app	2,000 farmers using surveillance tools (GoR, 2021a, 2021b)	9,000 farmers using surveillance tools by 2025 18,000 farmers using surveillance tools by 2030	• 2,356 farmers (329 youths [male and female], 1,072 adult males, and 975 adult females) mobilized to manage FAW • 200 extension agents trained in FAW management • 4,500 farmers registered on the BXW app by farmers' promoters and 4,000 farms diagnosed (MINAGRI, 2021)

NDC indicators (Rwanda's 2020 NDC)	Baseline values for 2019/20 (various sources listed in table)	Targets (NDC implementation framework)	Actual status 2020/21 (various sources listed in table)
Area of land under erosion control measures and being used optimally	Radical terraces: 127,339.7 ha; progressive terraces: 958,777 ha (MINAGRI, 2020)	142,500 ha of land with radical terraces by 2025 1,007,624 ha with progressive terraces by 2025	• Radical terraces: 131,056.7 ha; progressive terraces: 972,055 ha (MINAGRI 2021) • Radical terraces: 135,344 ha; progressive terraces: 986,276 ha (MINAGRI, 2022)

2.1 Storage Capacity Construction

The Strategic Plan for Agriculture Transformation 2018–2024 acknowledges the pressing need for investments in appropriate post-harvest and storage facilities to mitigate losses (MINAGRI, 2018). The management of farm produce after harvesting has become a top-priority initiative aimed at reducing post-harvest losses and enhancing food security and nutrition. Over the past 11 years, the GoR, through the MINAGRI and its affiliated agencies, such as the Rwanda Agriculture and Animal Resources Board (RAB), has actively supported the establishment and construction of post-harvest infrastructure, the provision of post-harvest equipment, and the provision of technical training in best practices for post-harvest handling. The following are some comments that underscore the benefits of storage facilities, as expressed by stakeholders during interviews:

> Storing and conserving agricultural production is crucial. Traditionally, pests would decimate our crops, leading to significant losses. We either threw away large quantities or risked non-food safety if consumed. This indicator ensures long-term storage and safe consumption of our stored produce.
>
> In times of need, stored agricultural production becomes a lifeline. Whether it's a prolonged drought, natural disaster, or any unexpected crisis, having a surplus helps a nation secure its food supply. A country's population can rest assured, knowing their food needs are met.
>
> The importance of storing and safeguarding our agricultural production cannot be overstated. Traditionally, pests and waste plagued us, leading to losses. With this indicator, we ensure prolonged storage and the safety of our stored food, which is ready for any contingency. It's a safety net for our nation's food security.

With support from the European Union to strengthen the Government of Rwanda's capabilities in the agricultural sector for sustainable land and water resource management, value generation, and nutrition security, an evaluation was conducted to gather on-site evidence concerning the quantity, capability, condition, ownership, and utilization of post-harvest infrastructure, along with any existing challenges related to post-harvest facilities (Ministry of Finance and Economic Planning [MINECOFIN] & MINAGRI, 2021). The findings from a study conducted in 2021 reported the presence of 567 drying grounds and 886 drying shelters (MINECOFIN & MINAGRI, 2021, p. ix). Regarding storage facilities, the same study identified a total of 518 warehouses and 11 metallic silos. In terms of cooling infrastructure, the country was found to have four packhouses, 41 cold rooms, and charcoal coolers (MINECOFIN & MINAGRI, 2021, p ix).

In 2022, MINAGRI, in partnership with MINECOFIN, initiated a comprehensive diagnostic analysis with the goal of identifying and documenting the status and existing challenges related to the utilization, upkeep, and sustainability of agricultural infrastructure. The assessment yielded the following key observations.

Underutilization of storage facilities: The analysis revealed that storage facilities for post-harvest handling are not being fully utilized or adequately maintained. Although around 75% of warehouses and storage facilities are actively used by farmers, there is room for improvement in optimizing the use of available space. Among the infrastructure assessed, 58.6% of storage facilities was found to be efficiently utilized, while the remaining 41.4% was not maximally utilized. The primary reason for the underutilization of existing storage facilities is the combination of low production levels and the considerable distances needed for transportation.

