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Situational Analysis of Nyamagana Social-Ecological Landscape in the Cibitoke Province of Burundi

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Terms and Acronyms

BPEAE	Bureau Provincial de l'Environnement, de l'Agriculture et de l'Elevage
DPSIR	Driver-Pressure-State-Impact-Response
DRC	Democratic Republic of the Congo
FABI	Faculty of Agronomy and Bioengineering (University of Burundi)
FGD	Focus Group Discussion
HA	Hectare
IGEBU	Institut Géographique du Burundi
IITA	International Institute of Tropical Agriculture
ILRI	International Livestock Research Institute
IRRI	International Rice Research Institute
ISABU	Institut des Sciences Agronomiques du Burundi (Institute of Agronomic Sciences of Burundi)
IWMI	International Water Management Institute
KII	Key Informant Interview
NGO	Non-Governmental Organization
SEL	Social Ecological Landscape
TAFS-WCA	West and Central Africa Agri-Food Systems Transforming
WP	Work Package

EXECUTIVE SUMMARY

In the developing world, the drivers behind changes in social ecological landscapes (SEL) are intricate and have been steadily intensifying over the years. Regions blessed with abundant natural resources, encompassing fertile soils, lush forests, freshwater bodies, valuable minerals, and more, tend to experience rapid population growth and heightened poverty rates. This often results in a heightened demand for essential livelihood components, including access to alternative livelihoods, education, food, healthcare, water, forest resources, housing, roads, and spaces for agriculture and aquaculture. Furthermore, the intersection of multiple national and global stakeholders continues to exert substantial pressure on exploiting natural resources at the sub-national level. To address the pervasive issue of land degradation, particularly in developing nations like Burundi, the implementation of landscape surveying and mapping emerges as a crucial tool. These methods provide valuable insights into ecosystem services and their interactions, paving the way for sustainable landscape conservation.

Employing the Driver-Pressure-State-Impact-Response (DPSIR) for Social-Ecological Landscape (SEL) assessment framework, a diverse array of methodologies was employed in the current study, with a focus on the sub-Nyamagana watershed on the Imbo plain in Burundi. This research aims to conduct a comprehensive situational analysis, shedding light on how drivers and pressures converge to define the state and impacts of SEL, while also emphasizing institutional and stakeholder responses. To delve deeper into the intricacies of the Nyamagana watershed, a complementary approach involving focus group discussions and individual questionnaires was undertaken. The survey covered a total of 166 households and six focus group discussions, each comprising twelve participants. The findings highlighted several factors and pressures, predominantly stemming from the intensive utilization of natural resources, as well as biotic and abiotic constraints such as drought, flooding, pests, diseases, and anthropogenic pressures like anarchic mining and rapid population growth. Of notable concern is the complexity of soil use and land cover, especially the widespread use of chemicals such as synthetic fertilizers and pesticides, which pose significant threats to ecosystem components. The social-ecological dynamics are characterized by a combination of ecological factors, including environmental disturbances like heavy rains, prolonged dry seasons, fires, deforestation, and climate change. The social component of the system encompasses all human activities, spanning the economy, technology, politics, and culture, that result in intricate interactions between communities and ecosystems.

Within the Nyamagana watershed, various institutions play a crucial role in landscape management, with identified stakeholders including research services (e.g., ISABU, IRRI, IITA, and Burundi University), extension services (e.g., BPEAE, NGOs, and projects), and policy entities (such as the local administration and mixed committees for water management). The study underscores the looming threats to biodiversity, livelihoods, and ecosystem processes, particularly in the provision of soil and irrigation water, due to soil erosion by landslide, unsustainable mining activities and the unsustainable utilization of natural resources. Addressing these challenges necessitates a comprehensive and collaborative approach involving both local and global stakeholders to foster sustainable development and conservation efforts.

1. INTRODUCTION

The productive landscape, also viewed as a social ecological system (SES), is a complex combination of natural and human-modified ecosystems shaped by ecological, historical, political, economic, and socio-cultural processes. These productive landscapes are rich in natural resources and offer opportunities for sustainable livelihoods; however, how these resources are utilized directly influences biodiversity, global climate dynamics, and the capacity to adapt to and mitigate climate change. Despite these potential benefits, landscape pressures are on the rise, particularly in regions with high population growth rates, where demands for infrastructure, housing, industry, trade, agriculture and aquaculture are intensifying. The escalating pressures on landscapes stem not only from local demands but also from the persistent demand by multiple stakeholders at the local, national, and global levels to exploit natural resources. This has led to a widespread threat to landscapes, characterized by overexploitation and misuse of resources, exacerbated by the compounding impacts of climate change (Atampugre et al. 2022a). Consequently, biodiversity and ecosystem services are diminishing, and the sustainability of agricultural production systems and livelihoods is increasingly in jeopardy.

Productive landscapes in Burundi, like in many developing countries, are often influenced by a combination of socio-economic, environmental, and institutional factors. In the context of Burundi, the pressures on landscape resources are intensifying due to various human factors, including the rising demand for high-quality and high quantity of food, competition for productive land for biofuel, urban expansion, and non-food uses. Additionally, unsustainable land use practices contribute to ongoing land degradation, manifested in diminished soil health and nutrient status. Anthropogenic climate change is further exacerbating these challenges, impacting agricultural yields and income stability, and thereby threatening the resilience of agro-ecologies and the stability of food systems in the country. Natural factors such as climate variability, extreme weather events, and wildfires also contribute to the complexity of managing landscapes for optimal yields and sustainable land use. Recognizing the significance of ecosystem services underscores a growing need for approaches that address the complex challenges in managing social-ecological landscapes.

Burundi's agricultural sector is primarily characterized by small-scale farming, resulting in various agroecological constraints and socio-economic system instability (Tata 2015). Despite abundant resources for agriculture, such as ample rainfall, an extensive river system, freshwater lakes, fertile agricultural land, and productive marshlands, the region is facing many challenges. Over the years, soil erosion has significantly increased, leading to adverse environmental effects, particularly due to inappropriate land use on hills and mountainsides. This erosion has contributed to higher sediment levels in rivers, leading to landscape degradation in highlands, resulting in an overall decline in crop yields and loss of agro biodiversity. This situation raises concerns about food insecurity, shortages, and heightened vulnerability to climate change (FAO and GEF 2017).

The significant expansion of farming territory has reduced forest coverage to only 6.6% of the country. This shift towards small-scale farming and land use changes has not only impacted the agro-ecological dynamics but has also contributed to socio-economic instability in Burundi (Tata 2015). Therefore, despite the abundant natural resources, the agricultural landscape is grappling with

challenges that necessitate sustainable and strategic interventions to ensure food security and environmental sustainability.

1.1. Context

This research, commissioned by the International Water Management Institute (IWMI) in Ghana, falls under the CGIAR initiative on Transforming Agri-Food Systems in West and Central Africa (TAFS-WCA) Work Package 3 (WP3), which focuses on inclusive landscape management and pathways for scaling land and water innovations for resilient agri-food systems. This initiative recognizes that equitable access to and responsible use of land and water resources are fundamental to creating a healthy, productive, and One-Health-sensitive environment that fosters resilient agrifood systems and livelihoods. This analysis is driven by the need to understand and identify synergies and trade-offs between landscape development and the intricate ecological resources and processes that exist within. The development aspect involves a more intensive engagement with space and land use, organization, and arrangement. The characteristics of land and space, along with their entire natural and built-up substratum, play a crucial role in determining the trajectory of future sustainable development. In this context, this research emerges as a critical undertaking, linking current development, potential development pathways, and the conservation of natural resources.

Utilizing the DPSIR-SEL framework and the sub-Nyamagana watershed in the Imbo plain as a case study, this research aims to conduct a comprehensive situational analysis, illuminating how drivers and pressures converge to shape the state and impacts of the socio-ecological landscapes (SEL). The study site serves as an ideal case due to its abundance of natural ecological resources, its diverse and competing land uses, including agriculture, forestry, conservation, mining, and industry, and its current experience of significant environmental degradation. The selected landscape is the primary spatial unit of analysis for this research. Consequently, this landscape assessment will be of significant value for decision-making in future land use, space organization, nature protection, and sustainable use of natural resources.

1.2 Objectives

1.2.1. Overall objective

The main objective of this study is to assess the status and trends of natural resources and ecosystem services while considering the possible impacts on human well-being and the institutional responses.

1.2.2. Specific objectives

- Assess the drivers and pressures underpinning landscape change in the sub-Nyamagana watershed.
- Examine the dynamics of the state of the social ecological landscape (SEL).
- Explore the impacts of landscape transitions on human wellbeing, biodiversity, and ecosystem services.

- Examine the existing institutional and policy responses to landscape drivers, pressures, dynamic states, and impacts.

2. METHODS AND MATERIALS

2.1. Landscape selection criteria

The study area was identified in the Imbo Plain and operating along the Rusizi River, as the project is shared among three countries (Burundi, the DRC, and Rwanda). Significant competing land uses and activities associated with soil degradation (i.e., agriculture, forestry, mining, settlement expansion, chainsaw operations, etc.) was another criterion for choosing this site. Other key factors that incited researchers to implement the project in the Nyamagana watershed include the diversity of staple crops (e.g., legumes, cereals, and vegetables) planted in the region, the quality and quantity of water provided by the managed Nyamagana River and its uses for irrigation, and the presence of existing initiatives in landscape management by different stakeholders in the Nyamagana River.

2.2 Description of the study area

2.2.1 Location of the Nyamagana watershed

The Nyamagana watershed, which is a part of the Rusizi watershed was identified as the study area, according to the criteria outlined in section 2.1.

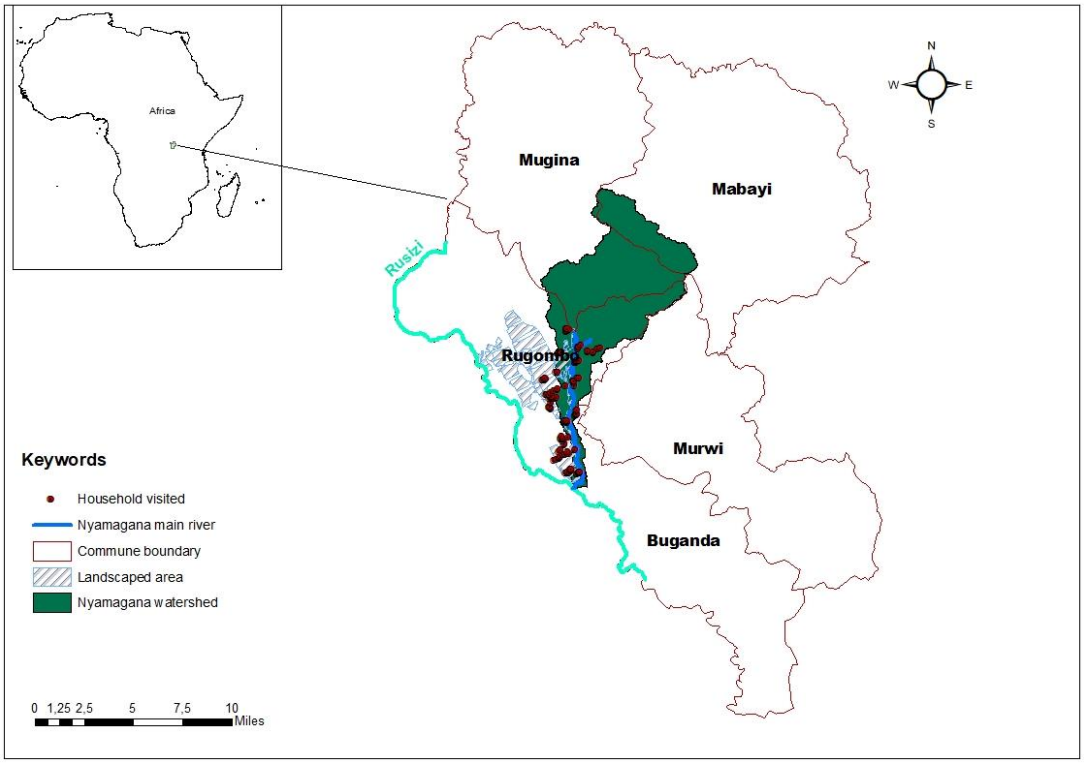

FIGURE 1. A map of the study area and its province

2.2.2 Land use and land cover in the Nyamagana sub-watershed

The sub-Nyamagana watershed includes urban areas, agricultural land, forests, and pastures consisting of spaced trees and shrubs, as well as grasslands. Upstream of the watershed, there is dominance of forests and meadows, while downstream there is dominance of agricultural land and urban areas (Figure 2). From the 1930s, the Rusizi plain was gradually drained, cleared, and populated, while natural areas were drastically reduced. Agricultural production has developed over the years, with "peasants" dominating the perimeters, growing mainly cotton and irrigated rice fields. A few years later with ethnic conflicts, there was progressive but fast densification in the plain of Rusizi and the hills of the Mirwa (hills overlooking the plain of Rusizi). The fragmentation of small agricultural exploitation and the multiplication of small plots of food crops have conquered a large part of the space of Mirwa, accelerating the phenomena of erosion and degradation of the slopes to the detriment of the natural forests (Sindayihebura 2005).

