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Local Community Appreciations of the Ecosystem-based Adaptation Restoration Outcomes Around Lake Kibare, Eastern Rwanda

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Abstract

The Ecosystem-based Adaptation (EbA) approach is used to help communities to adapt to climate change effects and to support biodiversity conservation. In Rwanda, the approach was used to protect degraded ecosystems and strengthen the resilience of local populations to climate change effects. One site where the intervention took place is Lake Kibare riparian zone, which was restored using bamboo and agroforestry tree species. However, limited research explored how local communities perceive the outcomes of the intervention. This knowledge gap raises concerns about whether restoration efforts genuinely have addressed community needs and ensured equitable benefit-sharing. The present study aims to examine community perceptions regarding the effectiveness of the restoration of Lake Kibare riparian zone using EbA approach. Data were collected using semi-structured interviews, focus group discussions, and field observations. The results indicate that, while the EbA interventions succeeded in promoting ecological benefits such as enhancing biodiversity conservation, improved vegetation cover and water availability, they fell short in delivering tangible livelihood benefits to residents. Majority of community members reported increased food insecurity and economic challenges after being restricted from using the riparian land for agricultural practices, which had previously served as a source of subsistence food. They recommend the involvement of local people in decision-making, improving communication about restoration goals and expected outcomes, and adopting restoration practices that combine ecological functions with livelihood benefits like planting tree species that offer both environmental and socio-economic value such as fruit trees and developing fair and inclusive systems for benefit-sharing. *Clinical trial number*: not applicable.

Introduction

Riparian zones are defined as transitional zones between terrestrial ecosystems and water bodies. They provide key ecosystem services such as water purification, carbon storage, and recreation [1], that improve human well-being and support biodiversity [2]. They also limit the runoff of pollutants like pesticides, nitrogen, phosphorus, and fine sediments into water sources [3], and hence inhibit the rate of topsoil loss through runoff and erosion, thus maintaining water quality [4, 2, 5]. Further, riparian zones are used for agriculture essential for socioeconomic development and food security; provide timber and alternative sources of income from non-timber forests such as forage, fruits, and plants traditionally harvested for medicine and building materials. Furthermore, they serve as grazing and watering areas for livestock during the dry season [6].

Studies have indicated that changes in the riparian land use have caused changes in vegetation composition, structure, quality, and diversity [7]. Further, riparian land use change cause forest fragmentation leading to the decline in water and biodiversity through edge-effect [8]. This is coupled with climate change effects [9], that alter precipitation, cause drought and flooding [10, 2, 11].These changes affect not only the ecosystems, but also the health of local communities in terms of food shortage, disease development and limited socioeconomic development [12].

The ecosystem-based adaptation (EbA) approach, a nature-based solution, is used for restoring degarded ecosystems and sustainably addressing the challenges imposed by climate change effects [13].The EbA strategies have been widely recognized as effective in reducing the risks associated with climate change induced disasters like floods and droughts by enhancing biodiversity and ecosystem health through ecosystem restoration, maintenance of ecosystem function, ecosyetem services and management while concurrently generating socio-economic benefits [14, 15].

In Rwanda, the EbA approach was used as a strategy to restore degraded wetlands and forests [16].The riparian zone of Kibare Lake was restored in this context, where restoration activities were initiated in 2018. The zone was converted into farmlands and livestock grazing areas. These practices have exacerbated climate change effects namely prolonged drought and soil erosion which have led to the loss of biodiversity and water quality while worsening the local community livelihoods [13].The recent study done within the restored area has revealed that the EbA approach has contributed to flood mitigation, erosion control and water quality improvements [17]. However, proper evaluation of restoration success is lacking. Furthermore, there is little empirical evidence of the effects of riparian restoration on ecosystem services supply to the local community.

