A Collaborative Evaluation of a Large-Scale Integrated Landscape Restoration Project in the Steep-Slope Regions of Central Africa

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38

39   **Abstract**

40   Landscape restoration projects are among the most extensive conservation actions at the global level that
41   have been promoted in the last three decades. Such projects, however, cannot exclusively be based on the
42   restoration of natural and semi-natural ecosystems, but should focus on a cultural landscape approach
43   balancing environmental and socio-economic needs. One of the largest restoration projects realized in the
44   last five years was the World Bank's Burundi Landscape Restoration and Resilience Project (PRRPB). PRRPB
45   utilized an integrated approach to restore the social-ecological systems in different steep-slope areas of
46   Burundi, adopting a mix of landscape restoration solutions (slow-forming terraces, reforestation, etc.) and
47   socio-economic measures. With a large-sample questionnaire, realized on the field with the local population,
48   the following work aimed at assessing the impact, at the local level, of one of the largest landscape
49   restoration projects carried out in a fragile region like Burundian sloping lands. The most perceived
50   vulnerabilities were "Soil erosion and degradation" followed by "Reduction of agricultural production and/or
51   food security". Most of the interviewed perceived that the project was successful in combating soil erosion
52   as well as in providing other benefits to the local population, and around 60% perceived an improvement in
53   socio-economic conditions. At the same time, results assessed the high reliance of the local food security on
54   traditional agricultural production and the possible positive/negative impacts of rural tourism as perceived
55   by local communities. Project results could be used by local and national stakeholders to implement further
56   initiatives at the local level and will be informative for similar projects in the region.

57   **Keywords:** Burundi, terraces, slow-forming terraces, participation, project evaluation, land and water
58   management, landscape perception, landscape restoration

59

1. Introduction

61   Landscape restoration projects are among the most expensive and extensive conservation actions at the
62   global level that have been promoted in the last three decades (Holl et al. 2003). Landscape restoration,
63   however, is not a simple procedure solely based on the restoration on natural values, but it requires the
64   integration of ecological, social, and economical issues, and should be based on restoring the long-term
65   sustainability of the agro-ecological systems rather than maximizing the short-term benefits, with
66   considerable additional difficulties where land tenure is insecure (Chazdon et al. 2017; Bullock et al. 2011).
67   In the last years, in fact, it has become evident that landscape restoration cannot be exclusively based on the
68   restoration of natural and semi-natural ecosystems from a purely ecological or productive perspective, but
69   has to be based on a cultural landscape approach balancing environmental and socio-economic needs
70   (Chazdon et al. 2020). Therefore, it is necessary to carefully consider and integrate local landscape structure
71   and features, with Traditional Ecological Knowledge (TEK) and local cultural heritage (Moreira et al. 2006;
72   Henze and Santoro 2024).

73   Landscape restoration can be motivated by several factors, including overexploitation of forest resources and
74   deforestation, occurrence of forest fires, overexploitation of rangelands, soil erosion due to unsustainable
75   agricultural practices, loss of soil fertility. Forest landscape restoration and slope terrain restoration for

76 hydrogeological purposes are among the most common types of landscape restoration (Stanturf et al. 2019;
77 Fusco Girard et al. 2019; LaFevor 2014), especially in developing countries.

78 The main challenges and criticalities of landscape restoration projects are related to the overall long-term
79 sustainability, limited monitoring, poor governance structures, and technical barriers due to institutional
80 weaknesses (Ota et al. 2020). In addition, while the ecological impact of landscape restoration projects can
81 be easily assessed after the project implementation (i.e. reduced hydrogeological risk, forest surface, soil
82 fertility,...), the social impacts (positive and negative) and the consequences on the wellbeing of local
83 communities are more difficult to evaluate (César et al. 2020). Monitoring the real social and economic
84 impacts of landscape restoration projects is of crucial importance for planning corrective measures and for
85 the further development of the project itself; therefore, to enhance benefits to local communities it is
86 necessary to integrate socioeconomic and political data into planning, implementation, and monitoring
87 (Erbaugh and Oldekop 2018). Different studies, in fact, reported that when the expectations and needs of
88 local communities are disregarded in landscape restoration planning and implementation, there is a high risk
89 of project failure (Höhl et al. 2020).

90 Research activities can, therefore, have a key role in contributing to the assessment of the perception and
91 consequences among local communities towards landscape restoration projects, both regarding the initial
92 needs, the expectations, and the impacts (Ullah et al. 2021). Among the different issues that needs to be
93 assessed among the local communities regarding landscape restoration projects, non-utilitarian values are
94 often less considered; however, these values are considered vital to understanding the holistic value of
95 restoration initiatives and the effective impact at the local level in the long-term (Wainaina et al. 2023). The
96 evaluation of benefits and real impacts on population wellbeing and according to their expectations is
97 particularly crucial in developing countries, where the socio-economic context can be really different and
98 where it is essential to actively involve the rural communities (Wolka et al. 2023). According to Ahammad et
99 al. (Ahammad et al. 2023), in fact, disregarding local communities' needs and expectations, during past forest
100 landscape restoration projects has led to limited long-term social and ecological benefits. In addition, the
101 evaluation of socio-economic impacts among the local communities can also provide relevant stakeholders
102 with reliable data that can help to better address further implementation activities.

103 One of the largest landscape restoration projects realized in fragile development contexts in the latest five
104 years was the World Bank's Burundi Landscape Restoration and Resilience Project - PRRPB (World Bank
105 2018). The project was approved on 11.04.2018 by the World Bank's board and run until 30.11.2024 (World
106 Bank 2024a). Burundi's landscapes are in fact threatened by severe land degradation (Tall et al. 2023) and
107 PRRPB implemented some innovative landscape restoration in Bujumbura Rural Province (in the Isare
108 Commune, the second administrative level) and Muyinga Province (in the Buhinyuza Commune) on a total of
109 22 "Collines" (Hills, namely the third level of national administration) (Preti et al. 2025). The Project
110 Development Objective (PDO) was to "to restore land productivity in targeted degraded landscapes and, in
111 the event of an eligible crisis or emergency, to provide immediate and effective response to said eligible crisis
112 or emergency."

113 The project adopted a slope class-based rule for landscape restoration: progressive (or slow-forming)
114 terraces (figure 1) were the main technique utilized (Castelli et al. 2024; Kraemer et al. 2019; Kagabo et al.
115 2013) between 6 and 60% slope, integrated with contour grass hedges (Yu et al. 2011) for slopes below 6%,
116 and afforestation for very steep slopes, above 60%. Where the soil was not deep enough for implementing
117 terraces, afforestation and perennial crop cover were proposed as alternatives to terracing. Furthermore,
118 the project supported the improved management of three protected areas in Burundi, and the development

119 of policies and capacities at local and national scale (World Bank 2018). After the first phase, the project was
120 also extended to Kayanza province from 24.05.2021 (World Bank 2021).

121

122 *Figure 1 - Progressive (slow-forming) terraces implemented through the World Bank's Burundi Landscape*
123 *Restoration and Resilience Project (PRRPB)*

124 According to World Bank official statistics (World Bank 2024b), in June 2024 PRRPB had achieved 102,757.00
125 ha of land under sustainable land management, with a "share of targeted community members with rating
126 'Satisfied' or above on project interventions of 70%. Such data, however, could not capture the complex and
127 potentially insightful perceptions of impacts of the local population. Therefore, the aims of this research were
128 to:

129 ● Assess the impact at the local level of one of the largest landscape restoration projects carried out in
130   a developing country in the last decade;
131 ● Provide local, national, and international stakeholders with reliable data that can be used for
132   correction activities or to plan new activities for sustainable rural development;
133 ● Propose a methodological framework for the assessment of the impact among the local population
134   of landscape restoration projects in developing countries.

135

136 **2. Materials and methods**
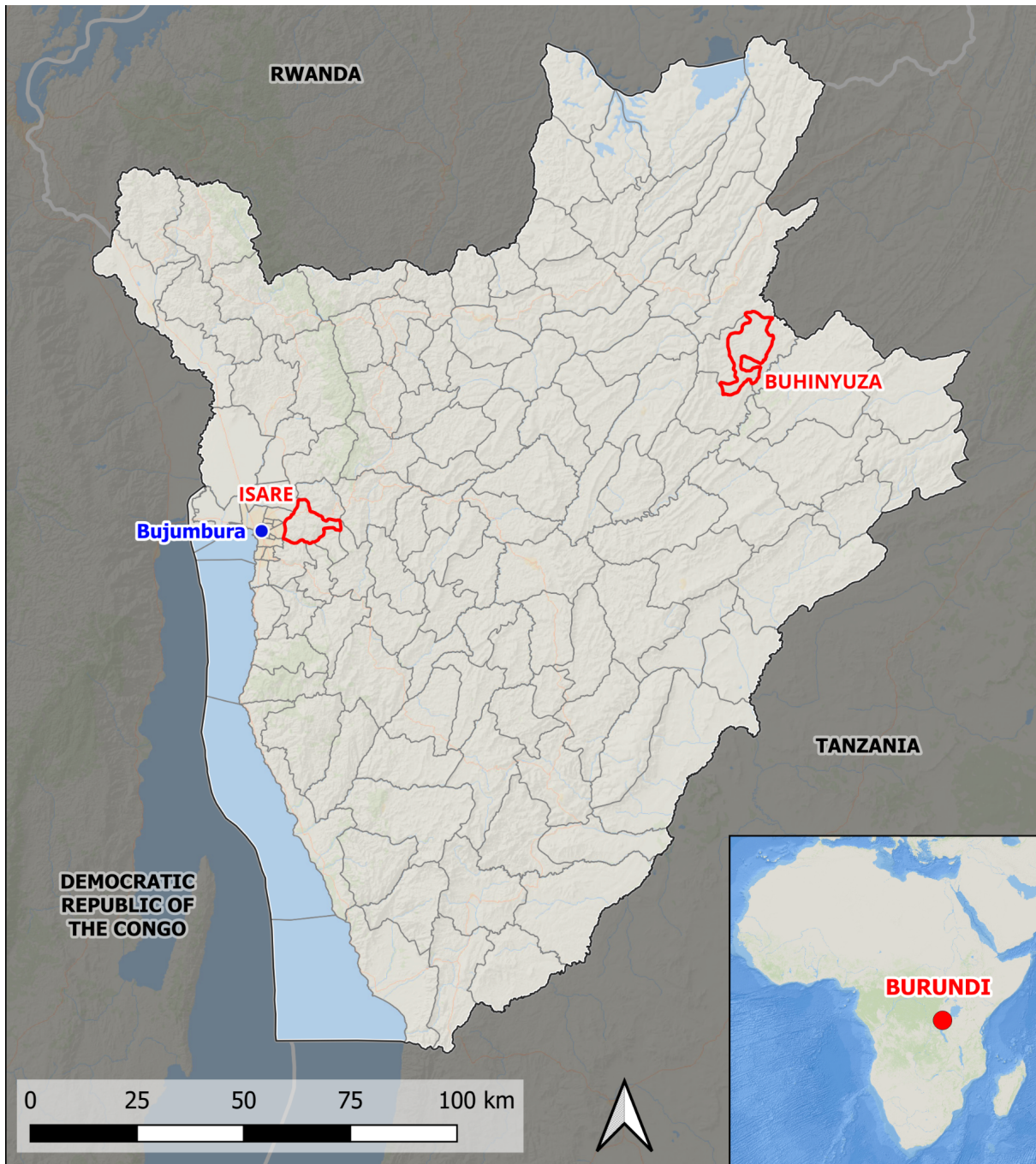
137 **2.1 The study area**

138 The study area corresponds to 20 different *collines* belonging to two different Burundian municipalities
139 (locally called *communes*) (Figure 2), covering the 90% of the administrative units where PRRPB was
140 implemented from 2018, excluding Kayanza province:

141 ● Isare commune: Benga, Bibare, Caranka, Gishingano, Karunga, Kwigere, Nyakibande, Nyambuye,
142   Rushubi, Rutegama.