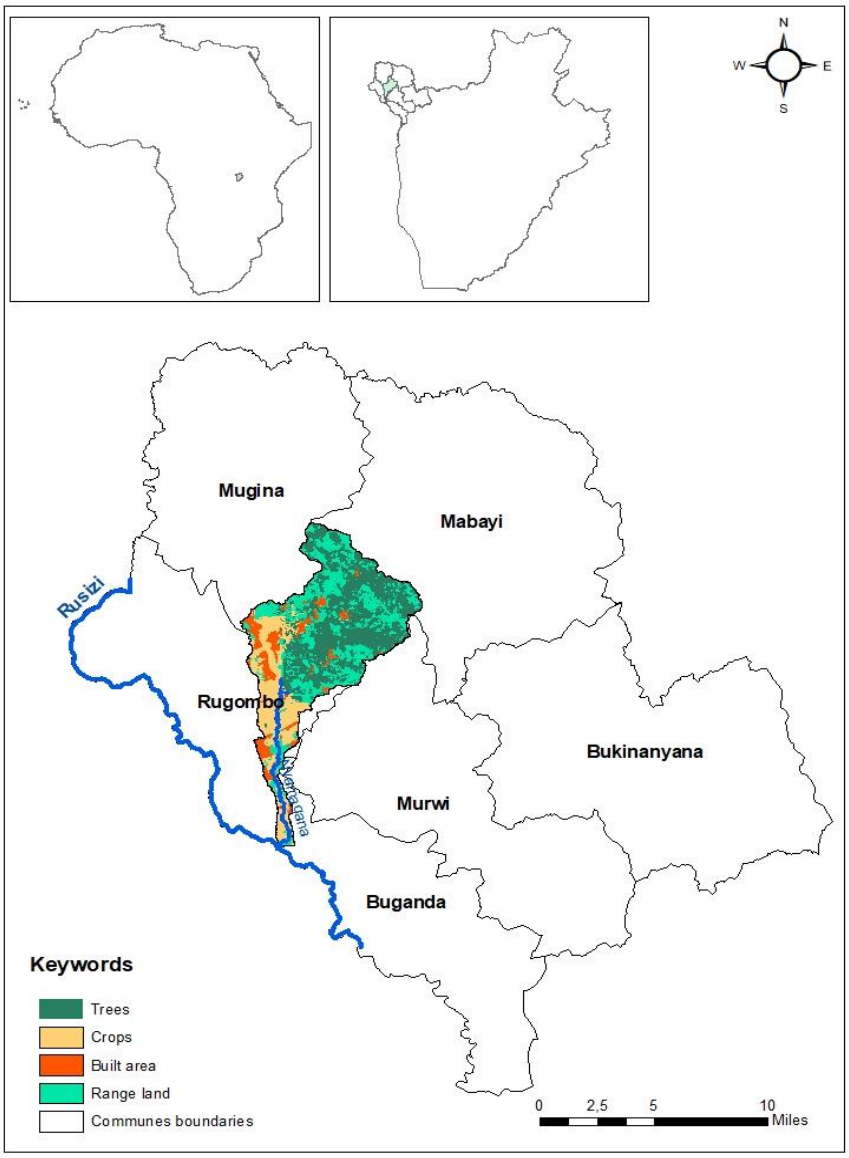

FIGURE 2. Land use and land cover in the Nyamagana sub- watershed of Cibitoke Province

2.2.3 Geology of the Nyamagana watershed

The geological configuration of the Sub-Nyamagana watershed consists essentially of two dominant units. These are highly metamorphic rocks (such as micaschists, paragneisses, amphibolites, dolomitic, and limestones) and some well-stratified quartzites and white quartzites, phyllite intercalations, dark grey quartzites and coarse conglomerates rich in iron oxides. Downstream of the river, in the plain of Rusizi, there is a dominance of alluvial cones, fluvial-lacustrine formations with coarse sands, fine silty-clay deposits, locally cemented pebbles by iron oxides; undifferentiated cenozoic, the Ruhagarika Formation; sandstone and alluvial conglomerates from valley bottoms, lake beaches, and low terraces; and sedimentary deposits (Figure 3).

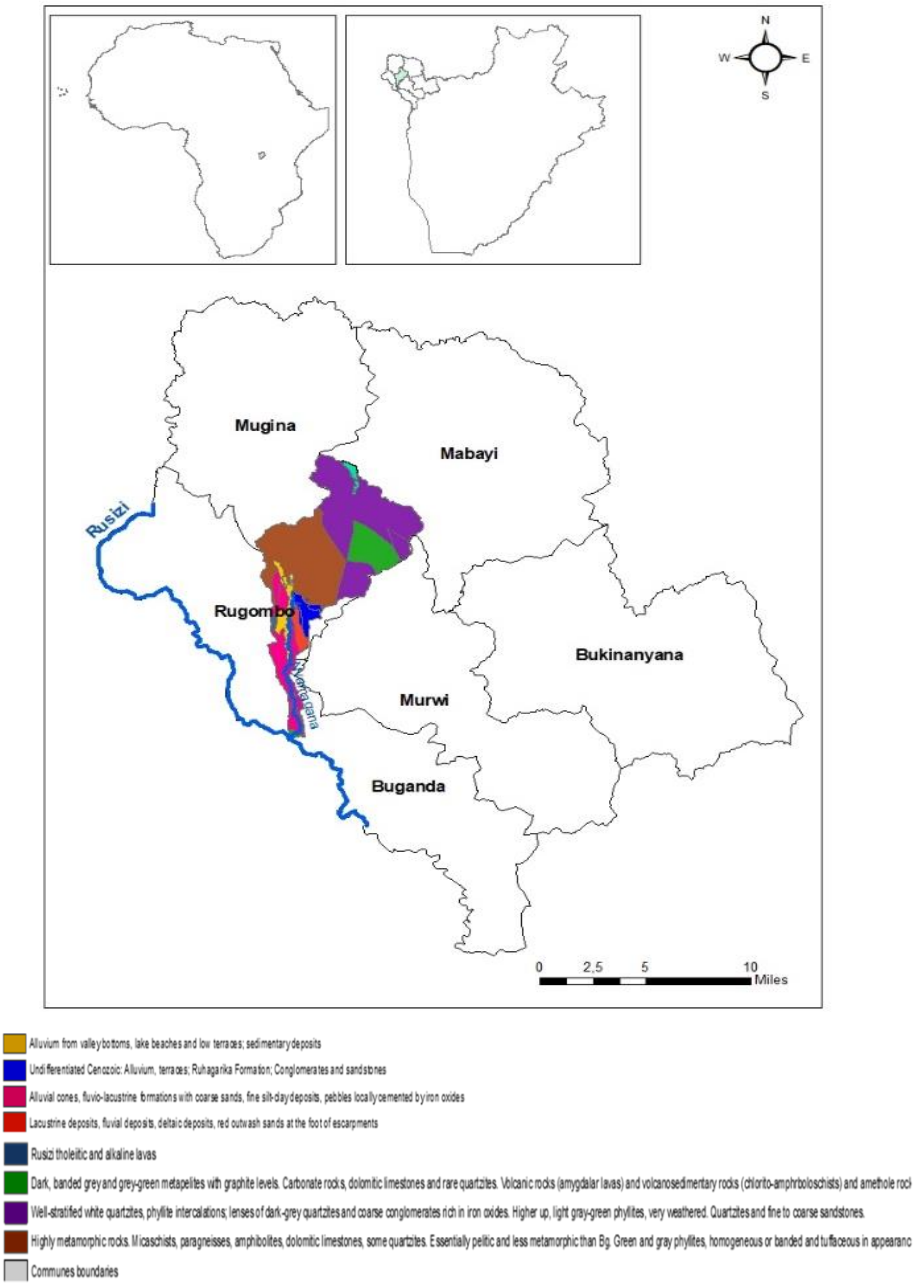

FIGURE 3. Geology map of the Nyamagana Landscape

2.2.4 Hydrology of the Nyamagana watershed

The sub-Nyamagana watershed is a part of the Ruzizi basin, which is the target area of the project. It is characterized by a dense hydrological network feeding it mainly upstream (see Figure 4). The hydrographic network of Nyamagana connects four municipalities spread over an altitude ranging from 850 m to 1500 m and crosses an escarpment of tens of kilometers with waterfalls of high flow upstream and average flows downstream. It offers the advantage of erecting dams for irrigation of vast areas for agriculture (Figure 4). In the Rusizi area, there are relatively abundant surface water resources because of high rainfall and storage in marshes and lakes. A dense hydrographic network means that it has a high hydroelectric potential. Among the internal rivers are the Kaburantwa, Kagunuzi, Mpanda, Nyamagana, and Muhira rivers (African Development Fund 2005).

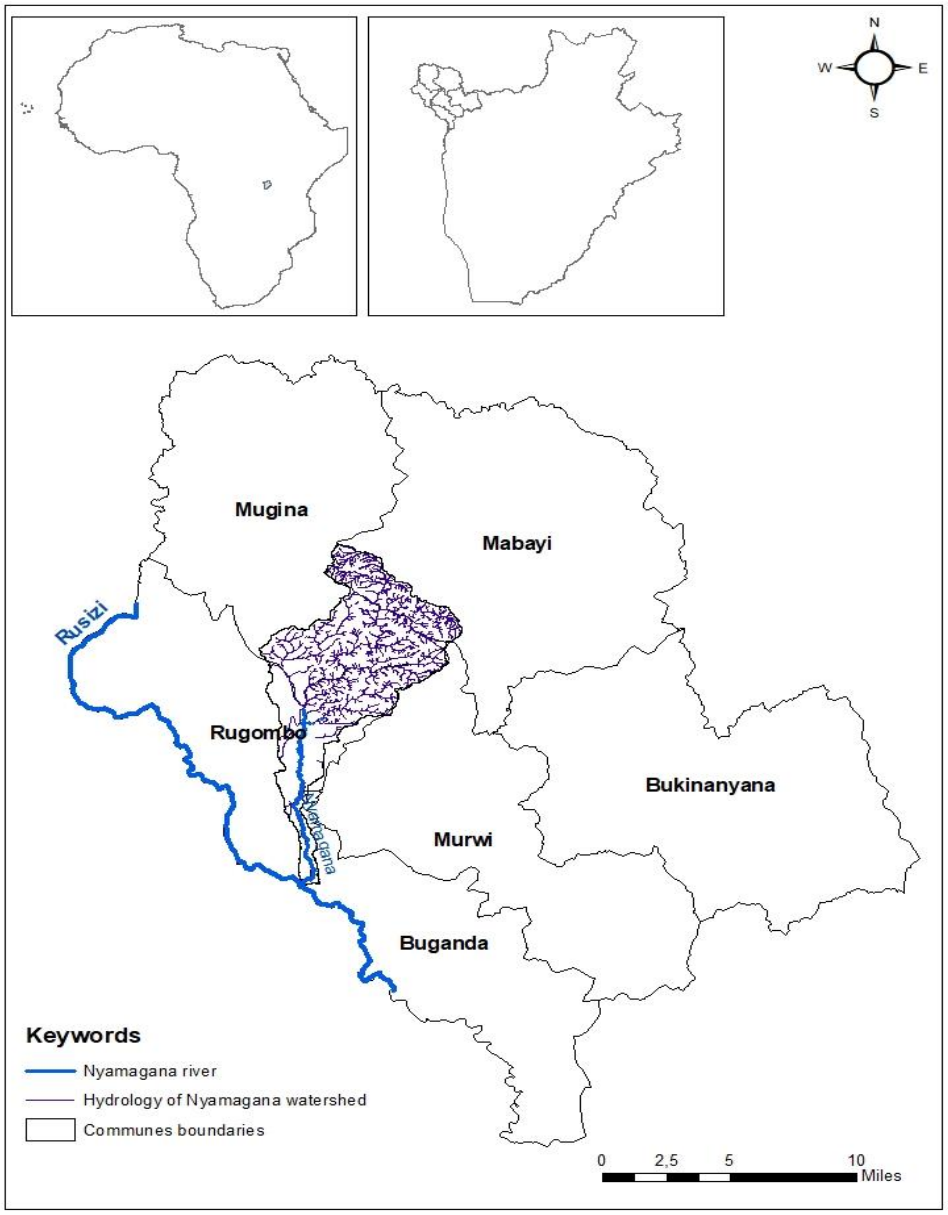

FIGURE 4. Hydrology of the Nyamagana sub-watershed

2.3 Sampling techniques

Purposive sampling was used to choose the participants for the focus group discussion (FGD). Therefore, the invited respondents came from farmer groups involved in irrigation water management of the Nyamagana River. Five FGDs were held with 12 persons in each. Each group of 12 (Figure 5) had six men and six women. Each FGD was conducted on a selected Colline (the lowest administrative subdivisions in Burundi) bordering the sub-Nyamagana watershed and/or one of the irrigation canals.

The sample size of respondents for household survey was determined using the Bernoulli sampling formula released as follows:

$$n = N.\frac{1}{1+\frac{N.L^2}{4.S^2}}$$

Where,

n = Sample size;

N = Size of the target population (number of households living on the Nyamagana watershed);

L = margin error of 10% with 90 chances of not making an error; and

S^2 = 0.25: maximum dispersion value.

EQUATION 1. Sampling size calculation equation

A sample of 166 respondents was obtained using the above formula for calculation.