Thus, this study seeks to address this knowledge gaps by examining the pereceptions of local community memmbers about the socioeconomic development related to the restoration outcomes of the Kibare Lake riparian zone using the EbA approach. The specific objectives were 1) to assess local community's perception of the major drivers of Kibare Lake riparian zone destruction, 2) assess the benefits from the restored riparian zone to the surrounding local community, 3) evaluate the levels of satisfaction among the local community members for the outcomes of the restoration efforts, and 4) assess the extent and understanding of community knowledge of other alternative intervention measures that would be better for both ecological and livelihoods development.

Materials and methods

Description of the study area

The research was conducted in the riparian zone of Kibare Lake, Eastern Province of Rwanda (Fig. 1), geographically located at 1°57'23"S, and 30°46'52"E, and the altitude of 1,287 m above the sea level. Kibare Lake covers the total surface of 336 ha. The temperature of the area is that of the region (max. 24°C) with the rainfall reaching 1000 mm per year [16, 17]. The water of the lake looks brown due to soil erosion and heavy siltation from Akagera River which passes in the Northern part of the lake [16]. The restored riparian zone is located in 50 meters measured from water edge of the lake as established by the Rwandan Ministerial Order N°007/16.01 of 15/07/2010 regulating the length of water body shores transferred to the public property [18].

Most of the surrounding communities are immigrants who occupied the land after the review of the boundaries of Akagera National Park in 1995 [17]. The main activities in the riparian zone located out of

the restored buffer zone are agriculture and livestock keeping. These activities have degraded the land, but they are also the main source of income for local communities, while the lake is the unique source of water and fish meat for the local communities. Cultivated crops are mainly rainfed crops including maize, sorghum, beans, banana, and potatoes [17]. Restoration activities were initiated in 2018 by Rwanda Environment Management Authority (REMA) through planting of bamboo in the buffer zone of the lake and agroforestry tree species (*Grevillea robusta, Mangifera indica, Carica papaya, and Persea americana*) in the farmlands used for agriculture.

Sampling design and data collection protocol

Sampling design and data collection protocol
To assess perceptions of the local communities in relation to the benefits from the restoration of Kibare lake riparian zone and maximize the validity of the field work; we have used mixed methods namely interviews, focus group discussion and field observation [19]. This study was approved by Institutional Review Board (IRB) the Director of Research and Innovation (UR-DR) ethic committee of the University of Rwanda. All methods were performed in accordance with the research and innovation policy of the University of Rwanda approved by the Board of Governors of the University of Rwanda in 9 August 2024.

After the review, questions were translated in Kinyarwanda, the national and local language of the participants in the study. This was essential for better understanding the meaning of the questions and to facilitate them to express their perceptions freely [13]. The guiding questions of both interview and focus group discussion were centered on objectives and were selected to understand the communities' overall perception about the effectiveness of Kibare lake restoration (Table 1). Questions were essential to initiate, direct and prompt the discussions during the interview and focus group discussion processes with local community members [20].

Table 1
List of validated survey guide questions

1. Why the restoration was needed
2. What key environmental changes have you observed since the restoration started?
3. Describe the improvements of the health of the riparian zone as result of restoration?
4. Which animal species are now present that were not observed prior to the restoration?
5. What are the most significant improvements in water quality since restoration?
6. How do water quality correlate with the observed biological and environmental indicators?
7. What are the benefits do you get today from the restored area compared with the time before restoration
8. How do land use practices adjacent to the Kibare Lake riparian zone affect water quality?
9. What strategies do you think should further improve the riparian zone health and water quality in the long term?
10. What challenges do you still face in maintaining and enhancing the restored riparian ecosystem?
11. Which lessons have you been learnt that could guide future restoration projects?
12. What are the alternatives you have developed to compensate lost benefits?

The participants were selected purposively considering the facts that they have been living at the area before and after restoration activities and have been doing some activities in the area such as agriculture, fishing, fetching water and keeping livestock among others [21]. In these conditions, we assume that they would have more experience in the knowledge of the activities that would have caused the degradation of the area, planning of the restoration activities and benefiting from the restoration outcomes. We also assume that they have been involved in decision-making about the restoration planning and implementation of the activities related to the restoration such as the selection of tree species, tree planting and management practices of planted tree species. At the beginning of the interview and focus group discussion sessions, the purpose of the research was presented to the participants, and the decision to participate in the study was personal decision.