143 ● Buhinyuza commune: Bugungu, Bunywana, Gasave, Gitaramuka, Karehe, Kibimba, Kiyange,
144   Muramba, Ntobwe, Nyaruhengeri.

145 Isare commune is located in the Bujumbura Rural province, with the steepest topography in the country. The
146 altitude ranges from about 1,000 to 2,000 m a.s.l. (MINEAGRIE 2022). The soils are mainly recent tropical
147 soils and kaolisols, classified as ferrisols and ferralsols with clay derived from shales (ISABU 2014). Here,
148 annual precipitation ranges from 1,000 to 1,900 mm/year, increasing with altitude (PRRPB 2021). Buhinyuza
149 commune, on the other side of the country, is located in the eastern depressions. The area has gentler hills
150 with milder slopes, which are increasing near the marshlands. The average altitude ranges from 1300 to 1500
151 m a.s.l. (PRRPB 2020). The soils are primarily ferralsols, ranging from clayey to clayey-sandy textures (ISABU,
152 2014). Rainfall is comprehended in the interval 1,000-1,100 mm/year (PRRPB 2021).

153 Additionally, there is a notable geographical and settlement difference: while the collines of Isare are located
154 adjacent to Bujumbura, the main city of Burundi, the collines of Buhinyuza are situated far from the main
155 urban centers of the country. Although both areas are rural, Isare is undoubtedly influenced by its proximity
156 to the city, which impacts the socio-economic dynamics of the region. In example, according to the 2021
157 Burundi Statistic Yearbook (Institut National de la Statistique du Burundi 2023), the operating revenues of
158 Isare municipality was equal to 270,725,000 FBU while for Buhinyuza only reached 133,260,000 FBU. This is
159 further reflected in the population density of the two communes, with Isare having 1,138 inhabitants per km²
160 compared to Buhinyuza's 304 inhabitants per km².

Figure 2. The location of the two study areas (in red); communes administrative borders (in grey).

2.3 Methodological framework

The applied methodology is based on the use of anonymous questionnaires. The use of questionnaires to investigate landscape perception, expectations and/or needs, as well as other territorial-based issue among different target groups has been attested since the 1980s, in particular to deepen the knowledge of how different landscapes or landscape characteristics are perceived by different groups to support planning and decision making (Zube et al. 1982; Purcell et al. 1994; Kaplan 1990; Myers and Thompson 2003). Anonymous questionnaires can be used to directly interview people in the field or can be administered through computer-based surveys; while the first option is related to the availability in the field of people who needs to be trained to avoid influencing the answers of the respondents, the second option often result to be heavily dependent on the practice of the respondents to use web-based tools and, therefore, can exclude a

174 significant part of the sample (i.e. elderly people, people having no access to internet or to electronic devices)
175 (Ducci et al. 2023; Zhou et al. 2023). Questionnaires can be structured in different ways, but they need to
176 follow simple principles in order to obtain reliable results. First of all, questionnaires have to be constructed
177 according to the characteristics of the target group, especially regarding the use of technical/everyday
178 language; in addition, it is necessary to include simple questions with a clearly understandable language and
179 suitable variables, with simple and clear instructions, while the overall number of the questions should be
180 limited and too similar questions should be avoided (Fernández Álvarez and Fernández 2021). In addition,
181 besides open or multiple-choice questions, they can integrate pictures and/or photomontages or virtual
182 images to better assess public preferences regarding different landscapes or different landscape features.
183 (Tempesta 2010; Torquati et al. 2020; Dupont et al. 2014; Kazemi et al. 2023). Finally, questionnaires can be
184 used to integrate environmental and landscape/or data collected in the field, applying a multidisciplinary
185 methodology (Boselli et al. 2020) to provide different data for local territorial and landscape planning in
186 different contexts and at different scales (Santoro et al. 2021; De Marinis et al. 2020).

187 In addition to the questionnaire results analyses, a spatial analysis of the morphology and of land cover has
188 been conducted to identify possible differences between the two investigated communes and to highlight
189 possible links with the answers of the respondents. Regarding the morphology, the analysis has been based
190 on a 10 m resolution Digital Terrain Model (DTM) produced in 2012 by the Bureau de Centralisation
191 Géomatique (BCG) of Burundi; a slope classification has been carried out according to the following slope
192 classes: 0-5%, 5-10%, 10-20%, 20-30%, 30-40%, 40-50%, >50%. The land cover analysis has been carried out
193 using the European Space Agency World Cover 2021 with a resolution of 10 m (Zanaga et al. 2022). All the
194 spatial analyses have been performed with the software QGIS 3.32. These preliminary analysis of
195 morphological and land cover characteristics, along with the geographical and settlement context, aids in
196 framing the distinct realities of Buhinyuza and Isare. This approach ensures that the unique environmental,
197 topographical, and socio-economic features influencing the regions are accurately represented, providing a
198 robust context for the subsequent analysis of questionnaire results.

199

200 **2.4 The questionnaires**

201 The questionnaire used in this study is based on 23 different questions (Annex 1). The questionnaire was
202 based on different types of questions to investigate different aspects: multiple-choice, close-ended, Likert-
203 type scale (from 1 to 5), and choice of preference between two photos. The decision to avoid completely
204 open questions is due to the fact that, in this way, results can be easily processed in a semi-quantitative way,
205 reducing biases (Stantcheva 2023). At the beginning of the questionnaire, a brief introduction was added
206 containing information about the aim of the survey, the overall framework, the fact that questionnaires were
207 completely anonymous, and that data would be collected and stored in accordance with the rules of the
208 General Data Protection Regulation (GDPR - EU Regulation 679/2016). Questionnaires were originally built in
209 English, and then were translated into French and Kirundi. The questionnaire was structured into five
210 different sections:

211 1. General information; this part has been set to collect general personal information, including age,
212   gender, education level, main occupation, place of residence;
213 2. Consumption of local agricultural products and role of women; the second section was based on
214   questions related to food habits, consumption of local agricultural products, food security, and to
215   the role of women in agricultural activities;
216 3. Environmental vulnerabilities; this part focused on the identification of the main environmental
217   vulnerabilities through a Likert scale question;

4. Landscape perception and communities' expectations; the last section focused on landscape perception, on different landscape features, on the role of local authorities, on the expectations, and on the possible role of ecotourism, through Likert scale questions and one photo-based question;

5. Local impact of the PRRPB project; this part focused on the assessment of the local awareness of the PRRPB project and of its impact at the local level.

Questionnaires were distributed in the field during the months of October and November 2024 (Figure 3) by an interviewer who administered the questionnaires in Kirundi (the local language spoken in Burundi).

Figure 3. Data collection through questionnaires on 19.11.2024

2.5 Clusterization and elaboration of the questionnaires results

DIfferent attempts of clusterization of the results have been made to link the perceived impacts with the local biophysical and/or socio-economic conditions. The first attempt was based on performing a cluster analysis using k-mean methodology (Peng and Guiqiong 2011; MacQueen 1967) using morphological data such as average altitude and slope per *collines* derived from the 10 meters resolution DTM. The goal of this analysis was to identify homogeneous groups of surveyed *collines* in terms of morphological characteristics, to better sort and explain the results of the questionnaires. As a result, four distinct clusters were identified (Supplementary material 1): one encompassing the entire area of Buhinyuza and three subdividing the area of Isare. While these findings highlighted the morphological diversity within Isare, due to the substantial differences between these clusters it became challenging to draw meaningful comparisons of the questionnaires; the difference in number of questionnaires per cluster was too wide, and some of the smaller clusters only had few results. Therefore, it was decided to clusterize the results only according to the administrative division based on the two *communes* involved (Buhinyuza and Isare), also because these two municipalities present some significant differences in socio-economic and landscape structure terms; this allowed to obtain a more coherent and comprehensive analysis of the results.

Once the decision to use clustering by *communes* was made, morphological and land cover analyses were conducted to provide context for the results, to help to outline the characteristics of the selected areas and to justify the choice of clustering. The introduction of morphological, land cover, and settlement analyses serves to contextualize the distinct environments where the questionnaires were collected. These analyses

248 highlight the significant differences and unique characteristics of the two study areas, Buhinyuza and Isare.
249 The geographical separation and the diversity in terrain and land cover confirmed the necessity of studying
250 these areas separately.

251 On the data resulting from 1-5 Likert scale questions, additional statistical elaboration was conducted to
252 assess the reliability using the Mann-Whitney test, with a significance level of 0.05. This non-parametric test
253 was chosen because the data are not normally distributed, and it is effective in comparing two independent
254 samples (Meléndez et al. 2020), allowing us to determine if there were statistically significant differences
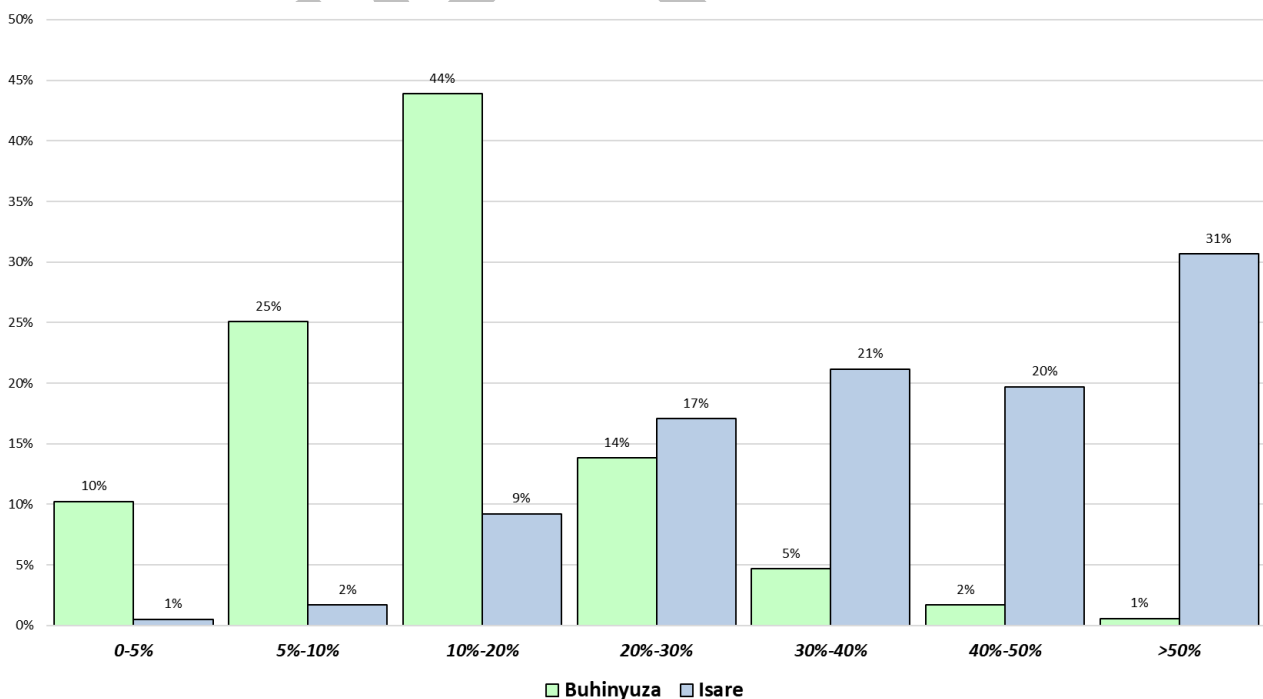255 between the distributions of the two groups.