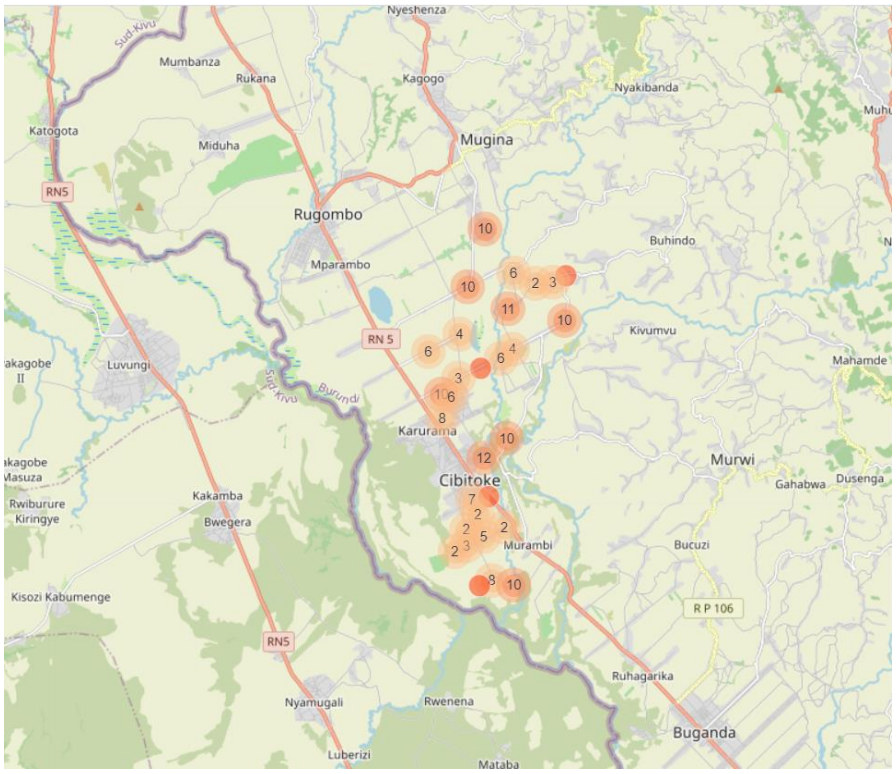

FIGURE 5. Sample distribution in the sub-Nyamagana landscape

2.4 Conceptual framework for DPSIR

The framework applied for this situation analysis report is shown in Figure 6. When addressing driving forces, agricultural and educational reforms, technological innovations, equity policies, and decision-support tools should be considered. In contrast, when addressing pressures, the strategy to be used would be based on land-use planning and management, human behaviour-change strategies, limiting discharges, resource-use management, awareness-raising, education, etc. Regarding reactions, factors to be considered include landscape condition, revitalization, remediation, landscape and community planning, restoration, assessment, etc. The components that are considered for impact-based solutions include adaptation methods, diversification of sources of income, mitigation, welfare indexing, and assessment and monitoring of ecological services, among others.

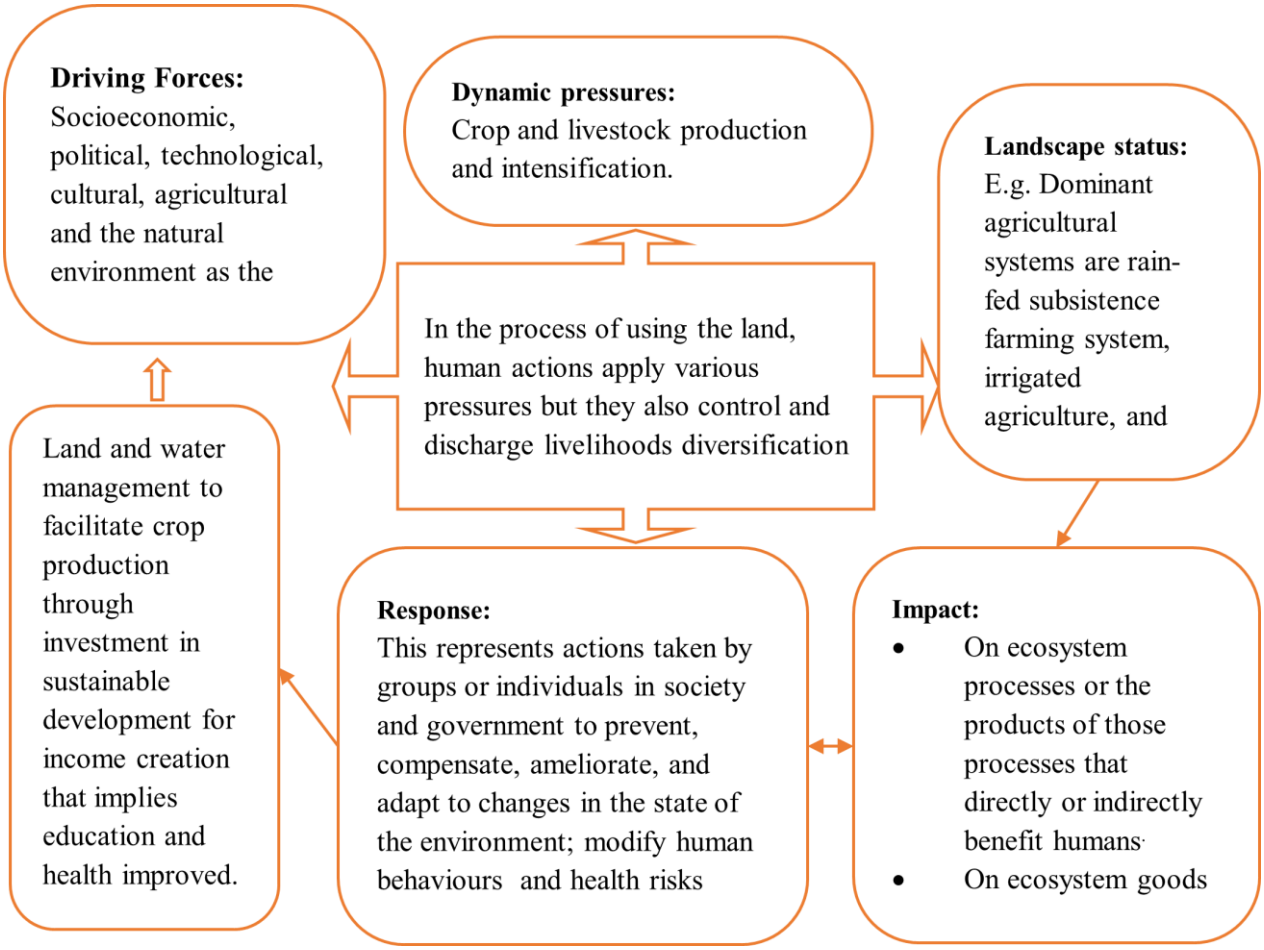

FIGURE 6. Conceptual framework for DPSIR

The interpretation of the framework leads to an understanding of the interaction between the different output land uses.

Driving Forces: This study has been conducted to assess driving forces in the landscape of the Nyamagana River in Cibitoke province. Driving forces are the forces that cause observed landscape changes, i.e., they are influential processes in the evolutionary trajectory of the landscape. These

forces have also been called keystone processes (Bürgi, Hersperger and Schneeberger 2005). The analysis emphasized on the socioeconomic, political, technological, cultural, agricultural, and natural environment as the main influential factors. These socio-cultural, economic, and political factors have been added to broaden the logical framework of the study. The driving forces form a complex system of dependencies, interactions, and feedback loops and they affect several temporal and spatial levels (Bürgi et al. 2005).

Dynamic pressures: Different land-use patterns in watersheds apply different types of demand on the watersheds. Understanding the many types of pressure exerted on a watershed is crucial. They are characterized as human actions connecting the forces that propel social and economic functioning and result in environmental changes. The variations seen in watersheds, the pollution discharges from industrial operations, or contamination due to agricultural practices as the use of mineral fertilizers, pesticides, the physical and biological degradations, the construction of artificial habitat; agricultural operations (such as cropping, fishing, tree felling), among others, are all frequently caused by changes in land and water use.

Landscape status: A watershed's condition includes both the natural environment and the area that people live in or use. The evaluation of the amount and quality of the elements that make up the environment or landscape, namely: 1) physical, 2) chemical, 3) biological, and 4) production systems modified by human action, is what is meant by the analysis of this state.

Impacts: The use of land and water will always influence ecosystems and human wellbeing. The availability, accessibility, and production of ecosystem goods and services are all impacted in some manner by changes in the structure, functioning, and composition of ecosystems (Atampugre et al. 2022b). The most obvious or perceptible changes in socioeconomic well-being of people are where these consequences may be seen. When we discuss ecosystem goods and services, we refer to all ecosystem processes or byproducts that benefit humans, either directly or indirectly. These might involve offering services, controlling ecosystem services, using ecosystem services for cultural purposes, and supporting ecosystem change processes.

Responses: The results of these interactions can be determined by using the DPSIR framework to analyse the interactions between different landscape elements. According to some authors, these are the results of the causal relationship between the various aspects of ecosystem exploitation. To understand the consequences of each composition, it is important to understand the steps taken by communities, people, and the government to prevent, make up for, mitigate, and adapt to changes in the landscape. In various circumstances, the occupants of a landscape or watershed can alter their behaviours, and these adjustments are likely to cause health problems that call for medical attention. Additionally, these human acts, through the consumption of ecosystem goods and services, counteract the social or economic impact of the human situation on wellbeing. The driving forces, pressure dynamics, landscape conditions, and impacts might all be the focus of responses.

2.5 Data collection

Data were collected from both primary and secondary sources to get information on the various DPSIR components. Primary data were obtained from household surveys, focus group discussions (FGDs), and key informant interviews (KIIs). Semi-structured questionnaires and checklists with

open-ended and closed-ended questions were used for household surveys, FGDs and KIIs. A structured questionnaire was employed to gather quantitative data, with the assistance of well-trained enumerators using KoboCollect software. The data were collected using questionnaires comprising household farm characteristics such as the number of farmlands, the size of the farmland, the land tenure, and the soil fertility of their farm.

Additionally, data on household food production and consumption, household livestock, household livelihood diversification and alternative income sources, external income and migration, social networks, household physical assets, and public services were also gathered.

Focus group discussions and key informant interviews were utilized to collect qualitative data. The participants in FGDs comprised the members of associations in charge of sub-Nyamagana water management, while the key informants were composed of ISABU researchers involved in the project implementation, the General Director of IGEBU, the Dean of FABI, the lecturers of Burundi University, the adviser in charge of planning, development and statistics of Rugombo commune, the head of the water distribution committees in the communes of Rugombo and Buganda, and the hydrologist officer at IGEBU. Six focus group discussions were conducted for each Colline, consisting of six women and six men each. The focus group discussion checklist aimed at understanding the types of land uses, the agricultural production systems, the wild biodiversity, the drivers of land degradation, and the institutions and partners operating in the landscape.

2.6 Data processing and analysis

Data were collected using the KoboCollect tool and analysed using SPSS statistical software. Descriptive statistics, frequencies, and percentages were calculated to provide an initial understanding of the gathered data. T-test and chi-square test were carried out on the data set at the 5% significance level to determine the significant difference and existence of any relationship between household livelihoods and land use, agricultural production systems, land size, state of institutional and policy support, etc. The data collected from KIIs and FGDs were analysed using a qualitative approach to understand the underlying factors and social dynamics influencing the status of the landscape.

3.0 RESULTS

In general, topography, demographic pressure, uncontrolled rice farming, anarchic mining and quarrying, and climate change collectively threaten the health and functioning of social-ecological landscapes (SEL). Within the Nyamagana sub-watershed, unsustainable agricultural practices and overexploitation of natural and artificial resources are threatening biodiversity, the livelihoods of farmers, and ecosystem processes, including soil services. This research assessed the status and trends of natural resources, considering the possible impacts on human well-being and institutional responses. Figure 7 summarizes the finding.

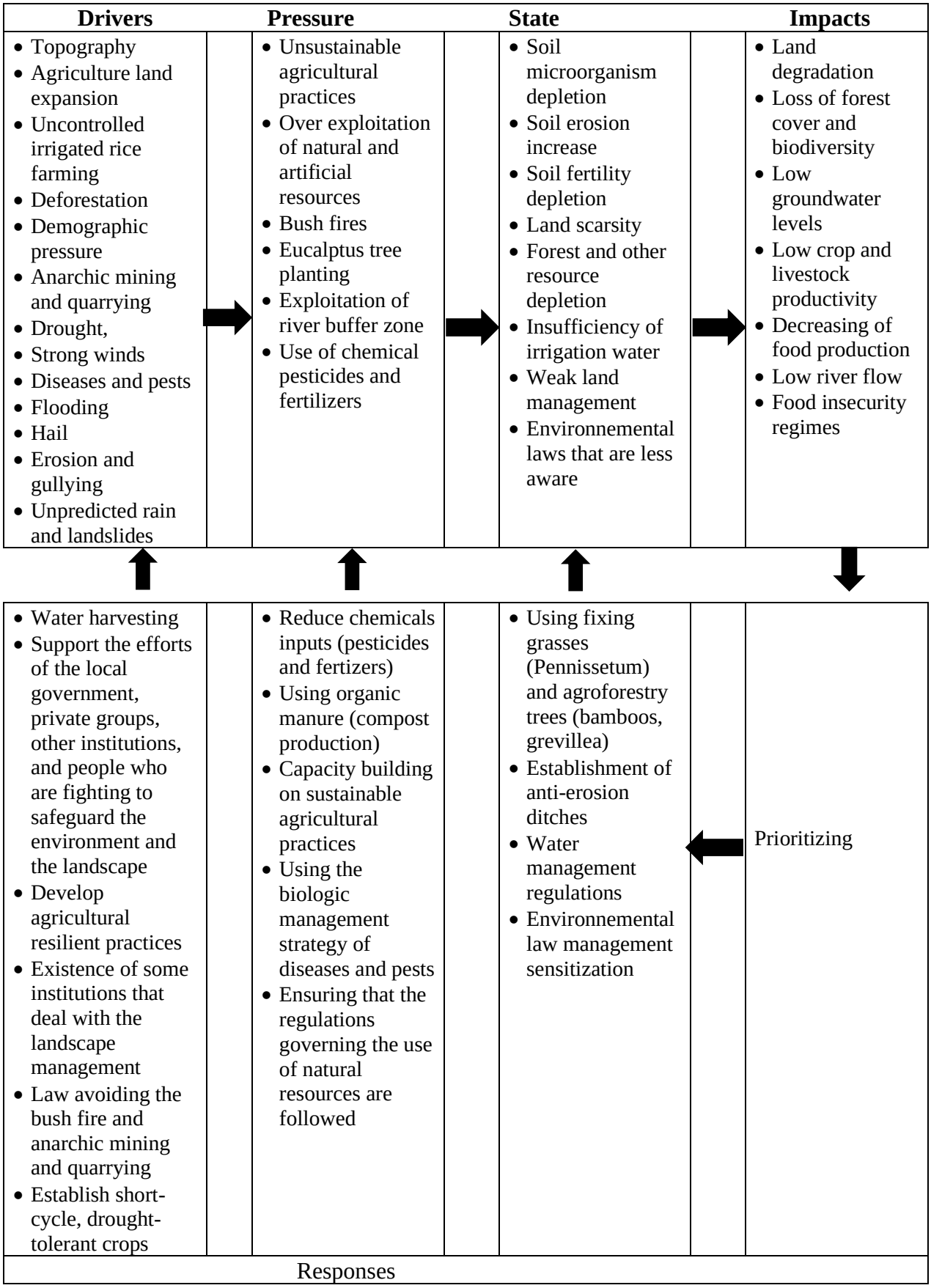

FIGURE 7. Summary of research results

3.1 Drivers underpinning landscape change in the Nyamagana sub-watershed

The drivers underlying the landscape dynamics in the Nyamagana sub-watershed are diverse and originate from several sources. Some factors are natural, such as weather (e.g., precipitation, temperature, humidity, etc.), geology, and topography, while others are the consequences of human activities (e.g., land degradation, deforestation, etc.) In addition, the demographic pressures are generating land scarcity, and overexploitation of both natural and artificial forests is posing a threat to the watershed according to those households surveyed during the data gathering phase.