The number of participants in the study were from Isangano cell specifically within Kanyinya, Kagoma and Kibare villages (Fig. 1). For the semi-structured interview, a total of 30 people (ten from each village) including 18 females and 12 males were interviewed. This number was enough in social science as the main purpose was not statistical comparison, but getting perceptions [22]. Each participant provided the feedback by writing or through conversation with the interviewer who recorded the answers on the paper sheet. Focus group discussions were held by mixing men and females. Those who accepted to participate have signed an informed consent letter along with the confidentiality assurance form while also giving permission to take photos and recording the interview during the discussions. Based on the number of participants willing to participate for group discussion in the study, a total of 32 participants

were selected consisting of eight people for each group (four males and four females) totaling four groups. All discussions took place at the cell office separately and each group discussion lasts one hour in the afternoon (2:00 to 3:00 PM).

The afternoon was preferred to reduce the interference with other household activities of local community members [21]. During the focus group discussion, participatory methods were applied to encourage everyone to participate and to manage power dynamics [20]. Data were recorded by taking notes or through video recording of the feedback from the respondents upon agreement to be recorded [13]. Furthermore, the field observations following the meandering line transect walks were used to complement and assess the information from the survey and focus-group discussions.

Data analysis

Data from the interviews and focus group discussions were coded and thematically analyzed [23]. Each respondent in the interview and focus group discussion was assigned a code based on gender. Specifically, the letters F and M coded for female and male respectively. Each letter was followed by the numbers (01, 02…) for both females and males based on the order of participation in the semi-structured interview and focus group discussions. For example, the complete code for female and male participants in the interviews were F01I/ M01I. Likewise F01F/ M01F are the codes given to the first female and male during focus group discussion. Using code data, emerging ideas were established, and relationships were identified by using words provided by the respondents. These were considered as indicators of most known restoration outcomes from the implemented EbA approach within Lake Kibare riparian zone [13]. An inductive approach was used to examine the coded data in more details and to organize themes relating to the guiding questions. The analysis also involved an iterative process that linked different perceptions of participants in the study by reading transcripts and comparing them with relevant literature and interpretations [24].

Results

Communities' perception of the riparian zone degradation that prompted the restoration

Results from semi-structured interview and focus group discussion revealed that local community members viewed Kibare Lake riparian zone as highly degraded before restoration. The most stated drivers which prompted its destruction include the nearby market, intensive farming, and overgrazing, all of which being worsened by climate change impacts that have accelerated erosion, sediment runoff, and waste accumulation into the lake and vegetation cover clearing. Their insights about the riparian zone before the restoration activities were captured in the following quotes:

"Before the restoration, the riparian zone was highly degraded; vegetation cover was cleared, and some biodiversity was reduced and some lost. It was looking so bad due to overgrazing and the market which

was in the proximity of the lake water body. The water of the lake was also polluted due to soil erosion, sediment runoff and waste deposit. The use of this dirty water for domestic purposes has led to the spread of a lot of diseases. Our kids always suffer from intestinal worms and malaria" (Respondent M01I).

"We used to cultivate sweet potatoes, vegetables, and yams within this riparian zone using chemicals and graze our domestic animals near the lake for the access of water resulting to the decline in water volume and quality. Before the restoration, everyone has access to this area, we used to daily get fish from this lake. The overexploitation of this riparian zone for forage, firewood, medicinal plants resulted to the decline of some plant species" (Respondent F05F).

"The wildlife had decreased due to the reduction of suitable habitats. It was believed that a lot of animals had migrated to the other areas. Particularly, the decrease in water levels and plant species forced hippos to move to other parts of the lake where forage was more available. Birds and snakes became rarely observed. As the area had become almost desert-like, even insects were difficult to find. Generally, it can be concluded that biodiversity in the area had been severely degraded" (Respondent F25I).

