Perception and Knowledge of Local Community on the Use of Indigenous Tree Species for Ecosystem Restoration in Gasabo District, Rwanda

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Abstract

Ecosystem restoration assists in the recovery of ecosystems degraded or destroyed by anthropogenic. This degradation poses significant negative impacts on ecosystem services and restoration is a mandatory approach to reverse the situation. This study aimed at assessing the perceptions and knowledge of the local community on utilization of indigenous trees for ecosystem restoration in order to optimize the delivery of ecosystem services and boost the collaboration among community members. The study was conducted in Gasabo District in seven sectors of Bumbogo, Gatsata, Jali, Kimihurura, Kacyiru, Gisozi, and Nduba. Semi-structured interviews, self-administered questionnaires and group discussion techniques were used to explore the perceptions and knowledge of local communities on the use of indigenous tree species for ecosystem. Data analysis was performed using Excel Microsoft and descriptive statistics was used to calculate the frequencies and percentages. The study indicated that most of the trees are used as agroforestry and that trees are mainly propagated by planting seedlings (72.9%) The most dominant agro-forestry trees are *Ficus thoningii* (73.6%), *Vernonia amygdalina* (54.3%) and *Dracaena afromontana (*52.1%). Other identified indigenous trees used to restore the ecosystem *Croton megalocarpus*, *Markamia luthea*, *Maesopsis eminii*, and *Erythrina abyssinica*. The local communities prefer indigenous trees that are identified most resistant to the climatic condition stress such as *Euphorbia tirucalli (*77.1%), *Markhamia lutea* (42.9%) and *Dracaena afromontana* (40%). The study found that two of these resistant trees (*Markhamia lutea* and *Dracaena afromontana*) are disappearing together with *Ficus thoningi* and at the rate respectively of 70%, 64.3%, and 75%. The main constraints faced by the local communities are lack of seeds or seedlings (83.6%), urbanization (82.9%), and high demand for medicinal use (75.7%). Regarding the importance of the ecosystem services, the local communities mentioned adventure and ecotourism exploration (41.8%), agriculture and erosion control (31.4%) and Wildlife conservation (24.3%). The ecosystem restoration using indigenous trees is accepted by local communities but it is threatened mainly by the lack of indigenous seedlings. All people should be then mobilized to avail indigenous tree seedlings for ecosystem restoration, biodiversity conservation and ecosystem services.

Keywords: Ecosystem restoration, ecosystem services, indigenous trees, ecosystem degradation, local community.

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1. Introduction

Across the world, the anthropogenic activities are severely threatening ecosystems (Halpern et al., 2007; Halmy et al., 2019; Prakash & Verma, 2022). This is mainly evident through various forms of environmental degradation, such as habitat destruction (Wilson et al., 2016), pollution (Arihilam et al., 2019), climate change (Mahmoud & Gan, 2018), overexploitation of natural resources, and the introduction of invasive species (Zimmermann et al., 2014). As population growth keep dramatically increasing their needs, aspirations and values increases toward improving quality of life (Kruk et al., 2018). As such, engagement in economic activities such as agriculture, industrialization, transportation, urbanization, and resource extraction, among others, became a promising paved way to the community prosperity (Rockström et al., 2017). However, these activities can pose significant negative impacts on ecosystems and biodiversity, leading to habitat loss, species extinction, disruption of ecosystem processes, loss of ecosystem services (Halpern et al., 2007; Halmy et al., 2019; Prakash & Verma, 2022), and deforestation. Indeed, owing to agriculture, industries and human settlement, the global deforestation rate reached to the pick in this century (Austin et al., 2017; Leblois et al., 2017). In tropical region, the main forests such as Amazon and african tropical forests and tropical asian area experienced a severe deforestation like never been in last decades (Rosa et al., 2016; Edwards et al., 2019). The inevitable reasons are associated with expansion of agricultural farms (Carlson et al., 2012; Ordway et al., 2019), and urbanization (DeFries et al., 2010; Clement et al., 2015). As a result of this deforestation, the species extinction rate was correspondingly high, with severe effects in tropics, a biodiversity hotspot, with several endemic species (Edwards et al., 2019). Therefore, restoration is thought to be a mandatory approach to reverse the situation (Bernhardt & Palmer, 2011; Lal, 2015, Strassburg et al., 2020) and therefore provide ecosystem services to local communities. Comprehending how the local community perceives and utilizes these species for ecosystem restoration is pivotal in optimizing the delivery of ecosystem services and enhancing the resilience of local ecosystems to environmental change (Nies et al., 2023; Bhattacharyya et al., 2023; Tian & Zhang, 2023). Indeed, engaging the local community in ecosystem restoration efforts fosters a sense of ownership, stewardship, and empowerment (Rockström et al., 2017).

A number of techniques have been adopted to enhance restoration success in accordance to the ecosystem types such as forests, wetlands, lakes and rivers (Verhoeven et al., 2014). As such, various species have been widely used such as number of plant/tree species (Pan et al., 2016). However, other organisms such as fungi, mammals, birds, invertebrates, fish, amphibians and reptiles among others, have been used in various restoration activities (Bhaduri et al., 2022; Borchard et al., 2014). These species have proved to be crucial in restoring biodiversity, enhancing ecosystem functions, and promoting ecosystem resilience (Oliver et al., 2015; Cerullo et al., 2019). On exceptional case, plants are vital for ecosystem restoration, and have been globally used in restoration (Strassburg et al., 2020). In fact, plants are primary producers in ecosystems, and form the base of the food chain, where they provide energy and nutrients to other organisms. Moreover, plants stabilize soil and prevent soil erosion, hence suitable for restoration approach (Zuazo et al., 2009; Castellano et al., 2015). In addition to the provision of habitat to other organisms such as insects, birds, mammals and fungi (Nagelkerken et al., 2008), plants play irreplaceable role in carbon sequestration (Nies et al., 2023; Bhattacharyya et al., 2023; Tian & Zhang, 2023), water regulation, and pollution remediation (Aborisade et al., 2023; Latif, et al., 2023). Consequently, their uses in restoration have a cumulative importance and

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exacerbate its success faster than other organisms. However, to ensure success and sustainable restoration, the choice of adopted species depends on the nature of ecosystem and the priority of the area being restored.

The variety of ecosystems expresses a significant influence on indigenous or exotic plant species being considered in restoration projects. Sowerwine et al. (2023) indicated therefore that indigenous species are preferred at regional and local scales; they represent the uniqueness of the areas, and play a crucial role in biodiversity and ecosystem services leading to sustainable and resilient landscapes (Sowerwine et al., 2023). In fact, indigenous plants are naturally suited to the specific ecological niches of their native habitats, making them more resilient (Mitchell, 2024). In addition, indigenous plants often possess high levels of genetic diversity, reflecting their long evolutionary history and adaptation to diverse environmental conditions (Ahmad et al., 2023). Thus, preserving and restoring indigenous plant populations helps to conserve genetic diversity, which is essential for the long-term resilience and adaptability of ecosystems to environmental changes (Ahmad et al., 2023). Indigenous plants also have cultural and traditional significance to local community, for their basic needs such as food, medicines, shelters, rituals, and cultural practices for generations (Nagelkerken et al., 2008; Jamshidi-Kia et al., 2017). Indigenous plant species also help in controlling invasive species through outcompeting them for resources and space and therefore reduce their spread and impacts. This is absolutely ecologically important, since they restore ecological balance and resilience in ecosystems affected by invasive species (Weidlich et al., 2020; Trammell et al., 2020).

The consideration of species to be incorporated in the restoration requires a comprehensive understanding and a superior perception of involved community about indigenous plants. Indeed, community perceptions on adopted approach in restoration project influence the success of the project to be implemented (Abukari & Mwalyosi; 2020). These community perceptions are shaped by a complex interplay of ecological, social, cultural, economic, and governance factors. As such, the restoration approach, including choice of species, depends heavily on meaningful engagement of local communities, their sensitivity to their values and priorities (Hemmerling et al., 2020). The consideration of indigenous plant species in the restoration projects by local communities reflects also their knowledge about their delivered services (e.g.: economic, medicinal or cultural) (Maroyi, 2013; Mahwasane et al., 2013; Bouyahya et al., 2017, Evbuomwan et al., 2023; Mishra & Kumar, 2023). Contrary to good knowledge and superior perception of involved community, the human-nature conflicts may arise against restoration projects, hampering therefore their success. In this regard, community involvement should be a priority in ecosystem restoration projects.