According to the results from the focus group discussions (FGDs), the participants of all 6 FGDs congruently stated, “Drought, strong winds, diseases and pests, flooding due to the lack of water drainage systems, hail, erosion and gullying, unpredicted rain, and landslides are the main natural drivers of the landscape change.” To overcome the natural disturbances cited above, the participants responded, ″some efforts are being implemented to address the issues, for instance there is increased irrigation to mitigate the frequent droughts”. They added that “pests and diseases are being controlled by spraying some chemicals pesticides and biopesticides despite those products being often not effective.” To address the effect of flooding and drought, the participants divulged, “We are trying to make drains manually; planting agroforestry trees in our farms; mulching is another option to address the effect of the water stress.” Additionally, they said, “Farmers establish short-cycle, drought-tolerant crops to cope with drought and have started to put in place anti-erosion ditches to address landslides and soil erosion.”

3.1.1 Demographic dynamics

The average number of household members in the study area in given in Figure 8.

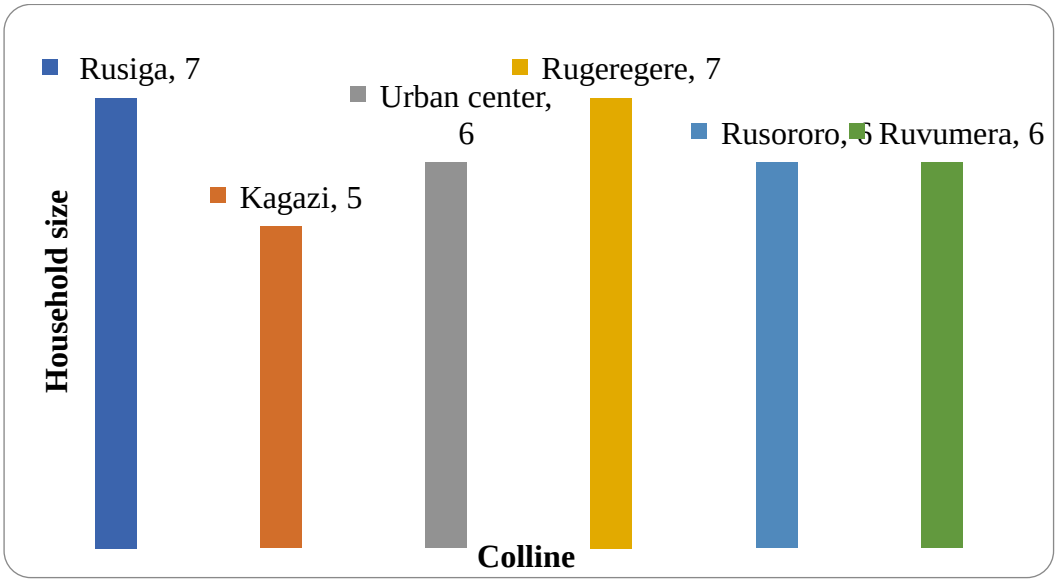

FIGURE 8. Average number of household members in the study area in different Collines (the lowest administrative subdivision in Burundi)

According to the results given in Figure 7, the average number of members living in the same household ranges between six and seven in most Collines of the study, except in the Kagazi colline, where the average household size is five. This indicates that the sub-Nyamagana watershed is overpopulated. This overpopulation could lead to land scarcity, overexploitation of natural and artificial forests, soil fertility depletion, reduction of soil microorganisms, etc. From a positive angle, however, overpopulation could also be the source of a workforce that could contribute to the improvement and diversification of natural resources.

3.1.2 Status of the food security in the Nyamagana sub-watershed

The number of months during which households struggle to get enough food is given in Figure 9. Based on the results presented in Figure 8, more than 50% of the households suffer from food shortages for a period ranging from 3 to 6 months, while only 38% of the households experience a short period of food shortages (1–3 months).

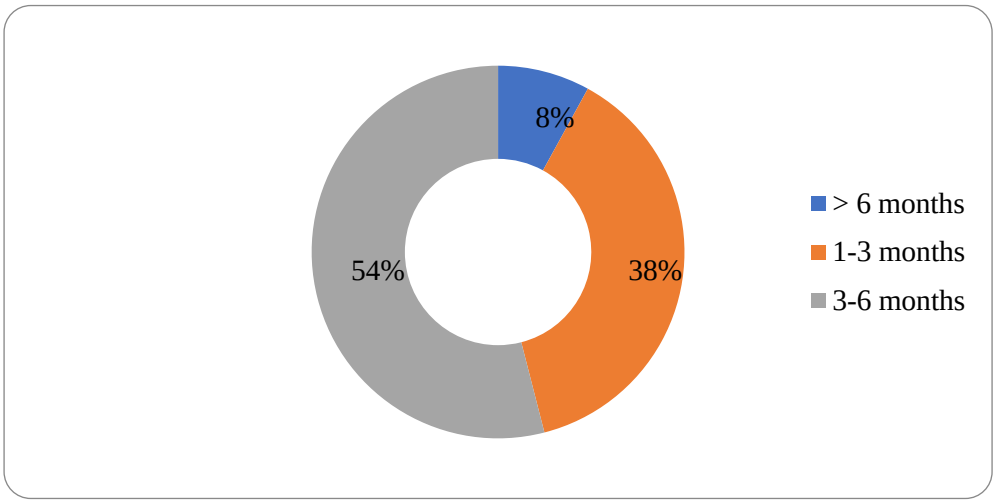

FIGURE 9. Number of months of household food shortages

The food shortage in households could lead to a lack of management of the existing natural resources. Moreover, the shortage of food may be a result of the insufficiency of natural resources within the sub-Nyamagana watershed. The months of the year with food shortages for householders interviewed in the sub-Nyamagana watershed are given in Table 1.

As indicated in Table 1, more than 50% of farmers reported insufficient food or struggled for sufficient food to feed their families from July to December. Notably, 72.5% of households do not depend on their own food production. Therefore, to meet sustainable production in the Nyamagana watershed, support in terms of farmland management systems and technical advice will be key to sustaining food security throughout the year.

TABLE 1: Lean months during the year

Colline	Jan (%)	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rusiga	0.18	0	0.2	0	0.18	0.18	0.2	0.36	0.54	0.72	0.54	0.54
Kagazi	0	0	0.4	1	0.54	1	0.7	0.72	0.9	1.08	1.08	0.36
Urban centre	0.54	0.18	0.4	1	1.8	2	2.3	2.5	2.5	2.7	2.3	1.6
Rugeregere	1	0.54	0.9	1	0.9	1	1.4	1.9	4.1	4.6	4.6	3.4
Rusororo	0.18	0	0.2	1	0.36	1	3.2	3.7	4.8	4.6	3.4	1.8
Ruvumera	1	0.36	0.4	1	0.72	1	2	2.5	2.8	2.7	2.3	1.9
Total	**3**	**1.08**	**2.3**	**5**	**4.5**	**6**	**9.9**	**10**	**15.8**	**20**	**14.4**	**9.7**

The mitigation strategies adopted by households to cope with food shortages during these periods are highlighted in Table 2.

TABLE 2. Mitigation strategies of households during food shortage period within the year

Colline	Food donations (%)	Food intake reduction (%)	Food donation and Food intake reduction (%)
Rusiga	5.3	94.7	0.0
Kagazi	0.0	100.0	0.0
Urban centre	0.0	100.0	0.0
Rugeregere	4.8	95.2	0.0
Rusororo	0.0	94.1	5.9
Ruvumera	0.0	92.3	7.7

According to the results presented in Table 2, most households reduce their dairy food consumption to cope with the food shortage. The food intake reduction strategy in Kagazi and urban centre Collines scored a high percentage (100%). The food donation strategy was undertaken only by Rusiga and Rugeregere Collines at the levels of 5.3% and 4.8%, respectively. The promotion of integrated farming production systems may improve the productivity of diversified crops to address the food shortage.

3.1.3 Land tenure systems in the study area

The land tenure systems encountered in the Nyamagana sub-watershed are given in Table 3. Based on the results highlighted in Table 3, most households practice agriculture on their own land. According to the land scarcity reported in the Imbo plain (Rusizi Feasibility Report 2022), the farmers in the sub-Nyamagana watershed are challenged to find enough cropping land, compelling

them to overexploit their cropping land. As a result, most forage species are facing extinction, and soil fertility is being depleted, worsening soil erosion, landslides, flooding, etc., which have been observed over the years.

TABLE 3. Land tenure systems encountered in the Nyamagana sub-watershed

Colline	Family owned (%)	Borrowed (%)	Short rent (%)
Urban centre	80.0	0.0	20.0
Kagazi	88.9	0.0	11.1
Rugeregere	100.0	0.0	0.0
Rusiga	91.5	2.1	6.4
Rusororo	96.7	0.0	3.3
Ruvumera	100.0	0.0	0.0

3.1.4 Water sources adopted in the Nyamagana sub-watershed

The water sources adopted in the Nyamagana sub-watershed are given in Figure 10. As depicted through the assessment of the water sources results in the Nyamagana sub-watershed, farmers in Rusiga, Kagazi, the urban centre, and Rugeregere are using irrigation canal water pathways for dwellings and agricultural purposes. In Ruvumera and Rusororo, farmers are not connected to irrigation canal pathways yet. They mostly depend on the rain, while a few farmers also use streams and tap water to irrigate their farms.

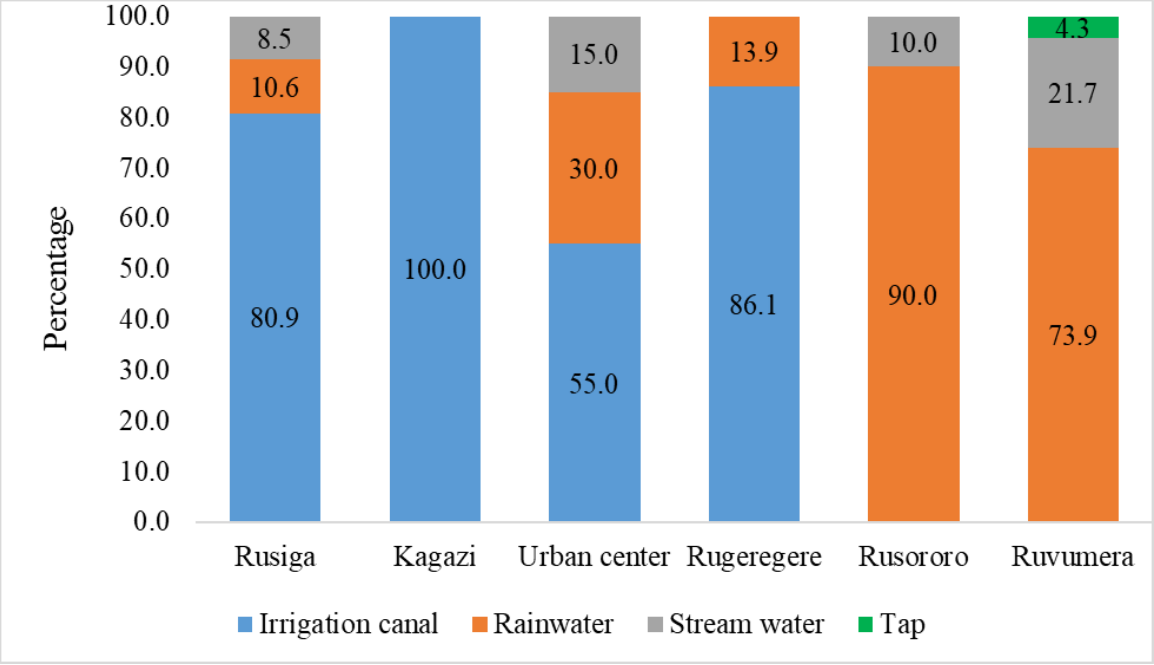

FIGURE 10. Water sources in the Nyamagana sub-watershed

As shown in Figure 9, irrigation canals are the primary source of water for most farmers (54.2%), while 36.1% do not irrigate their farmlands. Importantly, the presence of irrigation canals along the Nyamagana River is one of the opportunities to repopulate and diversify numerous crops that have been lost over the years.

Table 4 presents results based on farmers' perceptions of the water supply. Results reveal that 36.7% of farmers consider irrigation sources used on their farms to be insufficient, and 36.1% of farmers are uncertain whether irrigation water is sufficient or not. Only 11.4% of farmers concur that water availability is sufficient for irrigation. Consequently, activities that boost the diversity of natural resources could also be threatened by the lack of water for irrigation. The levels of farmer satisfaction regarding the water supply for irrigation is given in Table 4.