Benefits from the restoration using tree plantations within the area

For the benefits obtained from the restored riparian zone, participants reported that:

"*These restoration activities have provided several important ecological benefits, but we don't see direct benefits from these activities. They stated that the planted trees helped stabilize the soil, reducing sediment runoff, and controlled the soil erosion. The restoration has improved the overall ecosystem health by improving the vegetation cover, enhancing water quantity and quality, as well as providing better habitats for wildlife. In addition, the restored green spaces created a more attractive environment for community and supported long-term resilience against climate-related impacts"* (Respondent F17I).

"*Many animals such as amphibians, snakes, birds, cranes, butterflies, hippos, monkeys, and insects, were previously rare in this area. But nowadays, we can see many different animals as results of restoration. The number of fishes has been increased and some can be even caught within this riparian zone due to the increase of water volume. With different animals freely moving within the restored area, it is an indication of improved ecosystem health and biodiversity recovery*" (Respondent F19I).

*"Aesthetically, the riparian zone has been transformed into a remarkably beautiful and refreshing landscape. We can now enjoy a noticeably fresher and cleaner air by passing around this zone. The improved air quality and ecosystem health enhances the comfort of the surroundings and makes the area more inviting for research activities, resting, and observing nature" (*Respondent F06F)

"The planted fruit trees are very important because they provide nectar for bees, and the honey produced is valuable to the local community. It is used as medicine and sold to generate income. The trees also are used to hang beehives. We are harvesting grevilia for carpentry, firewood, and building while bamboos are used for fencing" (Respondent M23I)

Satisfaction with the restoration outcomes

For the satisfaction of the restoration outcomes, the respondents stated that:

"*We are not fully satisfied with the restoration outcomes. Lack of socioeconomic benefits from this restoration contributed to the feelings of dissatisfaction for us. Ever since we were relocated from this area without compensation up to now, we have not seen any direct benefits from this restoration. We are not satisfied because we used this area for various agricultural activities, but now our livelihoods have been negatively affected"* (Respondent F28I).

"*During the restoration, contour bands were constructed to separate the upland from the riparian zone. These structures were intended to control soil erosion and prevent hippos from entering the community farms. However, they did not function as expected; soil continued to erode into the lake, and hippos still came out and fed on our crops. Most of the time we stay out during the night to safeguard our crops and homes, but still since the number of the hippos is increasing, they feed in our farms resulting in persistence of poverty* (Respondent M014I).

Preferences of communities to inform policy decision makers of current benefits and gaps for future improvements

For future success of the riparian zone restoration, different alternatives were suggested by the participants during both semi-structured interview and focus group discussion:

"Before starting the restoration, strong participation in planning and implementing processes by integrating the indigenous knowledge into future decisions is required. We would be happy if restoration activities should balance ecological gains with tangible livelihood benefits such as access to resources, job opportunities, and income-generating options. There is a gap related to inadequate communication, limited compensation for lost land-use opportunities and insufficient follow-up support" (Respondent M07F).

"They should repair the contour bunds that were constructed during the restoration process. After the restoration activities, these bunds at least helped to prevent hippos from entering our farms, we should sleep, and harvest what we have cultivated. The construction of fence separating riparian zone from upland should be effective strategy to protect the restored riparian zone while preventing hippos from reaching in our farms and feed on our crops" (Respondent F011I).

"Another issue is that, both before and after the restoration, there used to be security people assigned to protect this area. Most of them had the land in this area and others are residents surrounding this riparian. But nowadays, we no longer see them; they have left the riparian zone open, and it is now entered and used freely by everyone. I should be better if Environment Management Authority (REMA) assign security personnel to this area to ensure its protection." (Respondent M08F).

"They should plant more trees, especially fruit trees that should adapt to survive in wet areas as well as provide both socioeconomic and ecological benefits. "You can see that they planted only a few trees, and

within 50 meters there is still land that was left unplanted, even though it could have been used to benefit the local community. That is why they should plant more trees to cover the remaining area". They should also replace bamboo, which is invasive species with sugarcane, which offers similar ecological benefits while supporting the local community livelihoods development" (Respondent F012F).