In Rwanda, following various international conventions and agreements on ecosystem restoration (Ramsar, 1971, 1996; CBD, 1992), and government policies in different countries, restoration activities have taken a strong and promising initiative (REMA, 2020). As such, various procedures and strategies were identified based on the country's priority (REMA, 2010, 2020). Restoration efforts have been met with significant acclaim, showcasing remarkable success and earning widespread recognition (IUCN, 2022; Buckingham et al., 2021). The restoration systems involve both exotic and indigenous trees (Ndayambaje, 2013; Ministry of Land and Forestry, 2018) while only indigenous trees in restoration of ecosystem revealed resilience and sustainability of ecosystem (Oliver et al., 2015; Cerullo et al., 2019). The

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consideration of these indigenous trees was given less attention while the country is home for several indigenous species (Ndayambaje, 2013), inhabited protected areas such as national parks, reserves and agroecosystems (REMA, 2009). The trees species such as *Ficus thoningii*, *Euphorbia tirucalli*, *Erythrina abyssinica*, *Vernonia amygdalina*, *Dracaena afromontana* among others, are the species of ecological, economic and cultural values for local community (REMA, 2009). However, their use among number of other native tress is still at infancy, yet it would scale up the restoration success, while ensuring of resilience of inhabited ecosystems.

Nowadays, Rwanda has surpassed its target of achieving a 30% forest cover, reaching 30.4% (IUCN, 2022). This was achieved mainly through the reforestation of the degraded areas for charcoal production, firewood, and construction materials, using both exotic and native species (IUCN, 2022). However, less effort is being invested in adopting indigenous trees in ecosystem restoration. Even though policies are striving for maximizing the use of indigenous species in ecosystem restoration in Rwanda, to effectively counteract the climate change and increase in resilience of ecosystem, indigenous plants need to inefficiently be adopted in restoration processes. Moreover, local communities as primary stakeholders prefer indigenous trees over exotic plants. Many studies investigate various topic regarding indigenous species in Rwanda, such as inventory (REMA, 2009; Hagumubuzima et al., 2022), their role in soil fertility (Rwibasira et al., 2021; Cyamweshi et al., 2023), and distribution among others. Unfortunately, there is no study conducted in Rwanda, specifically in Gasabo District, with the goal of assessing the perception and knowledge of local community on the utilization of indigenous species in ecosystem restoration.

Gasabo District is lagging behind in the use these indigenous trees to restore its degraded agroecosystem while its urban, peri-urban, and rural areas are experiencing various degradation (e.g.: settlement, industrial, agroecosystem, etc) (Irankunda, 2019). This study aims to assess the perception and knowledge of the local community regarding the utilization of indigenous trees for restoration purposes in this administrative entity and therefore promoting sustainable land management practices. The study specifically aims (i) to identifying the indigenous trees preferred by local community in ecosystem restoration, (ii) to determine the methods used by local community to propagate the indigenous trees, (iii) to assess the local community's knowledge of the value of indigenous trees to their livelihoods, and (iv) to identify the constraints faced by the local community in utilizing indigenous trees. The findings of the study will facilitate meaningful participation and collaboration among community members, researchers, and policymakers, thereby fostering more inclusive and equitable decision-making and planning processes.

2. Materials and Methods

2.1. Study Area

Gasabo District is one of the three districts of the Kigali City; it is located in its North East part. This largest district of Kigali City by geographical area with 429.3km^2, is located in the central part of the country, comprising 15 administrative sectors 15 sectors, 73 cells and 501 villages (Figure 1). It is enclosed with Kicukiro district (in South); Nyarugenge district (in West); Rwamagana (in East); Rulindo and Gicumbi districts (in North) (Figure 1).

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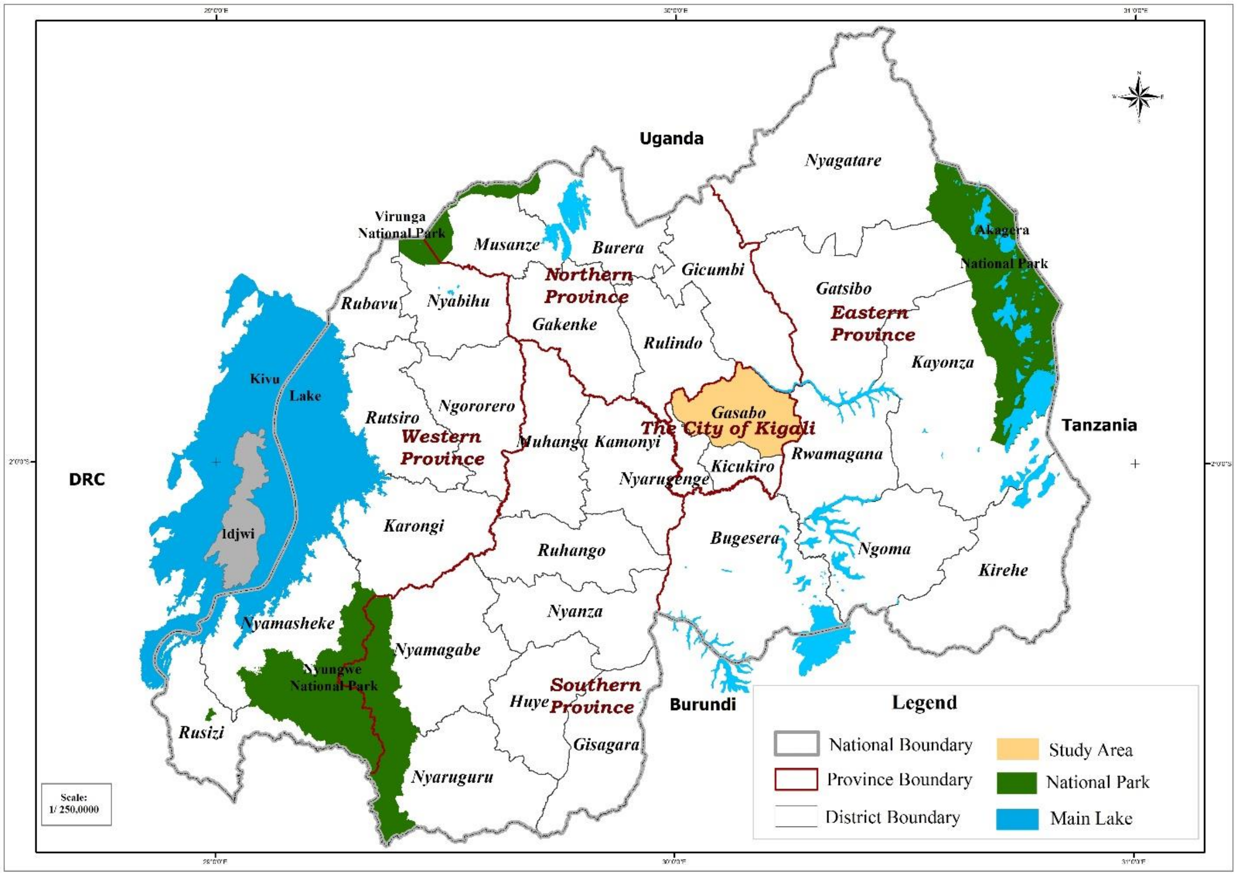

Figure 1: Location of the study area in City of Kigali, Rwanda

As for many areas in Rwanda, agriculture is a significant economic activity in the district. The district encompasses a mix of urban (about 90%), then peri-urban, and rural areas, with varying degrees of agricultural land use (Irankunda, 2019). Gasabo district receives annually a range of rains between (900-1500) mm and 20˚C of temperature (Henninger, 2009; Henninger, 2013; Nahayo, 2019). In Gasabo District, the agricultural activities include crop cultivation, livestock rearing, and agroforestry practices. The farmers grow a variety of crops such as maize, beans, potatoes, vegetables, and fruits. The livestock farming includes cattle, goats, sheep, and poultry.