256

257 3. Results

258 3.1 Morphological and land cover analysis

259 Analyzing the morphological characteristics, it is possible to observe a marked difference in altitude ranges.
260 Altitude values for the study area in Buhinyuza range from a minimum of 1340 m a.s.l. to a maximum of 1665
261 m a.s.l., with an average of 1462 m a.s.l. and a standard deviation of 51 m. In contrast, the study area in Isare
262 displays a broader altitude range, with values spanning from 907 to 2133 m a.s.l., an average altitude of 1433
263 m a.s.l., and a much larger standard deviation of 256 m. Notable differences can be observed by the slope
264 distribution in classes (Figure 4), especially considering that more than the half of Isare study area surface
265 has a slope higher than 40%, while most of the Buhinyuza one falls in the range 10–20%. Isare study area
266 surface is more uniform in the different slope classes, except for the lower ones considering that only 3% of
267 the surface has a slope lower than 10% compared to Buhinyuza's 35%. This indicates a more heterogeneous
268 and rugged landscape in Isare with a high percentage of the surface with steep slopes, compared to the
269 relatively uniform and gentler slopes of Buhinyuza. The average slope further accentuates this contrast, with
270 Isare exhibiting a significantly steeper average slope of 41.5% compared to Buhinyuza's 14.7%, confirming a
271 more rugged and uneven terrain in Isare.

272

274 *Figure 4. Slope distribution for the two study areas located in the communes of Isare and Buhinyuza.*

275

276　The land cover analysis revealed substantial differences between the two *communes* (Figure 5), as a
277　consequence of the different morphology. Buhinyuza is primarily characterized by herbaceous cultivations,
278　which constitutes 27% of its land cover, thanks to the gentler slopes, whereas Isare has a mere 4% of its area
279　dedicated to herbaceous cultivations due to a more rugged terrain. This stark contrast underscores
280　Buhinyuza's reliance on agriculture. In terms of built-up areas, Isare slightly surpasses Buhinyuza, with 3% of
281　its land classified as built-up compared to Buhinyuza's 1%. Grasslands are predominant in both areas,
282　covering 39% of Buhinyuza and 46% of Isare. However, Isare demonstrates a higher percentage of tree and
283　shrub cover (47%), while tree cover in Buhinyuza only reaches 33%. This dataset does not take into
284　consideration the land use, and is based on the types of land cover; therefore, tree and shrubs cover
285　corresponds to forests, agroforestry systems and specialized tree plantations, including oil palm plantations.
286　These differences in land cover types are reflective of the distinct morphological and anthropogenic
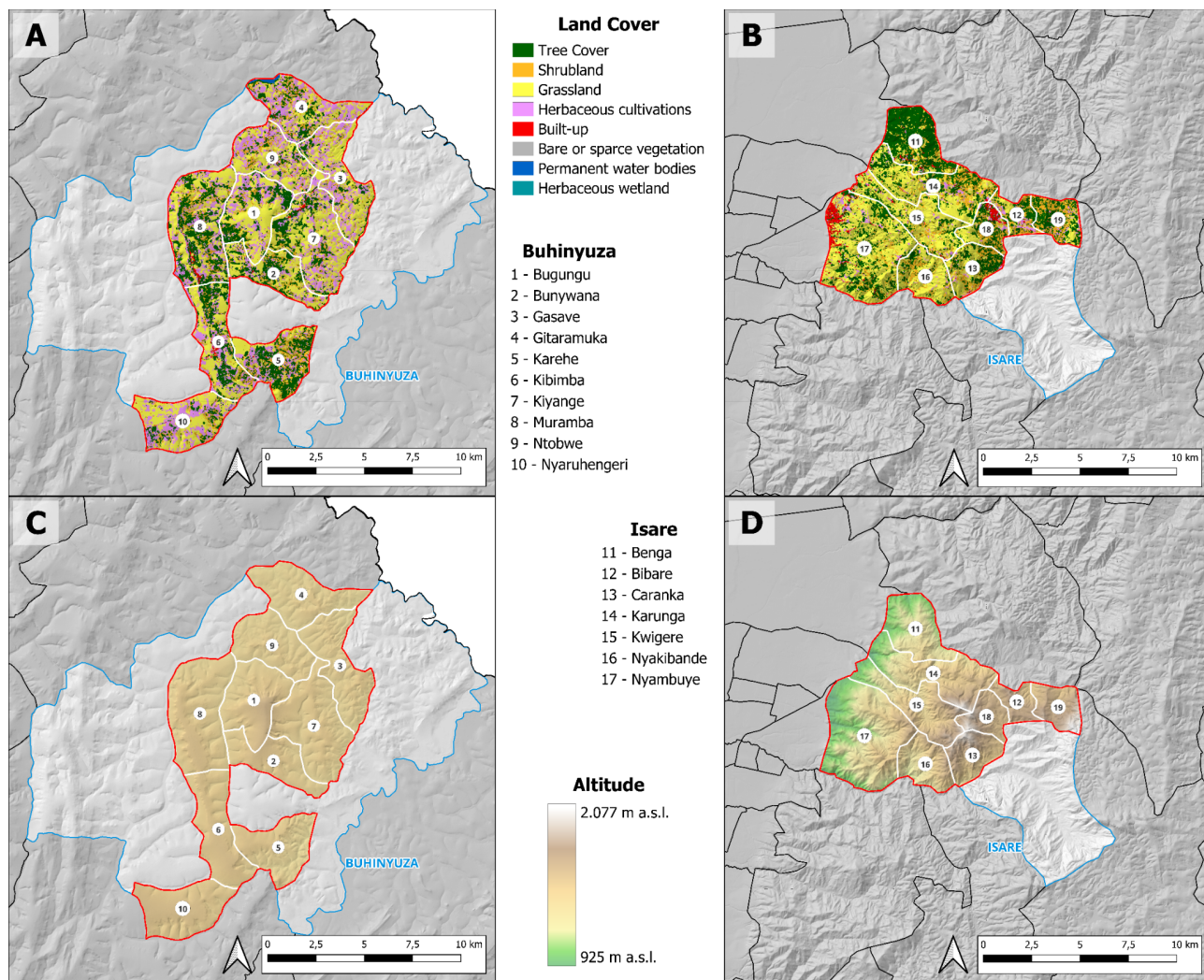287　influences in each *commune* (Figure 6).

288
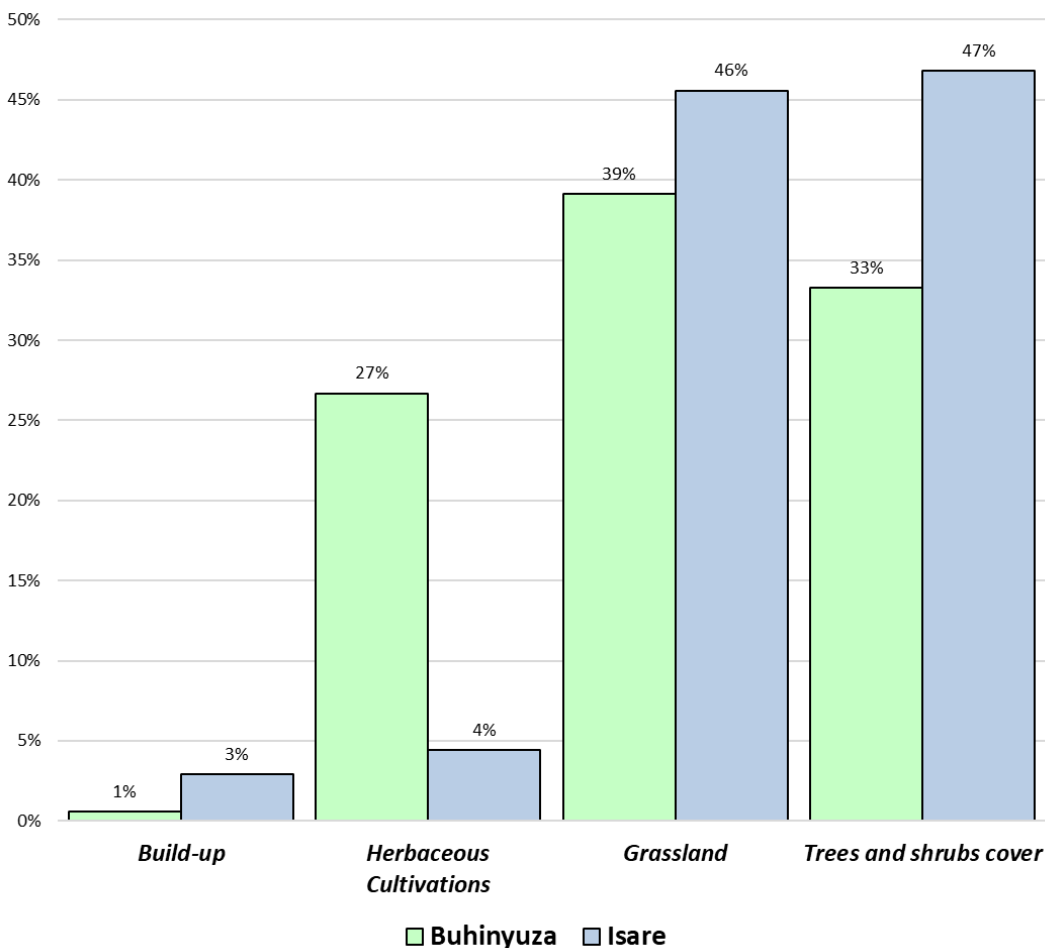
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290　*Figure 5. Main land cover categories for the two study areas located in the communes of Isare and Buhinyuza*
291　*according to 2021 data.*

292

Figure 6. Land cover (A and B) and altimetric (C and D) maps for the two study areas located in the communes of Buhinyuza (left) and Isare (right).