TABLE 4. Satisfaction levels for water supply

Colline	Insufficient (%)	Moderately sufficient (%)	Do not know (%)	Sufficient (%)
Rusiga	19.9	4.8	2.4	1.2
Kagazi	2.4	3.6	0	0
Urban centre	3	3	3.6	2.4
Rugeregere	9.6	3.6	3.6	4.8
Rusororo	0.6	0	16.3	1.2
Ruvumera	1.2	0.6	10.2	1.8
Total	36.7	1.6	36.1	11.4

3.1.5 Comparison of irrigated and non-irrigated land sizes in the Nyamagana sub-watershed

The results given in Table 5 indicate that there are no significant differences between irrigated and non-irrigated land sizes. The average size of irrigated land is 0.28 ha per farmer, while the land size of 0.27 ha represents the non-irrigated land per farmer. The similarity in size between irrigated and non-irrigated land is due to the hills in the study area in Ruvumera and Rusoro, where farmers do not practice irrigated agriculture yet.

TABLE 5. Comparison between irrigated and non-irrigated land sizes

Land size	Mean	t	Sig. (2-tailed)
Irrigated size of land (ha)	0.28±0.33	0.22	0.826
No irrigated size of land (ha)	0.27±0.31		

3.2 Dynamic pressures

Human-based activities causing pressures can be classified into three main categories: (i) excessive use of natural resources through contact; (ii) increased production and waste discharge into the environment without proper treatment, thereby contaminating ecosystems; and (iii) the complexity of land cover and soil use, particularly the use of chemicals (pesticides and fertilizers) that are detrimental to ecosystem components. The most significant factor among the several causes and variables influencing landscape change in the Nyamagana sub-watershed is the anarchic mining that takes place in the river and along its banks. Additionally, agriculture is carried out using less ecologically suitable methods, sometimes ignoring the buffer zone surrounding the Nyamagana River. These farming practices greatly degrade the soil, primarily along the riverbanks.

Four out of six of the FGDs *"converged on the bush fires as the anthropogenic disturbances that threaten the agricultural production in the landscape."* Most (five FGDs) reported that "*the deforestation for multiple purposes is another pressure on agricultural production."* One FGD cited *"the planting of eucalyptus trees on farms*" as a cause of agricultural production decline. Another FGD revealed that "*the use of degenerate seeds is the cause of the loss of the agricultural production"*, yet another FGD mentioned "*the destruction of irrigation canals"* as "*the cause of the drop in agricultural production."* According to three FGDs, "*the exploitation of the buffer zones and anarchic mining and quarrying threaten the increase of agricultural production in the study area.*" The limitations and challenges to agricultural productivity are perceived to be unsustainable natural resource management, including deforestation, agricultural land expansion, and inadequate waste management, according to the Rusizi basin feasibility study (2022). Due to harmful practices and inadequate land use planning, the Ruzizi Basin landscapes have been severely degraded. This has led to a decline in groundwater recharge, low groundwater levels, low river flow regimes, food insecurity brought on by degraded soil, and a progressive loss of forest cover and biodiversity.

3.2.1 Main household livelihood activities within the Nyamagana sub-watershed

The main household livelihood activities carried out in the Nyamagana sub-watershed besides agriculture are given in Table 6.

TABLE 6. Major activities carried out in the Nyamagana sub-watershed

Colline	Handi crafts (%)	Small trade (%)	Mining (%)	Remunerative employment (%)	Charcoal production (%)	Rice processing (%)	Local liquor brewing (%)
Rusiga	1.9	21.2	1.9	0	0	0	0
Kagazi	1.9	0	0	0	0	0	0
Urban center	0.0	7.7	0.0	1.9	0.0	0.0	0.0
Rugeregere	3.8	23.1	0.0	3.8	1.9	1.9	0.0
Rusororo	1.9	11.5	3.8	1.9	0.0	0.0	1.9
Ruvumera	0.0	7.7	0.0	0.0	0.0	0.0	0.0
Total	9.6	71.2	5.8	7.7	1.9	1.9	1.9

Apart from the agricultural activities implemented, most farmers (71.2% out of the total interviewed) practice small trade as their main source of income. The second most common source of income is handicrafts (9.6%), followed by mining (5.8%) and remunerative employment (7.7%). In the study area, charcoal production is insignificant (1.9%). This indicates that the Nyamagana sub-watershed lacks sufficient trees for making charcoal. All of the farmers who participated in the interview declared that their main occupation was agriculture.

3.2.2 Use of Fertilizers and pesticides within the Nyamagana sub-watershed

The level fertilizers and pesticides used by farmers is given in Figure 11. The interviewers reported that more than 80% of farmers apply fertilizers and pesticides in their crops. This implies that the excessive application and irrational use of these products can be harmful to human ecosystem services. Therefore, the sensitization and promotion of friendly agro-ecological practices may address the reported inappropriate use of synthesis fertilizers and pesticides over the years. The t-t test showed that there was a significant difference (P value<0.05) between the users of the chemical products and the non-users in terms of the number. To reduce the harmful effects of these chemical products, it is necessary to sensitize farmers to use organic products such as biopesticides and organic manure.

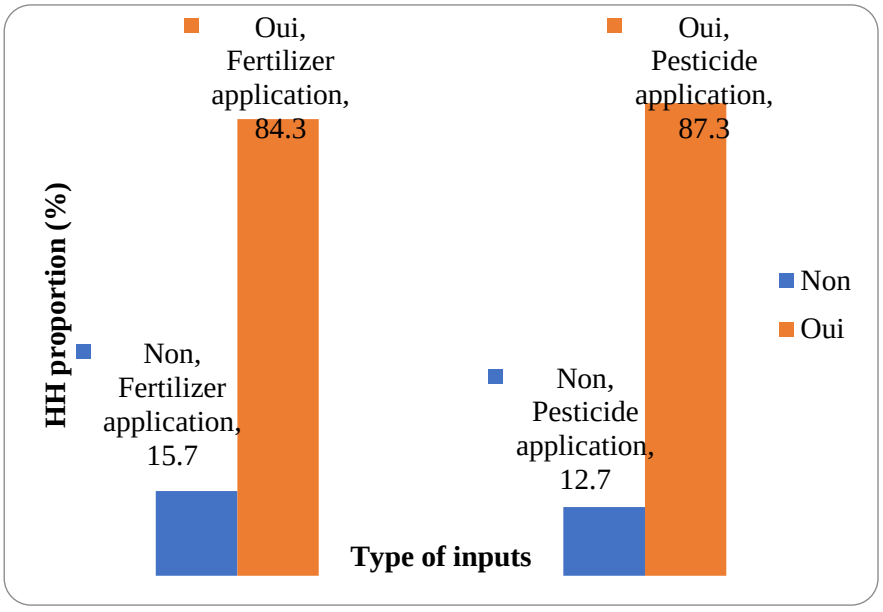

FIGURE 11. Usage of fertilizers and pesticides in farming

3.2.3 Diversity of fertilizers and pesticides applied during farming

The proportion of farmers who diverse of the agricultural inputs such as fertilizers and pesticides to improve the crop production are highlighted in Figure 12.

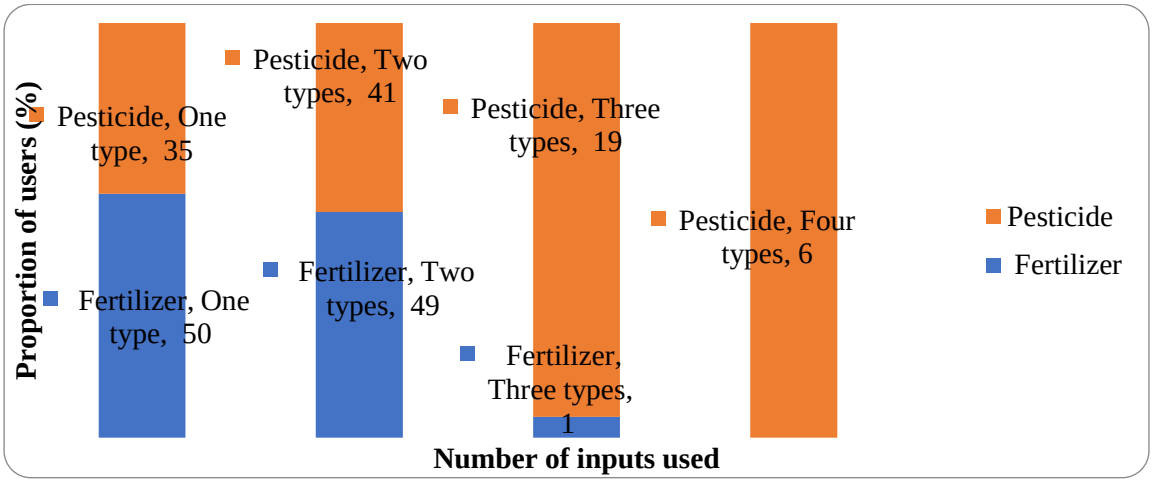

FIGURE 12. Diversification of the number of the fertilizers and pesticides applied

According to Figure 12, approximately 50% of farmers apply only one type of fertilizer, whereas 49% apply two types. Three different types of fertilizers are applied by just 1% of farms. In terms of pesticides, 35% of farmers spray only one kind, whereas 41% apply two types, 19% apply three types, and 6% can afford to apply four varieties. It has been observed that the greater their reliance on certain chemical inputs, the greater the threat to natural resources.

3.3 Landscape status in the Nyamagana sub-watershed

According to participants in the six FGDs, *"the biodiversity, water, soils, and forests are not optimally managed for current and future use."* The participants in five FGDs revealed that "there are no effective available management regimes in place for managing biodiversity, water, soils and forests," However, one FGD said that *"some management regimes are available such as the law against bush fire practices (administration) and water management committee."* The participants also suggested practical ways to manage resources to ensure their availability for current and future use: *"avoiding bush fires, planting agroforestry and forest trees; awareness-raising sessions on good agricultural practices, technical and financial support, regulation of mining and quarrying and soil erosion control."*

3.3.1 Crop diversity in the Nyamagana sub-watershed

The staple crops planted in the study area, crop production, and quantity consumed and sold are provided in Table 7.

According to the results presented in Table 7, a diverse range of staple crops are planted in the study area. However, most of the crops are not cultivated by the majority of farmers. This may be due to the scarcity of seeds in the study area. It is noted that the crops cultivated by the majority of farmers are maize (33.7%), bush beans (25%), cassava (20%), and rice (8.5%). Moreover, the interviewed farmers reported that the majority of crops planted by farmers are used for family consumption.

TABLE 7: Crop diversity, crop production, and usage of the production

Crops produced last season	Proportion of households (%)	Produced quantity (Kg)	Consumed quantity (Kg)	Sold quantity (kg)	Obtained income (BIF)
Amaranths	1.5	186.4	3.8571429	111.14	574,642.80
Groundnut	0.4	125	20	105	310,000.00
Eggplant	0.4	170	20	150	80,000.00
Banana	0.4	15	0.5	15	40,000.0
Cabbage	0.4	32.5	32.5	0	0
Taro	0.4	425	425	0	525,000.00
Cotton	0.2	150	0	150	135,000.00
Bush bean	25	1361.6	50.5	6.4	17,315.70
Climbing bean	0.2	50	50	0	0
Yam	0.2	60	60	0	0
Maize	33.7	281.1	207.5	53.7	78,688.40
Cassava	20	259.7	79.1	162.5	67,754.40
Cowpea	0.4	270.4	143.3	108.1	73,221.40
Sweet potato	2	321.1	116.4	53.4	99,664.40
Cajan pea	0.4	295.8	129.9	80.7	86,442.90
Rice	8.5	811.5	225.9	577.0	1,260,470.60
Soybean	3.7	48.6	12.8	33.0	62,906.30
Tomato	4	1769.8	307.2	1749.2	955,555.60

When it comes to income from crop sales, rice provides the highest income (1,260,470.00 BIF), followed by tomatoes (955,555.60 BIF), taro (525,000.00 BIF), and groundnut (310,000.00 BIF) even if they are cultivated by a small number of farmers.

3.3.2 Types of animals raised in the Nyamagana sub-watershed

The animal types raised in the study area, the number, and the income derived from the sale of animals are given in Table 8.

According to the results shown in Table 8, the animals raised by farmers in the study area are mostly goats (27.5%), pigs (26.3%), chickens (26.3%), and cows (12.9%). Farmers in the Nyamagana sub-watershed raise an average of 2 to 4 animals. The highest income (199,479.00 BIF) is generated by the sale of cows and their by-products. This is followed by the income from pig sales (108,515.00 BIF). As the income from the sale of livestock is insufficient, it may be deduced that farmers struggle with the lack of capital to properly manage and safeguard existing natural resources.

TABLE 8. Animal types, animal number and income from animal sale

Animal type	Proportion of households (%)	Animal number	Income (BIF)
Duck	0.8	4	30,000.00
Goat	27.5	3	49,691.17
Guinea pig	1.3	16	7,333.33
Rabbit	3.3	4	2,625.00
Sheep	1.7	4	30,000.00
Pig	26.3	2	108,515.87
Chicken	26.3	6	26,160.32
Cow	12.9	2	199,479.03

3.3.3 Status of the soil fertility in the Nyamagana sub-watershed

The appreciation of farmers in terms of soil fertility in the sub-Nyamagana watershed is given in Table 9.