2.2. Research design

The study was a cross sectional survey through different categories of population such as, local leaders and local communities and NGOs. Observations, self-administered questionnaires and focus group interview during data collection were used, the study population was divided into categories category one was local communities, category two was local leaders and category three was NGOs. Self-administered questionnaires were used for category one and interview and discussion for the 2nd and 3rd category. Data were analyzed using Excel.

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2.3. Target population

The targeted population for this study was the information rich area including community members, local leaders, and experts in forestry and nature conservation (e.g.: agronomists, conservationist, and land managers, among others). Moreover, whoever has experiences related to indigenous tree species and in one way or another has been engaged in ecosystem restoration in Gasabo District was considered. The priority was given to the areas which are highly degraded by either anthropogenic activities or disasters such as erosion and/or flooding including Bumbogo, Gatsata, Jali, Kimihurura, Kacyiru, Gisozi, and Nduba Sectors (Figure 2).

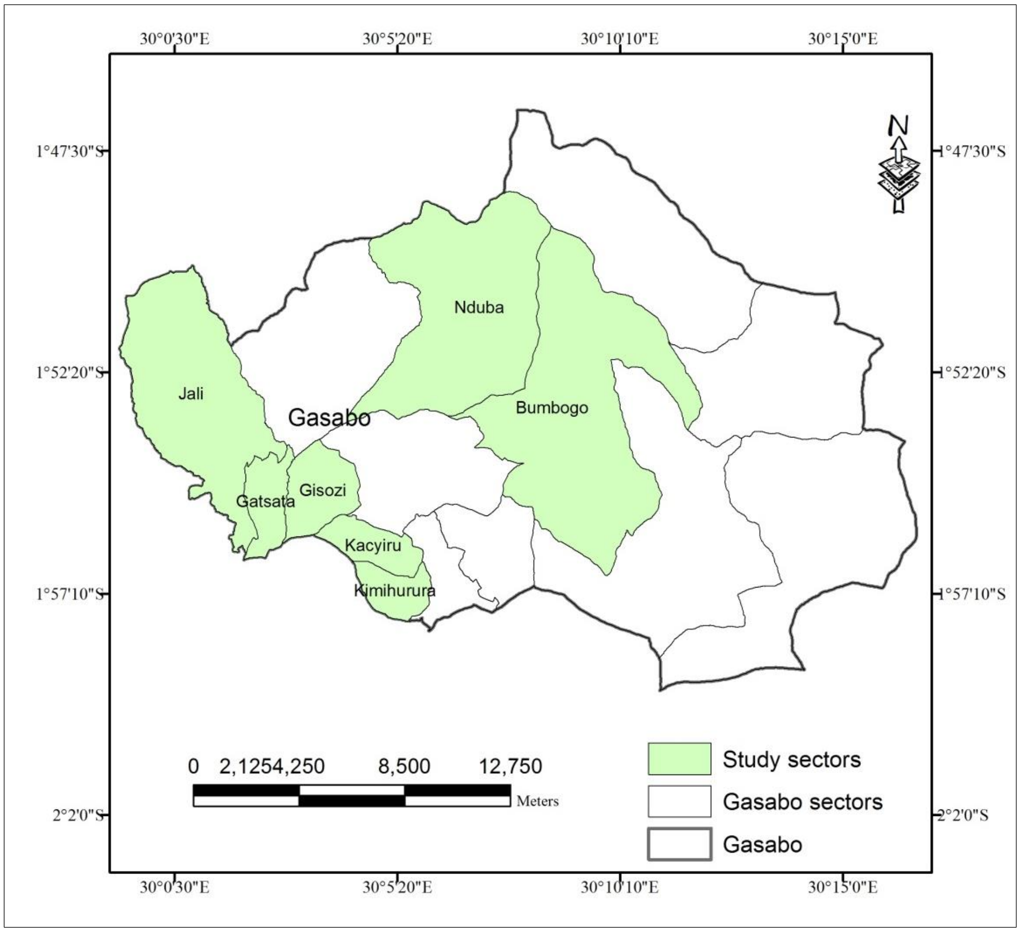

Figure 2: Study areas in Gasabo District

2.4. Sample size and sampling techniques

This study selected a purposive sample of 350 people for interviews and group discussion (means 50 individuals per Sector). And 140 people were selected for self-administered questionnaire (means 20 people in each sector). This study has focused on the population within Gasabo district with their respective sectors and during sampling multi-stage and purposive sampling was used for selection of respondents in the boarding Sectors. This multi-stage sampling involves the selection of population sample from selected clusters among many clusters

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and all the population units of each selected clusters are surveyed (Mjuma, 2014) from this sampling method, 7 sectors were selected among the 15 administrative sectors that are Bumbogo, Gatsata, Jali, Kimihurura, Kacyiru, Gisozi, and Nduba Sectors. Purposeful sampling was considered, samples were collected from information rich cases in the study for the most effective use of limited resources and time (Patton, 2002; Cresswell and Plano, 2011).

From the study population demography was assessed and comparison between age range and gender where 22.9% of the total respondents were in the range of 44-56 age and 20.7% were in the range 31-43 age range (Figure 3) while among the total respondent, 55% were males and 45% females (Figure 3) which implies gender equality consideration while collecting data. Below figure indicates the age range versus sex ratio:

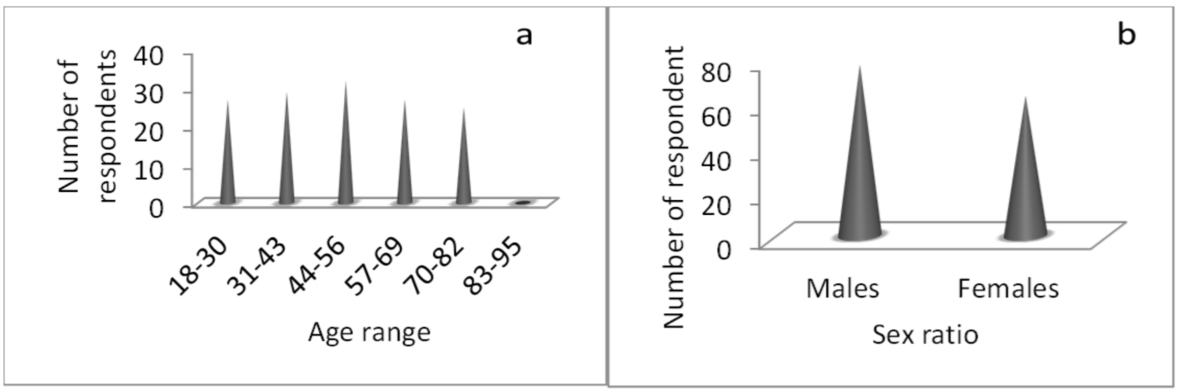

Figure 3**:** Gender equality during data collection: (a) Age range of respondents and (b) Sex ratio of respondents (Source: Field Survey; 2024).

Following the education status, it was identified that 46% and 30% did high school and primary school respectively, 20% and 4.3% did tertiary and university (Figure 4c) studies respectively while 20.7% are government employees and 17.9% are NGOs employees (Figure 4d). Below figure indicate the education level and occupation status:

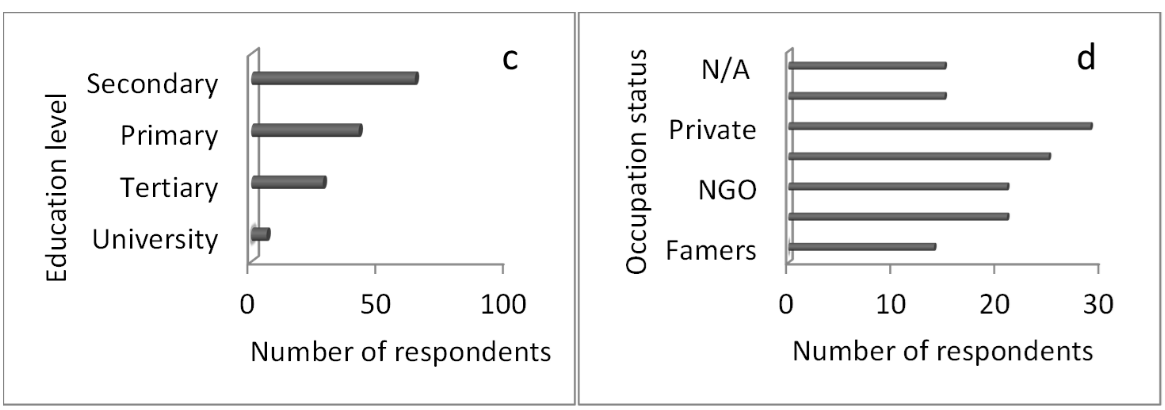

Figure 4: Data on education and occupation of respondents: (c) Education levels and (d) occupation status (Source: Field Survey; 2024).