3.2 General information of the interviewed sample

The total interviewed sample (complete database is reported in Supplementary material 2) resulted in 195 respondents (statistical significance with a confidence >90% and an error <10%), most of which residing in Isare municipality (128), and the remaining 67 in Buhinyuza municipality. Respondents resulted to be equally distributed among genders with 50% female and 50% male respondents, but in Isare women prevail (61% of the sample) while in Buhinyuza they represent only 28% of the sample. Most of the respondents (27.2%) fall within the age range 31-40, followed by the 26-30 (21% of the respondents) and 41-50 (16.9%) age ranges; females were more present in the younger age ranges, while men predominate above 40 years and also in the range 26-30 years (Figure 7). Overall, 56.9% completed the primary school, 21.5% completed the high school and 4.1% completed a higher educational level. Distribution regarding the level of education by gender is uniform in primary school and high school, but higher education was only completed by men, testifying a difficulty of accessing higher education for women especially in rural areas; 17.4% of the total respondents have no formal education. 81.5% of the sample is married, while 12.8% declare to be single and 5.6% widow/widower.
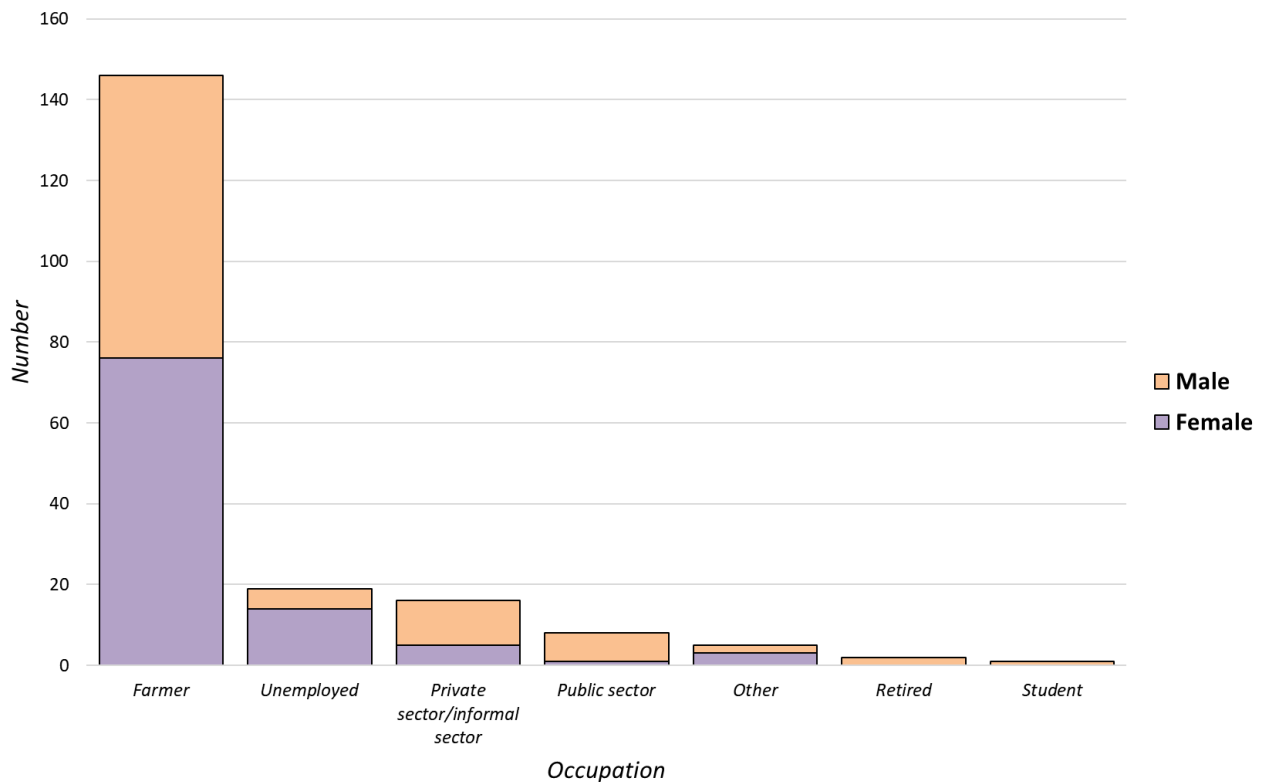
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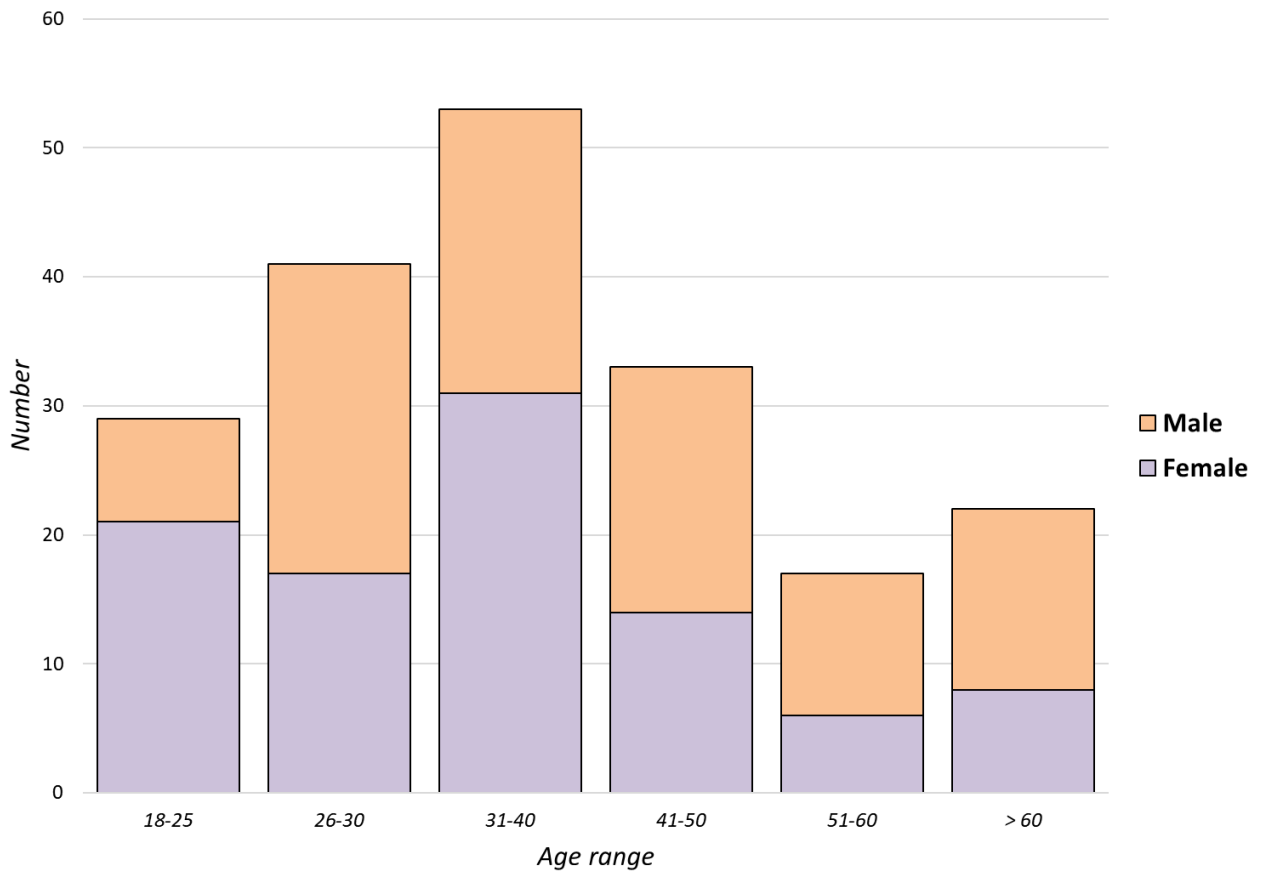
Figure 7. Age distribution according to the gender for the total interviewed sample.

314

Regarding the main professional activity/source of income, 74.9% of the respondents declare to be farmers (Figure 8), with a slight prevalence of women, while 9.7% are unemployed (almost all of them live in Isare municipality) of which two thirds are represented by women. Beside an 8.2% of respondents involved in the private/informal sector (most of them men in Isare municipality), the rest of the categories (students, public sector, retired) are scarcely represented.

320

Figure 8. Main professional activity/source of income according to the gender for the total interviewed sample.

323

The respondents are distributed within 20 different *collines*, with Rushubi being the most represented with 18 respondents and Nyaruhengeri being the least represented with only 5 respondents; the average number of respondents for *colline* is equal to 9.8 people. Overall, most of the respondents have been living in the same location for a relatively long time, considering that 84.1% of them affirmed that they are living in the in the same place before 2018, testifying a direct and well-established knowledge of the place and of the changes that may have affected it; only 9.2% of the respondents moved in the place after 2018, while 6.7% of them preferred not to answer to this question.

331

3.3 Consumption of local agricultural products and role of women

The consumption of local products and the role of the women section provided useful insight regarding the local agricultural sector. This latter one turned out to be crucial for the livelihood and the food security of the local population, but with significant differences between Isare and Buhinyuza. In Buhinyuza, 38.8% of the respondents rarely or never consume non-local food, while in Isare this percentage is only equal to 17.2%, but in both *communes* the consumption of local grown products seems to be particularly important for the local food security, as 80% of the total respondents consider them "very important" and the remaining 20% consider it "important" with no particular differences between the two *communes*.

The main reason for choosing locally grown agricultural products is due to an economic reason, especially in Buhinyuza where 90% of the respondents declared that the choice is due to the fact that local products have "Lower cost compared to non-local/imported food", while in Isare this percentage has a lower value (70%), probably due to the proximity of the capital, Bujumbura (Figure 9). Other significant drivers in choosing local food products are related to "support farmers and the local economy" (84% in Buhinyuza, 55% in Isare). In

Buhinyuza also "contribute to the preservation of the local landscape", "superior taste and quality", "health and nutritional benefits", or being "part of the culinary culture of the region" seemed to be important drivers (each of them chosen by more than 70% of the respondents, while in Isare the percentages of respondents who chose these reasons are all lower than 50%. In some *collines*, in addition, the main choice of preferring local agricultural products do not seem to be based on lower prices compared to non-local/imported food, as in Nyambuye, Bibare, and Karunga, but on different reasons including "support farmers and the local economy" and "contribute to the preservation of the local landscape".
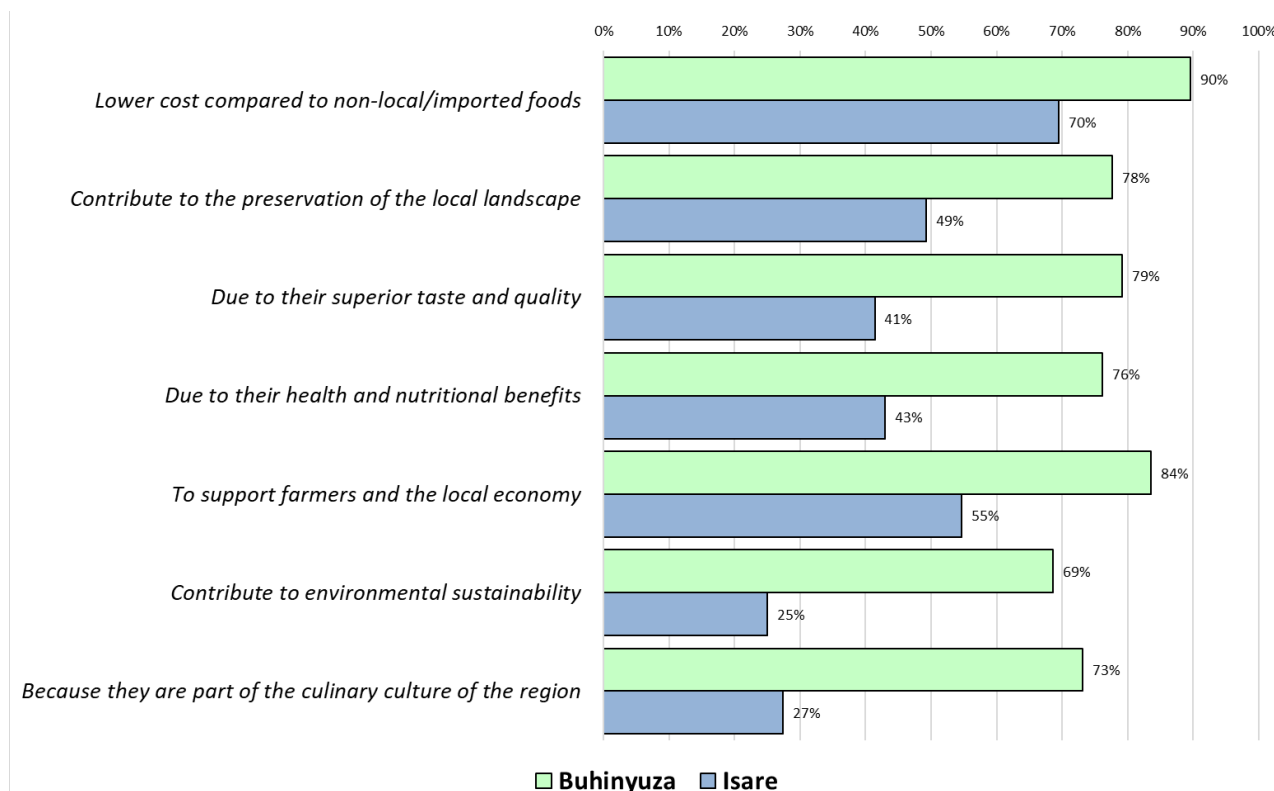
Figure 9. Main reasons for choosing locally grown food according to the opinions of the respondents of Isare and Buhinyuza study areas.