Inefficiencies in post-harvest facilities: The study highlighted inefficiencies in the use of various post-harvest facilities. Specifically, certain types of infrastructure were found to be underused. This includes warehouses (41.4%), cooling and cold rooms (72.2%), and milk collection centres (53.3%).

Suboptimal use of cooling and cold rooms: Despite the existence of approximately 53 cold rooms across the country, these facilities are not being optimally used and maintained. The diagnostic study (MINECOFIN & MINAGRI, 2022) indicated that these cold rooms were primarily established for highly perishable products, such as horticultural produce, meat, and fish. Regarding their operational status, about 51.1% of these cold rooms are currently functional, 25.5% are non-operational, and 23.4% are still under construction. Only 27.8% of the cold rooms are being fully utilized, with the remaining 72.2% being underutilized, meaning that they are operating below their potential capacity. There is a shortage of equipment in storage facilities for controlling factors like moisture and aflatoxins.

Insufficiency of drying facilities: The study found that available drying facilities are not sufficient, and some of the existing ones are gradually deteriorating. Maintenance is generally not a major issue, except for ensuring that existing maintenance processes are consistently followed to promptly address any observed damage to these drying grounds in a timely manner.

Incomplete construction of post-harvest handling infrastructures: Data from MINAGRI reported the incomplete state of storage facilities, cooling, and cold rooms, as well as drying facilities and grounds (MINAGRI, 2019). While some construction projects have been finished, there are still three big structures that are under construction (MINECOFIN & MINAGRI, 2022).

The various stakeholders who participated in interviews and workshops emphasized that critical challenges that hinder the effectiveness of storage solutions, particularly in agriculture and food security areas, include a lack of standards for storage construction in response to climate change, limited involvement of public entities such as the Ministry of Local Government (MINALOC) in storage management, limited involvement of the private sector in storage expansion, limited skills of storage users, and the high cost of storage equipment. These are elaborated below.

A lack of standards for storage construction in response to climate change, with a focus on managing storage conditions for quality (temperature fluctuations, humidity changes, extreme weather events, etc.):

- **The problem:** Climate change has led to increased variability in weather patterns, including more frequent and more severe extreme weather events, such as storms, floods, and droughts. These changes can have a significant impact on the reliability and functionality of storage facilities for agricultural products.
- **Consequences:** Without appropriate standards for climate-resilient storage construction, storage facilities are vulnerable to damage, leading to food and crop losses. This can exacerbate food insecurity and economic instability in some areas.

Limited involvement of public entities such as MINALOC in storage management:

- **The problem:** Effective storage management is essential for the preservation and distribution of agricultural produce. The limited involvement of relevant government agencies, including local entities through MINALOC, can lead to mismanagement, inefficiencies, and inadequate oversight of storage facilities.
- **Consequences:** Poor management of storage facilities may result in spoilage, contamination, and post-harvest losses, ultimately impacting food security and the livelihoods of farmers.

Insufficient investment from the private sector:

- **The problem**: Private sector entities such as agribusinesses and other investors may be hesitant to invest in storage expansion due to concerns about profitability, market volatility, and regulatory barriers.
- **Consequences:** Inadequate investment in this area can lead to a lack of modern and efficient storage facilities. This situation can result in post-harvest losses, reduced market competitiveness for agricultural products, and missed economic opportunities for the private sector.

Limited skills for storage users, including farmers:

- **The problem:** Farmers and other storage users often lack the necessary knowledge and skills to operate storage facilities optimally. Such skills include those related to proper handling, storage, and maintenance practices.
- **Consequences:** Inadequate and/or limited skills can lead to quality deterioration, spoilage, and losses in stored crops. Farmers may also miss opportunities for better market prices due to ineffective storage of their produce.

High cost of storage equipment:

- **The problem:** The cost of storage equipment, including refrigeration units, silos, and warehouses, can be prohibitively high for smallholder farmers and even larger agricultural enterprises.
- **Consequences:** High equipment costs may deter investments in modern storage solutions, pushing farmers back to traditional and less efficient storage methods, which can result in higher losses.