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2.6. Data collection

Data were collected in seven sectors of Bumbogo, Gatsata, Jali, Kimihurura, Kacyiru, Gisozi, and Nduba Sectors. Different approaches were used including interview where semi-structured interviews with local leaders, experts and NGOs in forestry and conservation to explore their perceptions, self-administered questionnaires were used to the local communities and group discussion with community gatherings after community works (Umuganda program).

2.7. Data analysis

Data analysis was performed using Excel datasheet. Tables and figures were performed using Excel while the typing of the full text MS word was used. GIS software was used to perform maps. Descriptive statistics were used to calculate frequencies and percentages of respondents while column chart used to present percentages and its related variables graphically.

3. Results

3.1. Indigenous trees preferred by local community in ecosystem restoration

During this study about perceptions and knowledge of local community on the use of indigenous tree species for ecosystem restoration in Gasabo district, population within the district were assessed with different approach purposely to know their understanding on use of indigenous tree species for ecosystem restoration. And of course, the study wanted to know at least if they know ecosystem services and their implication in daily life, their contribution to harm the ecosystem integrity through socio-ecosystem activities and other anthropogenic activities. Despite from the above collected information, we tried also to know if there are some challenges people are meeting with in case they need to restore the ecosystem or any other program to restore ecosystem for sustainable benefit. From the study, 490 population were assessed through self-administered questionnaire, interview and group discussion.

During this study, indigenous trees were assessed and most of the trees are used as agroforestry where 73.6%, 54.3% and 52.1% are *Ficus thoningii*, *Vermonia amygdalina* and *Dracaena afromontana* respectively. Some other indigenous trees were identified including *Maesopsis eminii, Markamia luthea* and *Erythrina abyssinica* (Figure 5).

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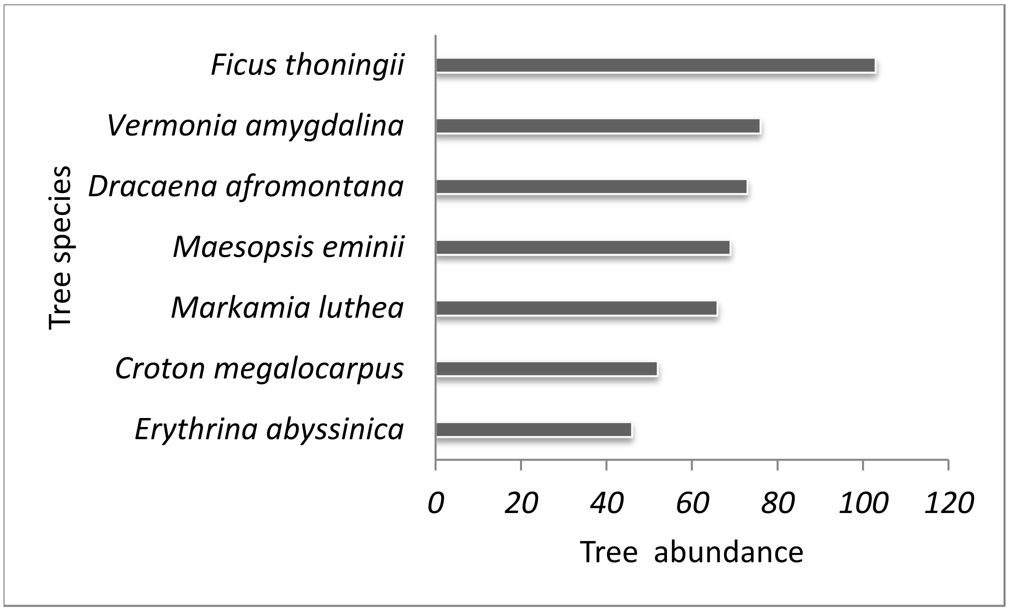

Figure 5: Indigenous tree abundances (Source: Field Survey; 2024)

3.2. Methods that local community utilizes to propagate the indigenous trees

Results in Figure 5 show the main technics used to propagate the indigenous trees where respondents indicated that they plant trees either by planting seedlings from nurseries either by direct seedlings. Planting seedlings from tree nurseries is the most predominant technique with 72.86% versus only 42.22% of responses (Figure 6).

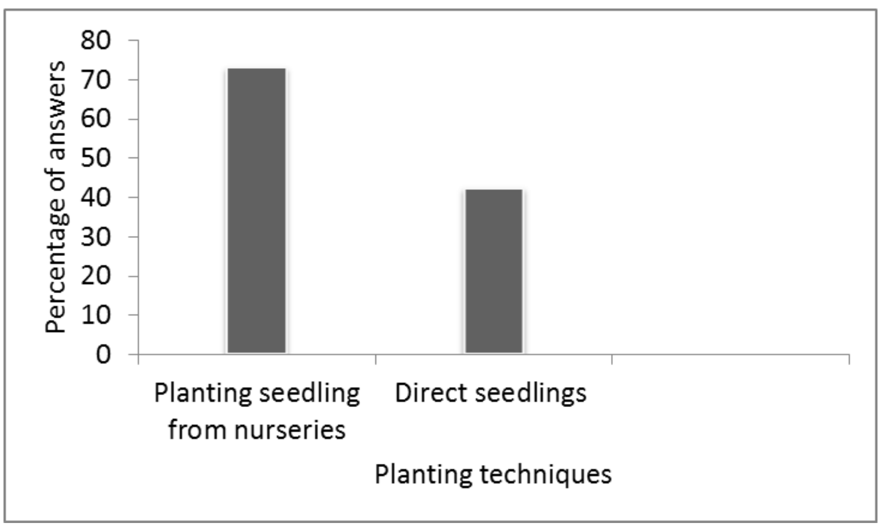

Figure 6: Methods used by the community to propagate the indigenous trees (Source: Field Survey; 2024)

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3.3. Community perception on the resistance and disappearance of indigenous trees

During this study, the respondents have identified most resistant indigenous trees to various pressures. The results indicated that *Euphorbia tirucalli*, *Vernonia amygdalina*, and *Markhamia lutea* are more abundant (Figure 7)

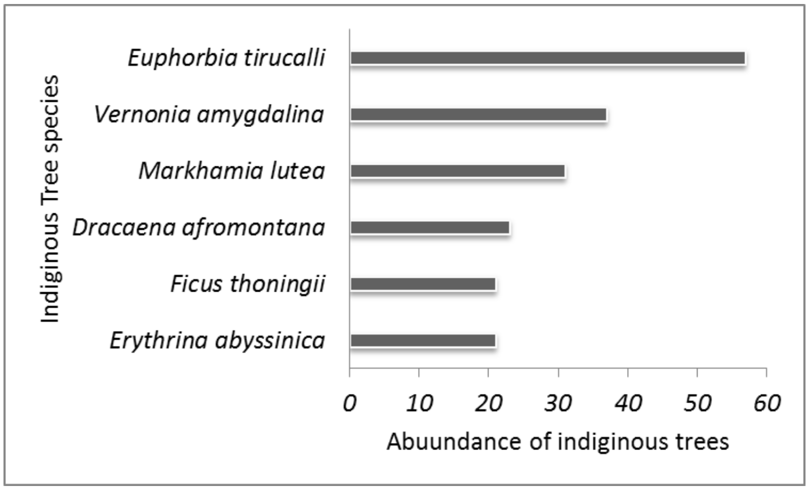

Figure 7: Most resistant indigenous trees to local stress factors for ecosystem restoration (Source: Field Survey; 2024)

Endagered indegenous trees that are disappearing due to different factors such us urbanization and industrialization and low economic values were identified. Where *Ficus thoningii*, *Markhamia luthea* and *Dracaena afromontana* were identied as the most disappearing indegenous tree species as confirmed respectively by 10%, 23%, 25% and 34% (Figure 8).