Among all the respondents, a large majority (97.4%) own cultivated land, and most of them cultivate it for self-consumption, while only few people cultivate agricultural products for selling at markets; this data testifies that most of the local agricultural activities is for self-consumption by the local families, both in Isare and Buhinyuza, therefore representing a key resource for their food security.

The role of women in the local agricultural sector seems to be important especially in Buhinyuza, where 94% of the respondents indicated that women "directly participate in agricultural activities as labour force" and 79% confirmed that women are indirectly involved "by choosing the crops to be cultivated", while in Isare this percentages are lower (69% and 59%, respectively). As in many rural societies, women are also responsible for "preserving the local seed varieties" (this option has been chosen by 72% of Buhinyuza respondents and by 47% by Isare respondents), while their involvement in "processing and market selling" resulted to be more limited (52% in Buhinyuza and 30% in Isare). FInally, the answer "No, women do not participate in agricultural activities" has been chosen by 4% of respondents in Isare while in Buhinyuza none of the respondents selected this option. Some differences are also reported for some *collines*, while in general no particular differences has been highlighted between the answers of men and women; in Karunga, Rushubi, GIshingano, and Kwigere, women seem to be less involved, directly or indirectly, in agricultural

371 activities; while, in Nyambuye, according to most of the respondents, women are more indirectly involved
372 rather than as a direct labour force.

373

374 **3.4 Environmental vulnerabilities**

375 Concerning the most meaningful environmental vulnerabilities impacting the area (Table 1) as perceived by
376 the local population, generally in Buhinyuza the different options reached higher scores, with the highest
377 being "Soil erosion, landslides, and degradation" (4.4 in Buhinyuza, 4 in Isare, difference statistically
378 significant p-value z 0.05). In Buhinyuza many vulnerabilities were scored higher than 4, including "Reduction
379 of agricultural production and/or food security", "Limited access to water for domestic use", "Frequency of
380 droughts and water scarcity", "Forests converted into agricultural surface", "Loss of traditional landscape",
381 and "Loss of traditional crop varieties". In Isare only the "Reduction of agricultural production and/or food
382 security" option received a score higher than 4. In addition, while in Buhinyuza problems related to water
383 quality and quantity ("Deterioration of water quality", and "Lowering of water levels in wells") both received
384 high scores (4 and 3.9, respectively) probably due to criticalities in the management of water sources, in Isare
385 municipality these issues received significantly lower values (2.7 and 2.3, respectively). Conversely, "Difficulty
386 in obtaining firewood or timber for construction" received a high score in Isare (3.9) while in Buhinyuza it
387 does not seem to represent a major concern (2.5). Some differences among the *collines* can also be found,
388 i.e. in some of the surveyed *collines*, "Difficulty in obtaining firewood or timber for construction"
389 (Nyakibande, Rutegama) and "Lowering the water level in wells" (Bunywana, Gasave, and Karehe) obtained
390 particularly high values, testifying local problems related to overexploitation of forest resources or to water
391 scarcity.

392
393
394 Table 1. Average environmental vulnerabilities in the communes of study area based on a 1 (low) to 5 (high)
395 Likert importance scale, with standard deviations in parenthesis. * indicates the difference statistically valid
396 at 95% confidence with the two-tail Mann-Whitney test.
397

Vulnerability	Buhinyuza	Isare	Average	p-value
Frequency of droughts and water scarcity	4.3 (1.0)	3.7 (1.3)	3.9	0.00714*
Soil erosion, landslides, and soil degradation	4.4 (0.8)	4.0 (1.1)	4.2	0.03078*
Forest sites converted into agricultural land, pasture land, or built-up areas	4.2 (0.9)	3.5 (1.2)	3.7	< 0.00001*
Abandonment of cultivated areas	1.9 (1.4)	2.2 (1.4)	2.1	0.05592
Loss of traditional landscape	4.2 (1.2)	3.3 (1.2)	3.6	< 0.00001*
Deterioration of water quality	4 (1.2)	2.7 (1.3)	3.1	< 0.00001*
Lowering of water levels in wells	3.9 (1.2)	2.3 (1.3)	2.9	< 0.00001*
Loss of traditional varieties of fruits and vegetables	4.1 (1.1)	3.3 (1.3)	3.6	< 0.00001*

Reduction in agricultural production and/or food security	4.1 (1.2)	4.1 (1.0)	4.1	0.36282
Limited access to water for domestic use	4.1 (1.1)	3.2 (1.3)	3.5	< 0.00001*
Difficulty in obtaining firewood or trees for construction	2.5 (1.8)	3.9 (1.0)	3.4	< 0.00001*

Regarding the changes perceived with respect to the past, the more voted option resulted in "changes in rainfall patterns" in both communes, but with a significant difference as this option was chosen by 64% of the respondents in Isare and by only 34% in Buhinyuza. Other selected options received lower attention, including "rising temperatures affecting agricultural production" (36% in Isare, 29% in Buhinyuza), "increase in the occurrence of pests and diseases" (21% in Isare, 27% in Buhinyuza), and "more frequent drought periods" (20% in Isare, 27% in Buhinyuza). In Isare, 13% of the sample answered that they do not perceive observable effects of climate change in their community, while in Buhinyuza this option was selected by only 2% of the respondents.

3.5 Landscape perception and communities' expectations

Meaningful differences between the two *communes* were found regarding the landscape perception and the importance of different landscape features (Table 2). In Buhinyuza "pastures" and "slope land" received values above 4 and all the other features received values lower than 3 with "forests" and "homegardens" totalizing the lowest values (1.9); differently, in Isare these last two landscape features received higher values (2.9 and 3.3, respectively) probably due to the importance of forests for the local economy and of the homegardens for food production in a high slope territory. In general, in Isare seems that all the landscape features have a similar importance, without particularly high or low values, all being comprised in the 2.6-3.3 range. Regarding the different collines, also some exceptions can be found, i.e. in Nyaruhengeri "cultivated areas" received a score equal to 5, in Karehe "marshes" received the same value, in Nyambuye "homegardens" seems to be important (4.7); "pastures" received high values in Kibimba (5.0), in Bunywana (4.8), in Gitaramuka (4.6), and in Ntobwe (4.5), while "forests" received a score above 4 in Bugungu, Gishingano, and Nyambuye.

Table 2. Average values in the communes of study area for the question "Rate each landscape element on a scale of 1 to 5 based on its importance to the traditional landscape of the region". Results are elaborated based on a 1 (low) to 5 (high) Likert importance scale, with standard deviations in parenthesis. * indicates the difference statistically valid at 95% confidence with the two-tail Mann-Whitney test.

Land Use	Buhinyuza	Isare	Average	p-value
Forest	1.9 (1.5)	2.9 (1.7)	2.5	0.00008*
Pastures	4.1 (1.3)	2.6 (1.3)	3.1	0.00001*
Family gardens	1.9 (1.5)	3.3 (1.4)	2.9	0.00001*
Streams/rivers	2.3 (1.7)	3.1 (1.3)	2.8	0.00006*

Sloping land	4.1 (1.5)	3.2 (1.3)	3.5	0.00001*
Marshes	3.0 (1.8)	2.6 (1.5)	2.8	0.12852
Cultivated areas	2.7 (1.8)	2.8 (1.4)	2.8	0.90448

426

427 To evaluate the preference regarding two different types of terracing two possibilities were presented:
428 radical bench terraces constructed with earth movement, and progressive terraces formed slowly
429 constructed from an anti-erosion bund (Annex 1).

430 Radical terraces are constructed with a labor-intensive and expensive process, with a cut-and-fill operation,
431 creating horizontal platforms which are immediately utilizable. By removing and storing the topsoil-layer and
432 putting it back at the end, the typical production dip of radical terraces can be reduced, due to the soil
433 alteration (Mesfin et al. 2019). Progressive (slow-forming) terraces are created by implementing contour
434 bunds with soil or stones in combination with ditches and vegetation reinforcement. Such a land
435 management system progressively forms in time by the natural process of erosion and sedimentation
436 (Dercon et al. 2003; Kagabo et al. 2013).

437 Two images have been shown to the respondents, asking them what type they prefer (Annex 1). In both
438 communes most of the respondents preferred the "Progressive terraces formed slowly constructed from an
439 anti-erosion bund", but with different percentages (90% in Buhinyuza, 95% in Isare).

440 The last two questions of this section focused on the expectations of the local population regarding to which
441 extent local authorities should focus on/protect/improve some selected topics, and on the possible impacts
442 (positive or negative) of tourism on other selected issues. In both cases respondents were asked to evaluate
443 the different topics on a 1-5 Likert scale.

444 Different options were proposed to the respondents in the first question (Table 3); "Support for agriculture
445 and livestock farming", "Nature protection", "Protection of the traditional landscape, "Protection against
446 hydrogeological risk", and "Improvement of basic services", all received high scores (4.0-4.8 range) in both
447 Buhinyuza and Isare. "Improvement of the road network and of the public transport" received a score of 3.9
448 in Buhinyuza and 4.6 in Isare (p-value < 0.05). "Promotion of tourism" received the lowest scores in both the
449 communes, but while in Buhinyuza it is scored 3.4, in Isare it is anyhow scored above 4 (p-value < 0.05). Little
450 differences were noticed among the *collines*, with the exception of Karehe where all the options were scored
451 lower than 3, and Kibimba and Nyaruhengeri where basic services received very low scores (2.2 or lower).
452 On the contrary, in Karunga, Kwigere, Nyakibande, and Rutegama, "Promotion of tourism" received high
453 values, equal to 4.4 or higher.

454

455 Table 3. Average values in the communes of study area for the question "Considering the following topics,
456 please rate from 1 to 5 the extent to which you think local authorities should focus on/protect/improve these
457 areas further?". Results are elaborated based on a 1 (low) to 5 (high) Likert importance scale, with standard
458 deviations in parenthesis. * indicates the difference statistically valid at 95% confidence with the two-tail
459 Mann-Whitney test.