Addressing these challenges requires a multi-pronged approach:

- Developing and implementing climate-resilient storage construction standards to mitigate the impact of climate change on storage facilities.
- Improving the involvement of public entities such as MINALOC in storage management, including regulatory oversight and capacity building for storage operators.
- Promoting collaboration between the public sector/the GoR and the private sector through public–private partnerships to share the investment burden, reduce risks, and encourage private sector participation in storage projects.
- Providing training and extension services to farmers and storage users to improve their skills in best practices for storage.
- Exploring financial incentives, subsidies, or cooperative models to reduce the cost burden of storage equipment on farmers.

2.2 Utilization of Surveillance Tools

Smartphone apps allow farmers to access up-to-date information regarding pests, diseases, and weather conditions; predict their potential impacts on crops and livestock; and recommend actions to counter those impacts. In Rwanda, various web-based apps have been created to deliver early warning information to both farmers and the public about potential disease and pest outbreaks.

FAW database: The FAW is an extremely harmful pest capable of causing extensive harm to maize and various other crops (Buchaillot et al., 2022). To assist farmers in addressing this threat, the FAW database was created. This web-based app serves as a source of information on the identification and control of the FAW and has proven to be a valuable tool for farmers, enabling them to promptly detect the presence of the FAW in their crops and implement effective measures to manage it.

BXW app: BXW is a bacterial disease that poses a threat to banana plants, especially in East Africa. The BXW app was developed to help banana farmers detect and control this disease. It offers guidance on recognizing BXW symptoms, provides advice on strategies to manage and prevent the disease, and facilitates connections between farmers and resource people or experts who can help in addressing the issue (NISR, 2020).

The use of the FAW database and the BXW app in Rwanda has proven to be highly effective in monitoring and controlling outbreaks of pests and diseases, resulting in substantial advantages for both farmers and agricultural systems (Food and Agriculture Organization of the United Nations [FAO], 2020a). These platforms facilitate real-time data collection and reporting of incidents related to pests and diseases.

An official from RAB reported that the early detection of outbreaks enables prompt response measures, including targeted pesticide applications and disease management strategies. He also cited a collaborative project between the FAO and RAB that provided farmers with traps and a mobile phone app for FAW. This mobile app enabled them to collect and exchange field status information effectively (FAO, 2020b, p. 4). Additionally, it was noted that when FAO intervened, it supplied each farmer with four traps and equipped them with complimentary mobile phones, each pre-loaded with a dedicated app (FAO, 2020b, p. 6). As a result, they launched a successful campaign against the FAW and gradually witnessed an improvement in their crop yields, ultimately achieving stability (FAO, 2020b, p. 7).

A noticeable contrast was observed in the Rwamagana District before and after the FAW infestation. Prior to the advent of the pest, maize harvests amounted to approximately 4.2 tonnes, whereas the yield dropped to 3.8 tonnes after the invasion. One year later, maize production bounced back, reaching an impressive 4.5 tonnes (FAO, 2020b, p. 7).

The adoption of the FAW database and BXW app represents a significant advancement in pest and disease management in agriculture. These tools not only minimize crop losses but also provide farmers with valuable information, leading to increased income and sustainable farming practices. The continued use and expansion of these tools have the potential to further enhance agricultural resilience and food security. Comments from interviewees attest to this development:

> This indicator is a game-changer for maize and banana farmers. By mitigating the threat of fall armyworm and reducing disease distribution, it paves the way for increased production and higher yields, ensuring food security and economic stability.
>
> The beauty of this indicator lies in its ability to fortify our maize and banana crops against the fall armyworm and diseases. It empowers farmers with the knowledge and tools needed for effective prevention, ultimately leading to improved yields and profitability.

Indeed, while the utilization of tools such as the FAW database and BXW app can bring substantial benefits in terms of pest and disease management in agriculture, several challenges and gaps need to be addressed to achieve the sustained effectiveness of these tools. Some of these challenges were highlighted in interviews with the stakeholders and in the workshop, as reflected in the following section.

Limited access to information technology (IT) tools and internet:

- **The problem**: In many rural areas, access to essential IT tools such as smartphones and tablets, as well as a reliable internet connection, remains limited. This can significantly hinder farmers' ability to use the BXW app for disease monitoring or to report pest infestations to the FAW database.
- **Consequences:** Farmers in areas with poor IT infrastructure may not benefit from these digital tools and may therefore miss getting timely information and support for pest and disease management.