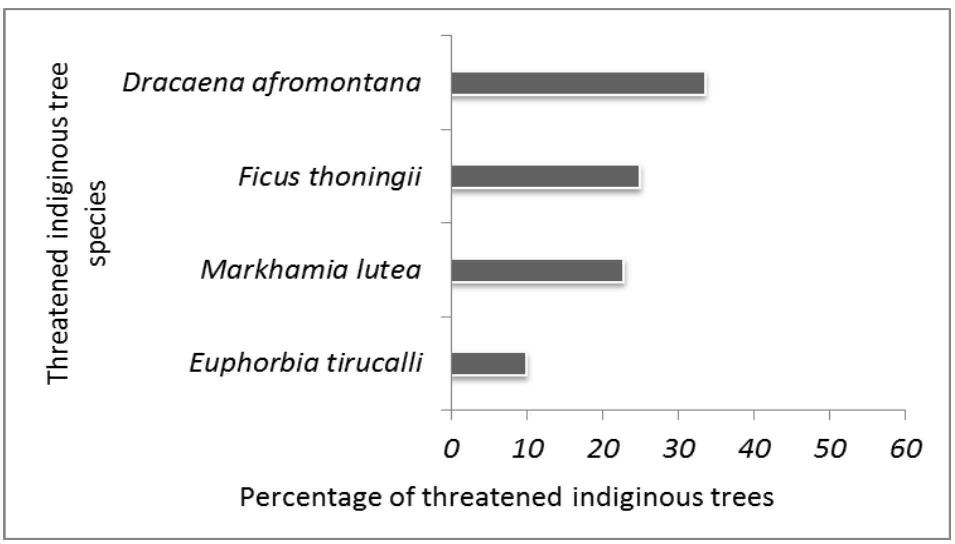

Figure 8: Most threatened indigenous trees in the community (Source: Field Survey; 2024)

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3.4. Constraints faced by Community in utilizing indigenous trees in ecosystem restoration

The figure 8 below illustrates constraints faced by communities in utilizing indigenous trees for ecosystem restoration namely lack of seeds or seedlings with 83.6%, urbanization with 82.9%, High demand for medicinal use with 75.7%. There are others including low adaptability, low economic values and preference of exotic species such as eucalyptus (Figure 9)

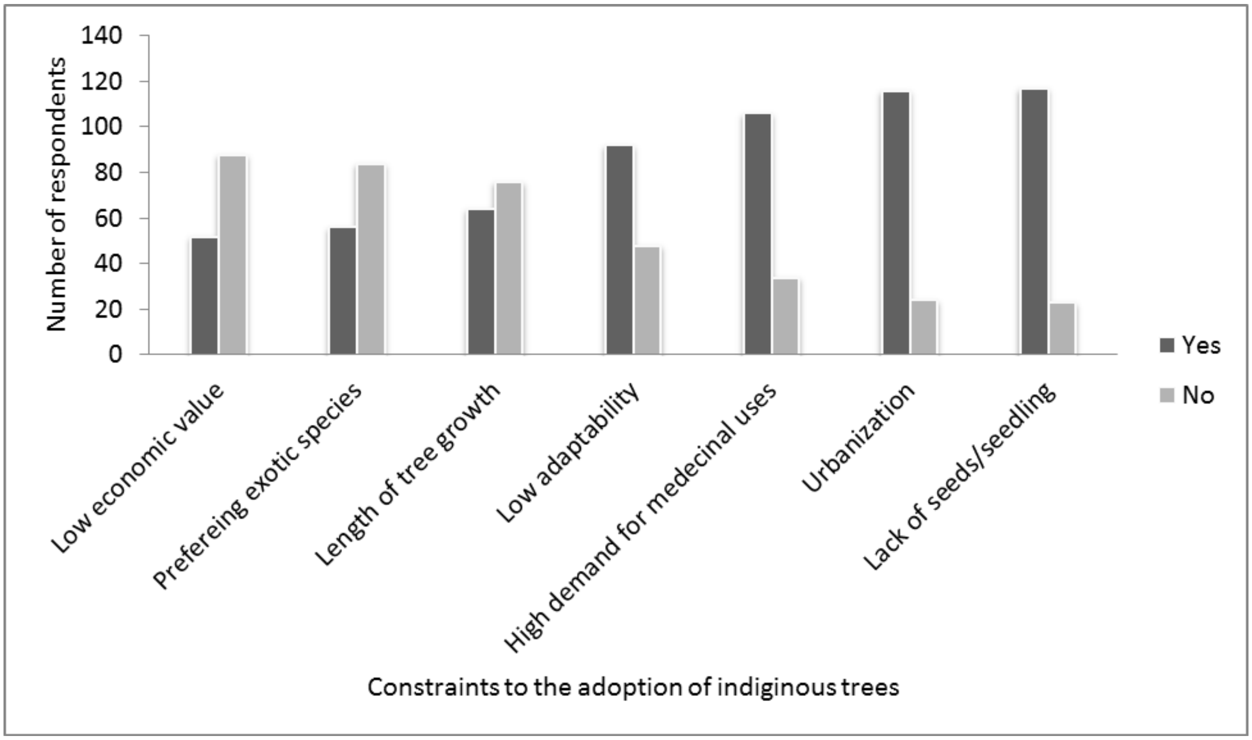

Figure 9: Constraints faced by Community in use of indigenous trees (Source: Field Survey; 2024)

3.5. Importance of ecosystems to local community

During this study, the importance of the ecosystem services was examined and community has expressed their reaction and the results are below: adventure and ecotourism exploration (41.8%), agriculture and erosion control 31.4% and wildlife conservation with 24.3% (Figure 10)

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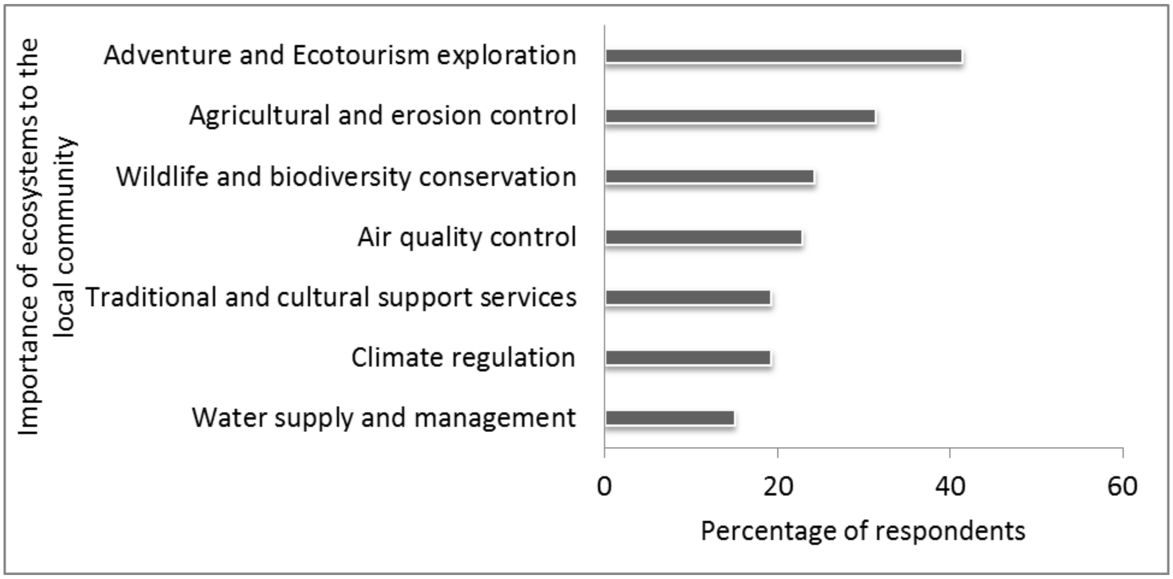