Questions	Buhinyuza	Isare	Average	p-value
Support for agriculture and livestock farming	4.4 (1.2)	4.8 (0.4)	4.6	0.15854

Nature protection	4.4 (1.2)	4.8 (0.4)	4.6	0.06876
Protection of the traditional landscape	4.1 (1.3)	4.7 (0.6)	4.4	0.00452*
Protection against hydrogeological risk	4 (1.4)	4.6 (0.6)	4.3	0.00714*
Promotion of tourism	3.4 (1.5)	4.1 (0.9)	3.7	0.00512*
Improvement of the road network and public transport	3.9 (1.5)	4.6 (0.7)	4.2	0.01278*
Improvement of basic services	4 (1.5)	4.7 (0.6)	4.3	0.01828*

460

461

Overall, according to the local communities, the consideration of possible impacts of tourism vary according to the collines and the municipality. According to the clusterization of the results based on the two municipalities, significant differences have been found; in Isare tourism seems to be an opportunity rather than a risk, while in Buhinyuza the situation is the opposite as it seem to be perceived more as a risk than as an opportunity for economic development (Figure 10). In Isare, in fact, an increase of the tourist flow is perceived by the local communities in a positive way, as options like "more job opportunities", "improvement of local services", and "more incomes for farmers" received significantly higher average values (3.1-3.3 range), compared to the ones of Buhinyuza (2-2.5). On the contrary, all the possible negative impacts received low average scores in Isare (1.7-2.9 range), while in Buhinyuza they all received average scores higher than 2.9 but the perceived negative impacts were more unevenly distributed in the 1-5 scale. The only exception is related to the "increase in traffic on roads and paths" that received particularly high average values in Buhinyuza (4.5) with reduced variability among the sample, but also an average score of 2.9 in Isare. The population of some *collines* (Gasave, GItaramuka, Karehe, Kibimba, Muramba, and Nyaruhengeri) expressed significant concerns about the possible negative impacts related to the "risk of cultural erosion and moral degradation" and oto "risk of school dropout".
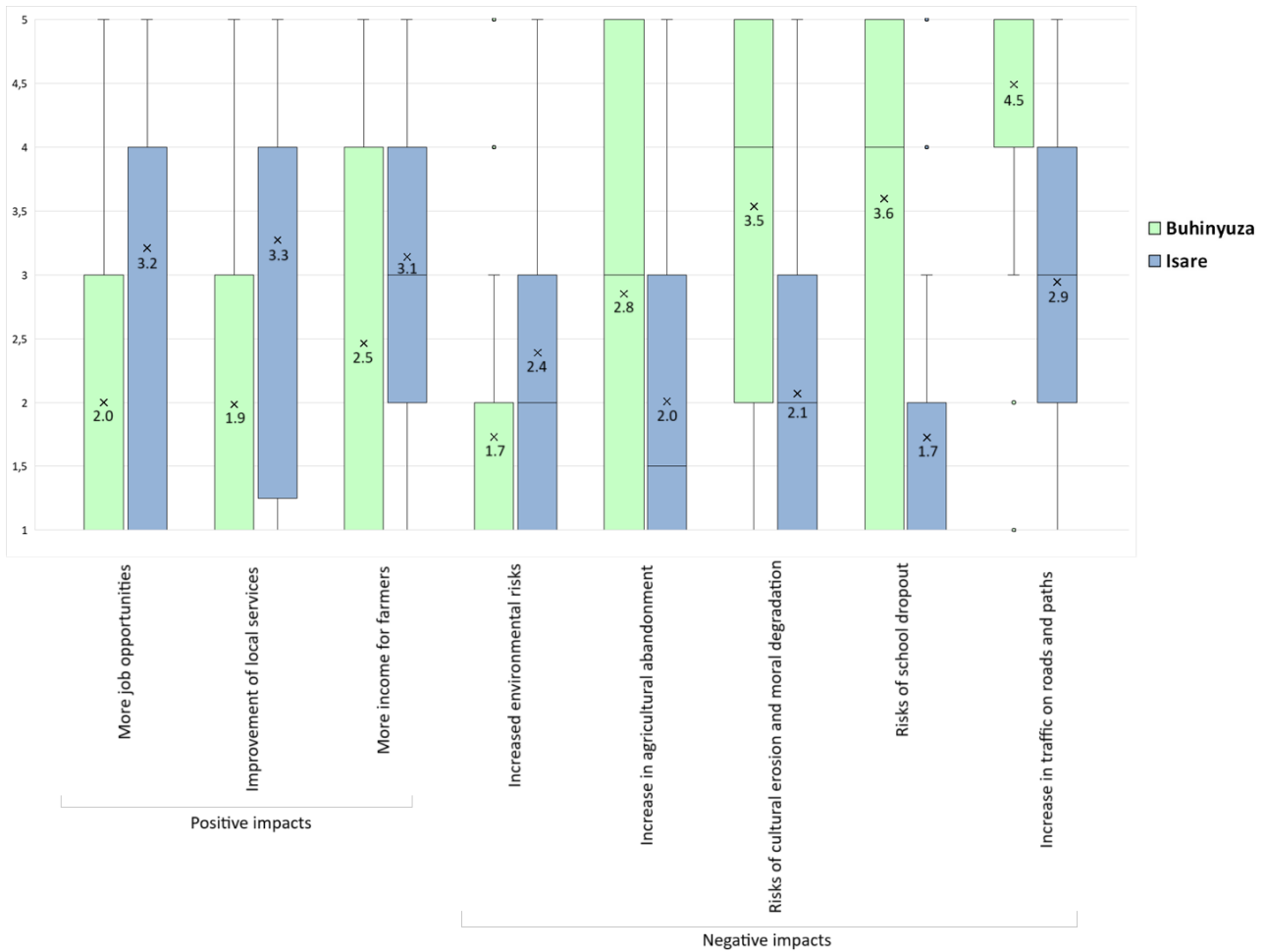
Figure 10. Possible positive and negative impacts of increased tourism for different topics as perceived by the local respondents of Buhinyuza and Isare.

3.5 Local impact of the PRRPB project

Regarding the awareness and the local impact of the PRRPB project funded by the World Bank, 98.5% of all the respondents affirmed to be aware that the project financed sustainable land management interventions in the region and about 95% of the overall sample affirmed that this project directly involved land cultivated or owned by themselves, highlighting the extended impact of this landscape restoration project in terms of people and communities involved.

The project has been evaluated very positively by the local population, considering that only 4% of Buhinyuza sample and 2% of Isare reported no benefits (Figure 11). The clusterization of the results according to the municipality demonstrated some differences regarding the perceived benefits. While in both communes the more perceived benefit resulted to be the "Increased soil conservation / Reduction of soil erosion", chosen by 96% of the respondents in Buhinyuza and by 97% in Isare, differences regarding the other possible benefits have been found (Figure 10). In Buhinyuza, in fact, other four different benefits were chosen by more than 70% of the respondents ("increased landscape conservation", "increased agricultural production", "increased food security for farmers", and "possibility to engage in livestock farming"); in Isare, instead, beside the "Increased soil conservation / Reduction of soil erosion", all the other potential benefits have been scarcely perceived, with the most voted represented by "Increased landscape conservation" chosen by 56% of the respondents and the others all chosen by less than 55% of the sample.In addition, the "possibility to grow

498 new perennial crops" was chosen by a minority of the respondents (19% in Buhinyuza and 22% in Isare),
499 meaning that the landscape restoration project have a reduced impact on the crop type.
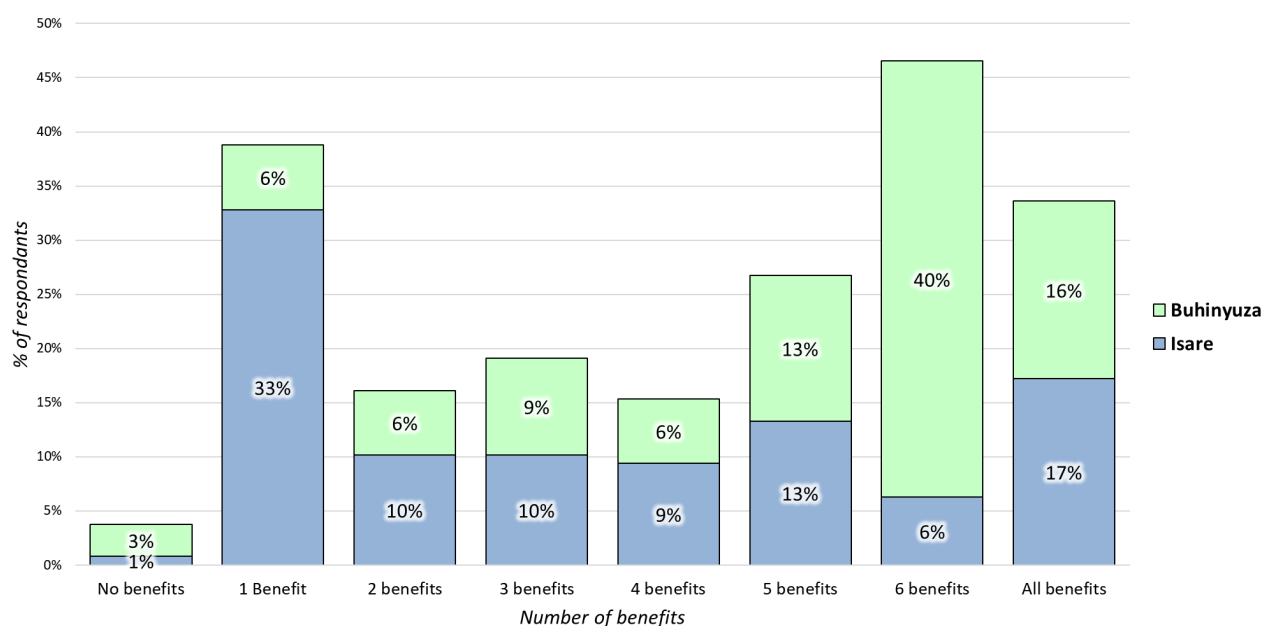
500
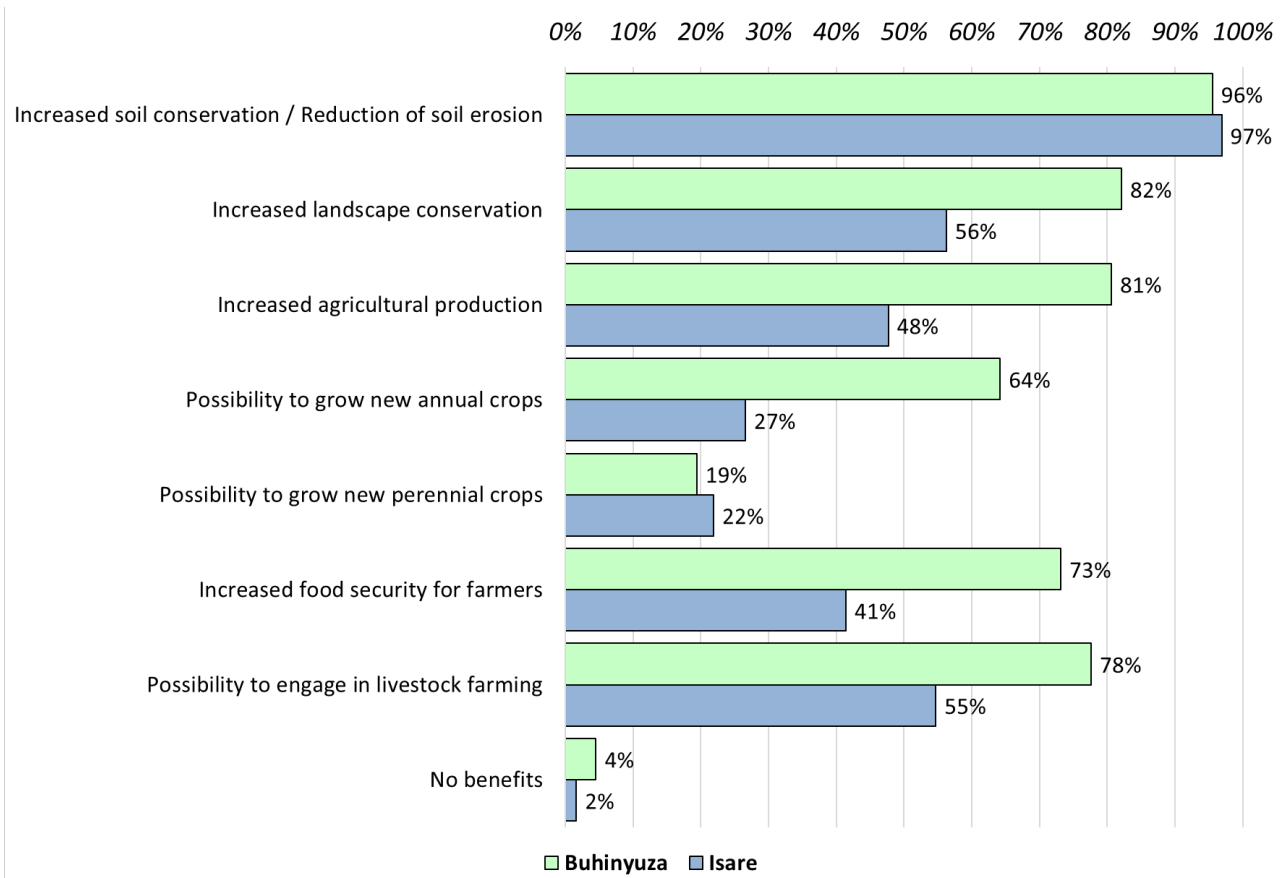
501

502 *Figure 11. Different benefits of the PRRPB landscape restoration project as perceived by the local population*
503 *of Buhinyuza and Isare.*

504

505 It is also interesting to evaluate the percentage of respondents who selected one or more benefits in
506 Buhinyuza and Isare, in order to assess the multiplicity of the local impact of the PRRPB project. in Buhinyuza
507 a meaningful percentage of respondents (69%) selected 5 or more benefits from the proposed list, compared
508 to the 36% of Isare respondents (Figure 12). In fact, 33% of Isare respondents chose only 1 benefit from the
509 list, compared to 6% of Buhinyuza, testifying that in this latter study area respondents perceived more
510 multiple benefits compared to Isare.