"The same approach should be applied to other degraded riparian zones. Although, they should allow us to continue using the riparian zone for farming while also taking care of the planted trees. Many people who were relocated here, relied on this area for their livelihoods, and it is now difficult for them to survive without it since farming in this area was their main source of livelihood development" (Respondent M20I).

During the field observations we have seen that restoration efforts successfully rehabilitated Kibare Lake riparian zone which by transforming the area into a thriving ecosystem with increased vegetation, reduced erosion, improved water quality, and wildlife habitats. While the restoration has enhanced ecological health and aesthetic value, ongoing challenges including damaged contour bunds, gaps in tree planting mostly fruit trees, and human-wildlife conflict were observed. Notably, hippos frequently leave their habitats at night to feed on crops cultivated outside of the restored zone, causing crop losses to local communities. Additionally, the presence of a port connecting Tanzania and Rwanda for commercial activities has introduced pressure on the riparian zone. Goods from Tanzania are often offloaded within this zone before being transported to local markets, while goods from Rwanda are similarly collected there prior to be taken to Tanzania.

Discussion

Communities' perception of the riparian zone degradation that prompted the restoration

The results from the current study demonstrated that before the restoration, Kibare Lake riparian zone was perceived by the local community as severely degraded. This is in line with a similar study [17] which has revealed that the area around Kibare Lake has experienced rapid and extensive land use and land cover changes over the past years. Several drivers such as intensive farming, overgrazing, market proximity activities, and climate change related impacts were identified as primary catalysts of this degradation. A previous study also found that land use change, deforestation, overgrazing, inputs of pesticides, and nutrients from agricultural sources all threaten riparian biodiversity and ecosystem services at different spatial scales [25]. The market proximity activities mentioned by respondents reflects a broader trend where informal settlements and commercial activities near water bodies lead to unmanaged waste disposal and physical habitat destruction [26].

Extreme weather events were highlighted as major drivers of this riparian zone degradation. A related study has revealed that changes in temperature, precipitation, hydrological patterns cause changes in hydrology, biodiversity, ecosystem function and services of the riparian zones [27]. Similarly, [27, 28] found that intense flooding, and prolonged droughts within riparian zones disrupt natural processes such

as water flow, nutrient filtering, and sediment transport. According to the community's observation of dirty water and sediment runoff indicate a loss of the natural filtration function typically provided by healthy riparian buffers, which are essential for controlling non-point source pollution and stabilizing banks [25, 29, 30].

The dramatic reduction in wildlife within Kibare Lake riparian zone before the restoration activities, particularly the migration of large mammals like hippos and the decline of snakes, insects and birds highlights the habitat mosaic loss common in degraded agricultural catchments [25]. Riparian zones support disproportionately high levels of biodiversity; when these are degraded, the resulting loss of ecosystem functionality can lead to a desert-like state that fails to support local fauna and flora [29]. The spread of intestinal worms and malaria diseases indicates the reality that contaminated lake water creates hazardous pathways for disease, disproportionately affecting vulnerable populations like children [31]. Furthermore, the decline in fish stocks and medicinal plants illustrates how the overexploitation and degradation of these zones compromised food security and traditional livelihoods [29].

Benefits from the restoration using tree plantations within the area

Although some community members reported a lack of direct benefits from the restoration, some ecological services such as biodiversity recovery, soil erosion control sediment retention and water quality improvements were mentioned. The contribution of the implemented EbA approach in controlling soil erosion and sediment runoff is a critical success aspect identified by the local community. This aligns with recent studies highlighting that restoration of riparian zones using EbA approach promotes soil stability, prevent floods, and filters agricultural pollutants from uplands, and enhance water volume and quality [32].The reported and observed improvement in water quantity and quality is consistent with other recent studies that revealed that healthy riparian zones increase water volume while enhancing water quality [3].

