UNIVERSITY of RWANDA

COLLEGE OF SCIENCE AND TECHNOLOGY

CENTRE OF EXCELLENCE IN BIODIVERSITY AND NATURAL RESOURCE MANAGEMENT

BIODIVERSITY OF KANYEGANYEGE AND GISHANDA WETLANDS EASTERN RWANDA

Huye, July 2025

Executive summary

This biodiversity assessment was conducted in March–April 2025 to evaluate the ecological status of the Kanyeganyege and Gishanda wetlands located in Kayonza District, Eastern Rwanda, and to inform the development of proposed irrigation systems. These wetlands are ecologically significant ecosystems that support a diversity of flora and fauna serving as key indicators of the status of agricultural wetlands. The assessment aimed to document existing biodiversity, identify taxa of conservation concern, and provide recommendations for sustainable management that balances irrigation development with conservation priorities.

Kanyeganyege wetland, covering approximately 22.6 km^2, is predominantly used for rice farming by community cooperatives and supports various plant species, birds, amphibians, and small mammals. Gishanda Wetland located in close proximity to Akagera National Park, features banana, maize, and bean cultivation and supports unique bird species including the endangered Grey Crowned Crane. Both wetlands serve as biodiversity hotspots and ecological corridors, yet they face increasing pressures from anthropogenic agricultural intensification.

Using standardized methods such as line transects and quadrats, the study recorded 183 plant species across 59 families dominated by herbaceous plants. Native species made up over 75% of the vegetation, with few invasive species found. Gishanda exhibited higher species richness and presence of unique taxa compared to Kanyeganyege. Among birds, 56 species were observed in Kanyeganyege and 63 in Gishanda, with notable migratory and endangered species at both sites. Nesting behavior was documented, showing bird reliance on specific native plants for reproduction. Amphibians and reptiles were assessed through visual, acoustic, and dip-netting surveys. Ten amphibian species and two reptiles were identified in Kanyeganyege, while Gishanda had nine amphibians and four reptiles. All were categorized as Least Concern, except one Data Deficient frog species. Diversity indices showed higher species richness in Gishanda, likely due to its habitat heterogeneity. Mammals, especially small mammals, were documented using live traps and indirect signs, highlighting species that are sensitive to habitat disturbance. Results have also indicated 3659 terrestrial arthropod individuals belonging to 76 families. Overall, these wetlands are biologically rich but exhibit signs of disturbance.

To mitigate biodiversity loss during irrigation development, the study recommends the adoption of a Biodiversity Management Plan (BMP) including preservation of riparian buffers, replanting native vegetation, and regular monitoring of sensitive species identified as key bioindicators of the wetlands. These actions are crucial to ensure the coexistence of agricultural productivity and biodiversity conservation, enhancing the ecological resilience of the region.

Table of content

List of figures

List of Table

List of appendices

1. General Introduction

1.1. Introduction

Wetlands are among the most productive and ecologically significant ecosystems on Earth (Herbert et al., 2015). They serve critical functions such as regulating water flow, controlling floods, purifying water, storing carbon, and supporting biodiversity (Hu et al., 2017). Wetlands also offer numerous socio-economic benefits by sustaining livelihoods through agriculture and fisheries (Dhir, 2013). In the context of climate change and biodiversity loss, wetlands have become focal points for conservation and sustainable development due to their role in buffering environmental disturbances and maintaining ecological resilience (Nsengimana et al., 2025).

In Rwanda, wetlands are invaluable for biodiversity conservation and agricultural development (REMA, 2022). They provide vital habitats for endemic and migratory species, including birds, amphibians, mammals, reptiles and diverse groups of macroinvertebrates (Nsengimana et al., 2025). Further, they support the rural population that relies on them for rice farming, fishing, grazing and natural resources (Nsengimana et al., 2025). Rwanda recognizes the importance of wetlands by integrating their conservation into national land use planning and environmental policies to harmonize ecological sustainability with the socio-economic development of wetland-dependent local communities (Nsengimana et al., 2024; REMA, 2019).

The Kanyeganyege wetland, located in Kayonza District of the Eastern Province of Rwanda form the prominent example of a wetland with significant ecological and economic importance. Covering approximately 22.6 km^2, it is dominated by rice fields cultivated by community organized into cooperatives. The wetland supports not only agricultural productivity but also sustains plant species, birds, amphibians, and small mammals. Despite its apparent agricultural focus, Kanyeganyege retains considerable biodiversity, which plays a pivotal role in sustaining the food web and ecosystem services such as soil stabilization and water purification.

Similarly, Gishanda fed by the Nyankora stream from Lake Gishanda, is critical for local agriculture, particularly banana, maize, and bean cultivation. Adjacent to Akagera National Park, it supports unique biodiversity, including birds of conservation concern such as the endangered Grey Crowned Crane and migratory species that are not yet fully studied. Gishanda's proximity to Akagera National Park enhances its ecological value, acting as an ecological corridor that facilitates species movement. Its plant and bird diversity also contributes to ecosystem resilience and makes it an important area for conservation investment.

Both Kanyeganyege and Gishanda serve as vital ecological and economic lifelines in Eastern Rwanda. While both wetlands are under pressure from agricultural intensification, they remain rich in biodiversity and ecosystem services, even though a full study is not yet conducted. Strategic planning, informed by thorough biodiversity assessments ensures that any development projects such as irrigation systems do not compromise ecological integrity. These wetlands must be managed through integrated conservation strategies that align biodiversity protection with local livelihoods, ensuring their long-term functionality and resilience.

1.2.Aim and objectives of the study

To fill these identified gaps in biodiversity knowledge, a comprehensive biodiversity assessment was conducted in March and April 2025. Specific objectives were (1) To identify the biodiversity across the agroecological zones of Kanyeganyege and Gishanda wetlands, with attention to native, invasive, and wetland obligate species, and (2) to provide recommendations for conservation and sustainable wetland use, especially concerning the design and operation of irrigation infrastructure that minimizes biodiversity loss and the services they provide.

1.3.Description of the area of study

Kanyeganyege marshaland (Figure 1) is in the eastern province of Rwanda in Kayonza District, covering 22.60 km². It is dominated by rice plantations and is surrounded by small hills used for various kinds of agricultural activities, including banana plantations, forests, and bean cultivation, among others. This wetland plays a vital role in rice production, supporting surrounding communities through cooperatives that harvest rice. In terms of biodiversity, Kanyeganyege features herbaceous plants, freshwater macroinvertebrates, birds, amphibians, and mammals. Further, Gishanda marshland (Figure 1) is also located in Kayonza district. It is used for agricultural activities dominated by banana plantations, maize and bean cultivation. It has a stream known as Nyankora, sourced from Gishanda Lake. This area is essential in social and economic activities, as many communities use it as a farm and agricultural area.

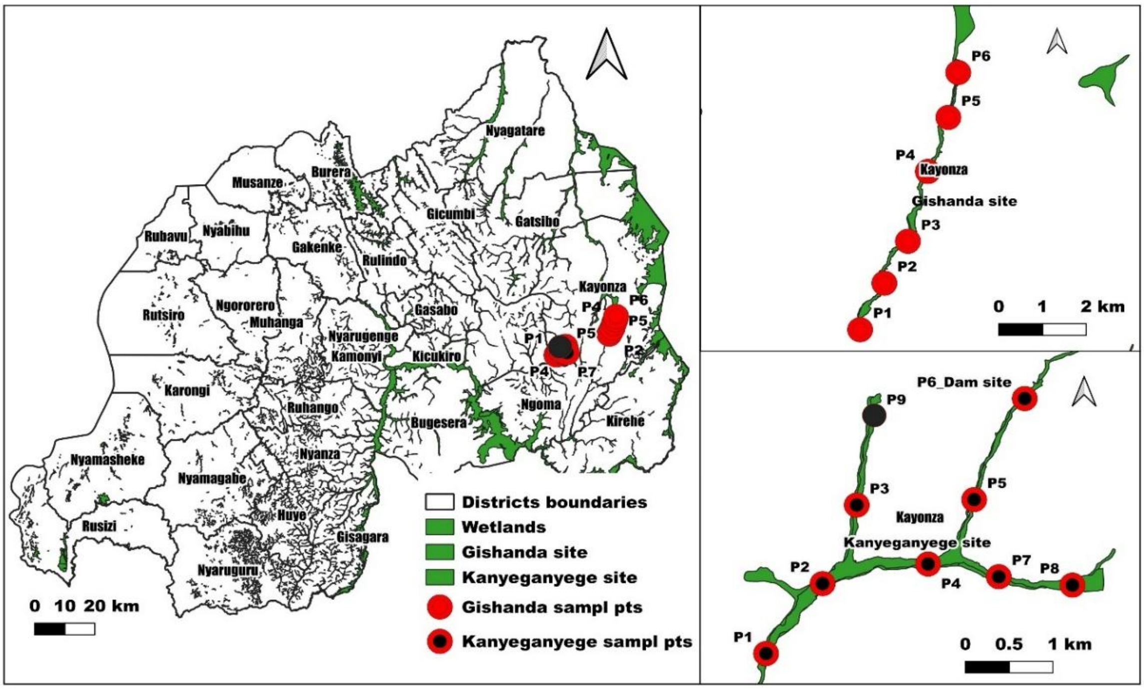

Figure 1: Location of Kanyegenyege (upper right side) and Gishanda (lower right side) in Kayonza District, Eastern Rwanda. P1…Pn indicates the sampling points in each wetland.

2. Methodology and findings

2.1. Plant biodiversity from Gishashanda and Kanyeganyege

2.1.1. Methodology

The sampling of plant diversity was done using the systematically established line transects, to capture changes in vegetation from edge of the wetland to water bodies. Along each transect, circular plots with a 10 m radius were set up at 100 m intervals. This design was chosen for its ease of use, minimal edge effects, and effective representation of species diversity (Silvestro et al., 2022). Each circular plot had nested quadrats for a thorough vegetation assessment. Trees were surveyed in the full 10-meter radius plot, while shrubs were assessed within 10 m^2 subplots. Herbaceous plants were recorded in 1 m^2 quadrats placed inside each main plot (Yager et al., 2019). Plot dimensions were accurately measured using diameter tapes, and 1-meter buffer was maintained between nested plots to minimize effects (Li et al., 2023).

In each plot and along transects, we recorded all encountered plant species. The abundance, frequency, and ground cover of each species were assessed. Further, the density and dominance through visual cover and stem counts was calculated. Transect walks supported plot data by capturing changes in vegetation, especially in transition zones (Pilliod & Arkle, 2013). Plant identification mainly occurred in the field using local botanical guides. Specimens that could not be confidently identified on site were collected and verified later at the Rwanda National Herbarium located at Huye through expert consultation. Further, we have identified wetland bioindicator species and rare or threatened plants. All observed species were assed for their conservation status using the IUCN Red List online database (Verspagen & Erkens, 2023).

Further, we georeferenced all plot locations using GPS to ensure spatial accuracy for future monitoring. We recorded coordinates at each plot center and took photographs of dominant vegetation type for visual vegetation and reporting (Hernández-Stefanoni et al., 2018).

2.1.2. Results

The recorded plant diversity was 724 in total, consisting of 183 species, 59 families and 32 orders. The life form analysis showed that herbaceous species dominated, followed by shrubs and trees. Herbaceous plant species made up 60% of all recorded observations, highlighting the agricultural and wetland nature of the study site. Shrubs and trees were mostly found in buffer zones and remaining woodlands, especially in Gishanda. Most of the recorded species were native, over 75%, with a smaller number of introduced species. Invasive species were present, but only in scattered instances. According to the IUCN conservation status, four species were classified as Data Deficiency (DD), one species was endangered (E), while 87 species were Least Concern (LC). The other 86 were not evaluated. Key indicator plant species are in Table 1.

Table 1: The categories of indicator plants species found in both sites

ID	Category	Indicator Species	Indicator
1	Invasive	1. *Lantana camara* 2. *Biancaea decapetala* 3. *Mimosa pigra*	Disturbed ecosystem
2	Native (Indigenous)	1. *Acanthus polystachyus* 2. *Dracaena afromontana* 3. *Tetradenia riparia* 4. *Gymnanthemum amygdalinum* 5. *Markhamia lutea* 6. *Momordica foetida* 7. *Ocimum gratissimum*	Healthy ecosystem
3	Wetlands obligate	1. *Nymphaea nouchali* 2. *Thelypteris palustris* 3. *Potamogeton nodosus* 4. *Azolla pinnata* 5. *Acmella caulirhiza*	Healthy ecosystem

Site comparison in terms of plants diversity baseline assessment

Plant diversity assessments revealed notable differences between Gishanda and Kanyeganyege. Gishanda exhibited higher species richness with a total of 120 recorded plant species, including 70 unique taxa, and was dominated by 79 native species (Appendix 1). The presence of indigenous tree species such as *Ficus thonningii*, *Markhamia lutea,* and *Rhus natalensis* highlights the persistence of natural woodland elements. In contrast, Kanyeganyege supported 113 plant species with 63 unique taxa, but its vegetation was largely characterized by herbaceous and cultivated species within an agricultural matrix dominated by rice fields and wetland margins. In terms of plant diversity, Gishanda had a higher Shannon diversity index (H' = 4.34) compared to Kanyeganyege (H' = 3.75). The mean species abundance was also significantly higher at Gishanda (Mean = 27.70) than at Kanyeganyege (Mean = 6.12). The ANOVA comparing species abundance between sites yielded a highly significant result ($F_{1,722} = 230.04$, $p < 0.001$), confirming that the observed differences are not due to chance.

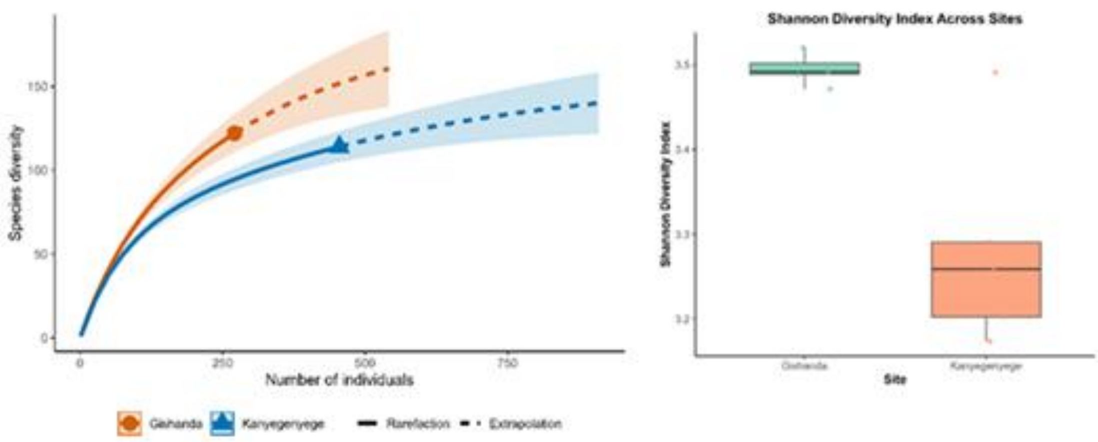

Figure 2: Box plot of species diversity and rarefaction curves indicating species diversity in terms of the number of individual species

2.1.3. Discussion of the findings

The observed differences in plant diversity and abundance between Gishanda and Kanyeganyege reflect the contrasting levels of habitat disturbance and land-use intensity. Gishanda exhibited higher species richness (120 species), greater Shannon diversity (4.34), and higher mean abundance (27.7), dominated by native flora and indigenous tree species indicative of relatively intact woodland ecosystems. In contrast, Kanyeganyege dominated by rice cultivation and herbaceous wetlands, supported lower species richness (113 species), diversity (3.75), and mean abundance (6.12), with dominance of introduced and cultivated species. The highly significant difference in abundance between sites ($F_{(1,722)} = 230.04$, $p < 0.001$) underscores the profound impact of agricultural land use on native biodiversity. These findings align with global evidence that agricultural expansion drives biodiversity loss by simplifying habitat structure and favoring generalist or non-native species (Newbold et al. 2015; Tscharntke et al. 2012), while remnant natural habitats, such as Gishanda, serve as important refugia for the conservation of native plant communities and ecosystem functions.

2.1.4. Ecological Implications and Recommendations

The plant diversity recorded highlights the critical ecological functions of riparian buffers, wetlands, and remnant woodlands. These ecosystems not only serve as habitats for a diverse assemblage of plants but also provide essential shelter for fauna biodiversity (Van Helden et al., 2021). Further, the role plant diveristy in water filtration and purification ensures the sustainability of water quality essential for both wildlife and agricultural irrigation needs. These ecosystems stabilize soils, reduce erosion, and enhance resilience against hydrological disturbances such as flooding and sedimentation (Biswal & Balasubramanian, 2022).

The dominance of native plant species across both sites reflects a relatively intact and functional ecosystem, with substantial potential for agriculture-based conservation approaches that harmonize production with biodiversity preservation (Mendenhall et al., 2016). The maintenance of these native plant communities is crucial, considering that plants function as primary producers, forming the foundation of most food chains and sustaining higher trophic levels. Additionally, pollination and seed dispersal are two ecological processes that play an important role in preserving ecosystem variety and agricultural productivity, which are supported by native plant species and their diversity (Sutter et al., 2017). Crop yields are increased, and resilient farming systems are supported when native plants are pollinated and coevolve (Celis-Diez et al., 2023). Furthermore, these plant communities can absorb carbon dioxide and help to regulate climate change effects (Solomon et al., 2024).

Considering these findings, irrigation development must incorporate biodiversity conservation by promoting agroecological land use practices that use biodiversity as a pillar of sustainable agriculture development. Maintaining native vegetation in the buffer will contribute to erosion control (Knapp & Sciarretta, 2023). Such integrative management will ensure that both biodiversity and agricultural productivity are maintained, providing long-term benefits.