TABLE 9. Soil fertility appreciation in the Nyamagana sub-watershed

Colline	High (%)	Low (%)	Medium (%)
Rusiga	17	31.9	51.1
Kagazi	0	90	10
Urban center	5	30	65
Rugeregere	2.8	11.1	86.1
Rusororo	3	20	77
Ruvumera	8.7	39.1	52.2

As shown in Table 9, more than 50% of surveyed farmers reported that their soils were moderately fertile. However, a significant number of farmers (39.1%) revealed that their soils were poor, while a few farmers (8.7%) claimed that their soils were very fertile. This low level of soil fertility is due to overexploitation and inadequate management of their farmlands, erosion, and flooding, which also threaten the diversity and abundance of natural resources.

3.3.4 Dynamics of the state of the social ecological landscape (SEL)

The state of the social ecological dynamics of the landscape is understood as the set of critical resources (i.e., natural, socio-economic, and cultural) whose flow and use are regulated by a combination of ecological and social systems (Mehring et al. 2017). Generally, it is a complex and dynamic system in perpetual adaptation. The concept also alludes to the dynamics of communities

in the sense of the evolution of their structure and composition. These dynamics are also the results of environmental disturbances such as heavy rains, long dry seasons, fires, deforestation, and climate change. Going deeper, we realize that these are complex adaptive systems in which human societies are integrated with nature. Thus, through the social component, which refers to all human activities, including the economy, technology, politics, and culture, we understand that there are interactions between communities and ecosystems. The states of the social ecological landscape (SEL) dynamics are illustrated in Figure 13. A good example of community-ecological interaction defining the state of landscape is that the team discovered that the installation of irrigation infrastructure in one of the Colline has the unintended consequence of further increasing landslide occurrences due to inadequate drainage and saturation problems (Figure 14).

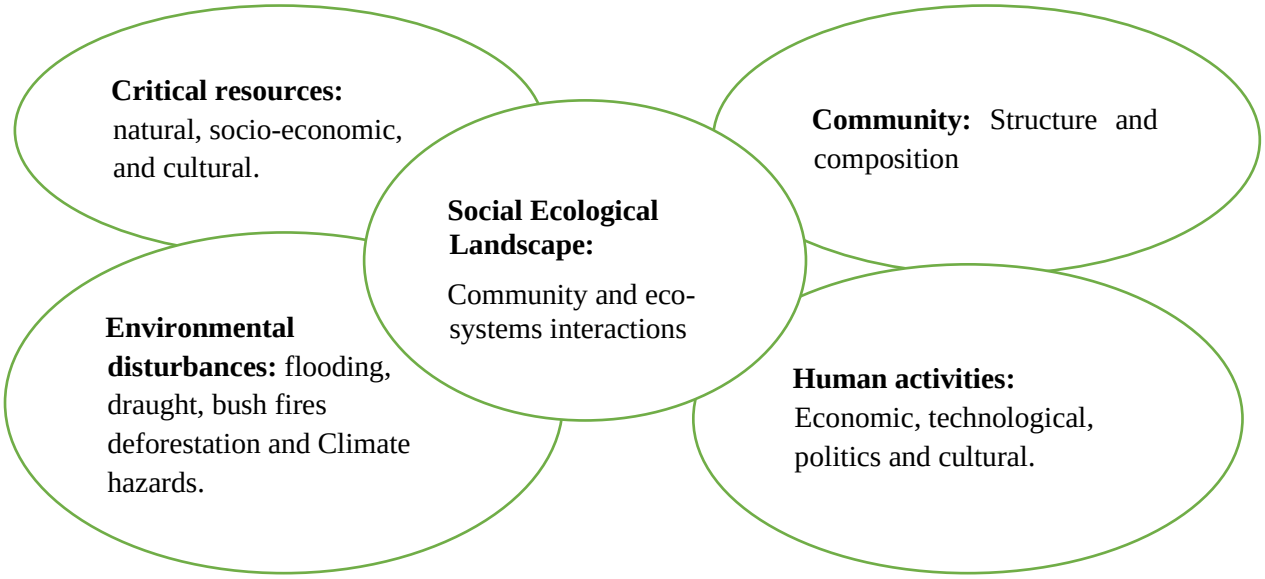

FIGURE 13. State of the social ecological landscape (SEL) dynamics

FIGURE 14. Poorly constructed irrigation canals causing landslides in the Nyamagana landscape

3.4 Impacts of landscape transitions on human wellbeing, biodiversity, and ecosystem services

At the level of a watershed, nature often provides benefits and services that play essential roles in the lives of households living in the watershed. In other words, ecosystems support human well-being by supporting, providing, regulating, and providing socio-cultural and economic services. However, well-being depends on the supply and quality of human services, technology, and institutions.

Ecosystem services are the benefits that people derive from ecosystems: provisioning services of goods and services such as food and water; regulating services such as flood, pests, and disease control; cultural services such as spiritual and recreational benefits; and supporting services, such as nutrient recycling, that contribute to the daily lives of individuals in households.

Through the focus discussion and structured questionnaires, households residing in the Nyamagana sub-watershed were interviewed for this study, which allowed researchers to pinpoint specific effects of watershed transitions on human well-being resulting from biodiversity and ecological services.

3.4.1 Causes of floods in the Nyamagana sub-watershed

Figure 15 indicates the primary causes of floods in the Nyamagana sub-watershed

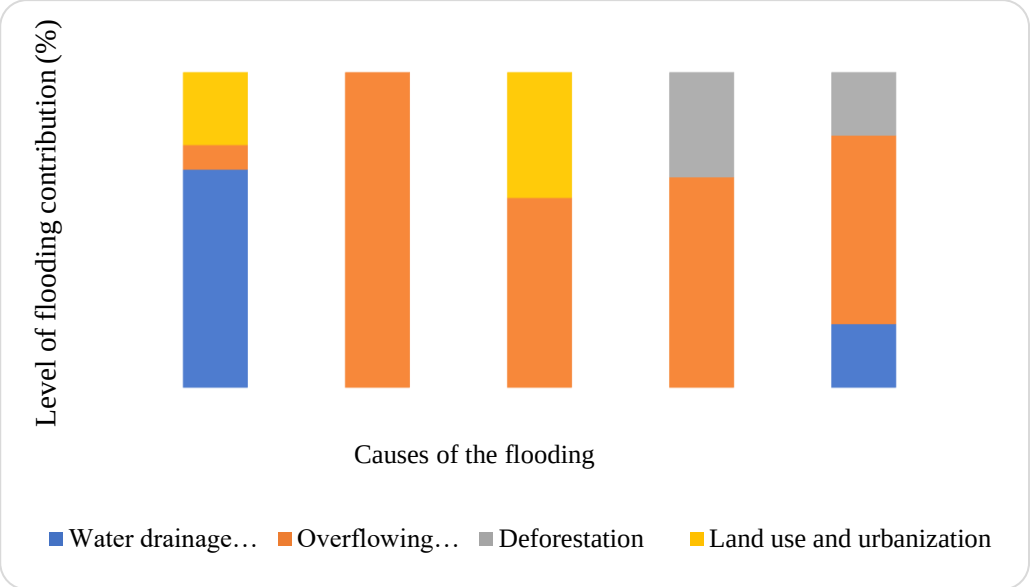

FIGURE 15. Flooding causes in Nyamagana landscape

Most of the interviewed farmers (32.4%) cited overflowing rivers or lakes as the first cause of flooding, followed by farmers who gave poor drainage systems as the second cause (31.1%). The climate change was ranked the third in terms of the cause of the flooding by farmers in the Nyamagana sub-watershed. The occurrence of flooding damages existing crops, animals, and microorganisms. This leads to the reduction of both plant and animal species.

3.4.2 Causes of soil erosion in the Nyamagana sub-watershed

The main causes of soil erosion in the study area are given in Table 10. The main cause of soil erosion cited by 33.5% of interviewed farmers was unsustainable agricultural practices, followed by the steep slopes and topography reported by 25.1% farmers. The third (15.6% of farmers) and the fourth (15% of farmers) cited wind erosion and deforestation and land clearance, respectively, as the causes of soil erosion. Therefore, there is a need to develop the capacities of farmers in sustainable practices that mitigate these causes of erosion.

TABLE 10. Soil erosion causes in the Nyamagana sub-watershed

Colline	Wind erosion (%)	Steep slopes and topography (%)	Deforestation and land clearance (%)	Unsustainable agricultural practices (%)	Construction and urban development (%)	Does not know (%)
Rusiga	3.6	4.8	4.2	7.8	3.6	3
Kagazi	0	1.8	0	0.6	0	0
Urban center	1.2	3.6	1.8	3	0	0.6
Rugeregere	4.8	4.2	5.4	11.4	1.8	1.2
Rusororo	5.4	3.6	2.4	8.4	0	0
Ruvumera	0.6	7.2	1.2	2.4	0	0.6
Total	15.6	25.1	15	33.5	5.4	5.4

3.5 Adoption level of landscape management

The level of sub-landscape management based on the three major techniques adopted, according to farmer perception, is indicated in Figure 16. Among the three major techniques adopted, most of the interviewed farmers reported that diseases and pest management strategies were the main techniques implemented in the study area. The causes that prompted the adoption of water harvesting, soil conservation, and disease control are multiple.

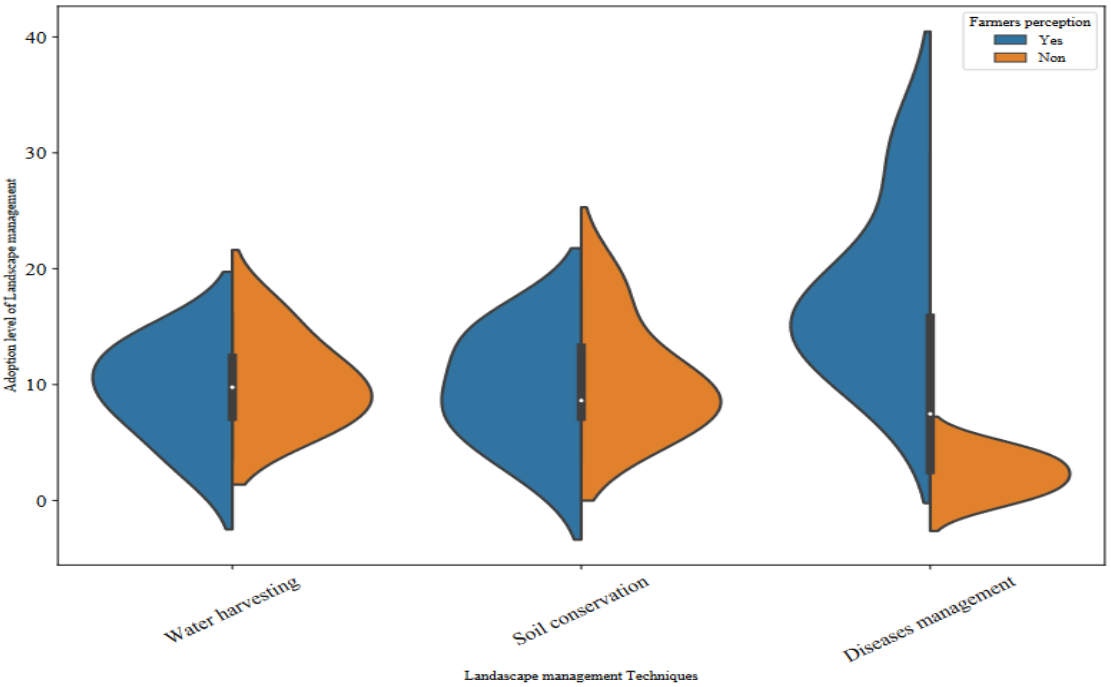

FIGURE 16. Adoption level of landscape management

The soil conservation was adopted by farmers to protect against erosion on their farmlands located on the steep Nyamagana watershed. The high temperature recorded in the study area exacerbates the proliferation of diseases and pests. Therefore, the farmers who own lands in the Nyamagana watershed must apply pesticides to fight these diseases.

3.5.1 Adoption of water harvesting techniques

The highlights of the findings on farmer adoption of water harvesting techniques are given in Figure 17. According to the results given in Figure 17, water harvesting techniques are mostly adopted in Rusiga (31.3%), followed by Ruvumera village (20.69%), among the villages that implemented these strategies. As the study area is located in a region with a prolonged dry season, farmers must use water conservation techniques in order to irrigate their crops during the period of water scarcity.

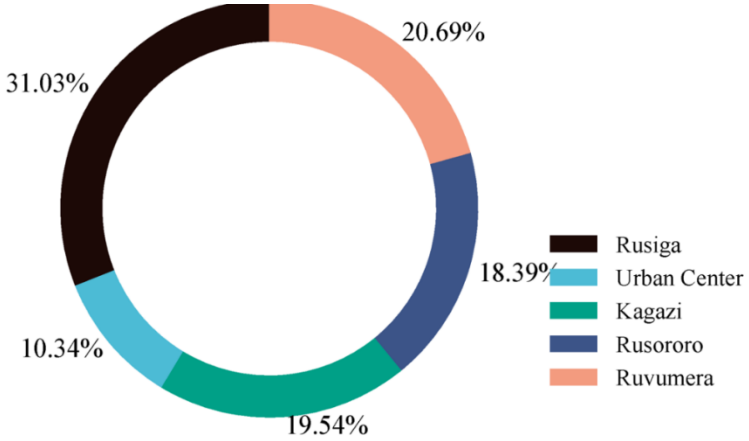

FIGURE 17. Adoption of water harvesting techniques by village

3.6 Existing institutional and policy responses to landscape drivers, pressures, dynamic states, and impacts

Despite the anthropogenic disturbances taking place, several concrete efforts have been implemented to mitigate their negative effects, such as the establishment of farmer associations for capacity building and raising awareness about smart farming. The protection of the riverbanks using fixing grasses (e.g., Pennisetum) and agroforestry trees (e.g., bamboos, grevillea) is being adopted, and agriculture close to riverbanks is prohibited. Farmers are adopting organic manure to fertilize their crops in order to improve soil productivity. Meanwhile, the government is continuing to raise public awareness of the harmful effects of bush fires on landscape degradation.