Furthermore, according to [25], the restoration of riparian zones returns back both terrestrial and aquatic species. The reappearance of diverse species such as amphibians, butterflies, hippos, monkeys, birds, and snakes in the restored area indicates ecological restoration success. The increase in fish productivity stated by local community, further demonstrates the linkage between aquatic and terrestrial habitats, where riparian vegetation provides essential organic matter and shade that support fish breeding and nursery grounds [29].

Satisfaction with the restoration outcomes

The results indicate a high level of dissatisfaction with restoration outcomes, particularly driven by unmet socioeconomic expectations and persistence livelihood challenges resulted from the negative impacts associated with being relocated without compensation and limited community involvement in decision making processes. Previous studies revealed that restoration projects that fail to deliver direct

or indirect socioeconomic benefits often face dissatisfaction from local communities, eventually undermining long-term sustainability [33]. Furthermore, participatory approaches are widely recognized as essential for successful restoration outcomes. When communities are excluded from planning and implementation, they are less likely to perceive the benefits of restoration or support its objectives. As highlighted by [34], inclusive governance and equitable benefit-sharing are key determinants of both community satisfaction and the long-term success of restoration initiatives.

Additionally, the perceived ineffectiveness of restoration measures such as contour bands, further contributed to dissatisfaction. In this study, increased human wildlife conflicts particularly crop raiding by hippos, indicate that the technical design and implementation may not have adequately accounted for local livelihoods support, environmental, and ecological dynamics. Recent similar studies highlighted that poorly adapted restoration infrastructure can fail to achieve intended outcomes and intensify vulnerabilities of communities if those structures are just restored without improvements in their design and quality [34, 35].

In the current study, respondents reported that before the restoration, agriculture and pastoralism were taking place in the whole riparian zone, and it was the most preferred land for these activities because it is close to water. However, the relocation of residents in Kibare Lake riparian zone without compensation, coupled with the ban on using it have reduced income, and increased food insecurity. This economic hardship appears to be the primary driver behind the community's refusal to illegally stop using the restricted land. The respondents' concerns about loss of agricultural land and reduced livelihood opportunities reflect broader challenges observed in riparian restoration across sub-Saharan Africa [36, 37]. According to [38], restoration efforts that exclude community benefit-sharing mechanisms, undermine the potential positive effects of restoration projects and risk exacerbating poverty and inequality, particularly in rural areas where dependence on natural resources is high.

Preferences of communities to inform policy decision makers of current benefits and gaps for future improvements

The call for balancing ecological restoration with tangible human well-being benefits such as income-generating opportunities and access to resources reflects broader findings that restoration success depends on linking conservation goals with community well-being [39, 40, 41]. The suggestion to construct effective fencing highlights the importance of maintaining restoration infrastructure to address human wildlife conflicts, particularly crop damage caused by animals such as hippos. Similar challenges have been widely reported in riparian and protected areas where ecological restoration without adequate mitigation strategies increased wildlife conflicts [42]. Furthermore, the recommendation to replace bamboo plantation with sugarcane and plant more fruit trees highlights a preference for multifunctional landscapes that provide both ecological and economic benefits. This is supported by other studies advocating for agroforestry and nature-based solutions that enhance biodiversity while supporting livelihoods [43].

The results from the field observation also demonstrated that the port that links Tanzania and Rwanda passing through Kibare Lake has degraded the riparian zone by altering water quality and biodiversity. This is in line with another study [44] which has indicated that building ports triggers environmental degradation through habitat destruction and water pollution. Similarly, [45] in his study has revealed that the port activities increase environmental problems such as waste production, key biodiversity loss due to fragmentation, pollution and noise generation.

Declarations

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Author contributions

JM conceived and designed the study, collected data, analyzed data, and wrote the manuscript. JPB supervised the study.VN critically reviewed and refined the manuscript.

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Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request

Consent to participate:

Informed consents were obtained from all participants. No participants under 18 participated in the study

Competing interests:

The authors declare no competing interests

Consent to publish:

Informed consent for publication was obtained from all participants in the study.