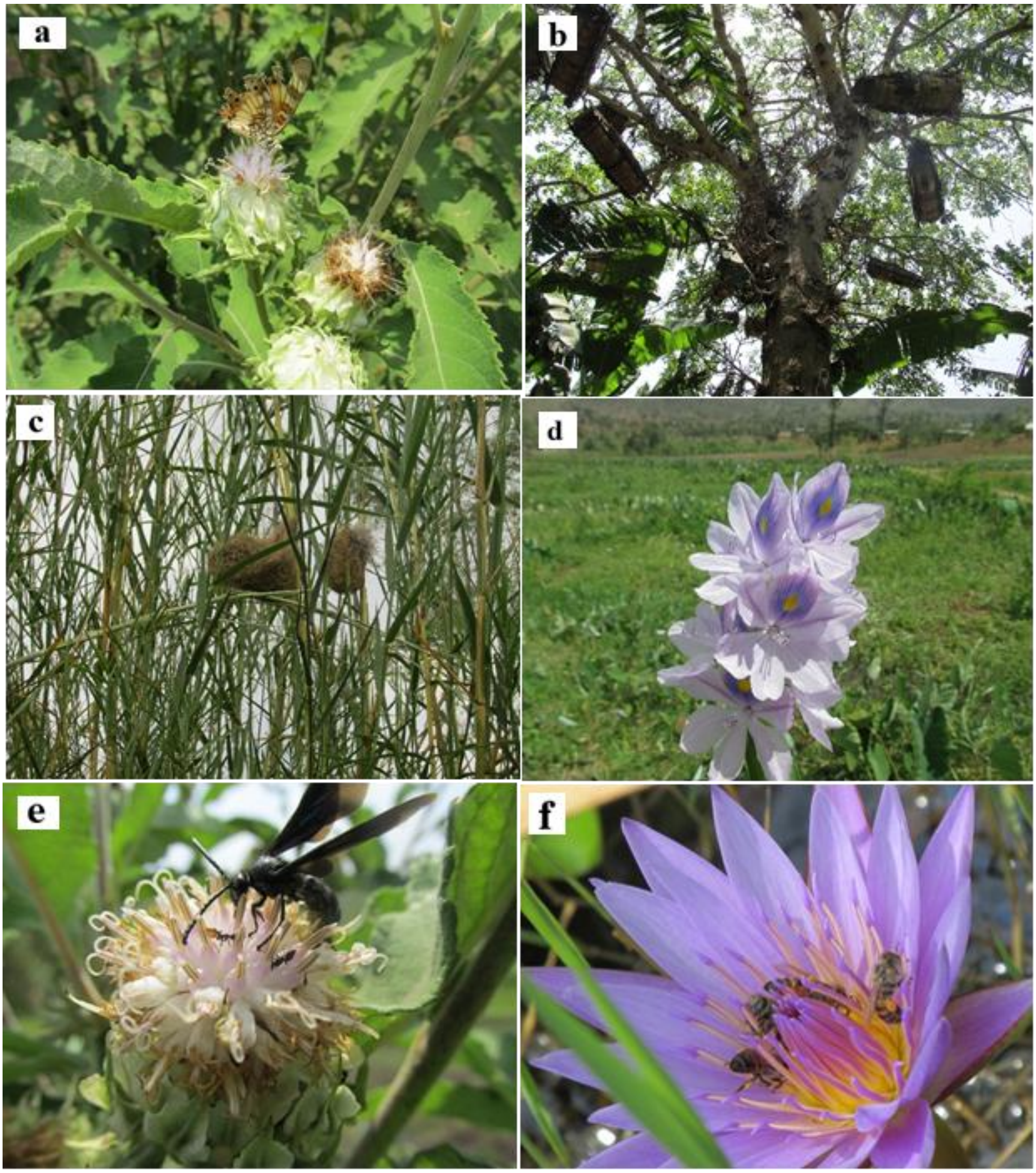

Figure 3: Indicator plants species : a & e: Baccharoides adoensis, b: Ficus, c: Phragmites mauritianus, d: Eichhornia crassipes, f: Nymphaea nouchali

2.2. Bird biodiversity from Gishanda and Kanyeganyege

2.2.1. Methodology

Point-counting and opportunistic sampling were used to sample birds' populations across Kanyeganyege and Gishanda wetlands (Volpato et al., 2009). Line transects were established within the sites to maximize species diversity and abundance (Rurangwa et al., 2021). Nine and six sampling points were selected in Kanyeganyege and Gishanda sites respectively. The point counts were conducted by standing at predetermined intervals of 200 meters along the transect lines. At each sampling location, surveys were conducted for 15 minutes using a binocular (Marian, M. 2024), and all birds were recorded. Nests and the host plants were documented. The sampling started from 7:00 to 11:00 before noon and from 15h30 to 18h00 in the afternoon following birds' activity and higher detectability. All bird species encountered between sampling points were maintained to ensure comprehensive data collection.

To minimize detectability differences among habitat types and reduce biases, observations were made within the 50-meter radius (Martínez-Lanfranco et al., 2022). In addition, geocoordinates were taken at each sampling station by using GPS. Detailed species characteristics including endemic and migrant status were identified by using the IUCN Red list. Data was tabulated in excel and used in R-Software for species diversity calculations.

2.2.2. Results

A total of 56 bird species belonging to 25 families were recorded from Kanyeganyege (Appendix 2). The Red-chested cuckoo (*Cuculus solitarius*) is listed as an Intra-African migrant and was recorded at 200 m from the area where the dam will be constructed. The Marico sunbird (*Cinnyris mariquensis*) was listed as a local migrant and was recorded in the middle and buffer of the wetland. All species recorded at Kanyegenyege are common, widespread, and tolerant of disturbed habitats. The assessment of nesting behavior indicated four bird species Black-headed Weaver, Hamerkop, African Paradise Flycatcher, and White-browed Robin-Chat across six host plant species namely *Persea americana*, *Eucalyptus microcorys*, *Markhamia lutea*, *Coffea arabica*, *Grevillea robusta*, and *Maesopsis eminii*, highlighting the diverse tree preferences among avian species for nest placement.

Further, a total of 63 bird species from 30 families were recorded in Gishanda wetland. Among them, three were of special conservation concerns. These include the endangered Gray Crowned Crane (*Balearica regulorum*) found near Akagera National Park; the Barn Swallow (*Hirundo rustica*), a palearctic migrant; and the Marico Sunbird (*Cynnyris mariquensis*), a local migrant. The rest of the bird species are common and can survive in degraded habitats.

Six bird species nests were found specifically the Speckled Mousebird, Black-headed Weaver, African Paradise Flycatcher, Hamerkop, Dark-capped Bulbul, and Bronze Mannikin. Their nests were built in six types of plants, including *Pennisetum purpureum, Eucalyptus, Ficus thonningii, other Ficus species, Grevillea robusta,* and *Senegalia polyacantha.* The average abundance in bird species was almost the same. Gishanda had a mean of 2.79 while Kanyeganyege had 2.84. The t-test showed that there is no significant difference (P = 0.9293) which means that the number of individuals per site is similar. Gishanda had higher Shannon diversity (H'=3. 92) than Kanyeganyege (H'=3.78).

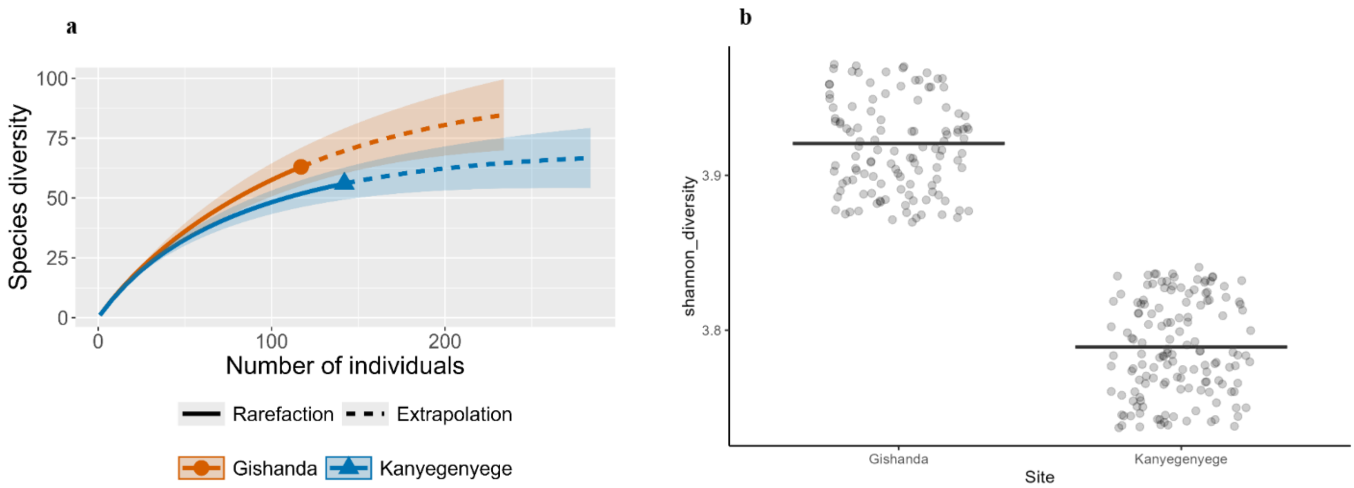

Figure 4: (a) Rarefaction curve comparing species diversity and (b) Box plot which compares species diversity against the number of individuals sampled in Kanyeganyege and Gishanda

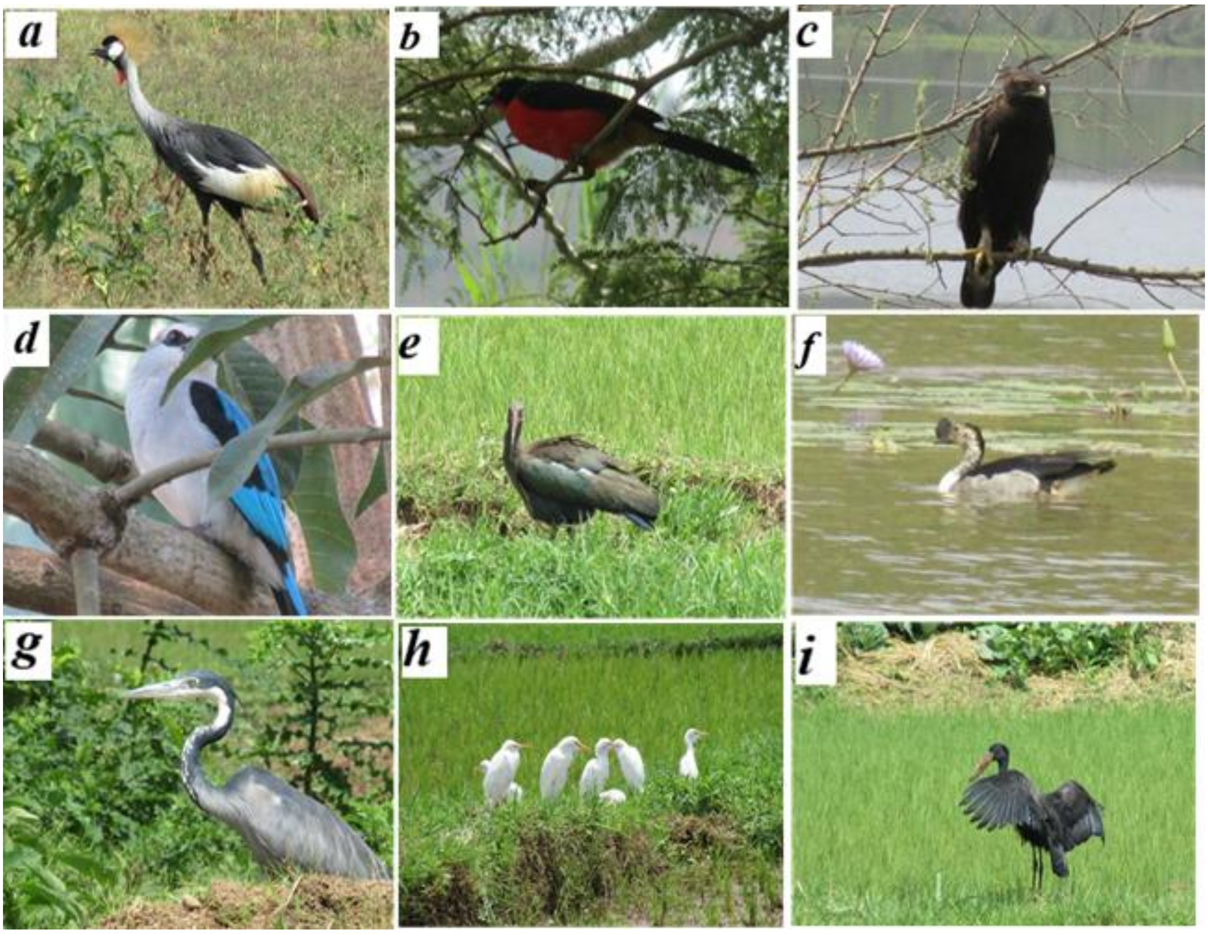

Figure 5: (a) Endangered Gray crowned Crane, (b) Black headed Gonolek, (c) Long Crested Eagle, (d) Woodland Kingfisher, (e)Hadada Ibis, (f) Knob-billed Duck, Black-headed heron. (h) Yellow-billed Egret. (I) African Openbill.

2.2.3. Discussion of the results

The findings from Kanyeganyege and Gishanda wetlands highlight both similarities and subtle ecological differences in their avian communities. Although both sites support a comparable mean abundance of bird species, evidenced by the non-significant t-test result (P = 0.9293), Gishanda demonstrates slightly higher species richness and diversity (H’ = 3.92) than Kanyeganyege (H’ = 3.78). This suggests that despite the similar number of individuals, Gishanda supports a more varied bird community, potentially due to its proximity to Akagera National Park and the presence of wetland-edge habitats that attract a broader array of species. The presence of intra-African and palearctic migrants such as the Red-chested Cuckoo and Barn Swallow further emphasizes the wetlands' role in supporting seasonal movements, while the detection of the endangered Gray Crowned Crane at Gishanda underscores the conservation value of maintaining such habitats, especially those connected to larger protected areas.

Additionally, nesting observations reveal the importance of diverse plant species for breeding, with both wetlands showing multiple bird species utilizing different host plants for nest placement. The shared nesting of species like the Hamerkop and African Paradise Flycatcher in both sites highlights overlapping habitat preferences, while the variety of nesting plants — including indigenous and exotic species — suggests that these wetlands’ mixed vegetation structure contributes significantly to avian breeding success. Results imply that while both wetlands currently support common and adaptable bird species, their conservation is critical for maintaining biodiversity, particularly for species of special conservation concern and migratory birds that rely on these areas as seasonal refuges.

2.2.4. Conservation Implication

The results from Kanyeganyege reveal that most bird species are common and tolerant of disturbed habitats. The presence of Red-chested Cuckoo and Marico Sunbird both with migration concern suggest Kanyeganyege to be a good stopover of migratory bird species. The occurrence of Red-chested Cuckoo at the proximity of where the dam for irrigation will be constructed means that the constructions will absolutely affect habitat and feeding patterns of this bird species. Moreover, the presence of native plants such *Markhamia lutea* and *Maesopsis eminii* which host most nests will be affected by the project and birds will lose the habitat.

At Gishanda, ecological care should be taken due to the presence of endangered Gray Crowned Crane (*Balearica regulorum)* and migratory species like the Barn Swallow. The habitat alteration will affect these species in terms of feeding, migration and breeding patterns, especially near Akagera National Park where these species are recorded. Modification of habitat and cutting off the nesting trees will reduce birds’ reproduction or disappear in the area.

Before construction and operation of the projects, the Biodiversity Management Plan (BMP) must be developed with specific measures of protecting the species of special conservation concern. In this regard, buffer zones with native plant species should be established to compensate for the habitat loss. Furthermore, regular birds monitoring should also be carried out to assess bird population changes during and after the project's implementation.

2.3.Amphibians and Reptiles Biodiversity from Kanyeganyege and Gishanda

2.3.1. Methodology

Amphibians were surveyed using both opportunistic visual and acoustic encounter surveys from 17th to 21st February 2025 (Kanyeganyege) and from 24th to 28th February 2025 (Gishanda). The sampling was supplemented with an opportunistic dip-netting for fully aquatic frogs and tadpoles (Ernst & Rödel, 2015). Fifteen sampling-points were randomly selected: nine in Kanyeganyege and six in Gishanda (Figure 1). In Kanyeganyege wetland, a selection of three major habitats that included rice farms, maize plantation and irrigation channels were sampled. At Gishanda, two major habitats that included banana plantation and central ditch were sampled. Sampled habitats were chosen based on differences in the structure of habitats. At each habitat, an encounter survey (Roelke & Smith, 2010) complemented by an active search (Burger et al., 2006) was done from 8h00 AM to 17h00 PM every day. Opportunistic calls that were heard in the habitat were recorded for call structure analyses. An estimate time of three hours was spent at each sampling point sampling for amphibians and reptiles.

All encountered amphibian species were identified based on key morphological characteristics, including skin color patterns, body structure (toe webbing, toe length, snout shape), and vocalizations (Dehling & Sinsch, 2023). For distant or inaccessible calls, a "home-in" approach was employed to locate the source (Mindje et al., 2020). Acoustic sampling involved recording frog calls using an iPhone 11 Pro, followed by the analysis of oscillograms and sonograms to verify species identification (Dehling & Sinsch, 2023; Mindje et al., 2020). For reptiles, collected specimens were identified by the examination of body features namely the skin and the scale patterns (pholidosis) using the identification guide by Spawls et al., (2002).

The collected data was compiled in Excel dataset for subsequent analyses. Cleaned data were then imported into R (R Core Team, 2024) through R Studio Posit Team (2025) for statistical processing. Descriptive statistics and graphical visualizations were generated in R ggplot2 and dplyr packages (Gromping, 2015). To examine the relationship between species abundance and richness across sampling locations, rarefaction curves were constructed using the iNEXT package (Cayuela et al., 2015), which employs interpolation and extrapolation techniques.

2.3.2. Results

A total of ten species distributed in five families were recorded at Kanyeganyege while nine species distributed in six families were recorded in Gishanda (Figure 6). The Hyperoliidae and Phrynobatrachidae families had 3 species each, followed by Ptychadenidae with 2 species and lastly Bufonidae and Pixycephaldae having one recorded species each in Kanyeganyege wetland. The most abundant species included *Ptychadena nilotica* with 94 individuals recorded, and the least observed species was *Kassina senegalensis*, *Ptychadena anchietae* and *Amietia nutti* with one observed individual species respectively. At Gishanda, Hyperoliidae and Phrynobatarchidae families had two species each, while remaining families each had one species recorded. All species were categorized as LC by the IUCN Red List of threatened species except for *Phrynobatrachus kakamikro* that remains Data deficient (Table 2).

Table 2. Amphibian species recorded from recorded in the Kanyeganyege (A) and Gishanda (B) wetlands with respective IUCN Red List (Dehling & Sinsch, 2023). LC: Least Concern, DD: Data Deficient.