Figure 10: Importance of ecosystems to local community (Source: Field Survey; 2024)

4. Results Discussion

4.1. Indigenous trees preferred by local community in ecosystem restoration

Ecosystem restoration efforts reflect a holistic approach that integrates environmental conservation, sustainable development, and community engagement. These initiatives align with global commitments such as the Bonn Challenge and the United Nations Decade on Ecosystem Restoration (CBD, 1992), this restoration is done mainly by replacing the lost trees with other indigenous trees to sustain the habitat for existing biodiversity. In Rwanda, the census revealed that indigenous plants contribute to the inhabited biodiversity and various ecosystems. Indeed, the forests, woodlands, and wetlands of Rwanda support a rich diversity of flora, including many other native trees that contribute to Rwanda's natural heritage and ecosystem services (REMA, 2010, 2020). From this study, some indigenous trees that are mainly used to restore the ecosystem especially in urban and cultivation areas were identified including *Croton megalocarpus*, *Markamia luthea*, *Maesopsis eminii*, *Ficus thoningii* and *Erythrina abyssinica*.
In fact, Rwanda has a diverse array of indigenous tree species, ranging from tropical rainforest species in the western region to savanna and montane forest species in the central and eastern parts of the country (Stelstra, 2021).

The indigenous trees in Rwanda encompass a variety of taxonomic groups, including hardwoods; softwoods, fruit-bearing trees, medicinal plants, and ornamental species, each adapted to specific ecological niches and habitat conditions (Leakey et al., 2022; Zerbe, 2022). Among these indigenous trees were identified to be resistant to local stress factors for ecosystem restoration including *Euphorbia tirucalli, Erythrina abyssinica, Vernononia amygdalina, Dracaena afromontana, Ficus thoningii, Markhamia lutea*.

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4.2. Methods does local community utilize to propagate the indigenous trees

The use of indigenous trees in ecosystem restoration plays a crucial role in promoting biodiversity, enhancing ecosystem services, and supporting sustainable development (Reyes arcía et al., 2019). This implies that using indigenous trees in ecosystem restoration since they are well-adapted to local environmental conditions and play a vital role in supporting native flora and fauna (Leakey et al., 2022; Zerbe, 2022). Therefore, planting indigenous tree species in degraded areas helps in recreating diverse and resilient ecosystems (Sowerwine et al., 2023; Mitchell, 2024). Most of the trees species found in these indigenous species are used in traditional medicine and some plants reveal important biochemical extracts and this include Ficus species. Most of these species are rich in wetlands and aquatic ecosystems.

The agro-ecosystems have adapted and accommodated many related wild species and plant forage crops including *Calliandra calothyris*, *Leucaena diversifolia*, and *Sesbania sesban* (MINITERE, 2003a). Some other tree species found in Rwanda include *Ficus thoningii*, *Euphorbia tirucalli*, *Erythrina abyssinica, Vernonia amygdalina, Dracaena afromontana,* among others and these tree species are used as agro-forestry and involve in agro-ecosystems through afforestation efforts (MINITERE, 2003a). This afforestation is being done through different projects from government program, NGOs initiatives, community groups and private companies as identified during this study. Some approaches or techniques were adapted within different restoration projects within community including planting seedling from nurseries and direct seedlings and these techniques are helping to propagate the indigenous trees for ecosystem restoration.

4.3. Constraints faced by community in utilizing indigenous trees in ecosystem restoration

During this study, the results has identified constraints that are limiting these ecosystem restoration projects to be implemented including lack of seeds/seedling where there are limited tree nurseries and most of them belongs to private companies and sell to high price, length of tree growth, here some of the indigenous trees do not grow bigger to the size that is preferred by people, high demand for medicinal uses, urbanization which is growing highly and continue to expand and clear down the ecosystem. Low adaptability for some trees that are not resistant to local stress conditions, preferring exotic species here some people prefer exotic species as they grow first and high to be more productive in terms of timber and woods and there is a low economic value for indigenous trees that are not economically viable when harvested.

Human pressures on the ecosystem is increasingly high due to the socio-economic activities including mining, infrastructure development leading to tree cutting and land modification, firewood collection and charcoal making and other human activities including animal grazing, fire and collection of medicinal plants (Plumptre, 2003; Rutagarama, 2003). This led to ecosystem destruction and affects ecosystem services that people are benefiting from ecosystem and this is affecting natural resources resulting to the pressure on natural resources and the rate of environmental degradation are extremely high (Bitariho, 2013). This indicates that socio-economic activities are degrading the ecosystem services and from this study, some of the socio-economic activities were identified including agriculture expansion, charcoal and energy development, industrialization, mining and extractive industries and urbanization and infrastructure development.

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4.4. Importance of ecosystem services to the community

This study shows that community are benefiting various ecosystem services to meet their needs including clean water, air filtration, climate regulation, erosion control and tourism products, raw material for handcraft, livestock grazing (Bitariho, 2013). Other ecosystem services provided by indigenous trees including tree collection for firewood and charcoal production, raw materials for infrastructure development, mining, and collection of medicinal plants (Kakuru et al., 2013). And from this study, indigenous trees were identified to be of importance including adventure and ecotourism exploration, agricultural and erosion control, air quality control, climate regulation, traditional and cultural support services, water supply and management, wildlife and biodiversity conservation. Those ecosystem services are important to the survival of people, however, this study demonstrates that to maintain the ecosystem services, there is a need to restore the ecosystem that is disturbed with human and development pressure such as urbanization and infrastructure development, mining and extractive industries, charcoal and energy development and industrialization. Therefore, there is a need of government interventions, non-governmental organizations and private sectors to intervene in ecosystem restoration through community support by providing tree seedlings, implementing many tree nurseries within community as well as capacity building on indigenous trees and sustainable ecosystem management.

5. Conclusion

Like other parts of Rwanda, ecosystems in the study area are experiencing human pressures as one of important drivers of ecosystem degradation. This study found that the major pressures on ecosystems include urbanization and infrastructure development. These pressures are altering ecosystems in Gasabo District at high extent and lead to the redution of ecosystem services and to disappearance of some tree species such *Markhamia lutea* and *Dracaena afromontana*. Indigenous trees are used in ecosystem restoration in the Gasabo district despite the lack of seedling and cuttings. Another challenge the local communities face is the low economic value of indigenous trees available in the study area. Face to this issue of low economic value, some local community members prefer to plant exotic tree species such as Eucalyptus despite its negative effects on water resources, undergrowth, soil nutrients and allopathy nearby agricultural crop. Eucalyptus is preferred for its Eucalyptus poles useful for farm implements and constructing houses and fences and for its potential to raise incomes through sale of poles and source fuel wood for both urban and rural inhabitants. People should mobilize their efforts to increase the public awareness on indigenous tree species and their ecosystem services, and to intervene in indigenous tree seeds preparation, tree nurseries establishment and tree seedling supply.

6. References

Aborisade, M. A., Geng, H., Oba, B. T., Kumar, A., Ndudi, E. A., Battamo, A. Y., ... & Zhao, L. (2023). Remediation of soil polluted with Pb and Cd and alleviation of oxidative stress in Brassica rapa plant using nanoscale zerovalent iron supported with coconut-husk biochar. Journal of Plant Physiology, 287, 154023.

Abukari, H., & Mwalyosi, R. B. (2020). Local communities' perceptions about the impact of protected areas on livelihoods and community development. Global Ecology and Conservation, 22, e00909.

https://dx.doi.org/10.4314/rjeste.v6i1.6

Ahmad, Z., Khan, S. M., Page, S. E., Balzter, H., Ullah, A., Ali, S., ... & Mukhamezhanova, A. S. (2023). Environmental sustainability and resilience in a polluted ecosystem via phytoremediation of heavy metals and plant physiological adaptations. Journal of Cleaner Production, 385, 135733.

Arihilam, N. H., & Arihilam, E. C. (2019). Impact and control of anthropogenic pollution on the ecosystem–A review. Journal of Bioscience and Biotechnology Discovery, 4(3), 54-59.