Four out of six FGDs revealed that there are *"no agricultural activities and other land use systems to enhance biodiversity and ecosystem services"* while two FGDs reported that *"some agricultural activities are being implemented in order to improve the biodiversity such compost production, planting agroforestry, forestry and fruit trees, protection of riverbanks with bamboo, installation of anti-erosion ditches".*

Institutions that are taking part in environmental protection as a part of the Cibitoke province's landscape management system have an impact on landscape management. The main initiatives in this direction are: (i) preserving the appearance of distinctive natural landscapes and specific geomorphological formations; (ii) promoting the revitalization of natural or close-to-natural environments; (iii) preserving the appearance of native fauna and flora as well as their natural living spaces; (iv) contributing to the maintenance and improvement of biodiversity; (v) supporting the efforts of the local government, private groups, other institutions, and people who are fighting to safeguard the environment and the landscape; and (vi) educating and enlightening the public about these issues. The results of the study show that there are already some institutions that deal with landscape management in the study area. There are also some institutions that manage landscapes based on different laws and regulations. Figure 18 illustrates the landscape management mechanisms identified during the study in the Nyamagana sub-watershed.

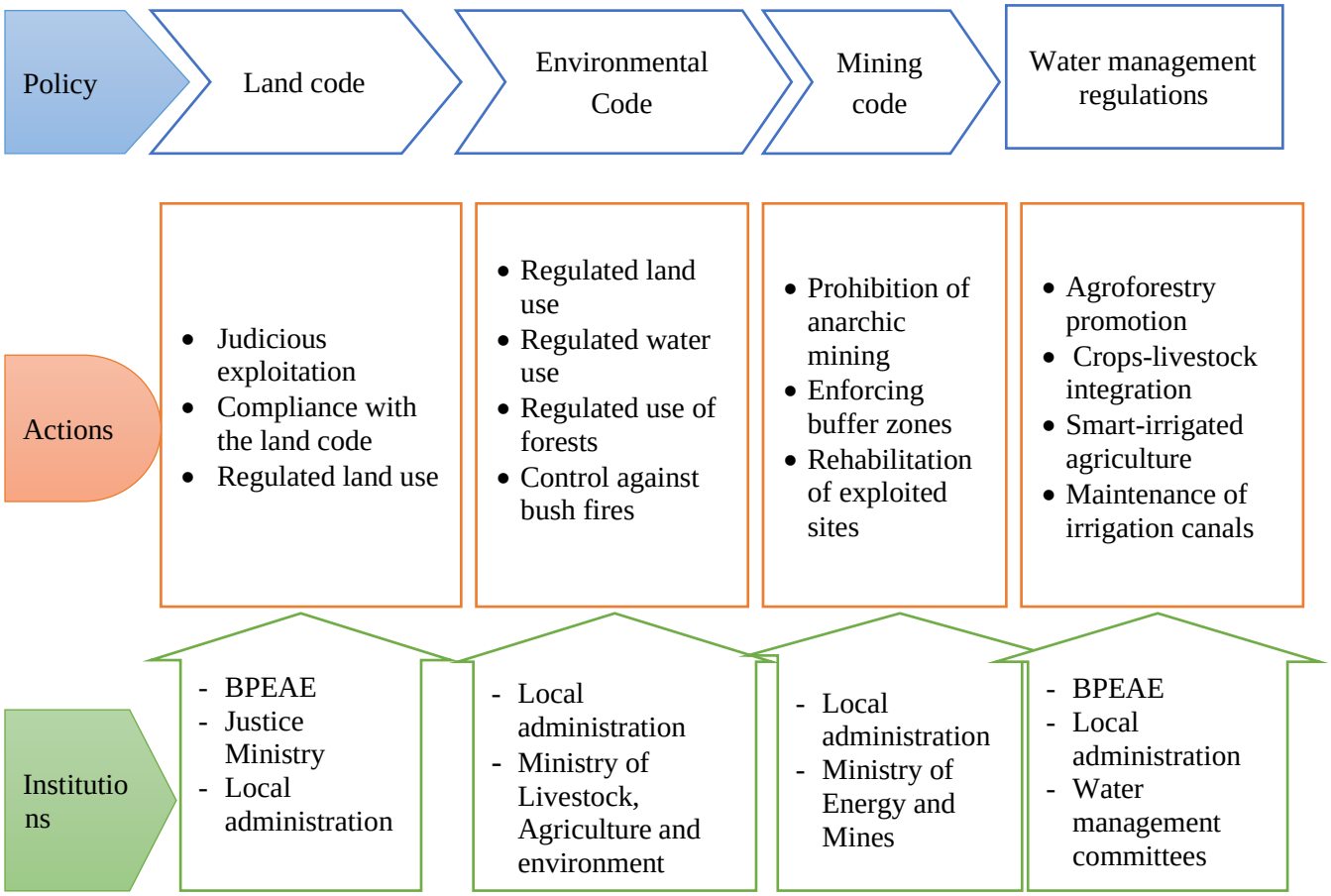

FIGURE 18. Existing institutional responses to landscape drivers, pressures, dynamic states, and impacts

4. CONCLUSION AND RECOMMENDATIONS

The current state of the landscape is described in this study based on the analysis of the Nyamagana sub-catchment region landscape. The investigation brought to light a number of urgent issues affecting the ecosystems of the Nyamagana sub-landscape as well as the specific organizations in charge of managing the ecosystem services of the watershed. The study employed a variety of methods, including focus group discussions and structured individual surveys, to collect both quantitative and qualitative data. These two methodologies helped develop a third technique, known as the Driver-Pressure-State-Impact-Response (DPSIR) strategy, which helped conceptualize the overall study.

This research defines the case that the unsustainable exploitation of natural resources and ecosystem services in the Nyamagana sub-watershed is typically motivated by the survival needs of local households rather than by the pursuit of high-level well-being based on the socio-economic characteristics of Cibitoke Province in general and the Nyamagana watershed in particular. As a result, the stresses that characterize the state and implications of the Nyamagana sub-watershed are primarily local in nature, although some are identified as regional. The study also found that

ecosystems were increasingly being converted into subsistence farming using less advanced technologies, unregulated small-scale mining, and unsustainable farming methods.

Biodiversity, livelihoods, and ecosystem processes, including the provision of soil and irrigation water, are under threat from the extraction of abiotic resources through mining and the unsustainable use of natural resources. Comparing the access to livelihoods of families in the research area revealed that there are unequal distributions of restricted livelihood options, food, raw materials for domestic use, health, education, and access to land for agricultural production among user households. The effects of the competition between ecosystem protection and development are visible in the over-exploitation of soils and the fragmentation of land due to non-ecological agriculture practices where soils are always occupied by crops without rotation or fallow systems. Due to the need to use chemical inputs that have huge impact on biodiversity, these practices deplete the soil and also contribute to environmental contamination. Another concern is the Nyamagana river's bank degradation and contamination because of unlawful community mining and farming that disregards the buffer zone between crops and the river's banks.

The outcomes of this situation analysis of the Nyamagana River landscape also revealed weak institutional capacity, insufficient human and financial capital, and limited access to information on natural resources for the appropriate planning and assessment, monitoring, and practical ecosystem service integration to support planning in Cibitoke province, Rugombo commune.

The study recommends several steps that can be performed to alleviate the limitations found in this analysis:

- Improve local capacity for managing and improving access to ecosystem services and natural resources.
- Assist local governments in ensuring integrated, sustainable development.
- Constantly build human capacity, especially in relation to integrated management of natural resources and the development of the Nyamagana River catchment area.
- Encourage multi-stakeholder, participatory methods for preserving ecosystems and enhancing the standard of living for residents of the Nyamagana Landscape.
- Encourage investments in landscapes that support sustainable development, including climate-smart goals.
- Promote top-down decision-making when addressing landscape challenges, such as land use management, as this should be effective in resolving the negative results of conflicting land uses.
- Keep an eye on changes to see if sustainable socio-ecological goals are being achieved.
- To safeguard areas with a variety of minerals in the subsoil, mining laws or mining codes need to be improved or put into effect.
- To achieve sustainable environmental management, strict procedures relating to the management of mining sites should be put into place to combat illicit and uncontrolled mining in the Nyamagana River landscape for the smart management of natural resources.

REFERENCES

- Atampugre, G., Mensah, E., Boateng, E., Mabhaudhi, T., & Cofie, O. O. (2022a). Situational analysis of a social-ecological landscape in the Ahafo Ano Southwest District of Ghana. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Initiative on West and Central African Food Systems Transformation. 57p. https://hdl.handle.net/10568/128221
- Atampugre, G.; Mensah, E.; Mabhaudhi, T.; Cofie, O. (2022b). Towards a framework for assessing the sustainability of social-ecological landscapes. Colombo, Sri Lanka: International Water Management Institute (IWMI). CGIAR Initiative on West and Central African Food Systems Transformation. 30p
- Bürgi, M.; Hersperger, A.M.; Schneeberger, N. 2005. Driving forces of landscape change - Current and new directions. *Landscape Ecology*, *19*(8), 857–868. https://doi.org/10.1007/s10980-004-0245-8
- FAO (Food and Agriculture Organization) and GEF (Global Environment Facility). 2017. Support for sustainable food production and enhancement of food security and climate resilience in Burundi's Highlands. 213.
- Mehring, M.; Zajonz, U.; Hummel, D. 2017. Social-ecological dynamics of ecosystem services: Livelihoods and the functional relation between ecosystem service supply and demand-evidence from socotra archipelago, yemen and the sahel region, West Africa. *Sustainability (Switzerland)*, *9*(7). https://doi.org/10.3390/su9071037
- Sindayihebura, B. 2005. De l'Imbo au Mirwa. Dynamique de l'occupation du sol, croissance urbaine et risques naturels dans la région de Bujumbura (Burundi).
- Tata, N. L. S. J. 2015. Integrating Gender and Nutrition within Agricultural Extension Services: Burundi Landscape Analysis. *Burundi Landscape Analysis*, (September).

APPENDICES

APPENDIX 1: Check list for focus group discussion

Assignment title: Situational Analysis of target social ecological landscape (SEL)

Identification

Community/colline Name:	Date:
*Name of community liaison person (CLP):	*Contact of CLP:
District name:	Region and Country:
Names of FGD facilitator(s):	
Start time:	End time:
*Information to be removed after data checks	

Starting point:

The main goals of sustainable landscape management is to conserve, maintain, and restore wild biodiversity and ecosystem services; provide for sustainable, productive, and ecologically compatible agriculture production and other land use systems; Sustain or enhance the livelihoods and well-being of all social groups in the landscape; and Establish and maintain institutions for inclusive, ongoing planning, negotiation, implementation, resource mobilization, and capacity-building in support of the previous three goals. Consequently, the issues to be discussed during the focused group discussions (FGDs) and participatory resource appraisal (PRA) will include the following indicators:

Agricultural production and other competing land use systems

- What are the various ***types of land uses*** in your community?

- Do agricultural production systems satisfy food security and nutrition requirements of producers and consumers in the landscape?

    - ✓ What are the agricultural production systems in the landscape (e.g., irrigation, rainfed subsistence farming, aquaculture, mixed cropping, mixed farming, etc.)?

    - ✓ What drivers influence the choice of agricultural production systems in the landscape?

- ✓ How do these drivers interact to influence sustainability of agriculture?

- ✓ How do the various agricultural production systems satisfy food security and nutrition requirements?

- ✓ Where does your community get majority (75%) of the food consumed?

- ✓ What agriculture-related interventions currently exist in your community?

- ✓ How effective are these interventions and mechanisms currently in place?

- ✓ What interventions can be put in place to ensure the sustainability of agriculture?

- Are agricultural production systems financially responsive to socio-economic and demographic changes? (e.g., price changes, increase in by-day wages, increases in populations, increase in household size, reduction in the availability of hired labor, etc.)

  - ✓ Are there any agricultural production financial systems in place (e.g., agriculture bank, savings and loans for farmers, farmer credit unions, etc.)?

  - ✓ What functions do these financial systems play in the production systems?

  - ✓ Are the financial systems effective in supporting your production?

  - ✓ In your view, can these systems help you respond to socio-economic changes? If yes, how? If no, why?

  - ✓ In your view, can these systems help you respond to demographic changes? If yes, how? If no, why?

- Are agricultural production systems resilient to natural and anthropogenic disturbances (**e.g., climate change, environmental degradation, pests and diseases, market shocks, etc.)**?
    - ✓ What natural disturbances affect/have affected agricultural production in this landscape?
    - ✓ How are the natural disturbances addressed?
    - ✓ What anthropogenic disturbances affect/have affected agricultural production /.Lin this landscape?
    - ✓ How are the anthropogenic disturbances addressed?

- Do agricultural activities and other land use systems improve or have a neutral impact on the wild biodiversity and ecosystem services in the landscape (***mushrooms, firewood, fruits, water for domestic purpose, aesthetic value, tourism, et***c.)?

1. Conservation, maintenance, and restoration of wild biodiversity and ecosystem services.
    - Is biodiversity, water, soils, and forests optimally managed for current and future use?
        - ✓ Are there any available management regimes in place for managing biodiversity, water, soils and forests?
        - ✓ What are these management regimes or standards?
        - ✓ How are these management regimes used in managing the above-mentioned resources? [Practicalexamples, if any]
        - ✓ In your views, are the resources managed optimally for current use?
        - ✓ Are the resources optimally managed for future use or ensure their sustainability?
        - ✓ If not, what practical ways can these resources be managed to ensure their availability for current and future use?

- Do land use patterns across the landscape optimize habitat value and landscape connectivity for native species?
    - ✓ What land use patterns exist across the landscape?
    - ✓ Do these land uses optimize habitat value? How?
    - ✓ Do the land use patterns optimize landscape connectivity for species? How?
    - ✓ What species native to this landscape are you aware of?
    - ✓ Has any of these species gone into extinction?
    - ✓ Has any of these species been marked to face extinction?
    - ✓ How has land use pattern influence the extinction or growth of native species?
    - ✓ What measures exist to ensure their sustainability?