Family	Taxon	Common name	KA	GI	IUCN Category	
					Global	National
Bufonidae*	*Sclerophrys gutturalis* (Power, 1927)	African common Toad	5	1	LC	LC

Hyperoliidae*	*Kassina senegalensis* (Duméril & Bibron, 1841)	Bubbling Kassina	1	0	LC	LC
	Hyperolius kivuensis Ahl, 1931	Kivu reed frog	3	3	LC	LC
	Hyperolius viridiflavus (Duméril & Bibron, 1841)	Common reed frog	0	1	LC	LC
	Afrixalus quadrivittatus (Werner, 1908)	Four-line spiny reed frog	2	0	LC	LC
Phrynobatrachidae*	*Phrynobatrachus kakamikro* Schick, Zimkus, Channing, Köhler & Lötters, 2010	Kakamega puddle frog	11	0	DD	LC
	Phrynobatrachus natalensis (Smith, 1849)	Common Toad-frog	14	3	LC	LC
	Phrynobatrachus parvulus (Boulenger, 1905)	Dwarf puddle frog	40	3	LC	LC
Ptychadenidae*	*Ptychadena nilotica* (Seetzen, 1855)	Nile ridged frog	94	29	LC	LC
	Ptychadena anchietae (Bocage, 1868)	Anchieta's Frog	1	9	LC	LC
Pipidae	*Xenopus victorianus Ahl, 1924*	Lake Victoria Clawed Frog	0	1	LC	LC
Pixycephalidae*	*Amietia nutti* (Boulenger, 1896)	Nutt's River Frog	1	2	LC	LC
Kanyeganyege	10 species	Five Families (families marked with a star (*)				
Gishanda	9 species	Six Families (All families)				

Figure 6. Amphibian species recorded a. Sclerophrys gutturalis, b. Kassina senegalensis, c. Hyperolius kivuensis, d. Afrixalus quadrivittatus, e. Phrynobatrachus kakamikro, f. Phrynobatrachus natalensis, g. Phrynobatrachus parvulus, h. Ptychadena nilotica, i. Ptychadena anchietae, h. Amietia nutti, K. Xenopus victorianus, L. Hyperolius viridiflavus.

In relation to reptiles, two reptile species distributed in two families were recorded in the Kanyeganyege wetland and four species distributed in four families were recorded in Gishanda site (Figure 7). In Kanyeganyege wetland, the family Chamaeleonidae had one species (*Trioceros ellioti*) with the most recorded abundance (2 individuals) and Typhlopidae with one recorded species, the *Afrotyphlops angolensis*. In Gishanda, *Hemidactylus mabouia* (Gekkonidae) was recorded as the most abundant species with nine individuals followed by *Trachylepis striata* (Scincidae) with seven individuals, while *Adolfus jacksoni* had four individuals. The least recorded species included *Varanus nilotica* with only one individual. All the recorded species were listed as LC by the IUCN Red List of threatened species (Table 3).

Table 3. Reptile species recorded in the Kanyeganyege (A) and Gishanda (B) wetland with respective IUCN Red List status. LC: Least Concern.

Family	**Taxon**	**Common name**	A	B	**IUCN Category**
					Global
Chamaeleonidae*	*Trioceros ellioti*	Elliot's Groove throated chameleon	2	0	LC
Typhlopidae*	*Afrotyphlops angolensis*	Angola Blind snake	1	0	LC
Scincidae	*Trachylepis striata (Peters, 1844)*	African Striped Mabuya	0	7	LC
Gekkonidae	*Hemidactylus mabouia*	House Gekko	0	9	LC
Lacertidae	*Adolfus jacksoni* (Boulenger, 1899)	Jackson's forest lizard	0	4	LC
Varanidae	*Varanus niloticus* (Linnaeus, 1766)	Nile Monitor lizard	0	1	LC
Kanyeganyege	Two families-Families with a star (*)				
Gishanda	Four families –No mark.				

Figure 7. Reptile species recorded in Kanyeganyege wetland. a. Trioceros ellioti, b. Afrotyphlops angolensis. c. Trachylepis striata, d. Hemidactylus mabouia, e. Varanus niloticus, f. Adolfus jacksoni.

Considering both Gishanda and Kanyeganyege wetlands, Findings revealed the highest amphibian species diversity in Kanyeganyege wetland (H'=1.77) compared to Gishanda (H'=1.45) and for reptiles, highest species diversity is observed in Gishanda (H'=0.69) compared to Kanyeganyege wetland (H'=0). Based on the sample rarefaction curves, findings of amphibians revealed that at both Kanyeganyege and Gishanda the sampling effort was likely sufficient. However, more samples are needed to cover all species in the area, especially for Kanyeganyege wetland. In relation to reptiles, findings showed that both sites need more sampling efforts, particularly Kanyeganyege wetland (Figure 8).

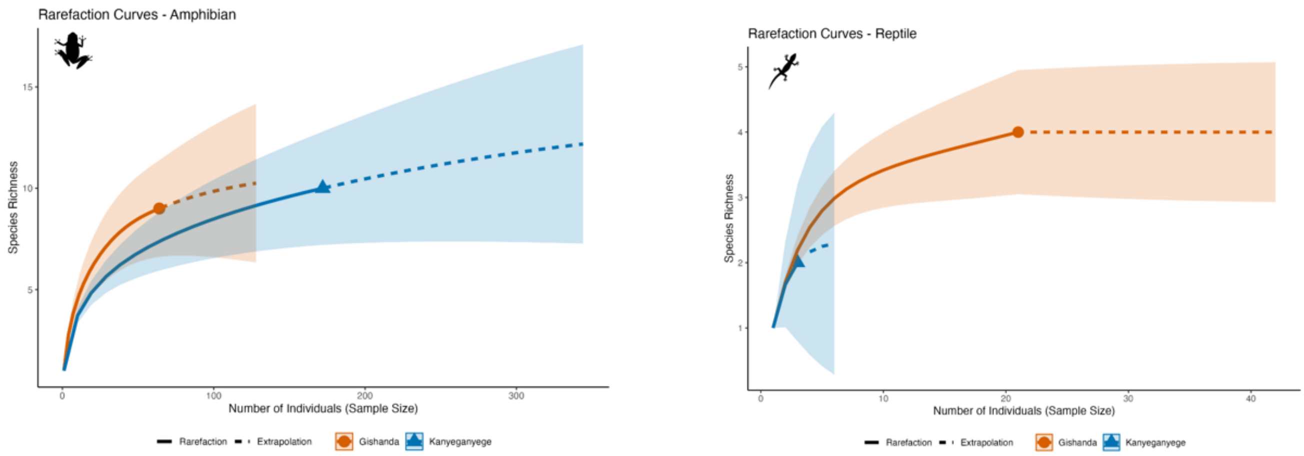

Figure 8. Sample rarefaction curves for amphibians and reptiles at Both Kanyeganyege and Gishanda sampled sites.

2.3.3. Discussion of results and interesting findings

The amphibian and reptile surveys recorded ten amphibian and two reptile species in Kanyeganyege wetland and nine amphibian and four reptile species in Gishanda across all sampled habitats. None of the recorded amphibian species was of special conservation concern, as all were classified as Least Concern on the IUCN Red List of Threatened Species (Dehling & Sinsch, 2023). Similarly, all observed reptile species are also categorized as Least Concern. Besides, amphibian species diversity was higher in Kanyeganyege than Gishanda, likely due to the heterogeneous structure (fully converted to rice fields with irrigation channels and maize plantation) at Kanyeganyege compared to Gishanda sampled habitats comprising mainly banana plantations with a running central ditch. These differences were reflected in the alpha diversity metrics, including species richness and abundance (Mindje et al., 2020).

In Rwanda *Hyperolius lateralis* and *Hyperolius cinnamomeoventris* amphibian species are known to be restricted to natural or near-natural wetlands (Dehling & Sinsch, 2023), others are endemic to wetlands and forests within protected areas like national parks (Dehling & Sinsch, 2023). However, due to heavy anthropogenic pressure, amphibian habitats in Rwanda have been degraded, leading to shifts in species diversity (Dehling & Dehling, 2021). As a result, heavily disturbed wetlands now primarily harbor widespread generalist species rather than habitat-specific ones. Consistent with other studies (Mindje et al., 2020; Tumushimire et al., 2020), the amphibians recorded in Gishanda and Kanyeganyege were predominantly disturbance-tolerant generalists, reflecting long-term exposure to agriculture and livestock farming, which have degraded or entirely replaced natural habitats. No habitat-specific species were found in this study. The conversion of natural habitats to anthropogenic landscapes significantly influences amphibian community composition and diversity (Mindje et al., 2020).

Like amphibians, reptiles are sensitive to environmental changes and can serve as biological indicators of ecosystem health (Falcón, 2025; Pinandita Faiz, 1998; Urbina Cardona, 2010). In Rwanda, little ecological research has explored reptiles as bioindicators, though some species are known to thrive in disturbed ecosystems (personal observation). For instance, *Trachylepis striata, Trioceros ellioti, Adolfus jacksoni,* and *Hemidactylus mabouia* are frequently found in human-dominated landscapes. Although these species were recorded in low abundance, their presence supports their utility as indicators of heavy ecosystem disturbance.

2.3.4. Conservation implications

This study provides the first comprehensive herpetofauna inventory for Gishanda and Kanyeganyege. The recorded species are primarily disturbance-tolerant, making them useful for long-term monitoring of habitat changes. Notably, the presence of *Varanus niloticus* (Nile monitor) is significant, as this species is typically restricted to eastern Rwanda (e.g., Akagera National Park). Its detection here suggests a range extension, which should inform future wetland management strategies. Given the dominance of generalist species in both sites, we conclude that Kanyeganyege and Gishanda are highly disturbed wetlands. These findings underscore the need for restoration efforts to enhance habitat heterogeneity and support more diverse amphibian and reptile communities. Further, the accumulation curves have exemplified the need for more surveys to fully document the herpetofauna diversity of the sampled sites.

2.4. Mammals' biodiversity from Kanyeganyege and Gishanda

2.4.1. Methodology

Mammals' exploration at Kanyeganyege and Gishanda wetlands employed a combination of systematic sampling approaches including live trapping, direct observation, and active search of signs to ensure maximum coverage of the sampling sites. For each site, sampling points were randomly selected where each point was surveyed within a day by employing a combination of trapping, active searches, and study of signs (Hoffmann et al., 2010). However small mammals are quite abundant, they are rarely observed, and the use of traps such as Sherman traps can help to overcome the issue. Trapping using Sherman traps requires a supplement of bait made of a mixture of oats and peanut butter to enhance capture rate (Mohd-Taib & Ishak, 2021), for each sampling point 30 traps were placed in various habitats leaving an interval of 10 meters between consecutive traps. Surveying medium and large mammals is particularly challenging and expensive compared to the small mammals because of the required equipment like camera traps, Tomahawks and Havahart cage traps (Hoffmann et al., 2010), alternatively a combination of occasional sightings and active search of signs were used to identify mammal groups that are very difficult to capture and observe (Davies et al., 2002; Wemmer et al., 1996).

Specimens were identified, recorded and released back into their habitats. Field identification involved the use of Field guidebooks, such as the Kingdon Field Guide to African Mammals (Kingdon et al., 2013) for morphological identification. Collected data were recorded into M-S Excel as a basis of other analysis tools, cleaned data were imported into R core team 2024 using RStudio Posit Team, 2025 to carry out statistical analyses with the purpose of generating interpretable descriptive statistics and visual graphics with the help of R packages such as ggplot2, and dplyr (Gromping, 2015). To indicate the sampling effort and relationship between species abundance and species richness across sampling areas, rarefaction curves were generated using (interpolation and Extrapolation) iNEXT package (Cayuela et al., 2015).

2.4.2. Results

A baseline survey of mammals at Kanyeganyege Wetland revealed 12 individuals across 6 species, categorized within one order, Rodentia, and one family, Muridae, among these, 5 individuals of *Praomys jacksoni* (Jackson's soft-furred mouse) were the most frequently captured. At Gishanda, we recorded a total of 9 individuals spanning 3 orders (Carnivora, Rodentia, Soricomorpha), 3 families (Herpestidae, Muridae, Soricidae), and 6 species, with 3 individuals of *Crocidura olivieri* (Olivieri's shrew) being the most commonly captured. The mean species abundance for both Kanyeganyege and Gishanda is 1.090909 and 0.81818 respectively. For both sites, all species are classified as Least Concern (LC) on the IUCN Red List (Appendix 4), with all species being listed as Least Concern on the IUCN Red List, highlighting a widespread prevalence of resilient species at both sampled sites (Group, 2021).

To evaluate if there is any significant difference between species richness between both sites Shapiro-Wilk normality test was applied to indicate whether the abundance data from each wetland (Kanyeganyege and Gishanda) are normally distributed; with Kanyeganyege have p value of $p = 0.001731$ which is less than 0.05, meaning that the data significantly deviate from a normal distribution and Gishanda with p-value equaling to $p = 0.01038$, Again, $p < 0.05$, so the data are not normally distributed. Having failed the normality test, a non-parametric alternative to the independent t-test called Wilcoxon rank-sum test (Mann–Whitney U test) were used to analyze for the significance difference between both sites, producing a p-value of 0.8605 which is much greater than 0.05, meaning that no statistically significant difference in species abundance between the two sampling areas (Figure 8).

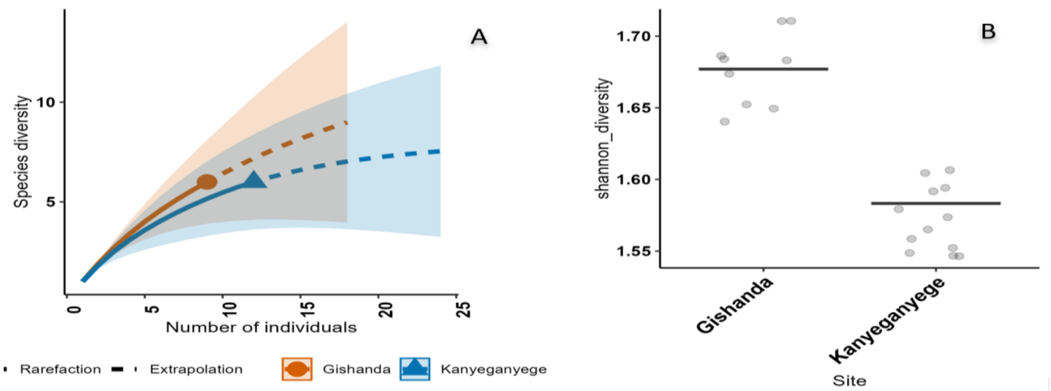

Figure 8: Rarefaction curve for the mammal's abundance and species richness across from Gishanda and Kanyeganyege wetlands

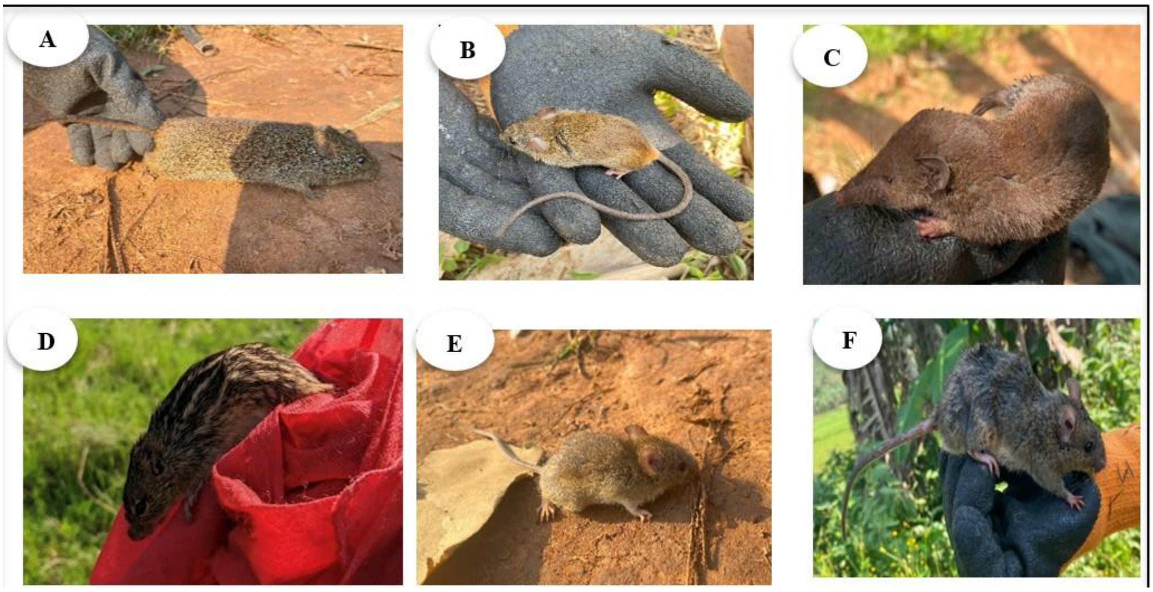

Figure 9: Some captured small mammals from Gishanda and Kanyeganyege wetlands; A: *Arvicanthis niloticus*, B: *Grammomys sp*., C: *Crocidura olivieri*, D: *Lemniscomys striatus*, E: *Mus musculus*, and F: *Praomys jacksoni*

Referring to the Shannon diversity Gishanda and Kanyeganyege, H' = 1.676988 and 1.583258, respectively, highlighted an even distribution of individuals among species at Gishanda, and slightly lower Shannon diversity index at Kanyeganyege, suggesting greater dominance of one species (Figure 8). Regardless of the surveys conducted, there is no record of rare, threatened, or ecologically sensitive species within the study. The species identified were primarily generalists and those commonly associated with human-modified environments. Six species of small mammals are presented in the photos taken during fieldwork (Figure 9).

2.4.3. Discussion of the results

Mammals' biodiversity assessment at Kanyeganyege and Gishanda wetlands highlighted insights into species composition, diversity, and the ecological status of these agricultural dominated habitats. A total of 12 individuals falling into 6 species were recorded at Kanyeganyege, all belonging to one order of Rodentia (Rodents) and the family of Muridae. The most recorded species was *Praomys jacksoni,* holding about half of the records. In comparison, Gishanda were found to have 9 individuals across 3 orders (*Carnivora*, *Rodentia*, and *Soricomorpha*), 3 families (*Herpestidae*, *Muridae*, and *Soricidae*), and 6 species, having *Crocidura olivieri* as the most recorded species.

Despite the total recorded individuals, species richness was the same with 6 species for each site as shown in figure1. Gishanda demonstrated a slightly even distribution of individuals across species with a Shannon diversity index of H': 1.677, while Kanyeganyege with H': 1.583 appeared to be dominated by a single species (*P. jacksoni*). These results highlight a moderately balanced community structure at Gishanda and domination of a single species at Kanyeganyege mainly due to habitat fragmentation driven by agricultural activities (Magurran, 2004). For both sites all species are listed as Least Concern on the IUCN Red List (Group, 2021; IUCN, 2025), indicating dominance of ecologically resilient taxa. Lack of rare, endemic, or conservation-priority species indicate the effects of anthropogenic disturbance and habitat modification in these areas. Recent studies have indicated habitat modification as the primary driver of community simplification and preferable by generalist species rather than specialists (Dos Santos et al., 2010; McKinney, 2006). Absence of any specialized species or threatened species, recalls the need for enhancing habitat complexity and connectivity known for supporting higher species diversity and presence of specialized biodiversity (Fischer & Lindenmayer, 2007).