Austin, K. G., González-Roglich, M., Schaffer-Smith, D., Schwantes, A. M., & Swenson, J. J. (2017). Trends in size of tropical deforestation events signal increasing dominance of industrial-scale drivers. Environmental Research Letters, 12(5), 054009.

Bernhardt, E. S., & Palmer, M. A. (2011). River restoration: the fuzzy logic of repairing reaches to reverse catchment scale degradation. Ecological applications, 21(6), 1926-1931.

Bhaduri, D., Sihi, D., Bhowmik, A., & Dari, B. (2022). A review on effective soil health bio-indicators for ecosystem restoration and sustainability. Frontiers in Microbiology, 13, 938481.

Bhattacharyya, S. S., Mondaca, P., Shushupti, O., & Ashfaq, S. (2023). Interplay between plant functional traits and soil carbon sequestration under ambient and elevated CO2 levels. Sustainability, 15(9), 7584.

Borchard, F., Buchholz, S., Helbing, F., & Fartmann, T. (2014). Carabid beetles and spiders as bioindicators for the evaluation of montane heathland restoration on former spruce forests. Biological Conservation, 178, 185-192.

Bouyahya, A., Abrini, J., Et-Touys, A., Bakri, Y., & Dakka, N. (2017). Indigenous knowledge of the use of medicinal plants in the North-West of Morocco and their biological activities. European Journal of Integrative Medicine, 13, 9-25.

Buckingham, K., Arakwiye, B., Ray, S., Maneerattana, O., & Anderson, W. (2021). Cultivating networks and mapping social landscapes: How to understand restoration governance in Rwanda. Land Use Policy, 104, 104546.

Carlson, K. M., Curran, L. M., Ratnasari, D., Pittman, A. M., Soares-Filho, B. S., Asner, G. P., ... & Rodrigues, H. O. (2012). Committed carbon emissions, deforestation, and community land conversion from oil palm plantation expansion in West Kalimantan, Indonesia. Proceedings of the National Academy of Sciences, 109(19), 7559-7564.

Castellano, M. J., Mueller, K. E., Olk, D. C., Sawyer, J. E., & Six, J. (2015). Integrating plant litter quality, soil organic matter stabilization, and the carbon saturation concept. Global change biology, 21(9), 3200-3209.

Cerullo, G. R., & Edwards, D. P. (2019). Actively restoring resilience in selectively logged tropical forests. Journal of Applied Ecology, 56(1), 107-118.

Clement, M. T., Chi, G., & Ho, H. C. (2015). Urbanization and land-use change: A human ecology of deforestation across the United States, 2001–2006. Sociological Inquiry, 85(4), 628-653.

Convention on Biological Diversity. (1992). Convention on Biological Diversity. Ramsar convention. https://www.cbd.int/convention/text/

Cresswell, J. W. and Plano Clark, V. L., 2011. Designing and conducting mixed method research (2nd ed.). Thousand Oaks, CA: Sage.

Cyamweshi, R. A., Kuyah, S., Mukuralinda, A., Ngango, J., Mbaraka, S. R., Manirere, J. D., & Muthuri, W. C. (2023). Farming with Trees for Soil Fertility, Moisture Retention and Crop Productivity Improvement: Perceptions from Farmers in Rwanda. Small-scale Forestry, 22(4), 649-667.

https://dx.doi.org/10.4314/rjeste.v6i1.6

DeFries, R. S., Rudel, T., Uriarte, M., & Hansen, M. (2010). Deforestation driven by urban population growth and agricultural trade in the twenty-first century. Nature Geoscience, 3(3), 178-181.

Edwards, D. P., Socolar, J. B., Mills, S. C., Burivalova, Z., Koh, L. P., & Wilcove, D. S. (2019). Conservation of tropical forests in the anthropocene. Current Biology, 29(19), R1008-R1020.

Evbuomwan, I. O., Stephen Adeyemi, O., & Oluba, O. M. (2023). Indigenous medicinal plants used in folk medicine for malaria treatment in Kwara State, Nigeria: an ethnobotanical study. BMC Complementary Medicine and Therapies, 23(1), 324.

Hagumubuzima, F., Nsabimana, D., Nsengimana, V., & Mukuralinda, A. (2022). Impact of removing Eucalyptus maidenii in regenerated native species in Gishwati-Mukura National Park, Rwanda. Journal of Research in Forestry, Wildlife and Environment, 14(3), 65-76.

Halmy, M. W. A. (2019). Assessing the impact of anthropogenic activities on the ecological quality of arid Mediterranean ecosystems (case study from the northwestern coast of Egypt). Ecological Indicators, 101, 992-1003.

Halpern, B. S., Selkoe, K. A., Micheli, F., & Kappel, C. V. (2007). Evaluating and ranking the vulnerability of global marine ecosystems to anthropogenic threats. Conservation biology, 21(5), 1301-1315.

Hemmerling, S. A., Barra, M., Bienn, H. C., Baustian, M. M., Jung, H., Meselhe, E., ... & White, E. (2020). Elevating local knowledge through participatory modeling: active community engagement in restoration planning in coastal Louisiana. Journal of Geographical Systems, 22, 241-266.

Henninger, S., 2009. Urban climate and air pollution in Kigali, Rwanda. The Seventh International Conferance on Urban Climate, Yokohama, Japan. pp: 1038-1041.

Henninger, S.M., 2013. When air quality becomes deleterious—a case study for Kigali, Rwanda. Journal of Environmental Protection, 4(08): 1-7. Available at: http://dx.doi.org/10.4236/jep.2013.48A1001.

Irankunda, E. (2019). Ambient particulate matter (PM) evaluation in Gasabo district, Rwanda. International Journal of Sustainable Development & World Policy, 8(2), 62-67.

IUCN (2020). Bonn Challenge. https://www.bonnchallenge.org/

IUCN, International Union for Conservation of Nature (2022). Restoring forest landscapes in Eastern Province of Rwanda. https://www.iucn.org/story/202205/restoring-forest-landscapes-eastern-province-rwanda

Jamshidi-Kia, F., Lorigooini, Z., & Amini-Khoei, H. (2017). Medicinal plants: Past history and future perspective. Journal of herbmed pharmacology, 7(1), 1-7.

Kakuru, W.; Turyahabwe, N. and Mugisha, J., 2013. Total economic value of wetlands products and services in Uganda, The Scientific World Journal, 2013 (13)

Bitariho, R. (2013). Socio-economic and ecological implications of local people's use of Bwindi Forest in south western Uganda (Doctoral dissertation, Mbarara University of Science and Technology).

Kruk, M. E., Gage, A. D., Arsenault, C., Jordan, K., Leslie, H. H., Roder-DeWan, S., ... & Pate, M. (2018). High-quality health systems in the Sustainable Development Goals era: time for a revolution. The Lancet global health, 6(11), e1196-e1252.

Lal, R. (2015). Restoring soil quality to mitigate soil degradation. Sustainability, 7(5), 5875-5895.

Latif, A., Abbas, A., Iqbal, J., Azeem, M., Asghar, W., Ullah, R., ... & Chen, Z. (2023).

https://dx.doi.org/10.4314/rjeste.v6i1.6

Remediation of environmental contaminants through phytotechnology. Water, Air, & Soil Pollution, 234(3), 139.

Leakey, R. R., Tientcheu Avana, M. L., Awazi, N. P., Assogbadjo, A. E., Mabhaudhi, T., Hendre, P. S., ... & Manda, L. (2022). The future of food: Domestication and commercialization of indigenous food crops in Africa over the third decade (2012–2021). Sustainability, 14(4), 2355.

Leblois, A., Damette, O., & Wolfersberger, J. (2017). What has driven deforestation in developing countries since the 2000s? Evidence from new remote-sensing data. World Development, 92, 82-102.

Mahmoud, S. H., & Gan, T. Y. (2018). Impact of anthropogenic climate change and human activities on environment and ecosystem services in arid regions. Science of the Total Environment, 633, 1329-1344.