Figure 12. Percentage of respondents per number of benefits of the PRRPB landscape restoration project as perceived by the local population of Buhinyuza and Isare.

The following table (Table 4) summarizes the main findings of each topic addressed in the study, highlighting the main differences between the study area of Buhinyuza commune and the one in Isare commune.

Table 4. Evaluation of the main findings of the study for each addressed topic for the study areas of Buhinyuza and Isare.

Topic	Study Area	
	Buhinyuza	**Isare**
Consumption of local agricultural products	Very high	High
Reasons for preferring locally grown food	Lower cost, but recognizing other added values	Lower cost
Role of women	Very important	Important
Main perceived environmental vulnerability	Soil erosion, landslides, and degradation	Soil erosion, landslides, and degradation
Other highly perceived environmental vulnerabilities	Reduction of agricultural production and/or food security, limited access to water for domestic use, frequency of droughts and water scarcity, forests converted into agricultural surface, loss of traditional landscape, loss of	Reduction of agricultural production and/or food security

	traditional crop varieties	
Main perceived environmental change (climate change)	Changes in rainfall patterns (highly perceived)	Changes in rainfall patterns (medium perceived)
Landscape perception	High importance landscape features: pastures, slope land.	Medium importance landscape features: Slope land, forests, rivers, family gardens.
Preferred terraces type	Progressive terraces formed slowly constructed from an anti-erosion bund	Progressive terraces formed slowly constructed from an anti-erosion bund
Main issues to be promoted by local authorities (communities' expectations)	Support for agriculture and livestock farming, Nature protection, Protection of the traditional landscape, Protection against hydrogeological risk, Improvement of basic services	Support for agriculture and livestock farming, Nature protection, Protection of the traditional landscape, Protection against hydrogeological risk, Improvement of basic services, Improvement of the road network and of the public transport
Potential role of tourism	Mainly negative	Mainly positive
Awareness level of the PRRPB project	Very high	Very high
Impacts perceived of the PRRPB project	Very positively: Increased soil conservation / Reduction of soil erosion, Increased landscape conservation, Increased agricultural production, Positively: Increased food security for farmers, possibility to engage in livestock farming, possibility to grow new annual crops	Very positively: Increased soil conservation / Reduction of soil erosion. Positively: increased landscape conservation, possibility to engage in livestock farming, Increased agricultural production
Multiplicity of benefits perceived of the PRRPB project	Very beneficial multipurpose project	Very beneficial project, but not a multipurpose one

521

4. Discussion

4.1 Consumption of local agricultural products and role of women

Results highlighted the key role of the local agricultural production for the livelihood and the food security of the local communities, especially in Buhinyuza where local communities heavily rely on local agricultural production; in Isare, instead, respondents reported a higher consumption of non-local food, probably due to the proximity with Burundi main city, Bujumbura. Burundian economy, in fact, mainly relies on subsistence agriculture (Muchiri and Paul 2023), but, unfortunately, the growth of agricultural production (+2%) that was recorded in the last decade was lower than the increase rate of the population (2.6-3%) (UNCDF 2022), making the national agricultural sector incapable of providing food for all the population. In addition, according to IFAD (IFAD 2021) this is worsened by the poor performance of the agricultural sector in terms of technical capacities and sustainability of the applied agricultural practices. The key role of locally grown food for food security is also confirmed by the fact that among all respondents a large majority own cultivated land for self-consumption, while only few of them cultivate agricultural products for the market.

Despite the fact that local food is mainly preferred for an economic reason (lower costs), in Buhinyuza local people also recognize multiple added values/benefits to consuming local agricultural products, including the support to local farmers and to the local economy, the contribution to the preservation of the local landscape, a higher perceived quality and health and nutritional benefits. Consumers' preferences regarding the food choice and purchasing reasons are still insufficiently investigated issues, but according to some studies consumers are becoming increasingly aware of food safety and food quality issues as urbanization proceeds (Ortega and Tschirley 2017; Vandeplas and Minten 2015).

The role of women in the local agricultural sector seems to be important, especially in Buhinyuza (less in Isare where probably women have more opportunities to be engaged in other job sectors rather than agriculture), with particular reference to direct participation in agricultural activities as labour force, for choosing the crops to be cultivated, and for preserving local seed varieties. However, women resulted to be poorly involved in food processing and market selling, confirming the findings of previous studies carried out in Burundi that highlighted a widespread gender inequality persists in the agricultural sector, especially in the access to improved seeds and to productive technologies (Ndabashinze et al. 2024), or to of climate-smart agriculture practices, making women and young farmers more severely affected by climate change-related threats than men (Nchanji et al. 2023).

4.2 Environmental vulnerabilities

The main perceived environmental vulnerability is in both municipalities the "Soil erosion, landslides, and degradation", with higher scores in Buhinyuza rather. This is only partly linked to the morphology of the area, considering that in Isare the terrain is much more rugged and subject to landslide problems than in Buhinyuza. In Buhinyuza study area, as it is more devoted to agricultural activities as land cover analysis demonstrated, local people also perceived many different vulnerabilities related to the agricultural productive sector, as "Reduction of agricultural production and/or food security", "Limited access to water for domestic use", "Frequency of droughts and water scarcity", "Forests converted into agricultural surface", "Loss of traditional landscape", and "Loss of traditional crop varieties"). These results are consistent with similar studies carried out in Burundi or in other Central African countries. According to Cuni-Sanchez et al. (Cuni-Sanchez et al. 2025) who investigated the perceived landscape and environmental vulnerabilities in ten African mountain regions, the most perceived ones included reduced crop yields, increased soil erosion, increased crop and livestock diseases and reduced human health, while in Burundi also a significant increase in landslides was reported.

Our findings revealed that regarding the changes perceived with respect to the past, the "changes in rainfall patterns", the "rising temperatures affecting agricultural production", the "increase in the occurrence of pests and diseases", and the "more frequent drought periods", were the main concerns among local communities. Similar findings were reported by Nkurunziza et al. (Nkurunziza et al. 2023) for mountainous regions of Burundi and Rwanda. According to the authors, in fact, farmers reported increasing temperatures during both dry and rainy seasons, increase in extreme floods and more landslides, a reduction in main crops' yields, and an increase in pests and diseases, and that people were overall less healthy. The effects of climate change are also worsened by the high rates of deforestation that affected Burundi in the last decades (Nkurunziza et al. 2023; United States Agency for International Development 2010), a trend that was also confirmed by the present study considering that "Forests converted into agricultural surface" and "Difficulty in obtaining firewood or timber for construction" were among the selected options. Burundi, in fact, is

577 particularly affected by the consequence of deforestation and of extreme weather events, considering that,
578 as reported by Nkunzimana et al. (Nkunzimana et al. 2019), change of rainfall patterns, more extreme
579 rainfalls, and significant decrease of rainfall from 1990 have been detected. Other recent studies carried out
580 in Burundi highlighted that despite the perceived vulnerabilities related to climate change, over 80% of
581 farmers have implemented adaptation strategies, including selection of different crop varieties and
582 introduction of shade trees in cultivated fields (Batungwanayo et al. 2023). In addition, specific problems
583 related to water quality and quantity ("Deterioration of water quality", and "Lowering of water levels in
584 wells") resulted to be highly perceived in Buhinyuza; Buhinyuza, in fact, corresponds to a remote rural area,
585 where the lack of necessary infrastructures for access to clean and safe water is common.

586

587 **4.3 Landscape perception and communities' expectations**

588 In general, landscape perception is highly influenced by the cultural background (Matijošaitienė et al. 2014;
589 Solymosi 2011), but the results of the survey seem to highlight that in this case is more correlated with the
590 land use and morphological structure of the landscapes of the two communes, with sloping lands
591 representing the more representative typology in both communes. Some differences are found regarding
592 specific landscape features, such as pastures that are relevant in Buhinyuza and not in Isare, or homegardens
593 that are instead more perceived as typical features in Isare than in Buhinyuza, probably due to the different
594 morphology.

595 In both communes most respondents largely preferred the "Progressive terraces formed slowly constructed
596 from an anti-erosion bund". This represents an interesting feature of the country since some similar projects
597 with radical terraces have been implemented in nearby countries such as Rwanda (Rutebuka et al. 2021;
598 Uwacu et al. 2021) and Uganda (Siriri et al. 2005; Karamage et al. 2017). However, scarce interest in radical
599 terraces and preferences for progressive terraces might be linked to the necessity of frequent maintenance
600 (Bizoza 2014), or to the possibility of collapse (Tarolli et al. 2014). Nevertheless, it is evident how this feature
601 is peculiar of Burundi, which is also the country with the steepest slopes compared to nearby countries, and
602 can be further investigated in more specific studies even at country scale.

603 The analysis of the farmers' expectations is particularly important in providing information about the real
604 needs of the community and in informing local stakeholders for planning future activities. it is well
605 demonstrated, in fact, that top-down development projects that do not involve the population and do not
606 investigate its needs and expectations, often result in investments with poor return and effectiveness (Dey
607 1982). Local communities of both municipalities call for more investments for agriculture and livestock,
608 nature and traditional landscape conservation, protection against hydrogeological risk and improvement of
609 basic services. These issues and needs are common to other developing countries with fragile agricultural
610 sector (Takahashi et al. 2020), especially in the ones where a large share of the GDP is represented by
611 agriculture in their GDP (Pawlak and Kołodziejczak 2020). According to GIller et al. (Giller et al. 2021), in many
612 SSA countries, the extent of food insecurity and poverty and consequent needs of increasing crop
613 productivity is greater in densely-populated locations despite a higher soil fertility, than in arid environments
614 with poor fertility and water scarcity. In Isare, in addition, the improvement of the road network and of the
615 public transport received a very high score likely due to the rugged topography and the frequent damages to
616 roads in the area (Preti et al. 2025).