2.4.4. Conservation Implications

Based on findings from both sites, there is prevailing ecological degradation driven by agricultural expansion, habitat fragmentation, and generally anthropogenic activities. The presence of disturbance-tolerant species and lack of sensitive mammals or indicator species indicate how difficult it is in setting recovery plans for these ecological systems. To enhance habitat quality and specialist mammal species habituation in these ecosystems, it is essential to initiate and implement restoration and sustainable land-use practices.

2.5.Aquatic Macro-invertebrates and Water quality Analysis

2.5.1. Methodology: Water properties

Water quality assessment was done along the Kanyegenyege, a wetland dominated by rice plantation, and Gishanda, that dominated by banana plantation and other agricultural activities. Fifteen sampling points were established, nine in Kanyeganyege Wetland (P01, P02, P04, P05, P06, P07, P08, and P09) and six in Gishanda (P10, P11, P12, P13, P14, and P16). The samples were taken at 1km intervals between sampling points at both Kanyegenyege and Gishanda. At each sampling point, water parameters were measured using HQ40d multimeter for pH, temperature, electrical conductivity, and dissolved oxygen using a specific probe (Figure 10).

Figure 10. Measuring water parameters at the field using HQ40d multimeter, IntelliCAL PHC101 probe, and HACH LDO probe (Left), and laboratory analysis of Phosphate, Nitrate, and Turbidity (right).

The pH, redox potential, and temperature were measured using the IntelliCAL PHC101 probe, while dissolved oxygen was measured using the HACH LDO probe. The electrical conductivity and redox potential, on the other hand, were measured using a Hach CDC401 probe. Additionally, water samples were collected at each sampling point in a 500 ml jar and taken to the laboratory of chemistry, College of Science and Technology, University of Rwanda, to analyze turbidity, nitrates, and phosphates. Turbidity was analyzed with a HACK 2100 Q turbidimeter, while Nitrates and phosphates were analyzed with a HACK 6000 UV-Vis spectrophotometer.

2.5.2. Methodology: Freshwater macroinvertebrates

Macroinvertebrate field surveys were conducted from February 17 to 25, 2025, at both Kanyeganyege and Gishanda (Figure). Fifteen sampling points were randomly selected using Google Earth and QGIS 3.38 to collect representative data that covers the areas of both Kanyeganyege and Gishanda. In total, 15 sampling points were surveyed. Nine sampling points were from Kanyeganyege and six were from Gishanda (Figure 11). Agricultural activities dominate both areas. Kanyeganyege was dominated by rice plantations and had water drainage channels used for rice irrigation. In contrast, Gishanda was dominated by banana plantations and had a single stream called Nyankora, which originated from Gishanda Lake. Macroinvertebrate samples were collected using a 500 µm mesh-size kick-net. At each sampling point, three kick-nets were taken on a quadrat of 9 m² by holding the kick-net

downstream, kicking and turning over the substrates and stones, and letting the macroinvertebrates flow into the kick-net, holding firmly downstream. Handpicking is involved for the specimens attached to the stones and substrates that are within water drainage channels. Collected substrates and macroinvertebrates gathered in the bucket were sorted by taking macroinvertebrates using forceps and conserved in the vials of 15 ml to 30 ml that contain 96% ethanol for preservation.

Figure 11. Sampling and sorting freshwater macroinvertebrates at the field

Collected macroinvertebrates were transferred to the laboratory of the Center of Excellence in Biodiversity and Natural Resources Management (CoEB), University of Rwanda, where they were identified to the family level using the freshwater macroinvertebrate identification guide, such as Day et al., 2001a; Day et al., 2007; Stals & de Moor. 2003; Day et al., 2001b; de Moor et al., 2003; Day et al., 1999; Day & de Moor. 2001a; Day & de Moor. 2001b and after preservation, kept at the Rwanda National Zoological Collection as future references. The analysis was done using R software for plotting graphs, calkculating Shannon diversity, mean abundance, test for normality using Shariro-Wilk test, and t-test analysis, and analysing diversity (R Core Team 2024).

2.5.3. Results

Water properties

The results revealed that the water parameters at the sampled points in Kanyeganyege (P01, P02, P03, P04, P05, P06, P07, P08, P09) and Gishanda (P10, P11, P12, P14, and P15) were slightly acidic (pH < 7), despite points P12 and P13 in Gishanda approaching slightly basic levels (pH > 7). Gishanda exhibits low dissolved oxygen levels of 2.1 mg/l and 2.96 mg/l for points P10 and P12, respectively, compared to Kanyeganye, which has high dissolved oxygen levels ranging from 4.85 mg/l to 7.19 mg/l. The minimum acceptable level of dissolved oxygen (DO) in surface water for supporting a healthy aquatic ecosystem is generally considered to be 4-5 mg/L (or ppm) (CCME (Canadian Council of Ministers of the Environment), 1999).

However, this can vary depending on the specific organisms and life stages present, with some invertebrates requiring higher levels for reproduction or survival (Pineda et al., 2022). The levels of turbidity, phosphates, and nitrates are within acceptable ranges, which are 25 NTU for turbidity (Nephelometric Turbidity Unit), 2.2 mg/l for phosphates, and 45 mg/l for nitrates, according to the RS EAS 12:2018 potable water specification (*Tables 4* and *5*).

Table 4: Water quality of Kanyegenyege wetland

Points	pH	T (°C)	Redox Pot. (mV)	EC (µ/cm)	DO (mg/l)	Do (%)	Turbid. (NTU)	Nitrate (mg/l)	Phosphate (mg/l)
P01	6.23	23.7	30.1	269	6.25	87.4	4.03	0.65	0.15
P02	6.54	29.2	13.7	302	5.8	89	8.52	1.16	0.2
P03	6.61	34	9.8	360	4.85	82	22.5	0.64	0.13
P04	6.62	21.7	8.4	287	7.17	97	20.5	0.93	0.27
P05	6.59	25.1	10.8	329	6.08	88.2	18	1.44	0.21
P06	6.57	28.3	11.9	343	5.69	86.5	7.42	1.90	0.16
P07	6.65	26.2	25.6	270	7.19	106.3	26.8	1.88	0.24
P08	6.59	25.4	10.4	257	7.14	104.5	5.55	1.99	0.32
P09	6.22	31	31.6	360	4.88	79.2	16.2	0.97	0.22

Table 5: Water quality of Gishanda

Points	pH	T (°C)	Redox Pot. (mV)	EC (µ/cm)	DO (mg/l)	Do (%)	Turbid. (NTU)	Nitrate (mg/l)	Phosphate (mg/l)
P10	6.54	23.7	13.1	316	2.1	29.7	4.67	0.70	0.17
P11	6.93	26.6	-8.3	340	6.81	67	13.6	0.86	0.22
P12	7.17	29.3	-21.2	514	2.96	46	7.12	0.70	0.21
P13	7.1	25.5	-17.6	362	6.09	82.8	7.06	0.68	0.18
P14	6.28	27.9	2.9	367	6.28	95.5	5.45	0.72	0.13

P15	6.91	24.3	-7.1	354	4.26	61.6	38.6	0.74	0.12

Water macroinvertebrates

Results revealed 1003 macroinvertebrates as total abundance at both sites composed by 3 phyla including Arthropoda, Annelida, and Mollusca, 5 classes (Insecta, Gastropoda, Clitellata, Bivalvia, and Archnida), 10 orders and 36 families (Appendix 5). The results show significant differences in benthic macroinvertebrates biodiversity at both sites. Kanyeganyege exhibits high diversity compared to Gishanda (Figure 12). At Kanyeganyege, a total of 601 macroinvertebrate individuals were collected, composed by 31 families, dominated by Arthropoda (60.57%), Mollusca (33.44%), and Annelida (5.99%), that belong to the classes Insecta (60.57%), Gastropoda (33.28%), Clitellata (5.99%), and Bivalvia (0.17%), 13 orders, and 31 families dominated families Coenagrionidae (13.48%) and Planorbidae (12.81%).

Gishanda's site had 402 total abundances comprising 25 families, dominated by Arthropoda (53.48%) and Mollusca (39.3%), classes Gastropoda, and Insecta, and dominate orders including Neogastropoda (28.11%) and Trichoptera (17.66%), within 25 families dominant by Thiaridae and Simuliidae at 28.11% and 16.17%. While both sites, Kanyeganye and Gishanda, have similarities in aquatic macroinvertebrates, including both Gastropoda and Diptera. However, even though Kanyeganyege exhibits high macroinvertebrate diversity, they are all known to thrive in the human-dominated area, and they are tolerant of pollution.

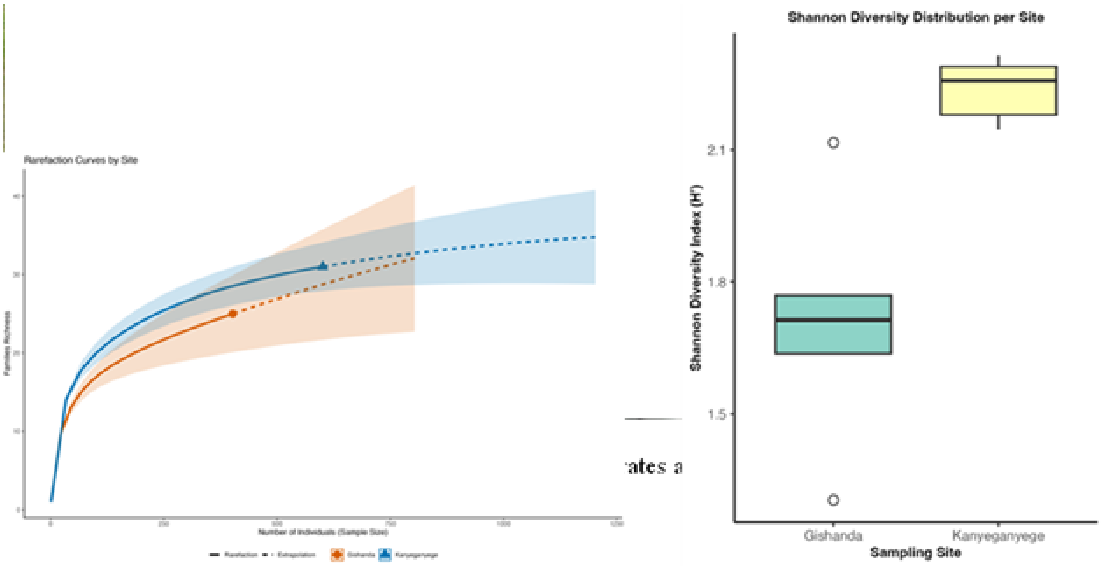

Figure 12. The left-side plot shows a rarefaction curve of sampling efforts, and the right plot demonstrates the Shannon diversity of freshwater macroinvertebrates at both sites, where Kanyeganyege has a high diversity of freshwater macroinvertebrates compared to Gishanda.

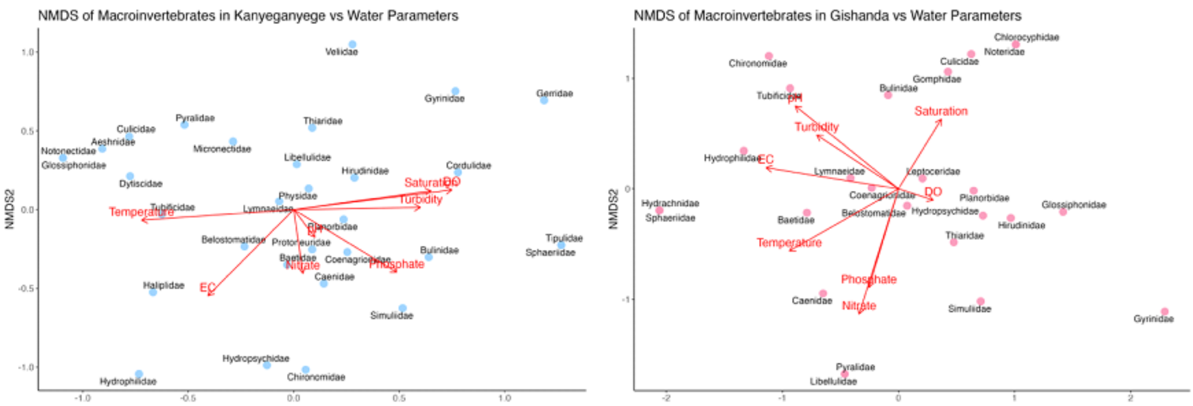

Figure 13. NMDS showing macroinvertebrate families relationship with water parameters at Kanyeganyege (left), NMDS showing macroinvertebrate families relationship with water parameters at Gishanda (right).

On the side of Gishanda, families such as Gomphidae, Culicidae, Bulnidae, Chlorocyphidae, Leptoceridae, and Hydropsychidae appear to be more aligned with dissolved oxygen (DO) and saturation (DO%), indicating well-oxygenated water conditions often associated with water quality. However, Caenidae, Libellulidae, and Pyralidae frequently correlate with phosphate and nitrate, revealing their strong association with nutrient pollution tolerance. Additionally, families like Planorbidae and Lymnaeidae near the central origin demonstrate that they are highly adaptable to various conditions. Overall, the findings on macroinvertebrates indicate that, even though most are generalists, there are exceptions, such as Chlorocyphidae, Leptoceridae, and Hydropsychidae that require special attention in conservation due to their preference to survive in good habitat, with high water quality particularly high DO, and minimal disturbances.

2.5.4. Discussion

The results of the freshwater macroinvertebrates show a notable difference across both sides in both abundance and diversity. The mean abundance of the macroinvertebrates was slightly higher in Gishanda (6.28) compared to Kanyeganyege (5.32). A Welch two sample t-test indicates the difference was nkt statistically significant ($t=0.705$, $df=92.96$, $p=0.483$). The shannon diversity index, accounting for both families' richness and eveness, showed that Kanyeganyege exhibits a higher diversity value of ($H' = 2.39$) compared to Gishanda ($H = 1.8$) (figure 12 left). However, the presence of Trichoptera (Leptoceridae and Hydropsychidae) and Chlorocyphidae suggest clean and highly oxygenated water with minimum disturbances found at Gishanda site (Kemabonta & Williams, 2016; Twagirayezu & Ngirinshuti, 2024; Stoyanova et al., 2014; Nsengimana, Twagirayezu, Habiyaremye, et al., 2025). These findings highlight how agricultural practices (rice farming) versus small flowing streams of Gishanda (banana plantation) shape macroinvertebrate diversity, where Kanyeganyege favors tolerance of stagnant water and nutrient-rich macroinvertebrates, while Gishanda supports some macroinvertebrates that need high oxygen and are adapted to flowing water bodies.

The Non-Metric Multidimensional Scaling (NMDS) shows how freshwater macroinvertebrate families correlated with water parameters at both sites (Figure x). The families are plotted in two-dimensional space (NDM1 on the x-axis and NMDS2 on the y-axis). From the plot, it is evident that macroinvertebrate communities are adapted differently to the water parameters at both sites. For instance, Kanyeganyege's macroinvertebrate findings, notably, show that the Simuliidae, Bulnidae, Caenidae, and Coenagrionidae are closely related to the pH, nitrate, and phosphate, suggesting that they are tolerant and possibly prefer to live in the nutrient-rich area characterised by agricultural runoff. On the other hand, they align against the temperature and electric conductivity, for instance, which means they prefer cooler and less ionic water.

Additionally, the dissolved oxygen (DO) and saturation (DO%) influence families like Cordulidae, which indicates that they are found in highly oxygenated water. Additionally, Lymnaeidae and Physidae shows to do not association with water parameters, therefore are generalists. This brings us to say that even though the parameters do not show the significance within sampling points, some families adapt according to the water parameters of each point.

2.5.5. Conservation Implications

The results highlight the critical influence of land use on freshwater macroinvertebrates. The higher diversity of Kanyeganyege is dominated by pollution tolerant taxa such as Odonata (Coenagrionidae), and Gastropoda (Planorbidae), that are adapted to the area of nutrient condition normally with higher nitrogen and phosphorus (eutrophic conditions). However, Gishanda's stream, supports taxa like trichoptera (leptoceridae, and Hydropsychidae), odonata that belong to the family Chlorocyphidae, which are sensitive to the pollution (they do not tolerate pollution), and require higher oxygenated water with minimum disturbances. The presence of pollution sensitive species such Leptoceridae, Hydropsychidae, and Chlorocyphidae, underscores the need for targeted conservation measures that includes the increase of water quality and reducing the disturbances. Conversely, Kanyeganyege has generalists and pollution tolerant macroinvertebrates that are adapted to live on disturbed area. Therefore, the reduction in the use of chemical fertilizers can enhance the freshwater biodiversity while doing the rice plantation in sustainable ways.

The NMDS analysis reinforces the importances of water quality to the survival of freshwater macroinvertebrates assemblages. Families like Coirdulidae, Hydropsychidae are particularly associated with oxygen, and this makes them also the key target for conservation. Therefore, community-based conservation including pollution control programs, and reduction in use of chemical fertilizers, should be a key strategy that can help the pollution sensitive species survive, and maintain the sustainability of both sites.

2.6. Arthropod Biodiversity from Kanyeganyege and Gishanda

2.6.1. Methodology

Terrestrial arthropods were sampled using line transect methods (Naranjo, 2008). Along each transect, sampling points were demarcated every 500 m. To avoid edge effect, which can alter species composition, due to external influences or adjacent differences, we leave 5 meters out of the subplots (Basset & et, 2012). The geographic coordinates at each sampling station were recorded by using the Global Positioning System (GPS) to make species distribution maps. At each sampling point, three sampling methodologies were used to ensure the capture of the diversity of terrestrial arthropods present. The first method is a hand collection method used to collect insects from the ground (McCravy, 2018), and collection under rocks, dead trees, and the leaf-litter layer (Ivanov, 2010). For hand-collecting insects, we demarcated a 1 m² plot on the ground, removed surface debris, and then searched for terrestrial arthropods moving on the ground using manual aspirators and forceps.