Limited awareness of surveillance tools:

- **The problem:** Some farmers may not be aware of the existence and/or benefits of surveillance tools like the FAW database and the BXW app. This lack of awareness can result in the underutilization of these tools.
- **Consequences:** Farmers who are unaware of these tools cannot make use of them, potentially leading to delayed responses to pest and disease outbreaks and increased crop losses.

Limited digital literacy skills:

- **The problem:** Digital literacy skill levels vary among farmers, and many may not possess the skills needed to effectively use these tools. This can be reflected in difficulties in navigating apps, inputting data, or troubleshooting technical issues.
- **Consequences:** Limited digital literacy skills can lead to frustration and reduced effectiveness when trying to use the BXW app or report data to the FAW database. Inadequate skills can also discourage older farmers from trying to use these tools, as they may be less comfortable with technology.

Limited adoption of new technology, particularly among older citizens:

- **The problem:** The adoption of new technology can be slow, particularly among older citizens, who may be less open to change or face greater challenges in adapting to digital tools.
- **Consequences:** Lower adoption rates, especially among experienced but older farmers, can limit the overall impact of these tools and slow down the dissemination of valuable information on pest and disease management.

Limited collaboration among stakeholders:

- **The problem:** Effective pest and disease management often requires collaboration among multiple stakeholders, including government agencies, agricultural extension services, non-governmental organizations, and farmers' associations. Limited coordination among these entities can result in inefficiencies and gaps in information dissemination and support.
- **Consequences**: Ineffective or limited collaboration can lead to the duplication of efforts, missed opportunities for data sharing, and confusion among farmers about where to seek help or report issues related to pests and diseases.

Addressing these challenges requires a concerted effort by various stakeholders:

- The government and its partners can work on improving IT infrastructure and internet access in rural areas to enable wider usage of digital tools.
- Efforts should be made to raise farmers' awareness of the existence and benefits of surveillance tools and to emphasize their effectiveness in enhancing pest and disease management.
- Training programs should be designed to enhance digital literacy skills among farmers, enabling them to use these tools effectively.
- Context-relevant approaches should be developed to encourage the adoption of technology, including providing support to older farmers who may need extra assistance.
- Improved collaboration and coordination among relevant stakeholders can ensure that these tools are effectively integrated into existing agricultural support systems.

By addressing these challenges and gaps, the agricultural sector can harness the full potential of digital tools such as the FAW database and the BXW app for more effective pest and disease management, ultimately benefiting farmers and improving food security.

2.3 Erosion Control Measures

Rwanda is highly vulnerable to soil erosion due to a combination of factors, including land-use patterns, vegetation cover, climate change, a topography characterized by steep slopes, abundant rainfall, and fragile soils (Ministry of Environment/Rwanda Water and Forestry Authority et al. 2020, p. 3). In response to the escalating problem of soil erosion, terracing—encompassing both radical and progressive terraces—has been introduced as a key soil conservation technique, playing a pivotal role in mitigating soil erosion.

On a small scale, erosion control measures have proven effective in reducing soil erosion and preserving soil quality, both of which are critical for sustainable agriculture and environmental protection. Evidence indicates that land husbandry technologies in Rwanda, particularly bench terraces, are technically efficient in controlling soil erosion when they are well established, well managed, and well maintained. This is further corroborated by Rutebuka et al. (2019), who found that bench terraces reduced soil loss from 23.5 ha to 1.7 t ha−1 yr−1[2] in a catchment landscape with slope gradients varying between 0% and 60%. Similarly, Rutebuka et al. (2020) indicate that bench and progressive terraces effectively control erosion, reducing soil and nutrient losses by up to 90%, when they are well established, well managed, and regularly maintained by landowners or farmers.

However, the usefulness of terrace development is not solely about erosion control; it also helps croplands deliver expected ecosystem benefits, with increased crop productivity being paramount. The implementation of integrated land husbandry technologies has transformed the livelihoods of impoverished areas by modernizing agricultural practices and raising income levels (Rutebuka, 2021).

Unfortunately, some terraces that have been developed have low crop productivity due to under-exploitation and/or abandonment. Productivity problems can arise from constructing terraces on very acidic and inherently infertile soils with insufficient supplies of organic manure, fertilizers, and lime and from other land-related issues (Rutebuka, 2019; Rutebuka et al., 2020).