Mahwasane, S. T., Middleton, L., & Boaduo, N. (2013). An ethnobotanical survey of indigenous knowledge on medicinal plants used by the traditional healers of the Lwamondo area, Limpopo province, South Africa. South African Journal of Botany, 88, 69-75.

Maroyi, A. (2013). Traditional use of medicinal plants in south-central Zimbabwe: review and perspectives. Journal of ethnobiology and ethnomedicine, 9, 1-18.

Ministry of Land and Forestry (2018). National Tree Reproductive Materials Strategy 2018 – 2024. https://faolex.fao.org/docs/pdf/rwa180223.pdf

MINITERE (2003a). National Strategy and Action Plan for the Conservation of Biodiversity in Rwanda. Ministry of Lands, Resettlement and Environment (MINITERE), Kigali.

Mitchell, R. J. (2024). A host-based approach for the prioritisation of surveillance of plant pests and pathogens in wild flora and natural habitats in the UK. Biological Invasions, 1-13.

Mjuma, A.N., 2014. Multistage sampling designs. Jakarta, Indonesia: Publisher.

Nagelkerken, I. S. J. M., Blaber, S. J. M., Bouillon, S., Green, P., Haywood, M., Kirton, L. G., ... & Somerfield, P. J. (2008). The habitat function of mangroves for terrestrial and marine fauna: a review. Aquatic botany, 89(2), 155-185.

Nahayo, L., 2019. Awareness on air pollution and risk preparedness among residents in Kigali City of Rwanda. International Journal of Sustainable Development & World Policy, 8(1): 1-9.

Ndayambaje, J.D (2013). Trees and woodlots in Rwanda and their role in fuelwood supply. PhD thesis, Wageningen University, Wageningen, https://edepot.wur.nl/272116

Nies, T., van Aalst, M., Saadat, N., Ebeling, J., & Ebenhöh, O. (2023). What controls carbon sequestration in plants under which conditions?. Biosystems, 231, 104968.

Oliver, T. H., Heard, M. S., Isaac, N. J., Roy, D. B., Procter, D., Eigenbrod, F., ... & Bullock, J. M. (2015). Biodiversity and resilience of ecosystem functions. Trends in ecology & evolution, 30(11), 673-684.

Ordway, E. M., Naylor, R. L., Nkongho, R. N., & Lambin, E. F. (2019). Oil palm expansion and deforestation in Southwest Cameroon associated with proliferation of informal mills. Nature communications, 10(1), 114.

Pan, B., Yuan, J., Zhang, X., Wang, Z., Chen, J., Lu, J., ... & Xu, M. (2016). A review of ecological restoration techniques in fluvial rivers. International Journal of Sediment Research, 31(2), 110-119.

Patton, M. Q., 2002. Qualitative research and evaluation methods (3rd ed.). Thousand Oaks, CA: Sage.

Plumptre, A.J., 2003. Lessons learned from on the-ground conservation in Rwanda and the

https://dx.doi.org/10.4314/rjeste.v6i1.6

Democratic Republic of Congo. In: S.V. Price, ed. 2003. War and Tropical Forests: Conservation in areas of armed conflict. New York: The Haworth Press Inc. 71-91.
Prakash, S., & Verma, A. K. (2022). Anthropogenic activities and Biodiversity threats. International Journal of Biological Innovations, IJBI, 4(1), 94-103.
Pullaiah, T., & Galbraith, D. A. (Eds.). (2023). Botanical Gardens and Their Role in Plant Conservation: General Topics, African and Australian Botanical Gardens, Volume 1. CRC Press.
Ramsar Convention Secretariat. (1996). Convention on Wetlands in Africa. Ramsar convention. https://www.ramsar.org/sites/default/files/documents/library/cop8_res.4_e.pdf
Ramsar Convention. (1971). Convention on Wetlands of International Importance Especially as Waterfowl Habitat. Ramsar convention. https://www.ramsar.org/
REMA, 2010. Tool and Guideline: Practical Tools on Restoration and Conservation of Protected Wetlands. https://rema.gov.rw/rema_doc/Wetlands_Restoration_Consevation.pdf
REMA, 2020. Environment and Natural Resources Management (ENRM): National Wetlands Management Framework for Rwanda. Kigali, Rwanda.
REMA, Rwanda Environment Management Authority (2009). Rwanda State of Environment and outlook report. Chap.5: Biodiversity and genetic resources. https://www.rema.gov.rw/soe/chap5.php
Reyes García, V., Fernández-Llamazares, Á., McElwee, P., Molnár, Z., Öllerer, K., Wilson, S. J., & Brondizio, E. S. (2019). The contributions of Indigenous Peoples and local communities to ecological restoration. Restoration Ecology, 27(1), 3-8.
Rockström, J., Williams, J., Daily, G., Noble, A., Matthews, N., Gordon, L., ... & Smith, J. (2017). Sustainable intensification of agriculture for human prosperity and global sustainability. Ambio, 46, 4-17.
Rosa, I. M., Smith, M. J., Wearn, O. R., Purves, D., & Ewers, R. M. (2016). The environmental legacy of modern tropical deforestation. Current Biology, 26(16), 2161-2166.
Rutagarama, E., 2003. Adaptive Partnerships for Conservation: A Prescriptive Case Study from Rwanda. University of East Anglia, Norwich, UK.
Rwibasira, P., Naramabuye, F. X., Nsabimana, D., & Carnol, M. (2021). Long-term effects of forest plantation species on chemical soil properties in Southern Rwanda. Soil Systems, 5(4), 59.
Schoene, D. H., & Bernier, P. Y. (2012). Adapting forestry and forests to climate change: A challenge to change the paradigm. Forest Policy and Economics, 24, 12-19.
Sowerwine, J., Mucioki, M., Sarna-Wojcicki, D., McCovey, K., Morehead-Hillman, L., Hillman, L., ... & Bourque, S. (2023). Enhancing Indigenous food sovereignty and community health through the Karuk Agroecosystem Resilience Initiative: We are caring for it: xúus nu'éethti. Health Promotion Practice, 24(6), 1096-1100.
Stelstra, R. E. (2021). Implementation of native tree species in Rwandan forest plantations.
Strassburg, B. B., Iribarrem, A., Beyer, H. L., Cordeiro, C. L., Crouzeilles, R., Jakovac, C. C., ... & Visconti, P. (2020). Global priority areas for ecosystem restoration. Nature, 586(7831), 724-729.
Tian, Q., & Zhang, X. (2023). Plant diversity drives soil carbon sequestration: Evidence from 150 years of vegetation restoration in the temperate zone. Frontiers in Plant Science, 14, 1191704.
Trammell, T. L., D'Amico III, V., Avolio, M. L., Mitchell, J. C., & Moore, E. (2020). Temperate deciduous forests embedded across developed landscapes: Younger forests harbour invasive

https://dx.doi.org/10.4314/rjeste.v6i1.6

plants and urban forests maintain native plants. Journal of Ecology, 108(6), 2366-2375.

Weidlich, E. W., Flórido, F. G., Sorrini, T. B., & Brancalion, P. H. (2020). Controlling invasive plant species in ecological restoration: A global review. Journal of Applied Ecology, 57(9), 1806-1817.

Verhoeven, J. T. (2014). Wetlands in Europe: perspectives for restoration of a lost paradise. Ecological Engineering, 66, 6-9.

Wilson, M. C., Chen, X. Y., Corlett, R. T., Didham, R. K., Ding, P., Holt, R. D., ... & Yu, M. (2016). Habitat fragmentation and biodiversity conservation: key findings and future challenges. Landscape Ecology, 31, 219-227.

Zerbe, S. (2022). Restoration of Multifunctional Cultural Landscapes: Merging Tradition and Innovation for a Sustainable Future (Vol. 30). Springer Nature.

Zimmermann, H., Brandt, P., Fischer, J., Welk, E., & von Wehrden, H. (2014). The Human Release Hypothesis for biological invasions: human activity as a determinant of the abundance of invasive plant species. F1000Research, 3.

Zuazo, V. H. D., & Pleguezuelo, C. R. R. (2009). Soil-erosion and runoff prevention by plant covers: a review. Sustainable agriculture, 785-811.

https://dx.doi.org/10.4314/rjeste.v6i1.6