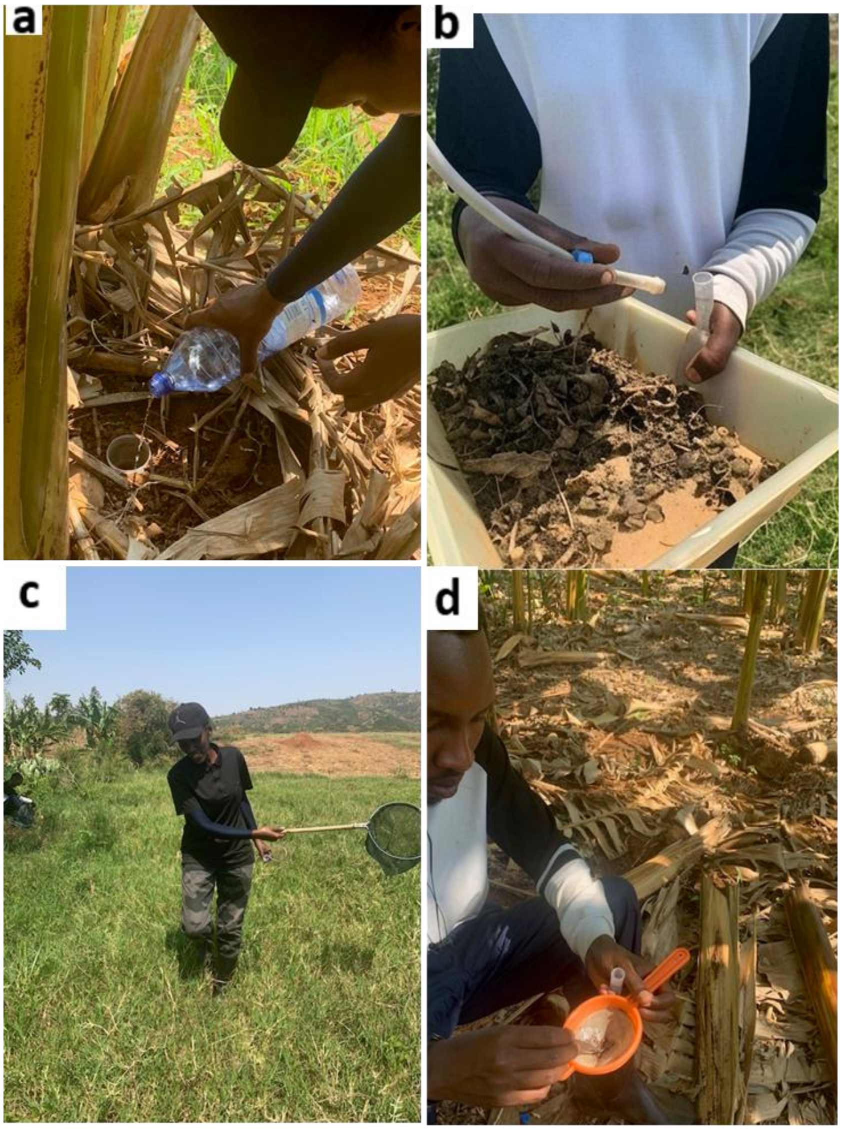

Figure 14: a) setting pitfall traps at Gishanda site, b) sorting arthropods by aspirator, c) sampling flies by sweep net, d) sorting arthropods by forceps

Captures arthropods were kept in concentrated ethanol (96%) for preservation. The second method used was sweep-netting to collect insects from the air (Spafford & Christopher, 2013), as some terrestrial arthropods can fly or jump and may move from the ground to the vegetation cover. We used nets to sweep across the vegetation around the sampling point for 15 minutes, transferring the captured insects into tubes as they became captured in the net.

To capture a diverse range of terrestrial arthropods, we also used pitfall traps made of a transparent plastic bottle, which was buried in a soil pit and partly filled with 25 ml of 75% ethanol as a preservation of insects (Nsengimana et al. 2023). At each sampling point, we placed five traps to increase sampling efforts. Each trap was set after the removal of the leaf-litter layer, and it was maintained in place for 24 hours to maximize chances of collecting terrestrial arthropods Nsengimana et al. 2023).

Once captured, regardless of the method, specimens were transferred to plastic tubes containing 96% concentrated alcohol for preservation. We archived 3659 arthropod samples in the laboratory at the Center of Excellence in Biodiversity and Natural Resource Management, Collections Management Unit at the University of Rwanda for identification.

We conducted the identification of species in the laboratory using identification keys, including the Field Guide to the Insects of South Africa (Hough, 2017), the Kakamega forest book from Kenya, and comparison to the reference species insect collections found at the Centre of Excellence in Biodiversity and Natural Resource Management. Specimens of arthropods were morphologically identified by examining key physical characteristics, including body structure, wings, antennae, legs, mouthparts, and coloration (Ranjan, 2015). In this survey, specimens were identified to the family level.

The collected data were digitized into Microsoft Office (Microsoft Excel) and later processed, and we calculated the Shannon Diversity Index, species richness, and their combined analysis aims to provide insights into the overall health status of the wetland. Data were analyzed using R programming software (Hyndman, 2023).

2.6.2. Results

We sampled a total of 3659 terrestrial arthropod individuals belonging to 76 families across both sampling sites in the Eastern Province of Rwanda. At the Gishanda site, we found a total of 66 families **(Table 2),** followed by the Kanyeganyege site with 63 families **(Table 2).** Figure 2 shows the family richness rarefaction curves and indicates that more sampling could uncover additional species in Gishanda, while for Kanyeganyege, the curves indicate that the species richness for this taxon has been adequately sampled.

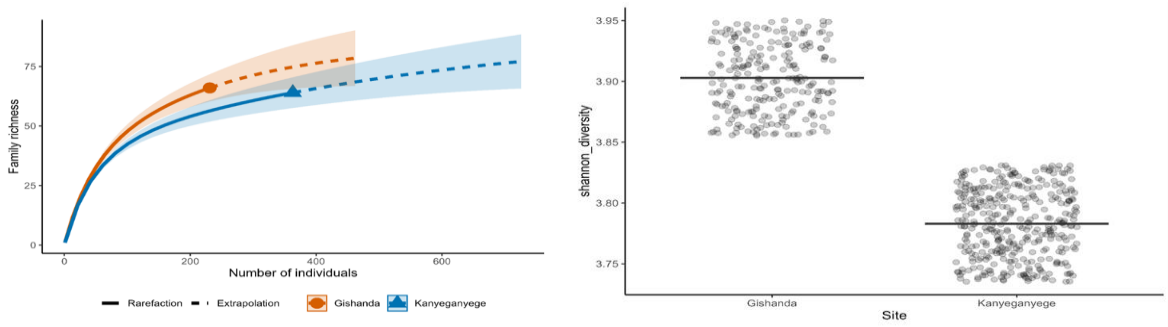

Figure 15. Terrestrial arthropod rarefaction curves and Shannon diversity across the Gishanda and Kanyeganyege sites

In Gishanda, we observed 1405 individuals across 66 families, highlighting a rich and varied composition of terrestrial arthropods (Figure 15), whereas in Kanyegenyege we have identified 63 families. The Hymenoptera (Formicidae) was the most observed terrestrial arthropod family, constituting 34.73% of the observed terrestrial insects. The Syrphidae, Apidae, and Halictidae commonly known as pollinators together with frugivores like Tephritidae (Dipetra), Coenagrionidae and Libellulidae (Odonata) were less observed compared with Formicidae (Table 1). The Gishanda exhibits a Shannon Diversity of 4.954, reflecting a balanced distribution and high species compared to Kanyeganyege, which has an index of 4.394.

Fruit flies (family Tephritidae) that feeds only on plants signify economic importance in agriculture affecting fruit crop yield (De Cock, 2020). The presence of Formicidae, with their omnivorous nature, suggests a well-functioning ecosystem where these ants play vital roles in nutrient cycling, pest control, and seed dispersal. The presence of the family Syrphidae, Apidae, and Halictidae is evidence of a pollination network within both sites, emphasizing its ecological significance.

2.6.3. Conservation Implications

Even though the dentification did not go to species level, some families are known to play a key role in the environment (Table 5).

Table 6: Most special terrestrial arthropod families across both sites

Class	Order	Family	Function Group	Kanyeganyege Abundance	Gishanda Abundance
Insecta	Diptera	Syrphidae	Pollinator	1	4
	Hymenoptera	Apidae		6	0
		Halictidae		1	2
	Diptera	Tephritidae	Frugivores	36	2
	Odonata	Coenagrionidae	Predator	3	9
		Libellulidae		0	3

2.6.4. Discussion

The results demonstrate that both Gishanda and Kanyeganyege wetlands support a diverse and functionally important community of terrestrial arthropods, with a total of 76 families recorded across the two sites. Gishanda, with 66 families and a higher Shannon Diversity index (H' = 4.954), shows slightly greater family richness and a more balanced distribution compared to Kanyeganyege (63 families; H' = 4.394). The rarefaction curves indicate that while Kanyeganyege's terrestrial arthropod diversity has been adequately sampled, additional effort at Gishanda could reveal even more families, highlighting its potential as a biodiversity hotspot. The dominance of Formicidae (ants) in both sites — comprising over a third of all individuals — underscores the ecological importance of this group in maintaining soil health, nutrient cycling, and regulating other invertebrate populations.

Furthermore, the detection of specialized groups such as pollinators (Syrphidae, Apidae, Halictidae) and frugivores like Tephritidae emphasizes the functional roles these wetlands play in supporting vital ecosystem services. Though these pollinator groups were less abundant than Formicidae, their presence indicates active pollination networks that benefit local vegetation and nearby agricultural systems. The finding of economically significant species such as Tephritidae also highlights the wetlands' connection to surrounding agricultural landscapes, suggesting a need for integrated management to balance biodiversity conservation with crop protection. In nutshell, high arthropod diversity and functional group representation reinforce the ecological value of both sites and the importance of conserving these wetland habitats to sustain key processes like pollination, pest control, and nutrient dynamics

Appendix 1: Plants species recorded at Kanyeganyege and Gishanda sites

Taxonomy			IUCN Status	Origin	Gishanda Plant species abundance						Kanyeganyege									Total
Order	Family	Species			P1	P2	P3	P4	P6	P6	P1	P2	P3	P4	P5	P6	P7	P8	P9	
Alismatales		*Colocasia esculenta*	LC	Native	0	0	0	0	0	0	0	12	3	14	1	0	3	2	2	**37**
	Araceae	*Lemna minor*	LC	Native	0	0	0	0	0	0	3	4	0	8	8	0	3	0	3	**29**
		Pistia stratiotes	LC	Native	0	0	0	0	0	0	9	11	0	6	9	0	9	0	9	**53**
	Potamogetonaceae	*Potamogeton schweinfurthii*	LC	Native	0	0	0	0	60	0	0	0	0	0	0	0	0	0	0	**60**
Apiales	Apiaceae	*Centella asiatica*	LC	Native	71	0	0	0	0	0	23	8	12	20	0	28	12	8	12	**194**
	Araliaceae	*Hydrocotyle mannii*	NE	Native	0	0	0	0	0	0	21	6	15	12	0	0	7	0	1	**62**
Asparagales	Asparagaceae	*Dracaena afromontana*	LC	Native	0	188	0	0	0	0	0	0	0	0	4	0	0	0	0	**192**
Asterales	Asteraceae	*Acmella caulirhiza*	LC	Native	0	0	0	0	0	0	6	2	3	4	11	13	5	0	10	**54**
		Ageratum conyzoides	LC	Introduced	125	0	0	0	0	0	3	0	0	3	0	4	10	4	0	**149**
		Baccharoides adoensis	LC	Native	0	0	0	0	0	21	0	0	0	0	0	0	0	0	0	**21**
		Bidens pilosa	NE	Introduced	348	0	0	0	0	0	13	4	3	10	5	8	8	4	0	**403**
		Bothriocline longipes	NE	Native	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	**1**
		Crassocephalum vitellinum	NE	Native	0	0	0	0	0	0	2	6	0	0	4	3	3	2	1	**21**
		Emilia coccinea	NE	Native	0	138	0	0	0	0	2	0	1	0	2	3	3	6	1	**156**

		Erigeron bonariensis	LC	Introduced	0	99	0	0	0	0	0	0	0	0	0	0	0	0	0	**99**
		Erigeron sumatrensis	NE	Native	0	68	0	0	0	0	1	1	0	1	0	0	2	0	1	**74**
		Ethulia conyzoides	LC	Native	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
		Galinsoga parviflora	NE	Introduced	0	0	90	0	0	0	4	30	16	3	25	10	16	13	10	**217**
		Guizotia scabra	NE	Native	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	**1**
		Gymnanthemum amygdalinum	NE	Native	0	0	0	0	0	225	0	0	2	0	0	0	0	0	0	**227**
		Helianthus annuus	LC	Native	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	**3**
		Melanthera scandens	NE	Native	0	0	0	0	0	0	10	2	4	0	2	3	3	0	2	**26**
		Micractis bojeri	NE	Native	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	**3**
		Senecio vulgaris	NE	Introduced	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	**21**
		Sigesbeckia serrata	NE	Introduced	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	**4**
		sonchus asper	NE	Introduced	0	0	0	0	0	79	0	0	3	1	5	2	0	4	2	**96**
		Sphaeranthus suaveolens	NE	Native	0	0	0	0	0	0	0	2	0	1	0	0	4	0	0	**7**
		Tagetes minuta	NE	Introduced	0	0	0	0	0	160	0	0	2	0	1	2	0	0	0	**165**
		Tithonia diversifolia	NE	Introduced	0	0	0	0	0	9	0	0	0	4	0	0	4	0	0	**17**
		Vernoniastrum aemulans	NE	Native	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	**2**

Boraginales	Boraginaceae	*Hackelia virginiana*	NE	Introduced	0	0	24	0	0	0	0	0	0	0	0	0	0	0	0	**24**
		Symphytum officinale	NE	Introduced	0	0	0	0	0	18	0	0	0	0	0	0	0	0	0	**18**
Brassicales	Moringaceae	*Moringa oleifera*	LC	Introduced	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	**9**
	Caricaceae	*Carica papaya*	DD	Introduced	39	0	0	0	0	0	0	0	0	3	0	0	0	0	0	**42**
Caryophyllales	Amaranthaceae	*Achyranthes aspera*	NE	Introduced	70	0	0	0	0	0	0	4	0	0	0	0	0	0	0	**74**
		Amaranthus viridis	NE	Native	0	0	0	0	0	0	0	2	3	3	0	5	17	0	5	**35**
		Chenopodium ugandae	NE	Native	103	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**103**
	Polygonaceae	*Persicaria attenuata*	LC	Introduced	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**
		Persicaria decipiens	NE	Native	0	0	0	0	0	0	0	2	0	10	2	13	2	0	2	**31**
		Phytolacca dodecandra	NE	Native	0	0	0	0	0	0	0	0	0	0	5	2	0	0	1	**8**
		Polygonum attenuata	NE	Introduced	0	0	0	0	39	0	0	0	0	0	0	0	0	0	0	**39**
		Polygonum glabrum	LC	Native	0	0	0	0	32	0	0	0	0	0	0	0	0	0	0	**32**
		Polygonum nepalense	NE	Introduced	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	**21**
		Rumex bequaertii	NE	Native	0	0	0	0	0	0	17	3	1	4	7	2	6	0	0	**40**
Celastrales	Celastraceae	*Gymnosporia senegalensis*	LC	Introduced	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0	**22**
		Maytenus senegalensis	LC	Native	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2	**4**

Ceratophyllales	Ceratophyllaceae	*Ceratophyllum demersum*	LC	Native	0	0	0	0	0	0	6	6	0	1	6	0	6	0	12	**37**
Commelinales	Pontederiaceae	*Eichhornia crassipes*	NE	Introduced	0	83	0	0	0	0	0	0	0	0	0	0	0	0	0	**83**
	Commelinaceae	*Commelina africana*	LC	Native	181	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**181**
		Commelina diffusa	LC	Native	307	0	0	0	0	0	14	18	10	10	10	0	12	0	4	**385**
Cucurbitales	Cucurbitaceae	*Cucumis metuliferus*	NE	Introduced	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**50**
		Cucurbita maxima	NE	Native	17	0	0	0	0	0	0	2	0	0	0	0	2	0	0	**21**
		Momordica foetida	NE	Native	0	0	0	0	0	0	0	0	1	0	2	0	0	2	1	**6**
		Zehneria scabra	NE	Native	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	**2**
Ericales	Primulaceae	*Maesa lanceolata*	LC	Native	0	0	5	0	0	0	0	0	1	0	0	1	0	0	0	**7**
Fabales	Fabaceae	*Acacia polyacantha*	LC	Native	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**4**
		Caesalpinia decapetala	LC	Introduced	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	**3**
		Calliandra calothyrsus	NE	Native	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	**3**
		Calliandra haematocephala	LC	Introduced	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**4**
		Calliandra parvifolia	LC	Native	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**21**
		Canavalia rosea	LC	Introduced	91	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**91**
		Crotalaria pallida	LC	Introduced	117	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**117**

		Crotalaria spectabilis	NE	Native	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	**2**
		Desmodium uncinatum	NE	Native	42	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**42**
		Erythrina abyssinica	LC	Native	0	13	0	0	0	0	0	3	0	0	1	2	0	3	0	**22**
		Indigofera homblei	NE	Introduced	0	0	164	0	0	0	0	0	0	0	0	0	0	0	0	**164**
		Mimosa Pigra	LC	Introduced	0	0	0	67	0	0	0	0	0	0	0	0	0	0	0	**67**
		Mimosa pudica	LC	Introduced	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	**2**
		Ononis rotundifolia	NE	Introduced	0	0	0	19	0	0	0	0	0	0	0	0	0	0	0	**19**
		Phaseolus vulgaris	LC	Introduced	0	0	0	0	0	0	0	1	0	0	0	0	6	0	0	**7**
		Pseudarthria hookeri	NE	Native	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	**2**
		Senegalia polyacantha	LC	Native	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**
		Senna didymobotrya	LC	Native	0	0	0	0	188	0	0	2	0	0	0	0	0	0	0	**190**
		Senna occidentalis	LC	Introduced	0	0	0	0	29	71	0	0	0	0	0	0	0	0	0	**100**
		Senna spectabilis	LC	Introduced	0	0	0	0	0	55	0	0	0	0	0	2	0	0	0	**57**
		Sesbania sesban	LC	Native	0	0	0	0	0	5	0	2	0	0	2	3	2	0	0	**14**
		Vachellia farnesiana	NE	Introduced	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**1**
		Vigna vexillata	NE	Native	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	**1**
Gentianales	Apocynaceae	*Cascabela thevetia*	LC	Native	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**4**

	Rubiaceae	*Coffea arabica*	EN	Introduced	0	0	0	0	0	0	0	0	0	8	0	0	43	4	0	**55**
		Spermacoce princeae	NE	Native	0	0	0	0	0	10	0	0	0	0	0	0	2	0	0	**12**
Lamiales	Acanthaceae	*Hygrophila auriculata*	LC	Native	0	0	92	0	0	0	0	0	0	0	1	0	0	3	0	**96**
		Acanthus polystachyus	NE	Native	12	0	0	0	0	0	0	1	0	0	0	0	0	0	0	**13**
		Asystasia gangetica	NE	Introduced	0	0	0	0	0	0	0	10	0	0	0	0	0	0	4	**14**
		Brillantaisia owariensis	LC	Introduced	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**11**
		Clerodendrum johnstonii	LC	Native	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	**2**
		Clerodendrum rotundifolium	LC	Introduced	20	0	0	0	0	0	0	2	0	0	0	0	0	0	1	**23**
		Jasminum abyssinicum	LC	Native	0	0	38	0	0	0	0	0	0	0	0	0	0	0	0	**38**
		Lantana camara	NE	Native	0	0	116	0	0	0	0	5	0	0	2	3	3	3	0	**132**
		Leonotis nepetifolia	NE	Native	0	0	162	0	0	0	0	3	2	16	1	4	3	3	0	**194**
		Leucas martinicensis	NE	Native	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	**3**
		Ocimum gratissimum	NE	Native	0	0	0	31	0	0	0	0	0	4	0	2	0	0	0	**37**
		Plectranthus barbatus	NE	Native	0	0	0	0	92	0	0	0	0	0	0	0	0	0	0	**92**
		Tetradenia riparia	NE	Native	0	0	0	0	0	72	0	0	0	0	0	0	0	0	0	**72**
		Thunbergia alata	NE	Native	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0	**4**
	Verbenaceae	*Verbena halei*	LC	Introduced	0	0	0	0	0	31	0	0	0	0	0	0	0	0	0	**31**