Another obstacle to successful terrace development lies in the socio-economic context. Farmers may be hesitant to adopt land husbandry technologies such as terraces if they do not achieve optimal yields in the first few years. Indeed, it typically takes at least 4 years to restore soil fertility on the land where terraces have been developed. This lack of understanding can lead to inefficient terrace utilization (Burger & Zaal, 2019; Kessler, 2006).

A recent study identified the problems leading to the poor performance of developed land due to both technical and socio-economic factors (Ruganzu et al., 2020). These include inadequate design, improper construction, lack of maintenance, and soil fertility depletion, among others. Some possible and promising solutions include ensuring that lands are optimally utilized to improve crop productivity, enhancing soil fertility through lime and organic amendments, and intensifying agroforestry systems on under-exploited or abandoned terraced lands. For the soils with pH less

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[2] The rate of 1.7 tonnes per ha per year is often considered within the context of a sustainability threshold or tolerance limit. This is a critical value that is believed to be sustainable for the long-term productivity of the soil and the ecosystem it supports. Rates of soil loss at or below this threshold are generally considered manageable or acceptable, if soil formation processes can keep pace with the loss, thereby not significantly degrading soil quality or agricultural productivity over time.

than 5.5, at least 2.5 t ha−1 of lime and good-quality organic manure at a rate of 10 t ha−1[3] should be applied each cropping season. Additionally, addressing socio-economic challenges can involve organizing and/or strengthening farmer cooperatives and providing financial and technical support to alleviate identified financial barriers. All these measures can help prevent unstable terraces that could exacerbate runoff volumes and lead to landslides, mass movements, and gullies (Arnáez et al., 2015; Rutebuka et al., 2020).

At a larger scale, despite various erosion control initiatives in place, soil erosion continues to be a pressing issue. In 2020, an erosion control mapping revealed that approximately 33.2% of provincial land in Rwanda, estimated at 1,402,446 ha, was identified as being at high risk for erosion, with varying degrees of risk (MoE/Rwanda Water and Forestry Authority et al., 2020). However, in 2022, another erosion control mapping exercise showed that 45% of provincial land, estimated at 2,385,830 ha, was classified as having a high erosion risk, with a similar range of risk levels (Rwanda Resources Board & International Union for Conservation of Nature, 2022). These results point to an increase in erosion risk between 2020 and 2022, particularly in areas with high and moderate erosion risk.

It should be noted that the adoption of erosion control techniques remains relatively low. Out of the total land at risk in Rwanda, only 26% is protected against erosion through various erosion control methods, such as contour bank terraces, forests, bench terraces, and hedgerows and shrubs contributing to erosion control (Rwanda Resources Board & International Union for Conservation of Nature, 2022). However, a significant portion of the land, approximately 74%, remains unprotected, highlighting the urgent need for extensive erosion control measures and increased protection of vulnerable lands to address the growing erosion risk in the country.

Additionally, some constructed terraces are not being optimally utilized and/or maintained. Among the inspected terrace sites, it was reported that 21% were not being effectively utilized and maintained (MINECOFIN & MINAGRI, 2022, p. 24). One factor hindering optimal terrace utilization was the limited capacity among small-scale farmers to invest in essential inputs such as inorganic fertilizers and lime. Moreover, there is often a decline in soil fertility after the construction of terraces due to subsequent nutrient losses and increased soil acidity when appropriate inputs are unavailable or when terraces are not effectively constructed and maintained by users. As a result, farmers rely heavily on the government's supply of chemical fertilizers and soil amendments because many of them cannot afford them. The government has been addressing this input gap through an ongoing subsidy program.

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[3] For soils exhibiting a pH value below 5.5, indicating acidic conditions, the recommendation is to apply a dual treatment approach to amend the soil and enhance its fertility and structure for agricultural purposes. This approach involves two processes: lime application and organic manure application. **Lime application:** At least 2.5 tonnes of lime per ha should be added to the soil. Lime is primarily used to neutralize soil acidity, raising the pH closer to neutral. A neutral or slightly acidic pH is favourable for most crops because it optimizes nutrient availability and reduces the presence of toxic elements like aluminum and manganese, which become more soluble and harmful to plants in acidic conditions. **Organic manure application:** Alongside lime, it is advised to incorporate good-quality organic manure at a rate of 10 tonnes per ha. Organic manure enriches the soil with organic matter and nutrients, improving soil structure, moisture retention, and microbial activity. The addition of organic matter is crucial for sustaining soil fertility, enhancing aeration, and facilitating root growth.