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Figures

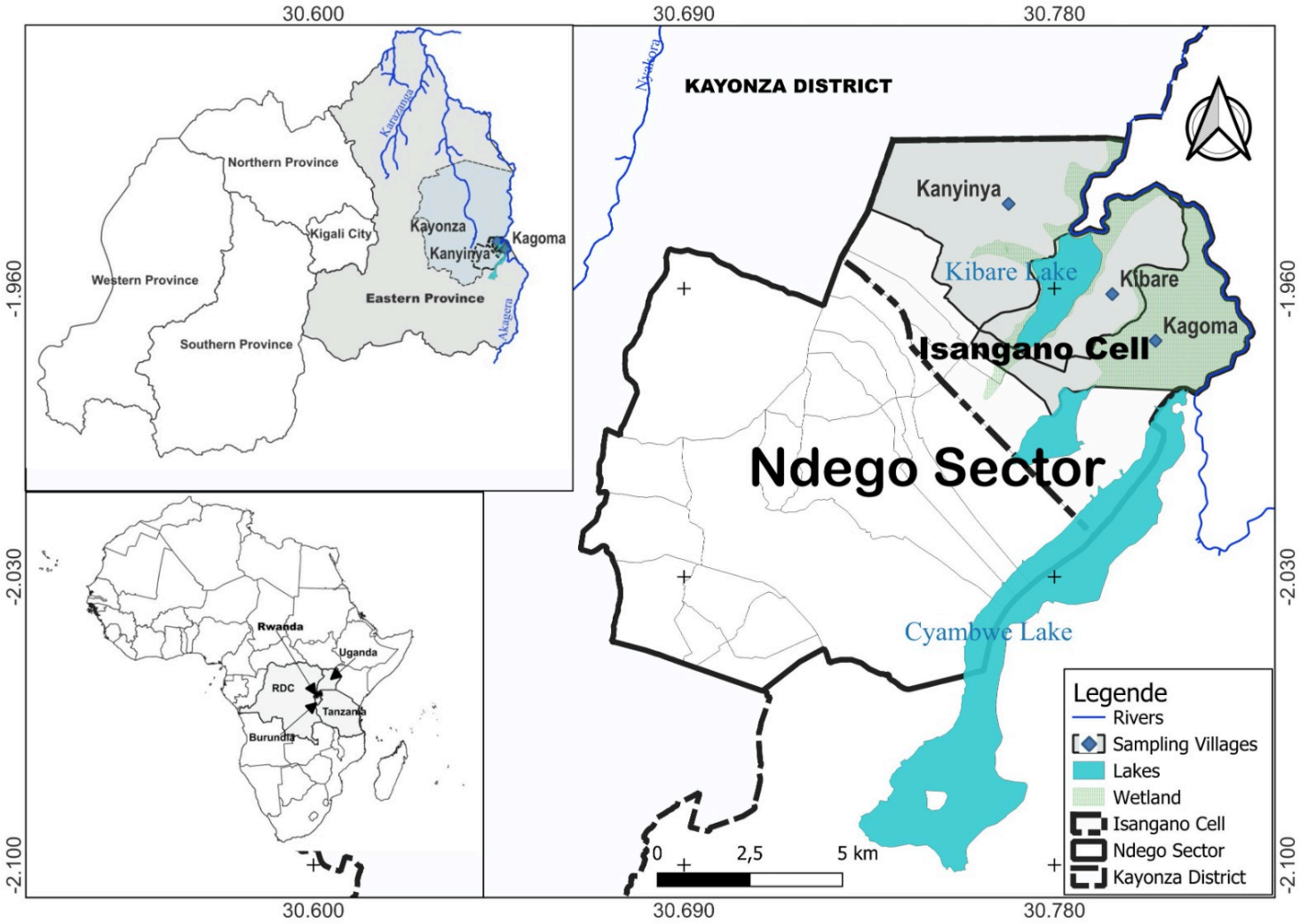

Figure 1

Map of Rwanda showing the location of Rwanda in Africa and the location of Lake Kibare in the Eastern Province. Each point on the map inset represents a sampling site.