	Bignoniaceae	*Markhamia lutea*	LC	Native	0	0	0	19	0	0	0	0	1	3	1	2	0	0	0	**26**
		Spathodea campanulata	LC	Native	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	**3**
Laurales	Lauraceae	*Persea americana*	LC	Introduced	0	0	0	36	12	0	0	3	2	0	0	2	2	3	2	**62**
Malpighiales	Phyllanthaceae	*Bridelia brideliifolia*	LC	Native	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	**1**
	Euphorbiaceae	*Euphorbia grantii*	NE	Native	0	141	0	0	0	0	0	0	0	0	0	0	0	0	0	**141**
		Euphorbia heterophylla	LC	Introduced	0	21	0	0	0	0	0	0	0	0	0	0	0	0	0	**21**
		Euphorbia hirta	NE	Introduced	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	**10**
		Euphorbia tirucalli	LC	Native	0	131	0	0	0	0	0	0	2	0	0	2	2	0	0	**137**
		Euphorbia umbellata	NE	Native	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	**2**
		Manihot esculenta	DD	Introduced	0	0	0	72	0	0	0	0	0	0	0	0	0	3	0	**75**
		Passiflora edulis	NE	Introduced	0	0	0	48	0	0	0	0	0	3	0	0	0	0	0	**51**
		Phyllanthus niruri	NE	Introduced	0	0	0	0	0	0	0	0	2	2	2	0	0	2	3	**11**
		Ricinus communis	NE	Introduced	0	0	0	0	188	0	0	0	1	7	1	2	3	0	2	**204**
Malvales	Malvaceae	*Abutilon angulatum*	NE	Native	138	0	0	0	0	0	0	0	0	3	0	0	0	0	0	**141**
		Abutilon indicum	NE	Introduced	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**21**
		Hibiscus calyphyllus	LC	Native	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	**10**

		Malva pusilla	NE	Introduced	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	**40**
		Pavonia urens	NE	Native	0	0	0	0	0	0	0	3	2	0	0	8	3	0	0	**16**
		Sida rhombifolia	NE	Native	0	0	0	0	0	41	0	0	0	0	0	0	0	0	0	**41**
		Sida tenuicarpa	NE	Native	0	0	0	0	0	0	2	3	3	1	3	2	0	0	2	**16**
		Triumfetta rhomboidea	LC	Native	0	0	0	0	0	3	0	2	0	0	0	0	0	0	0	**5**
Metteniusales	Metteniusaceae	*Calatola costaricensis*	LC	Introduced	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Myrtales	Myrtaceae	*Eucalyptus sp.*	NE	Native	0	17	0	0	0	0	0	0	0	0	0	0	0	0	0	**17**
		Ludwigia abyssinica	LC	Introduced	0	0	0	0	0	0	3	3	3	0	0	8	3	11	1	**32**
		Ludwigia octovalvis	LC	Native	0	0	114	0	0	0	0	0	0	0	0	0	0	0	0	**114**
		Psidium guajava	LC	Introduced	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	**7**
	Combretaceae	*Terminalia mantaly*	LC	Introduced	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	**1**
Nymphaeales	Nymphaeaceae	*Nymphaea nouchali*	LC	Native	0	0	0	70	0	0	0	0	0	0	0	0	0	0	0	**70**
Oxalidales	Oxalidaceae	*Oxalis corniculata*	NE	Introduced	0	0	0	20	0	0	0	0	2	2	0	0	2	0	20	**46**
		Oxalis latifolia	NE	Introduced	0	0	0	120	0	0	9	3	0	10	0	0	3	0	0	**145**
Poales	Poaceae	*Bambusa vulgaris*	NE	Introduced	44	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**44**
		Cenchrus clandestinus	LC	Native	21	0	0	0	0	0	33	28	1	22	24	1	41	0	0	**171**
		Cyperus ajax	NE	Native	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	**1**
		Cyperus difformis	LC	Native	0	0	0	0	0	0	4	7	0	4	8	0	4	0	11	**38**
		Cyperus dives	LC	Native	60	0	0	0	0	0	5	0	1	4	0	5	3	0	6	**84**

		Cyperus iria	LC	Native	0	0	0	0	0	0	2	5	0	2	10	0	2	0	2	**23**
		Cyperus polystachyos	LC	Native	39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**39**
		Digitaria abyssinica	NE	Introduced	70	0	0	0	0	0	33	69	28	3	71	30	25	0	39	**368**
		Dinebra chinensis	NE	Introduced	0	0	0	0	0	0	3	2	0	3	3	0	3	0	3	**17**
		Echinochloa crus-galli	LC	Introduced	0	0	0	0	0	0	5	5	0	4	11	0	5	0	5	**35**
		Juncus effusus	LC	Native	0	0	69	0	0	0	0	0	0	0	0	0	0	0	0	**69**
		Kyllinga appendiculata	NE	Introduced	0	0	0	0	0	0	8	3	7	4	0	0	12	0	2	**36**
		Oryza sativa	LC	Introduced	0	0	0	0	0	0	97	50	48	48	41	0	64	0	1	**349**
		Pennisetum purpureum	LC	Native	0	0	0	8	0	0	0	0	11	22	0	0	3	0	23	**67**
		Phragmites mauritianus	LC	Native	0	0	0	0	25	0	0	0	0	0	0	0	0	0	0	**25**
		Saccharum officinarum	NE	Introduced	0	0	0	0	79	0	0	0	0	0	0	9	0	0	0	**88**
		Setaria viridis	NE	Native	0	0	0	0	0	1	3	0	22	3	12	36	14	0	1	**92**
		Sorghum halepense	NE	Introduced	0	0	0	0	0	71	0	0	0	0	0	0	0	0	0	**71**
		Typha latifolia	LC	Native	0	0	0	0	0	33	0	0	0	0	0	0	0	0	0	**33**
		Zea mays	LC	Introduced	0	0	0	0	0	0	0	51	1	0	0	72	0	0	0	**124**
Polypodiales	Pteridaceae	*Adiantum latifolium*	NE	Introduced	0	0	0	0	0	0	6	0	0	0	0	0	0	0	2	**8**
		Pityrogramma calomelanos	NE	Introduced	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	**3**
	Dennstaedtiaceae	*Pteridium aquilinum*	LC	Introduced	0	0	0	0	44	0	0	0	0	0	0	0	0	0	0	**44**

	Aspleniaceae	*Thelypteris palustris*	LC	Introduced	0	0	0	0	0	0	2	2	0	15	0	2	0	0	0	**21**
Proteales	Proteaceae	*Grevillea robusta*	LC	Native	0	0	63	0	0	0	0	0	0	0	0	2	2	0	6	**73**
Ranunculales	Ranunculaceae	*Clematis simensis*	NE	Native	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	**3**
		Ranunculus multifidus	LC	Native	0	0	0	0	0	0	8	3	0	3	2	2	0	0	0	**18**
	Menispermaceae	*Stephania abyssinica*	NE	Native	0	0	0	0	0	0	0	0	1	0	0	0	4	0	3	**8**
Rosales	Moraceae	*Artocarpus heterophyllus*	NE	Introduced	17	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**18**
		Ficus asperifolia	LC	Native	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	**1**
		Ficus gnaphalocarpa	NE	Native	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
		Ficus sur	LC	Native	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	**9**
		Ficus thonningii	LC	Native	0	11	11	0	0	0	0	0	0	0	0	0	0	0	0	**22**
		Ficus vallis-choudae	NE	Introduced	0	0	29	0	0	0	0	0	0	0	1	0	0	0	0	**30**
	Urticaceae	*Obetia radula*	LC	Native	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	**4**
	Rosaceae	*Rubus pinnatus*	NE	Introduced	0	0	0	0	41	0	0	0	0	0	0	0	0	0	0	**41**
Salviniales	Salviniaceae	*Azolla pinnata*	LC	Introduced	64	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**64**
	Marsileaceae	*Marsilea minuta*	LC	Native	0	0	0	147	0	0	0	0	0	0	0	0	0	0	0	**147**
	Anacardiaceae	*Mangifera indica*	DD	Introduced	0	0	43	0	0	0	0	1	0	0	1	0	0	0	0	**45**
		Searsia pyroides	LC	Native	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	**5**
	Sapindaceae	*Allophylus abyssinicus*	NE	Native	10	0	0	0	0	0	0	0	0	2	0	0	0	0	0	**12**
		Cardiospermum halicacabum	LC	Introduced	0	0	0	0	0	0	0	2	0	0	0	0	0	2	0	**4**
Saxifragales	Crassulaceae	*Kalanchoe crenata*	NE	Native	0	0	70	0	0	0	0	0	0	0	0	0	0	0	0	**70**

Solanales	Solanaceae	*Capsicum frutescens*	LC	Native	71	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**71**
		Datura stramonium	LC	Introduced	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**11**
		Ipomoea batatas	DD	Introduced	0	0	0	0	0	0	0	0	0	0	0	53	0	0	0	**53**
		Ipomoea biflora	NE	Native	0	0	17	0	0	0	0	0	0	0	0	0	0	0	0	**17**
		Nicandra physalodes	NE	Introduced	0	0	0	110	0	0	0	0	2	0	0	0	0	0	0	**112**
		Physalis chenopodiifolia	LC	Introduced	0	0	0	0	0	0	0	0	1	0	0	0	0	0	2	**3**
		Physalis peruviana	NE	Introduced	0	0	0	0	21	0	0	0	0	0	0	0	0	0	0	**21**
		Solanum betaceum	LC	Introduced	0	0	0	0	0	122	0	0	0	0	0	0	0	0	0	**122**
		Solanum linnaeanum	LC	Introduced	0	0	0	0	0	127	0	0	0	0	0	0	0	0	0	**127**
		Solanum melongena	NE	Introduced	0	0	0	0	0	0	0	1	0	0	0	0	2	12	0	**15**
		Solanum nigrum	NE	Introduced	0	0	0	0	0	182	0	2	0	1	0	1	0	0	0	**186**
		Solanum torvum	NE	Introduced	0	0	0	0	0	91	0	0	0	1	0	0	0	0	0	**92**
	Sphenocleaceae	*Sphenoclea zeylanica*	LC	Native	0	0	0	0	0	21	10	5	0	12	6	0	10	0	5	**69**
Vitales	Vitaceae	*Cyphostemma adenocaule*	NE	Introduced	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	**4**
Grand Total					**2206**	**931**	**1179**	**780**	**901**	**1453**	**370**	**415**	**243**	**336**	**319**	**361**	**413**	**100**	**227**	**10234**

Appendix 2: Bird species recorded at Kanyeganyege and Gishanda wetlands and its IUCN status

Oder	**Family**	**Species**		**Kanyeganyege**	**Gishanda**	**Total**

			IUCN status	P1	P2	P3	P4	P5	P6	P7	P8	P9	P1	P2	P3	P4	P5	P6	
Accipitriformes	Accipitridae	*Buteo augur*	LC	0	3	0	0	0	0	0	0	0	1	0	0	1	0	0	5
		Icthyophaga vocifer	LC	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3
		Lophaetus occipitalis	LC	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
		Milvus aegyptius	LC	1	1	0	2	3	0	0	1	0	0	2	0	0	0	0	10
Anseriformes	Anatidae	*Anas undulata*	LC	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3
		Sarkidiornis melanotos	LC	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Charadriiformes	Jacanidae	*Actophilornis africanus*	LC	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	3
Ciconiiformes	Ciconiidae	*Anastomus lamelligerus*	LC	0	6	0	1	0	0	0	0	0	0	0	0	0	0	0	7
		Mycteria ibis	LC	0	0	0	3	1	0	1	0	0	0	0	0	0	0	0	5
Coliiformes	Coliidae	*Colius striatus*	LC	0	0	0	0	1	0	0	0	0	5	0	0	0	0	0	6
Columbiformes	Columbidae	*Spilopelia senegalensis*	LC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3
		Streptopelia capicola	LC	0	0	0	0	0	1	0	0	0	0	0	50	0	0	0	51
		Streptopelia semitorquata	LC	1	0	1	1	1	0	1	0	1	8	2	0	0	0	0	16
		Turtur afer	LC	0	0	0	0	1	0	0	0	0	1	0	0	1	0	0	3
Coraciiformes	Alcediinidae	*Corythornis cristatus*	LC	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	4
	Alcedinidae	*Ceryle rudis*	LC	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	3
	Nectariniidae	*Cinnyris mariquensis*	LC	1	0	0	0	0	0	0	0	0	3	0	0	0	0	0	4
Cuculiformes	Cuculidae	*Centropus superciliosus*	LC	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
Gruiformes	Gruidae	*Balearica regulorum*	EN	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	3
	Rallidae	*Gallinula chloropus*	LC	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
		Porphyrio porphyrio	LC	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
		Zapornia flavirostra	LC	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
Passeriformes	Acrocephalidae	*Acrocephalus rufescens*	LC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	Cisticolidae	*Cisticola chubbi*	LC	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	2
		Cisticola marginatus	LC	0	5	0	0	1	0	0	0	0	0	0	0	0	0	1	7
	Corvidae	*Corvus albus*	LC	0	3	0	2	0	0	5	0	0	0	0	0	0	0	0	10
	Dicruridae	*Dicrurus adsimilis*	LC	0	0	0	0	0	0	0	0	0	1	0	0	0	0	5	6
	Estrildidae	*Estrilda astrild*	LC	0	0	1	0	0	1	0	0	0	2	2	0	0	0	5	11

		Lagonosticta senegala	LC	0	1	1	0	4	4	0	1	0	1	4	0	2	3	0	21
		Spermestes cucullata	LC	0	7	1	5	2	8	6	0	0	3	22	1	0	2	12	69
		Uraeginthus bengalus	LC	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2
	Fringillidae	*Crithagra frontalis*	LC	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	2
		Crithagra mozambica	LC	0	0	1	0	0	1	0	0	0	0	0	0	0	3	1	6
		Crithagra striolata	LC	0	0	0	0	0	3	0	2	0	0	0	0	0	0	0	5
		Crithagra sulphurata	LC	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4
	Hirundinidae	*Hirundo angolensis*	LC	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2
		Hirundo rustica	LC	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
		Hirundo smithii	LC	0	0	0	0	1	3	0	0	0	0	0	5	0	0	0	9
		Psalidoprocne albiceps	LC	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	2
		Psalidoprocne pristoptera	LC	0	1	0	0	1	1	0	0	0	0	1	0	0	0	0	4
	Laniidae	*Lanius excubitoroides*	LC	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0	4
	Leiothrichidae	*Turdoides jardineii*	LC	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	2
	Malaconotidae	*Laniarius aethiopicus*	LC	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	2
	Monarchidae	*Terpsiphone viridis*	LC	0	0	0	0	0	0	1	0	0	3	0	0	0	0	0	4
	Motacillidae	*Macronyx croceus*	LC	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	2
		Motacilla aguimp	LC	0	1	3	0	0	3	0	0	0	1	0	0	0	0	0	8
		Motacilla capensis	LC	0	0	2	0	2	0	1	0	0	1	0	0	0	0	0	6
	Muscicapidae	*Cercotrichas leucophrys*	LC	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	2
		Cossypha heuglini	LC	0	0	0	0	1	0	0	5	0	0	0	0	0	0	0	6
		Dessonornis caffer	LC	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
		Muscicapa aquatica	LC	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
	Nectariniidae	*Chalcomitra senegalensis*	LC	0	0	1	1	0	0	1	0	0	0	1	0	0	1	0	5
		Cinnyris erythrocercus	LC	2	0	0	0	0	0	0	0	0	1	0	0	1	4	1	9
		Cinnyris venustus	LC	0	2	1	2	0	0	3	0	0	1	1	0	1	1	0	12
		Nectarinia kilimensis	LC	1	0	0	0	2	0	0	1	0	1	2	0	0	0	0	7
	Passeridae	*Passer griseus*	LC	0	1	0	0	0	0	1	0	0	2	4	0	0	0	0	8
	Ploceidae	*Euplectes axillaris*	LC	0	1	0	1	2	2	0	0	0	0	1	0	0	0	0	7
		Euplectes capensis	LC	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	2

		Euplectes hordeaceus	LC	0	0	0	0	0	0	0	0	0	0	0	1	0	0	5	6
		Euplectes orix	LC	0	0	0	0	0	1	0	2	0	0	0	0	0	0	1	4
		Ploceus baglafecht	LC	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	2
		Ploceus intermedius	LC	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
		Ploceus melanocephalus	LC	30	0	6	4	1	10	30	0	15	10	21	3	0	3	8	141
		Ploceus ocularis	LC	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2
		Ploceus subaureus	LC	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
		Ploceus xanthops	LC	0	0	0	0	0	0	0	0	0	1	0	0	0	0	5	6
		Quelea quelea	LC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5
	Pycnonotidae	*Pycnonotus barbatus*	LC	2	0	0	0	1	0	0	0	0	0	4	0	0	3	1	11
	Sturnidae	*Lamprotornis chalybaeus*	LC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
		Lamprotornis purpuroptera	LC	0	0	0	0	0	0	0	0	0	0	0	0	0	2	5	7
	Turdidae	*Turdus pelios*	LC	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3
	Viduidae	*Vidua macroura*	LC	0	0	0	0	0	3	0	0	0	1	0	0	0	0	0	4
Pelecaniformes	Ardeidae	*Ardea alba*	LC	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
		Ardea brachyrhyncha	LC	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	3
		Ardea cinerea	LC	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
		Ardea intermedia	LC	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
		Ardea melanocephala	LC	0	2	0	4	0	2	1	0	0	0	0	1	0	0	1	11
		Ardea purpurea	LC	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
		Bubulcus ibis	LC	0	13	0	0	0	0	0	0	0	0	0	0	0	0	0	13
		Egretta garzetta	LC	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2
		Scopidae	LC	2	7	4	4	3	0	3	0	0	1	2	0	0	0	0	26
		Scopus umbretta	LC	2	7	4	4	3	0	3	0	0	1	2	0	0	0	0	26
		Threskiornithidae	LC	4	14	10	23	2	0	8	8	1	1	1	1	0	2	5	80
		Bostrychia hagedash	LC	2	4	4	12	0	0	5	3	1	1	1	1	0	2	5	41
		Threskiornis aethiopicus	LC	2	10	6	11	2	0	3	5	0	0	0	0	0	0	0	39
Piciformes	Lybiidae	*Pogoniulus bilineatus*	LC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3
Cuculiformes	Cuculidae	*Cuculus solitarius*	LC	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	2
		Grand Total		**46**	**69**	**37**	**58**	**41**	**47**	**65**	**22**	**18**	**71**	**75**	**73**	**6**	**28**	**73**	**729**