It is obvious from the information above that Rwanda faces significant challenges related to soil erosion and ineffective utilization of erosion control measures. While progress has been made in addressing these issues, sustained efforts are needed to mitigate erosion risks, enhance terrace utilization, and improve soil fertility. The information collected in interviews with stakeholders and workshops with participants from different institutions indicates that the following issues, gaps, and challenges require further attention.

Ineffective methods used to measure erosion:

- **The problem:** Measuring erosion rates and identifying erosion-prone areas accurately are crucial practices for effective erosion control. However, the methods used to measure erosion in Rwanda may be inefficient and/or outdated.
- **Consequences**: Inaccurate data on erosion can lead to the misallocation of resources for erosion control efforts and the ineffective implementation of erosion control measures.

A lack of scientific evidence in assessing erosion fragility:

- **The problem:** There seems to be a lack of comprehensive scientific studies and data on the fragility of erosion-prone areas in Rwanda. Understanding the extent and severity of erosion is essential for informed decision making.
- **Consequences:** Without scientific evidence, it is challenging to prioritize erosion control efforts, allocate resources effectively, and develop targeted strategies.

Need for additional indicators for erosion control:

- **The problem:** Promoting terrace practices is essential for erosion control, but relying solely on this approach may not be enough to address all erosion-related challenges.
- **Consequences:** Focusing solely on terraces may lead to overlooking other effective erosion control methods and holistic approaches to soil conservation.

A lack of integrated planning for soil erosion at the national level:

- **The problem:** Soil erosion is a complex and cross-cutting issue that requires coordinated efforts from multiple government departments and agencies. A lack of integrated planning at the national level can hinder effective erosion control.
- **Consequences:** Fragmented efforts and a lack of coordination can result in inefficiencies, duplicated efforts, and a limited impact in combating erosion.

Insufficient public awareness of—and resistance to—erosion control practices:

- **The problem**: Many farmers and communities may not be fully aware of the importance of erosion control measures or may resist adopting new practices due to traditional farming methods or a lack of knowledge.
- **Consequences**: Resistance to erosion control practices can impede progress and limit the adoption of sustainable and effective farming techniques.

Challenges in the maintenance of existing terraces:

- **The problem:** While terraces can be effective for erosion control, their construction and maintenance can be labour intensive and costly. There may also be challenges in ensuring that existing terraces remain functional.
- **Consequences:** Poorly maintained or abandoned terraces can lead to soil erosion, undermining their intended purpose.

The lack of an integrated participatory approach at the micro-level:

- **The problem:** Effective erosion control often requires active participation and engagement from local communities and farmers. A lack of integrated and participatory approaches at the micro-level can hinder the success of erosion control projects.
- **Consequences:** Without community involvement and ownership, erosion control efforts may not be sustainable or culturally and contextually appropriate.

Addressing these challenges requires a multi-faceted approach that involves scientific research, integrated planning, community engagement, and awareness campaigns. Efforts should be focused on enhancing the understanding of erosion, promoting sustainable erosion control practices, and fostering collaboration among various stakeholders to create effective solutions for soil erosion in Rwanda.

3. Conclusion

This assessment underscores the fact that the initiatives to increase storage capacity, utilize surveillance tools, and implement erosion control measures have yielded mixed outcomes (both positive and negative) in terms of enhancing resilience, managing pests and diseases, and conserving soil. Expanding storage capacity has led to improved food security, reduced post-harvest losses, and better access to markets. The effective use of surveillance tools has contributed to more effective pest and disease management. However, some challenges associated with each of these three NDC actions remain. They are as follows:

1. **Insufficient/inadequate storage capacity (in tonnes)**: (i) inadequate storage facilities, increasing the risk of spoilage or agricultural produce wastage; (ii) seasonal variations in production, with greater yields often exceeding available storage capacity; (iii) a lack of proper ventilation and pest control in storage facilities, potentially leading to post-harvest losses; and (iv) financial constraints hindering the expansion of storage infrastructure.
2. **Limited utilization of surveillance tools (FAW database and BXW app), resulting in the following issues:** (i) limited access to—and awareness of—these digital tools among farmers and agricultural stakeholders; (ii) limited or a lack of connectivity and technology infrastructure in rural areas, which impedes effective usage of these tools; (iii) issues regarding data accuracy and reliability, which affects the credibility of surveillance results; and (iv) the need for regular updates and maintenance of the tools.
3. **Optimal utilization of erosion control measures:** The results of this assessment have provided evidence that the implementation of erosion control measures alone may not be enough to reduce soil loss. Various other factors are associated with farmers and erosion control, including (i) insufficient funding and resources for effective implementation of erosion control practices; (ii) limited awareness of and knowledge about erosion prevention methods among farmers; (iii) resistance to changing traditional farming practices that contribute to soil erosion; and (iv) vulnerability to climatic variability and extreme weather events, which can undermine erosion control efforts.

Addressing these challenges is crucial to ensuring the sustained success of these adaptation actions and promoting sustainable agriculture and environmental resilience.

4. Recommendations

We have initiated the assessment of storage capacity effectiveness, utilization of surveillance tools, and erosion control measures concerning their impact on adaptation outcomes. We have put forward the following recommendations for each of these three indicators:

1. Insufficient/inadequate storage capacity:

- The government and other relevant partners should invest in building and upgrading storage facilities, including warehouses, silos, and cold storage units. This should be done at both the community and local levels.
- Encourage community-based storage solutions such as communal warehouses or storage cooperatives to address local storage needs effectively.
- Provide financial incentives, grants, or loans to farmers and cooperatives for storage facility construction or expansion.
- Explore cost-sharing arrangements between the government and the private sector to make storage equipment more affordable.
- Offer training and support to farmers on proper storage techniques, including ventilation and pest-control measures, to minimize post-harvest losses.

2. Limited utilization of surveillance tools:

- Conduct awareness campaigns and training programs to educate farmers and stakeholders on the benefits and usage of digital surveillance tools.
- Invest in rural connectivity infrastructure, including mobile network coverage and internet access, to ensure that even remote areas can effectively use these tools.
- Implement mechanisms for data validation and quality control to enhance the accuracy and reliability of surveillance results.
- Ensure that surveillance tools have user-friendly interfaces and are accessible to individuals with varying levels of digital literacy skills.

3. Optimal utilization of erosion control measures:

- Implement farmer-training programs and extension services to educate them on erosion prevention methods and sustainable farming practices.
- Establish a centre of excellence for land use, husbandry, and agricultural exchange extension to enhance the knowledge of technicians.
- Set up learning centres at the village level to enhance accessibility.
- Reinforce the National Programme for Soil Erosion Control and other task forces dedicated to soil erosion.

- Draw insights from the studies conducted in the volcano project flood management[4] to inform erosion control methods.
- Raise awareness of existing guidelines for soil erosion control.
- Promote community engagement and participation in erosion control initiatives.
- Encourage the adoption of climate-resilient farming practices that complement erosion control efforts, such as agroforestry and cover cropping.
- Invest in scientific research and data collection and analysis to better understand local erosion dynamics and tailor erosion control strategies to local contexts.
- Redesign existing information to enrich farmer field school initiatives and facilitate the dissemination of best practices.
- MINECOFIN should consider requesting development sectors, including agriculture, to incorporate specific NDC indicators into their reporting processes as integral components of sector working groups and joint-sector reviews.

Addressing these challenges is crucial to ensuring the sustained success of these adaptation actions and promoting sustainable agriculture and environmental resilience.

[4] The aim of the Volcanoes Community Resilience Project in Rwanda is to mitigate flood risks, enhance watershed management practices, and elevate the living standards of residents within the project vicinity. This initiative encompasses a broad spectrum of measures, such as implementing strategies to reduce flood risks, enhancing the efficiency of flood early warning systems, fostering preparedness for floods at the community level, restoring landscapes and managing catchments, rejuvenating livelihoods, conducting monitoring and evaluation, and bolstering capacity building. Further, it includes a provision for emergency responses when necessary, among other activities.

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