617 Tourism, as a possible economic opportunity to be supported for future rural development and economic
618 differentiation, was evaluated very differently in the two surveyed study areas. In Isare tourism seems to be
619 a relevant economic opportunity, as according to local communities it can provide more job opportunities,
620 improvement of local services, and also more income for farmers. Conversely, in Buhinyuza it is perceived
621 mainly as a risk that can lead to agricultural abandonment, cultural erosion, risks of school dropout, and to
622 an increase of traffic on roads and paths. The different perception of the possible role of increased tourism
623 in the region reported in this study, is due to the location of the different study areas, as Isare is very close
624 to Burundi's main city, Bujumbura, while Buhinyuza is located far from urban centers. It is in fact assessed
625 that the proximity to a large urban area can affect this choice, as rapid urbanization can influence the decline
626 of agricultural activities and the replacement with other job opportunities, also in developing countries (Li et
627 al. 2019). These findings are consistent with the one of (Wondirad et al. 2020) who found out that the lack
628 of collaboration amongst ecotourism stakeholders in a poorly resourced and remote destination of Southern
629 Ethiopia, have failed in empowering the local community by providing more incomes and job opportunities
630 and jeopardizes the local ecosystems and communities themselves in the long-term. The relation between
631 rural tourism (or ecotourism, or community-based tourism) and rural development is a complex one, as it
632 involves a wide range of variables and actors (Priatmoko et al. 2023). While in some socio-cultural contexts,
633 as in rural China, sustainable rural tourism plays a positive role in promoting the development of rural
634 communities, this often happens because of economic investments in infrastructures, accommodation and
635 other touristic facilities (He et al 2021) or as in indirect effect of the increased market value of typical food
636 products (Li et al. 2023), in African countries where public investments are limited, this positive correlation
637 is more uncertain (Folarin and Adeniyi 2020; Zielinski et al. 2021; Siakwah et al. 2020).

638

639 **4.4 Local impact of the PRRPB project**

640 The awareness level of the PRRPB project resulted to be particularly high in the surveyed area, with
641 widespread benefits, in particular regarding the increase of soil conservation and the reduction of soil
642 erosion, that represented the main perceived threat. In Buhinyuza, where the local community based their
643 livelihood on local agricultural activities, the project also contributed significantly to the increase of
644 agricultural production and food security, but also to the conservation of the local traditional landscape, as
645 testified by the large portion of respondents (69%) who selected 5 or more benefits so that the PRRPB project
646 has been perceived as a "multipurpose" landscape restoration project with relevant impact on different
647 topics. The study demonstrated the effectiveness of the PRRPB project in addressing the main environmental
648 challenges and in providing effective benefits to the local population, confirming that large landscape
649 restoration projects can provide tangible and short term benefits to local communities especially when
650 related to an active communication and involvement of the local communities and stakeholders (Palmer et
651 al. 2022; Chazdon et al. 2021). In addition, integrating the Traditional Ecological Knowledge in research and
652 landscape restoration proved to improve the chances of success and of positive impacts at local level (Henze
653 and Santoro 2024; Gornish et al. 2024; Adade Williams et al. 2020).

654

655 **4.5 Final remarks**

656 The study confirmed the general dependence of the Burundian agricultural sector and livelihood from small-
657 scale and family farming, making it very vulnerable from environmental criticalities. As demonstrated by
658 Manzvera et al. (Manzvera et al. 2023), SSA smallholder and family farmers are the most vulnerable to the

threats posed by climate change. The reasons for the intrinsic vulnerability of the Burundian agricultural sector are not to be found only in the socio-economic conditions, but also in the environmental context, in particular in the rough morphology and/or in the high rates of deforestation (United States Agency for International Development 2010). Deforestation combined with rough morphology caused high and widespread slope instability and hydrogeological problems, confirmed by the fact that these are the more perceived environmental threats by the local communities. Given the fragile context, future activities should be addressed to training to enhance skills about sustainable agricultural practices to minimize soil erosion and hydrogeological risks (Nyamweru et al. 2024), to empower the role of local women in the agricultural sector, to promote public and private investments for improving market opportunities (Muchiri and Paul 2023). Sustainable rural tourism can play an important role for the economic development of Burundian rural areas (Rosalina et al. 2021), but the concerns of the local communities need to be taken into consideration; in addition, the promotion of sustainable rural tourism has to be accompanied by significant investments on infrastructures and training, and by seizing the opportunities related to international programmes such as the UNESCO World Heritage List or the FAO GIAHS (Globally Important Agricultural Heritage Systems).

4.6 Limitations

Some limitations of this study need to be reported. 1) No precise and updated data regarding the population living in the different collines is available, therefore, the confidence and error calculation for evaluating the level of statistical significance has been done on the population of the entire municipalities that is significantly higher. Despite this, results of most questions resulted to be really clear regarding the answers, with low variability, testifying a high consistency of opinions within the sample, especially clustering the results according to the two municipalities. 2) The difference in the number of respondents between Buhinyuza and Isare study areas needs to be considered, as two thirds of all the respondents were located in Isare; consequently, the size of the Buhinyuza sample is particularly reduced. 3) The time frame between the end of the PRRPB project and the performed survey only allowed to evaluate the impact of the landscape restoration project in the short term. To assess the possible benefits in the long term, it would be particularly interesting to perform a similar survey with the local population after a longer time frame.

Despite these limitations, survey findings allowed to obtain a reliable amount of data, capable of describing the local agricultural sector, its main characteristics and perceived vulnerabilities, the community expectations, as well as to evaluate the local impact of one of the largest landscape restoration projects funded and implemented in Central Africa.

5. Conclusions

The present study revealed how the large-scale PRRPB in Burundi was perceived as a successful project in combating erosion and having a positive impact on the socio-economic conditions of the population of the two areas of intervention (Isare commune in Bujumbura Rural province, Buhinyuza commune in Muyinga province). The analysis also revealed that the two areas have different environmental vulnerabilities: while in the steep slope area of Isare "Soil erosion, landslides, and degradation" is considered the main issue, the communities of Muyinga rather perceived a multidimensional system of vulnerabilities, including also "Reduction of agricultural production and/or food security", "Limited access to water for domestic use", "Frequency of droughts and water scarcity", "Forests converted into agricultural surface", "Loss of traditional landscape", and "Loss of traditional crop varieties". Despite this, results show that PRRPB managed to improve the livelihoods of the two different social-economical settings thanks to its integrated approach. The analyses carried out also offered a detailed structural understanding of the socio-economic setting in the two

areas highlighting the importance of local food systems and of the homegrown food production, linked with the different perceptions of landscape. Our results reinforce the call for developing really multidimensional and integrated projects for targeting landscape restoration and the importance of an active involvement of the local population. At the same time, they revealed how territorial and social-ecological systems' diversity should always be kept into account even when working in relatively small countries like Burundi.

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1. **Age:**

- 18-25 years old
- 26-30 years old
- 31-40 years old
- 41-50 years old
- 51-60 years old
- 61+ years old

2. **Gender:**

- Male
- Female
- Other

3. **Education Level:**

- None
- Primary school
- High school
- Higher education (university degree, master, PhD)

4. **What is your main professional activity/source of income?**

- Farmer
- Student
- Public sector
- Private sector/informal sector
- Retired
- Unemployed
- Other (please specify) _____

5. **Marital Status:**

- Single
- Married
- Surviving spouse

6. **Please specify where your community is located:**

- Benga
- Bibare
- Bugungu
- Bunywana
- Caranka
- Gasave
- Gishingano
- Gitaramuka
- Karehe
- Karunga
- Kibimba
- Kiyange
- Kwigere
- Muramba
- Ntobwe
- Nyakibande
- Nyambuye
- Nyaruhengeri
- Rushubi
- Rutega

7. **Since when have you been living in this locality?**

- After 2018
- Before 2018

8. **Please rate each environmental hazard/vulnerability on a scale of 1 to 5 based on its impact in your community/region.**

	1	2	3	4	5
Frequency of droughts and water scarcity					
Soil erosion, landslides, and soil degradation					
Forest sites converted into agricultural land, pasture land, or built-up areas					
Abandonment of cultivated areas					
Loss of traditional landscape					
Deterioration of water quality					
Lowering of water levels in wells					
Loss of traditional varieties of fruits and vegetables					
Reduction in agricultural production and/or food security					
Limited access to water for domestic use					
Difficulty in obtaining firewood or trees for construction					

9. Compared to 10 years ago, have you noticed any of the following changes in your community? (multiple choice)

- (Yes) There are changes in rainfall patterns
- (Yes) Increase in the occurrence of pests and diseases
- (Yes) More frequent droughts
- (Yes) Rising temperatures affecting agricultural production
- (Yes) Others
- There is no observable effect of climate change in our community
- I don't know

10. Are you aware that the 'Burundi Landscape Restoration and Resilience Project (PRRPB)' by the World Bank financed sustainable land management interventions in your region?

- Yes   ● No

11. Did the World Bank project involve land cultivated/owned by you?

- Yes   ● No

12. Have the interventions of the World Bank brought benefits? (multiple choice)

- Increased soil conservation / Reduction of soil erosion
- Increased landscape conservation
- Increased agricultural production
- Possibility to grow new annual crops
- Possibility to grow new perennial crops
- Increased food security for farmers
- Possibility to engage in livestock farming
- No benefits
- I don't know
- Other (please specify) _____

13. How often do you consume non-locally grown foods?

- Every day
- Three to four times a week
- Once a week

- Once or twice a month
- Rarely or never

14. How would you rank the importance of local food products for the culture and identity of your community?

- Very important
- Important
- Slightly important
- Not important at all
- I don't know

15. Can you state the added value of consuming locally grown foods?

- Lower cost compared to non-local/imported foods
- Contribute to the preservation of the local landscape
- Due to their superior taste and quality
- Due to their health and nutritional benefits
- To support farmers and the local economy
- Contribute to environmental sustainability
- Because they are part of the culinary culture of the region
- Other (Please specify) _____

16. Normally, where do you primarily purchase local food products?

- Local markets
- Small local shops
- Directly from the farmer/producer
- Large-scale distribution

17. Do you own cultivated land?

- Yes, mainly for self-consumption
- Yes, mainly for selling at markets
- No

18. Are women in your community involved in decision-making regarding agricultural activities? (Multiple choice)

- Yes, direct participation as labor force
- Yes, indirect involvement: choosing crops to cultivate
- Yes, indirect involvement: seed preservation of local varieties
- Yes, indirect involvement: food processing and market selling
- No, women do not participate in agricultural activities

19. Can women or girls in your community own agricultural land? (multiple choice)

- Yes, by inheritance from their parents differently than their brothers
- Yes, by inheritance from their parents equally with their brothers
- Yes, by inheritance in their husband's family without strong decision-making power
- Yes, by inheritance in their husband's family with strong decision-making power

- Yes, by purchase with full rights
- Yes, by purchase under the supervision of their parents or brothers
- No

20. Rate each landscape element on a scale of 1 to 5 based on its importance to the traditional landscape of the region.

	1	2	3	4	5
Forest					
Pastures					
Homegardens					
Streams/rivers					
Sloping land					
Marshes					
Cultivated areas					

21. Looking at the following images, what type of terraced landscape do you think would be the most beneficial for your region?

A: Radial bench terraces, constructed with earth movement

B: Progressive terraces formed slowly, constructed from an anti-erosion bund

22. Considering the following topics, please rate from 1 to 5 the extent to which you think local authorities should focus on/protect/improve these areas further?

	1	2	3	4	5
Support for agriculture and livestock farming					
Nature protection					
Protection of the traditional landscape					
Protection against hydrogeological risk					
Promotion of tourism					
Improvement of the road network and public transport					
Improvement of basic services					

23. In your opinion, what could be the impact of increased tourism in the region on the following issues?

	1	2	3	4	5
More job opportunities					

Improvement of local services					
More income for farmers					
Increased environmental risks					
Increase in agricultural abandonment					
Risks of cultural erosion and moral degradation (Burundian tradition)					
Risks of school dropout					
Increase in traffic on roads and paths					