Appendix 3: Frequency of mammal's from Kanyeganyege and Gishanda

Taxonomic classification			Kanyeganyege										Gishanda							
Order	**Family**	**Species**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**Total**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**Total**	**Total**
Carnivora	Herpestidae	*Atilax paludinosus*	x	x	x	x	x	x	x	x	x	**0**	x	1	x	x	x	x	**1**	**1**
Rodentia	Muridae	*Arvicanthis niloticus*	x	x	x	x	x	x	x	x	1	**1**	x	x	x	x	x	x	**0**	**1**
		Dasymys incomtus	x	1	x	x	x	1	x	x	x	**2**	x	x	x	x	x	x	**0**	**2**
		Grammomys sp	x	x	x	x	x	x	x	x	x	**0**	x	1	x	x	x	x	**1**	**1**
		Lemniscomys striatus	x	x	1	x	x	x	x	1	x	**2**	x	x	x	x	x	x	**0**	**2**
		Mastomys natalensis	x	x	x	x	x	x	x	x	x	**0**	x	x	2	x	x	x	**2**	**2**
		Mastomys sp	x	x	x	x	x	x	x	x	x	**0**	x	x	1	x	x	x	**1**	**1**
		Mus musculus	x	x	x	x	x	x	x	x	1	**1**	x	x	x	x	x	x	**0**	**1**
		Oenomys hypoxanthus	x	x	1	x	x	x	x	x	x	**1**	x	x	x	x	x	x	**0**	**1**
		Praomys jacksoni	1	3	1	x	x	x	x	x	x	**5**	x	x	x	x	x	1	**1**	**6**
Soricomorpha	Soricidae	*Crocidura olivieri*	x	x	x	x	x	x	x	x	x	**0**	2	1	x	x	x	x	**3**	**3**

Appendix 4: Freshwater Macroinvertebrates from Kanyeganyege and Gishanda

Macroinvertebrates' taxonomy				Kanyeganyege									Gishanda						Total
Phylum	**Class**	**Order**	**Family**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	
Annelida	Clitellata	Arhynchobdellida	Hirudinidae	7	0	16	1	2	2	1	1	0	5	1	0	1	5	0	**42**
Annelida	Clitellata	Rhynchobdellida	Glossiphonidae	0	1	0	0	0	0	0	0	0	11	0	0	0	3	0	**15**
Annelida	Clitellata	Tubificida	Tubificidae	0	2	1	0	1	1	0	0	0	0	0	0	0	0	3	**8**
Arthropoda	Arachnida	Trombidiformes	Hydrachnidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	**1**
Arthropoda	Insecta	Coleoptera	Dytiscidae	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Arthropoda	Insecta	Coleoptera	Gyrinidae	1	0	0	0	0	0	1	0	0	1	0	0	0	0	0	**3**
Arthropoda	Insecta	Coleoptera	Haliplidae	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	**2**
Arthropoda	Insecta	Coleoptera	Hydrophilidae	0	0	0	0	0	1	0	0	0	0	0	2	0	0	1	**4**
Arthropoda	Insecta	Coleoptera	Noteridae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**1**

Arthropoda	Insecta	Diptera	Chironomidae	0	0	0	0	0	0	0	4	2	0	0	0	0	0	1	**7**
Arthropoda	Insecta	Diptera	Culicidae	0	3	0	0	0	0	0	0	0	0	0	0	2	0	0	**5**
Arthropoda	Insecta	Diptera	Simuliidae	2	0	0	1	35	21	0	0	8	0	7	0	1	57	0	**132**
Arthropoda	Insecta	Diptera	Tipulidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	**1**
Arthropoda	Insecta	Ephemeroptera	Baetidae	2	2	6	2	14	11	0	3	6	0	3	5	0	0	2	**56**
Arthropoda	Insecta	Ephemeroptera	Caenidae	1	0	2	9	0	4	0	4	1	0	7	0	0	0	0	**28**
Arthropoda	Insecta	Hemiptera	Belostomatidae	0	2	0	2	2	2	0	2	1	3	2	3	4	13	4	**40**
Arthropoda	Insecta	Hemiptera	Gerridae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	**1**
Arthropoda	Insecta	Hemiptera	Micronectidae	1	6	6	0	0	0	0	0	0	0	0	0	0	0	0	**13**
Arthropoda	Insecta	Hemiptera	Notonectidae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
Arthropoda	Insecta	Hemiptera	Veliidae	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**3**
Arthropoda	Insecta	Lepidoptera	Pyralidae	1	3	0	0	0	0	0	0	0	0	1	0	0	0	0	**5**
Arthropoda	Insecta	Odonata	Aeshnidae	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	**2**
Arthropoda	Insecta	Odonata	Chlorocyphidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	**1**
Arthropoda	Insecta	Odonata	Coenagrionidae	26	2	0	21	0	8	9	13	2	0	5	2	3	4	2	**97**
Arthropoda	Insecta	Odonata	Cordulidae	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	**3**
Arthropoda	Insecta	Odonata	Gomphidae	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	**5**
Arthropoda	Insecta	Odonata	Libellulidae	0	2	27	3	0	0	0	0	1	0	1	0	0	0	0	**34**
Arthropoda	Insecta	Odonata	Protoneuridae	0	6	0	12	5	7	7	11	1	0	0	0	0	0	0	**49**
Arthropoda	Insecta	Trichoptera	Hydropsychidae	0	0	0	0	0	4	0	7	0	31	3	0	7	3	0	**55**
Arthropoda	Insecta	Trichoptera	Leptoceridae	0	0	0	0	0	0	0	0	0	0	2	0	21	4	0	**27**
Mollusca	Bivalvia	Sphaeriida	Sphaeriidae	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	**2**
Mollusca	Gastropoda	Hygrophila	Bulinidae	0	0	0	8	0	0	1	0	9	0	0	0	5	0	2	**25**
Mollusca	Gastropoda	Hygrophila	Lymnaeidae	0	17	0	6	0	1	1	1	0	0	4	2	2	1	2	**37**
Mollusca	Gastropoda	Hygrophila	Physidae	2	7	14	6	0	1	7	0	4	0	0	0	0	0	0	**41**
Mollusca	Gastropoda	Hygrophila	Planorbidae	9	16	0	22	1	2	10	1	16	19	2	0	2	0	3	**103**

Mollusca	Gastropoda	Neogastropoda	Thiaridae	14	11	0	0	0	0	11	0	2	27	12	0	36	17	21	**151**

Appendix 6: Terrestrial arthropod families from Gishanda and Kanyeganyege

Order	Family	Kanyeganyege									Gishanda						Total
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P1	P2	P3	P4	P5	P6	
Aranea	Atypidae	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	2
Aranea	Linyphiidae	3	1	18	3	1	1	5	0	6	0	6	9	4	1	0	58
Aranea	Tetragnathidae	0	6	0	0	0	0	2	0	4	0	1	0	0	4	0	17
Aranea	Thomisidae	0	5	0	0	1	1	0	0	0	7	0	1	1	6	0	22
Trombidiformes	Trombidiidae	0	0	2	0	0	2	1	4	0	0	2	2	0	0	2	15
Geophilomorpha	Mecistocephalidae	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	3
Entomobryomorpha	Entomobryidae	39	15	44	11	68	13	11	78	8	37	8	0	14	58	2	406
Poduromorpha	Poduridae	0	0	8	2	3	0	0	44	127	0	0	0	0	12	0	196
Symphypleona	Sminthuridae	0	0	16	7	0	1	0	4	0	0	0	0	0	0	0	28
Isopoda	Oniscidae	17	0	4	4	7	8	1	0	0	4	11	4	14	9	0	83
Ixodida	Ixodidae	0	2	8	2	2	1	0	6	6	0	3	2	2	2	2	38
Julida	Julidae	1	1	0	0	1	0	0	0	0	0	1	0	0	0	0	4
Aranea	Lycosidae	10	11	7	7	5	6	2	7	4	9	3	0	2	7	7	87
Blattodea	Blaberidae	0	0	0	0	0	0	0	0	1	0	2	2	0	0	0	5
Blattodea	Blattidae	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	3
Coleoptera	Bostrichidae	0	0	0	0	1	5	0	0	0	0	0	0	0	3	0	9
Coleoptera	Carabidae	0	2	0	3	0	1	1	2	2	3	0	1	4	0	2	21
Coleoptera	Chrysomelidae	2	1	1	0	2	1	0	3	0	6	4	23	15	10	0	68
Coleoptera	Curculionidae	1	0	3	0	0	4	1	0	2	1	2	1	0	2	0	17

Coleoptera	Nitidulidae	2	3	1	0	6	0	0	0	0	3	3	0	0	10	1	29
Coleoptera	Rhizophagidae	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	3
Coleoptera	Scarabaeidae	0	0	0	1	0	0	1	0	0	0	0	2	0	0	0	4
Coleoptera	Scydmaenidae	0	0	2	0	2	0	1	0	7	0	0	0	1	2	3	18
Coleoptera	Staphylinidae	9	2	4	2	9	5	2	18	7	28	14	3	3	33	3	142
Coleoptera	Tenebrionidae	0	1	0	0	0	0	0	0	0	0	0	4	0	0	0	5
Dermaptera	Labiduridae	0	7	0	0	0	1	4	0	0	0	0	0	0	0	0	12
Diptera	Agromyzidae	14	11	6	1	6	5	9	19	0	49	20	8	3	19	0	170
Diptera	Asilidae	9	3	0	0	0	0	0	0	0	0	0	0	3	0	0	15
Diptera	Culicidae	2	8	4	0	4	0	3	1	7	7	4	0	0	3	0	43
Diptera	Diopsidae	1	0	0	0	0	0	0	1	2	3	1	0	0	0	0	8
Diptera	Drosophilidae	2	10	2	2	6	2	3	12	2	15	18	2	17	21	2	116
Diptera	Neriidae	14	0	0	0	0	21	0	9	17	7	12	21	0	3	0	104
Diptera	Phoridae	0	0	0	0	0	0	0	0	1	1	1	2	3	3	0	11
Diptera	Sciaridae	1	1	0	1	0	3	2	4	0	1	2	0	11	3	0	29
Diptera	Sepsidae	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	5
Diptera	Syrphidae	1	0	0	0	0	0	0	0	0	0	0	0	1	3	0	5
Diptera	Tephritidae	3	9	6	0	0	1	15	0	2	0	0	0	0	2	0	38
Diptera	Tipulidae	0	2	0	0	0	1	1	3	0	0	0	1	0	2	0	10
Hemiptera	Aphididae	8	1	6	1	2	0	3	6	4	3	4	0	0	0	0	38
Hemiptera	Cicadellidae	12	14	3	0	0	10	5	5	1	4	2	9	0	2	0	67
Hemiptera	Cicadidae	0	2	2	1	0	2	4	0	0	8	1	0	2	10	0	32
Hemiptera	Cydnidae	1	0	0	2	0	0	0	0	0	0	0	0	0	0	1	4
Hemiptera	Dictyopharidae	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	2

Hemiptera	Lygaeidae	2	0	0	0	0	0	0	0	0	0	1	0	0	1	0	4
Hemiptera	Miridae	1	1	1	0	1	2	1	0	0	5	1	3	0	5	0	21
Hemiptera	Pentatomidae	4	0	4	0	1	0	3	2	3	0	3	0	4	6	0	30
Hemiptera	Pyrrhocoridae	1	1	2	1	0	0	1	0	0	0	1	0	0	0	2	9
Hemiptera	Reduviidae	0	0	0	0	1	5	1	0	0	0	3	1	0	1	0	12
Hymenoptera	Apidae	3	1	0	0	1	0	1	0	0	0	0	0	0	0	0	6
Hymenoptera	Braconidae	1	1	0	0	5	1	0	1	0	0	1	0	0	2	0	12
Hymenoptera	Cynipidae	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	3
Hymenoptera	Formicidae	63	168	188	167	39	50	86	120	45	68	69	179	57	88	27	1414
Hymenoptera	Halictidae	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	3
Hymenoptera	Pompilidae	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	2
Hymenoptera	Scelionidae	0	0	0	2	0	1	1	2	0	4	0	3	3	0	0	16
Isoptera	Termattidae	0	0	0	0	0	16	0	0	0	0	0	0	0	0	0	16
Mantodea	Mantidae	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	3
Odonata	Coenagrionidae	0	1	0	0	0	0	1	1	0	4	0	0	3	2	0	12
Orthoptera	Acrididae	0	0	0	0	0	1	0	0	0	0	0	1	2	8	0	12
Orthoptera	Gryllidae	0	2	2	3	3	2	0	3	0	0	0	1	2	8	0	26
Orthoptera	Pyrgomorphidae	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
Orthoptera	Tettigoniidae	2	3	0	0	1	2	0	0	1	0	1	3	3	4	0	20
Thysanoptera	Phlaeothripidae	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	4
Coleoptera	Coccinellidae		0	0	0	0	0	0	0	0	1	1	0	0	2	0	4
Coleoptera	Elateridae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Coleoptera	Lycidae	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
Coleoptera	Meloidae	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	4

Hemiptera	Alydidae	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
Hemiptera	Plataspidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Hemiptera	Scutellidae	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1
Hemiptera	Tingidae	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	6
Hymenoptera	Pteromalidae	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
Odonata	Libellulidae	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	3
Orthoptera	Tetrigidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2
Diptera	Platystomatidae	0	0	0	0	0	0	0	0	0	13	0	3	0	0	0	16
Diptera	Bibionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1

References

Ali, M., Nessa, B., Khatun, M., Salam, M., & Kabir, M. (2021). A Way Forward to Combat Insect Pest in Rice. *Bangladesh Rice Journal*, *25*(1), 1–22. https://doi.org/10.3329/brj.v25i1.55176

Alikhani, S., Nummi, P., & Ojala, A. (2021). Urban wetlands: A review on ecological and cultural values. Water (Switzerland), 13(22), 1–47. https://doi.org/10.3390/w13223301

Alroy, J. (2015). Current extinction rates of reptiles and amphibians. Proceedings of the National Academy of Sciences of the United States of America, 112(42), 13003–13008. https://doi.org/10.1073/pnas.1508681112

Ane, N., Hayat Campus, H., jattan road, J., Mubashar Hussain, P., Correspondence Noor Ul Ane, P., & Hussain, M. (2015). Diversity of insect pests in major rice growing areas of the world. *Journal of Entomology and Zoology Studies*, *4*(1), 36–41.

Banamwana, C., Dukuziyaturemye, P., & Rwanyiziri, G. (2021). Evaluating the Trend in Managing Human-Wildlife Conflicts in and around Akagera National Park, Rwanda. *Rwanda Journal of Engineering, Science, Technology and Environment*, *4*(1), 1–16. https://doi.org/10.4314/rjeste.v4i1.1

Basset, Y., & et, a. (2012). Arthropod diversity in a tropical forest. Science, 1481-1484.

Birmingham, P., & Wilkinson, D. (2003). *Using Research Instruments:A Guide for Researchers*. RoutledgeFalmer.

Biswal, B. K., & Balasubramanian, R. (2022). Constructed Wetlands for Reclamation and Reuse of Wastewater and Urban Stormwater: A Review. Frontiers in Environmental Science, 10(March), 1–21. https://doi.org/10.3389/fenvs.2022.836289

Burger, M., Pauwels, O. S. G., Branch, W. R., Tobi, E., Yoga, J.-A., & Mikolo, E.-N. (2006). An Assessment of the amphibian fauna of the Gamba Complex of protected areas, Gabon. Bulletin of the Biological Society of Washington, 12, 297–308.

Cayuela, L., Gotelli, N. J., & Colwell, R. K. (2015). Ecological and biogeographic null hypotheses for comparing rarefaction curves. Ecological Monographs, 85(3), 437–455. https://doi.org/10.1890/14-1261.1

CCME (Canadian Council of Ministers of the Environment). (1999). Canadian Water Quality Guidelines for the Protection of Aquatic Life - Dissolved Oxygen (Freshwater). DISSOLVED OXYGEN (Freshwater), 6.

Celis-Diez, J. L., García, C. B., Armesto, J. J., Abades, S., Garratt, M. P. D., & Fontúrbel, F. E. (2023). Wild Floral Visitors Are More Important Than Honeybees as Pollinators of Avocado Crops. Agronomy, 13(7), 1–13. https://doi.org/10.3390/agronomy13071722

CoEB. (2023). Report by the UNESCO Category 2 Center of Excellence in Biodiversity and Natural Resource Management (CoEB) OF Biodiversity Baseline Survey in Nyandungu Urban Wetland Eco-Park , Rwanda (Issue October).

Day, J. A., & de Moor, I. J. (2001). Guides to the freshwater invertebrates of Southern Africa, Vol. 7. Arachnida & Mollusca: Araneae, Water Mites and Mollusca. Pretoria: South African Water Research Commission Report TT182/02.

De Cock, M. (2020). Comparative Microbiomics of Tephritid Frugivorous Pests (Diptera: Tephritidae) From the Field: A Tale of High Variability Across and Within Species. Frontiers in Microbiology, 1-13.

De Moor, I. J., Day, J. A., de Moor, F.C. (2003). Guides to the freshwater invertebrates of Southern Africa, Vol. 7. Insecta 1: Ephemeroptera, Odonata, and Plecoptera. Pretoria: South African Water Research Commission Report TT207/03.

Dehling, D. M., & Dehling, J. M. (2021). Elevated alpha diversity in disturbed sites obscures regional decline and homogenization of amphibian diversity (pp. 0–2).

Dehling, J. M., & Sinsch, U. (2023). Amphibians of Rwanda: Diversity, Community Features, and Conservation Status. Diversity, 15(4). https://doi.org/10.3390/d15040512

Doherty, T. S., Balouch, S., Bell, K., Burns, T. J., Feldman, A., Fist, C., Garvey, T. F., Jessop, T. S., Meiri, S., & Driscoll, D. A. (2020). Reptile responses to anthropogenic habitat modification: A global meta-analysis. Global Ecology and Biogeography, 29(7), 1265–1279. https://doi.org/10.1111/geb.13091

Dos Santos, F. S., Johst, K., Huth, A., & Grimm, V. (2010). Interacting effects of habitat destruction and changing disturbance rates on biodiversity: Who is going to survive? Ecological Modelling, 221(23), 2776–2783. https://doi.org/10.1016/j.ecolmodel.2010.08.005

Dusek, R., & Popelkova, R. (2012). Theoretical view of the Shannon index in the evaluation of landscape diversity. AUC Geographica, 47(2), 5–13.