- Are natural and semi-natural areas (rivers, forests, reserves) within the landscape highly intact?
    - ✓ Has there been any change(s) in natural areas within the landscape
    - ✓ Has there been any change(s) in semi-natural areas within the landscape
    - ✓ What is the nature of this change?

- Do the natural and semi-natural areas ensure environmental security (hazards)?

- Are all critical ecosystems within the landscape conserved?
    - ✓ What are some of the critical ecosystems found within this landscape?
    - ✓ What conservation strategies exist for conserving critical ecosystems within this landscape?
    - ✓ How suitable are these conservation strategies in conserving critical ecosystems within the landscape?

- Does the landscape provide a high level of locally, regionally, and globally beneficial ecosystem services?
    - ✓ What beneficial ecosystem services are associated with the current landscape?
    - ✓ What locally beneficial ecosystem services are associated with this landscape?
    - ✓ What is the regional and global ecosystem benefits derived from the landscape?

- ✓ What is the level (e.g., low, moderate, or high) of local ecosystem benefits associated with the landscape?
- ✓ What is the level of regional and global ecosystem benefits associated with the landscape?
- ✓ Are there any ecosystem disservice (e.g., flood, hits, soil erosion, pests, etc.) in the landscape?

- Do productive areas of the landscape limit the degradation of near-by natural areas, upstream and downstream?
  - ✓ What impact does productive areas of the landscape have on natural areas?
  - ✓ To what extent does the productive areas of the landscape reduce degradation?
  - ✓ Do productive areas of the landscape limit the degradation of natural areas, upstream and downstream?

2. Sustained/enhanced livelihoods and well-being for all social groups in the landscape.
   - Are households and communities able to meet their basic needs while sustaining natural resources?
     - ✓ What are the major livelihood activities of households and communities?
     - ✓ How sustainable are these livelihood activities in meeting the basic needs of households and communities?
     - ✓ How do these livelihood activities impact on the environment?
     - ✓ How do these livelihood activities affect the sustainability of natural resources?
     - ✓ What programs/interventions/activities are/should be in place to ensure the sustainability of both livelihoods and natural resources?
   - Is the value of household and community livelihood assets increasing?
     - ✓ What changes have you observed about the household and community livelihood assets? [Natural, Physical, Financial, Social, Human]
     - ✓ How do you consider the changes in these livelihood assets?
     - ✓ How do these changes affect the value of household and community livelihood assets?
     - ✓ What livelihood support systems (health insurance,…) exist to help enhance the livelihood activities and assets of households and communities?

- Do households and communities have sustainable and equitable access to critical natural resource stocks and flows (ecosystems services)?
    - ✓ What natural resource stocks and flows are available to households and communities?
    - ✓ How accessible are these natural resources to households and communities?
    - ✓ Are these resources accessed equitably among different groups at the household and community levels?
    - ✓ What factors account for these differences if any?

- Are local economies and livelihoods resilient to changes in human and non-human dynamics?
    - ✓ What are some of the human and non-human (ex. Drought, flood) dynamics that local economies and livelihoods are vulnerable to?
    - ✓ How do these human and non-human dynamics impact on local economies and livelihoods?
    - ✓ What coping mechanisms exist for local economies and livelihoods in response to these vulnerabilities?
    - ✓ How sustainable are these coping mechanisms?

3. Establishment and maintenance of institutions for inclusive governance/management, ongoing planning, negotiation, implementation, resource mobilization, and capacity-building in support of the previous three goals of social ecological landscape sustainability.
    - Are mechanisms in place and functioning for cross-sectoral planning, monitoring and decision making at a landscape scale?
        - ✓ What mechanisms are in place for cross-sectoral planning, monitoring and decision making at a landscape scale?
        - ✓ How do these mechanisms foster cross-sectoral planning, monitoring and decision making at a landscape scale?
        - ✓ How effective are these mechanisms in enhancing cross-sectoral planning, monitoring and decision making at a landscape scale?
        - ✓ What challenges confront institutions in charge of cross-sectoral planning, monitoring and decision making at a landscape scale?
    - Do farmers, other land users, stakeholder platforms/forums, and communities have adequate capacity and are they effective in support of sustainable landscape innovations?
    - Do public institutions support effectively social and environmental sustainability?

- Do markets provide incentives (inputs) for social and environmental sustainability?
- Are supporting organizations in place to facilitate social and environmental sustainability?
- Does local knowledge, norms, and values support the sustainability of the social and environmental sustainability?

APPENDIX 2: Questionnaire for household survey

A. Household characteristics

A1. How many persons currently live in this household? .....

A2. Could you please supply the following information for all persons currently living here?

Person No.	**Relationship with head/ reference person**	**Age (years)**	**Sex**	**Marital status**	**Education attainment**	**Farming experience (in years)**
a						
b						
c						
d						
e						
f						
g						
	1. Head/reference person 2. Spouse 3. Daughter 4. Son 5. Grandchild 6. Parent/parent in-law	Age in years	1. Male 2. Female	1. Never married 2. Married 3.Separated 4. Divorced	1. No formal education 2. Basic (primary /junior secondary/ middle school	Years of farming

	7. Other…… …			5.Widowed	3. Secondary (Senior secondary/ vocational training 4. Tertiary (University/ polytechnic/ collage of education)	

A3. House ownership: 1. Owned [ ] 2. Family owned [ ] 3. Rented [ ] 4. Other [ ], please specify……..

A4. Overall condition of House Structure: 1. good [ ] 2. Average [ ] 3. Poor / needs repair

A5. Household water source:

a. For domestic purposes: 1. Pipe-borne [ ] 2. Borehole 3. Dugout well [ ] 4. Stream water [ ] 5. Other [ ], please specify…….....
b. For farming purposes: 1. Pipe-borne [ ] 2. Borehole 3. Dugout well [ ] 4. Stream water [ ] 5. Other[ ], please specify……
c. Other[ ], please specify……

B. Household farm characteristics

Could you please tell us about the characteristics of your main farm by supplying information on the following questions:

B1. How many farmlands (properties) do you have?.....

B2. Could you please estimate the size of your main farmland (Property)?.....

B3. What type of tenure does your main farmland have?

1. Owner
2. Family owned
3. Short rent
4. Long rent
5. Others, please specify……..

B4. How do you rank the soil fertility of your main farmland?

1. Low
2. Medium
3. High

B5. Please explain your answer in question B4?……

…….

…….

B6. Do you apply fertilizers on your farm?

B7. If yes, Which fertilizer is used?

B8. What is the rate of application?

B9. How often do you apply it?

B10Please indicate the date in a growing season

B11. Do you manage diseases/Pests on your crops?

B12 If yes, Which pesticides/ insecticides are used?

B13. What is the rate of application?

B14. How often do you apply it?

B15. Please indicate the date in the growing season.

B16. Do you use soil water conservation practices on your farm?

C. Household food production and consumption

C1. Please supply information on crop production in the last season:

No.	Crops	Yield	Quantity consumed	Quantity sold	Income from sale
a	Maize				
b	Millet				
c	Sorghum				
d	Rice				
e	Soya beans				
f	Bambara beans				

g	Vegetables				
h	Tree crops (cash crops)				
i	Other, specify… ……..				
Notes:					

C2. Does your household depend on its own production of food?

1. Yes [ ] Go to question C3
2. No [ ] Go to question D1

C3. What percentage of your household food do you produce?

1. ≤ 20%
2. 21-40
3. 41-60
4. 61-80
5. ≥ 81

D. Household food security

D1. Are there times within the year that your household does not have enough food?

1. Yes[ ] Go to questions D2, D3, & D4
2. No[ ] Go to question E1

D2. How many months in a year does your household struggle to get enough food?

1. 1-3 months
2. 3-6 months
3. > 6 months

D3. During which period of the year does your household struggle the most to get enough food? **(Multiple answers allowed)**

1. January to April
2. May – August
3. September - December

D4. How does the household cope with food shortages during these periods? (**Multiple answers allowed**)

1. Buy food from market
2. Friends and relatives bring us food
3. Reduce food intake
4. Other, please specify…….

E. Household Livestock

E1. Does your household own any livestock?

1. Yes [ ]Go to question E2
2. No [ ] Go to question F1

D2. Please supply information on household livestock in the following table (**Multiple answers allowed):**

No.	**Livestock/poultry**	**Quantity**	**Estimated income**
a	Goats		
b	Sheep		
c	Cattle		
d	Pigs		
e	Drought animals (e.g., bullocks and donkeys)		
f	Chickens		
g	Guinea Fowls		

h	Ducks		
i	Others, please specify……..		

F. Household livelihood diversification and alternative income sources

F1. Do you or any members of your household engage in any other livelihood activities apart from farming?

1. Yes [ ] Go questions F2 and F3
2. No[ ] Go to question G1

F2. How many members of your household engage in other livelihood activities? …….

F3. Do you or other household members of your household engage in any of the following livelihood activities? (**Multiple answers allowed**)

No.	Livelihood activities	Tick box	
		Yes	No
a	Occasional off-farm work (e.g. labour)		
b	Handicrafts (e.g. weaving and wood carving)		
c	Fishing		
d	Commerce (small scale trading)		
e	Mining		
f	Salaried permanent work		
g	Charcoal production		
h	Logging		
i	Shea butter processing		

j	Rice processing		
k	Local alcohol brewing		
l	Other, please specify……		

G. External income and migration

G1. Do you have family members and/or friends working outside the community?

1. Yes
2. No

G2. Do you receive any remittance from family members and/or friends who live outside this community?

1. Yes [ ] Go to question G3
2. No [ ] Go to question G4

G3. Approximately, how much do you receive as remittance from relatives and/or friends in a year?

1. ≤ 100GhS
2. 101 – 300 GhS
3. 301 – 400 GhS
4. 401- 500 GhS
5. ≥ 501 GhS

G4. Do you have any intentions of moving away from this community or sending any household member to the city?

1. Yes[ ] Go to question G5 & G6
2. No[ ] Go to question H1

G5. Who in the household is most likely to go?

1. Household head
2. Spouse
3. Son/daughter
4. Brother/sister
5. Other, please specify…….

G6. What are the reasons for moving away from this community or sending any household member to the city? …….

……

……...

H. Social network

H1. Do you belong to any group or association?

1. Yes [ ] Go to question H2
2. No [ ] Go to question I1

H2. Could you please supply information on the type of group, the benefits from the group, and your contribution to the group:**Multiple answers allowed.**

No.	Name of group/association	Name of group	Benefits from the group	Contribution to the group
a	Faith-based			
b	Communal			
c	Farm-based			
d	Other, please specify……..... ……			

I. Household physical assets

I1. Do you or any member of your household own any of the following assets? **(Multiple answers allowed)**

No.	Physical assets	Tick box	
		Yes	No
a	Radio set		
b	TV set		
c	Mobile phone/Landline		

d	Mosquito nets		
e	Tricycle/Bicycle		
f	Car/Motor bicycle		
g	Sewing machine		
h	Water tank/Well		
i	Hoe/cutlass/pickaxe/shovel		
j	Tractor		
k	Plough (wooden/Iron)		
l	Pesticide/weedicide sprayer		
m	Wheel Barrow		
n	Diesel/electric irrigation pump		
o	Fodder cutting machine		

J. Irrigation

J1. Do you practice irrigation in your agricultural practices?

J3. What crops do you cultivate using irrigation?

J4. Indicate the farm area under irrigation and the area that is non-irrigated (hectare)

J5. What is the primary source of water for irrigation on your farm?

J6. What is the distance of water from the farm? (In minutes)

J7. Are there alternative water sources available for irrigation?

J8. If yes, please specify.

J9. How reliable and consistent is the water supply for irrigation on your farm?

J10. What type of pump do you use for irrigation?

J11. Do you divert water from rivers by gravity?

J12. If other please, specify

J13. What irrigation method(s) do you use on your cocoa farm? (Select all that apply)

J14. How do you determine when to irrigate your farm?

J15. How frequently do you irrigate your farm during the growing season?

J16. Are there any specific challenges or limitations you face in managing irrigation on your farm?

J17. If yes, please explain.

J18. Are you considering any negative changes or improvements in your irrigation practices?

J20. If yes, please describe.

J21. Would you be interested in receiving further training or support related to irrigation practices?

J22. If yes, please specify the topics of interest.

F. Floods and erosion

F1. Have you or anyone in your community experienced a flood (or soil erosion) that significantly affected your livelihood?

F2. If yes to the above, in which part of the area or landscape component, flood (soil erosion) is significantly happening?

F3. How frequently do floods (or soil erosion) occur in your area or landscape?

F4. What are the primary causes of floods in your area or landscape? (Select all that apply)

- Heavy rainfall
- Poor drainage systems
- Overflowing rivers or lakes
- Deforestation
- Urbanization and improper land use
- Climate change
- Other (please specify)

F5. Are you aware of the causes of soil erosion in your area? (Select all that apply)

- Water erosion (rainfall-runoff, rivers, etc.)
- Wind erosion
- Steep slopes and topography
- Deforestation and land clearance
- Unsustainable agricultural practices
- Construction and urban development
- Other (please specify)

F6. How has your livelihood been impacted by past flood events (or soil erosion), if applicable? (Select all that apply)

- Loss of crops or agricultural produce
- Damage or loss of livestock
- Disruption of business operations
- Loss of income or employment
- Damage to infrastructure or property
- Inability to access markets or customers
- Other (please specify)

F7. Are there any flood management (or soil erosion control) efforts in the area?

F8. If yes to the above, what are those efforts? how satisfied are you with the current flood management (or soil erosion control) efforts?