Ernst, R., & Rödel, M. (2015). Measuring and monitoring amphibian diversity in tropical forests . I . An evaluation of IN TROPICAL FORESTS . I . AN EVALUATION OF METHODS WITH. 10(August), 1–14.

Ernst, R., & Rödel, M.-O. (2012). Anthropogenically Induced Changes of Predictability in Tropical Anuran Assemblages. America, 86(11), 3111–3118.

Falcón, N. (2025). Impacts of Habitat Transformation on Amphibian and Reptile Communities in a Heterogeneous Andean Landscape. 0–2.

Fischer, J., & Lindenmayer, D. B. (2007). Landscape modification and habitat fragmentation: a synthesis. Global Ecology and Biogeography, 16(3), 265–280. https://doi.org/10.1111/j.1466-8238.2006.00287.x

Gromping, U. (2015). Using R and RStudio for Data Management, Statistical Analysis and Graphics (2nd Edition) . Journal of Statistical Software, 68(Book Review 4), 1–7. https://doi.org/10.18637/jss.v068.b04

Group, P. W. (2021). Guidelines for using the IUCN red list categories and criteria. European Journal of Taxonomy, 2021(733), 42–113. https://doi.org/10.5852/ejt.2021.733.1219

Hakuzimana, J., & Masasi, B. (2020). Performance evaluation of irrigation schemes in Rugeramigozi Marshland, Rwanda. *Water Conservation and Management*, *4*(1), 15–19. https://doi.org/10.26480/wcm.01.2020.15.19

Heinrichs, E. A. (1994). BIOLOGY AND OF RICE. In *Biology and Management of Rice Insects*. Wiley Eastern LTD.

Hernández-Stefanoni, J. L., Reyes-Palomeque, G., Castillo-Santiago, M. ángel, George-Chacón, S. P., Huechacona-Ruiz, A. H., Tun-Dzul, F., Rondon-Rivera, D., & Dupuy, J. M. (2018). Effects of sample plot size and GPS location errors on aboveground biomass estimates from LiDAR in tropical dry forests. Remote Sensing, 10(10), 1–15. https://doi.org/10.3390/rs10101586

Hinkel, H. (2023). Snakes of Nyandungu Eco-Park. Report on the findings of a 10-day survey (Issue November).

Hoffmann, A., Decher, J., Rovero, F., Schaer, J., Voigt, C. C., & Wibbelt, G. (2010). Field Methods and Techniques for Monitoring Mammals. In Manual on field recording techniques and protocols for All Taxa Biodiversity Inventories and Monitoring (Vol. 43, Issue 2).

Hölting, M., Bovolo, C. I., & Ernst, R. (2016). Facing complexity in tropical conservation: how reduced impact logging and climatic extremes affect beta diversity in tropical amphibian assemblages. Biotropica, 48(4), 528–536. https://doi.org/10.1111/btp.12309

Hough, S. H. (2017). Guide Picker is a comprehensive design tool for visualizing and selecting guides for CRISPR experiments. BMC Bioinformatics, 1-10

Hyndman, R. (2023). Forecasting Mortality, Fertility, Migration and Population Data.

Ilahi, H. (2021). Accentuating the Impact of Inorganic and Organic Fertilizers on Agriculture Crop Production: A Review. *Indian Journal of Pure & Applied Biosciences*, *9*(1), 36–45. https://doi.org/10.18782/2582-2845.8546

Iliyasu, R., & Etikan, I. (2021). Comparison of quota sampling and stratified random sampling. Biometrics & Biostatistics International Journal, 10(1), 24–27. https://doi.org/10.15406/bbij.2021.10.00326

IUCN. (2025). The IUCN Red List of Threatened Species. IUCN Red List. https://www.iucnredlist.org

Ivanov, K. (2010). Effects of forest edges, exotic ants and nonnative plants on local ant (Hymenoptera: Formicidae) diversity in urban forest fragments of northeastern Ohio. ETD Archive.

Kemabonta, K., & Williams, B. A. (2016). Composition and Abundance of Odonates At Alatori Stream South-. UNILAG Journal of Medicine, Science, and Technology, 96–110.

Kenneth W. McCravy. (2018). A Review of Sampling and Monitoring Methods for Beneficial Arthropods in Agroecosystems. insects.

Kim, K. H., Kabir, E., & Jahan, S. A. (2017). Exposure to pesticides and the associated human health effects. *Science of the Total Environment*, *575*, 525–535. https://doi.org/10.1016/j.scitotenv.2016.09.009

Kingdon, J., Happold, D., Butynski, T., Hoffmann, M., Happold, M., & Kalina, J. (2013). Mammals of Africa Volume I-V. In Bloomsbury Publishing: Vol. I. https://doi.org/10.1007/978-1-4615-6424-9_34

Knapp, J., & Sciarretta, A. (2023). Agroecology: protecting, restoring, and promoting biodiversity. BMC Ecology and Evolution, 23(1), 1–3. https://doi.org/10.1186/s12862-023-02140-y

Koç, C. (2015). A study on the role and importance of irrigation management in integrated river basin management. *Environ Monit Assess*, *187*, 1–20. https://doi.org/10.1007/s10661-015-4647-7

Leroy, D. (2023). An empirical assessment of the institutional performance of community-based water management in a large-scale irrigation system in southern Mexico. *Agricultural Water Management*, *276*(July 2022), 108051. https://doi.org/10.1016/j.agwat.2022.108051

Li, S., Chen, X., Sun, Y., Lv, C., Yuan, F., & Fang, L. (2023). Method and Device for Measuring the Diameter at Breast Height and Location of Trees in Sample Plots. Forests, 14(9). https://doi.org/10.3390/f14091723

Magurran, A. E. (2004). Measuring biological diversity. Blackwell Publishing company. https://doi.org/10.1016/j.cub.2021.07.049

Marian, M. (2024). Avian ecology field methods. In Avian ecology field methods (Section: Point counts and area searches). Retrieved from https://en.wikipedia.org/wiki/Avian_ecology_field_methods

Martínez-Lanfranco, C. G., Pérez, A., & Gómez, R. (2022). Opportunistic bird sampling and structured monitoring: Complementary approaches for avian diversity assessment. Journal of Avian Ecology, 18(3), 245–259. https://doi.org/10.1234/jae.2022.034

May, M. L. (2019). Odonata: Who they are and what they have done for us lately: Classification and ecosystem services of Dragonflies. Insects.

McKinney, M. L. (2006). Urbanization as a major cause of biotic homogenization. Biological Conservation, 127(3), 247–260. https://doi.org/10.1016/j.biocon.2005.09.005

Mendenhall, C. D., Shields-Estrada, A., Krishnaswami, A. J., & Daily, G. C. (2016). Quantifying and sustaining biodiversity in tropical agricultural landscapes. Proceedings of the National Academy of Sciences of the United States of America, 113(51), 14544–14551. https://doi.org/10.1073/pnas.1604981113

Mind'je, R., Mindje, M., & Patient Mindje, K. (2021). The influence of anthropogenic activities on wetland integrity dynamics : a case study of the Rwampara wetland in Rwanda. Environmental Sustainability, 4, 833–849. https://doi.org/10.1007/s42398-021-00209-2

Mindje, M., Tumushimire, L., & Sinsch, U. (2020). Diversity assessment of anurans in the mugesera wetland (Eastern rwanda): Impact of habitat disturbance and partial recovery. Salamandra, 56(1), 27–38.

Mohd-Taib, F. S., & Ishak, S. N. (2021). Bait preferences by different small mammal assemblages for effective cage-trapping. Malaysian Journal of Science, 40(2), 1–15. https://doi.org/10.22452/MJS.VOL40NO2.1

Naranjo, S. E. (2008). SAMPLING ARTHROPODS Steven. In https://link.springer.com/referencework/10.1007/978-1-4020-6359-6 (pp. 3231–3246).

Newbold, T., Hudson, L. N., Hill, S. L., Contu, S., Lysenko, I., Senior, R. A., ... & Purvis, A. (2015). Global effects of land use on local terrestrial biodiversity. Nature, 520(7545), 45–50. https://doi.org/10.1038/nature14324

Ngangi, J., & Hong, S. (2021). Adoption of small-scale irrigation technologies and its impact on land productivity: Evidence from Rwanda. *Journal of Integrative Agriculture*, *20*(8), 2302–2312. https://doi.org/10.1016/S2095-3119(20)63417-

NISR. (2024). *Seasonal agricultural survey Season A 2023 Report*.

Nsengimana, Nsenganeza, Hagenimana, & Dekoninck. (2023). Impact of chemical fertilizers on diversity and abundance of soil-litter arthropod communities in coffee and banana plantations in southern Rwanda. Current Research in Environmental Sustainability, 100215.

Nsengimana, V., A. Beth , K., Donat , N., Wouter , D., & Frédéric , F. (2021). Diversity and abundance of soil-litter arthropods and their relationships with soil physicochemical properties under different land uses in Rwanda. Biodiversity, 41-52.

Nsengimana, V., Nsenganeza, J. d., Hagenimana, T., & Dekoninck, W. (2023). Impact of chemical fertilizers on diversity and abundance of soil-litter arthropod communities in coffee and banana plantations in southern Rwanda. Current Research in Environmental Sustainability, 100215.

Nsengimana, V., Rurangwa, M. L., Nsenganeza, J. D. D., Kayonga, S., Uwineza, J., Furaha, E., Niyomwungeri, J. F., Masengesho, P., Ruhagazi, D., & Nsengimana, O. (2025). Diversity and abundance of arthropod communities from Rugezi Marshland, Northern Rwanda: Call for effective and sustainable biodiversity conservation planning. Journal of Tropical Ecology, 41. https://doi.org/10.1017/S0266467425000094

Nsengimana, V., Twagirayezu, E., de Dieu Habiyaremye, J., Rutegwa, M., Nyandwi, V., & Ndatimana, G. (2025). Application of aquatic macroinvertebrates in water quality assessment of the Nyabarongo and Akagera Rivers in Rwanda. Environmental Monitoring and Assessment, 197(4). https://doi.org/10.1007/s10661-025-13817-w

Ogunjobi. (2017). Wild Vertebrates Associated with Crop Raiding Around Kainji Lake National Park, Nigeria. *Applied Tropical Agriculture*, *21*(3), 138–142.

Pescott, O. L., Powney, G. D., & Boyd, R. J. (2024). Adaptive sampling for ecological monitoring using biased data: A stratum-based approach.

Pilliod, D. S., & Arkle, R. S. (2013). Performance of quantitative vegetation sampling methods across gradients of cover in great basin plant communities. Rangeland Ecology and Management, 66(6), 634–647. https://doi.org/10.2111/REM-D-13-00063.1

Pinandita Faiz, R. (1998). Area-sensitivity of reptiles and amphibians: Are there indicator species for habitat fragmentation. Ecoscience, 43(March), 1–9.

Pineda, J., Muñoz-Rojas, J., Morales-García, Y. E., Hernández-Gómez, J., & Sigarreta, J. (2022). Biomathematical Model for Water Quality Assessment: Macroinvertebrate Population Dynamics and Dissolved Oxygen. Water, 14(18), 1–16. https://doi.org/10.3390/w14182902

Pollet, I., & Bendell-Young, L. I. (2000). Amphibians as indicators of wetland quality in wetlands formed from oil sands effluent. Environmental Toxicology and Chemistry, 19(10), 2589–2597. https://doi.org/10.1002/etc.5620191027

Poppy, S., Gibbons, J. W., Winne, C. T., Scott, D. E., Ryan, T. J., Buhlmann, K. A., Tuberville, T. D., Metts, B. S., Greene, J. L., Mills, T., & Leiden, Y. (2000). The global decline of reptiles, deja vu amphibians. BioScience, 50(8), 653–666. https://doi.org/10.1641/0006-3568(2000)050[0653:tgdord]2.0.co;2

Posit Software, PBC. (2025). RStudio: Integrated development environment for R (Version 2025.05.0+496) [Computer software]. https://posit.co. Accessed on 16th May 2025.

Ranjan, R. (2015). a Review on Insect Collection and Preservation Techniques. Certified Journal │ Kumar et al. European Journal of Pharmaceutical and Medical Research.

REMA. (2009). Rwanda State of Environment and Outlook. In Ministry of Natural Resources. http://www.rema.gov.rw/soe/

REMA. (2019). Economic Assessment of Akagera Wetland Complex: Identifying Finance Solutions for Improved Management Final Report

REMA. (2022). Rwanda State of Environment and Outlook Report 2021. www.rema.gov.rw

Roelke, C. E., & Smith, E. N. (2010). Herpetofauna, Parc National des Volcans, Republic of Rwanda. Check List 6(4), 6(4), 525–531.

Roque, F. D. O., Menezes, J. F. S., Northfield, T., Ochoa-Quintero, J. M., Campbell, M. J., & Laurance, W. F. (2018). Warning signals of biodiversity collapse across gradients of tropical forest loss. Scientific Reports, 8(1), 1–7. https://doi.org/10.1038/s41598-018-19985-9

Rurangwa, M. L., Aguirre-Gutiérrez, J., Matthews, T. J., Niyigaba, P., Wayman, J. P., Tobias, J. A., & Whittaker, R. J. (2021). Effects of land-use change on avian taxonomic, functional and phylogenetic diversity in a tropical montane rainforest. Diversity and Distributions, 27(9), 1732–1746. https://doi.org/10.1111/ddi.13364

Saber, S., Tito, W., & Said, R. (2017). Amphibians as Bioindicators of the Health of Some Wetlands in Ethiopia. The Egyptian Journal of Hospital Medicine, 66, 66–73. https://doi.org/10.12816/0034635

Shanono, N. J., Nasidi, N. M., Maina, M. M., Bello, M. M., Ibrahim, A., Umar, S. I., Usman, I. M. T., & Zakari, M. D. (2019). Socio-Hydrological Study of Water Users' Perceptions on the Management Of Irrigation Schemes at Tomas Irrigation Project, Kano, Nigeria. *Nigeria Journal of Engineering Science and Technology Research*, *5*(2), 139–145.

Silvestro, D., Goria, S., Sterner, T., & Antonelli, A. (2022). Improving biodiversity protection through artificial intelligence. Nature Sustainability, 5(5), 415–424. https://doi.org/10.1038/s41893-022-00851-6

Solomon, N., Birhane, E., Teklay, M., Negussie, A., & Gidey, T. (2024). Exploring the role of canopy cover and environmental factors in shaping carbon storage in Desa'a forest, Ethiopia. Carbon Balance and Management, 19(1). https://doi.org/10.1186/s13021-024-00277-x

Spafford, R. D., & Christopher, J. L. (2013). Sweeping beauty: is grassland arthropod community composition effectively estimated by sweep netting? Ecology and Evolution, 3347-3358

Spawls, S., Drewes, R., Howell, K., & Ashe, J. (2002). A Field Guide to the Reptiles of East Africa. Kenya, Tanzania, Uganda, Rwanda and Burundi.

Stals, R. H., & de Moor, I. J. (2003). Guides to the freshwater invertebrates of Southern Africa, Vol. 9. Coleoptera. Pretoria: South African Water Research Commission Report TT230/07

Stoyanova, T., Vidinova, Y., Yaneva, I., Tyufekchieva, V., Parvanov, D., Traykov, I., & Bogoev, V. (2014). Ephemeroptera, plecoptera and trichoptera as indicators for ecological quality of the Luda Reka River, Southwest Bulgaria. Acta Zoologica Bulgarica, 66(2), 255–260.

Sun, P., Bariyanga, J. D., & Wronski, T. (2025). Human-wildlife conflict in Rwanda: Linking ecoregion, changing conservation status and the local communities' perception. *Global Ecology and Conservation*, *59*(March), e03550. https://doi.org/10.1016/j.gecco.2025.e03550

Sutter, L., Jeanneret, P., Bartual, A. M., Bocci, G., & Albrecht, M. (2017). Enhancing plant diversity in agricultural landscapes promotes both rare bees and dominant crop-pollinating bees through complementary increase in key floral resources. Journal of Applied Ecology, 54(6), 1856–1864. https://doi.org/10.1111/1365-2664.12907

TRAIDE. (2024). *Rwanda's Agri-Economic Outlook*. https://trendeconomy.com/data/h2?reporter=Rwanda&trade_flow=Export,Import&partner=World&indicator=T-

Tscharntke, T., Clough, Y., Wanger, T. C., Jackson, L., Motzke, I., Perfecto, I., ... & Whitbread, A. (2012). Global food security, biodiversity conservation and the future of agricultural intensification. Biological Conservation, 151(1), 53–59. https://doi.org/10.1016/j.biocon.2012.01.068

Tumushimire, L., Mindje, M., Sinsch, U., & Dehling, J. M. (2020). Anuran diversity of cultivated wetlands in Rwanda: melting pot ofgeneralists? Salamandra, 56(2), 99–112.

Twagirayezu, E., & Ngirinshuti, L. (2024). A Comparative Survey Of Freshwater Macroinvertebrates In Natural Forest Streams And. Journal of Environmental Science, Toxicology and Food Technology, 18(6), 58–63. https://doi.org/10.9790/2402-1806015863

Urbina Cardona, J. N. (2010). Y Patrones De Endemismo En Anfibios Y Reptiles De Colombia : Facultad de Ciencias Basicas, 7(1), 74–91.

Van Helden, B. E., Close, P. G., Stewart, B. A., & Speldewinde, P. C. (2021). Managing gardens for wildlife: Features that predict mammal presence and abundance in gardens vary seasonally. Ecosphere, 12(3). https://doi.org/10.1002/ecs2.3453

Verspagen, N., & Erkens, R. H. J. (2023). A method for making Red List assessments with herbarium data and distribution models for species-rich plant taxa: Lessons from the Neotropical genus Guatteria (Annonaceae). Plants People Planet, 5(4), 536–546. https://doi.org/10.1002/ppp3.10309

Vlami, V., Zogaris, S., Djuma, H., Kokkoris, I. P., Kehayias, G., & Dimopoulos, P. (2019). A field method for landscape conservation surveying: The landscape assessment protocol (LAP). Sustainability (Switzerland), 11(7). https://doi.org/10.3390/su11072019

Volpato, G. H., Lopes, E. V., Mendonça, L. B., Boçon, R., Bisheimer, M. V., Serafini, P. P., & dos Anjos, L. (2009). The use of the point count method for bird surveys in the Atlantic Forest. Zoologia, 26(1), 74–78. https://doi.org/10.1590/S1984-46702009000100012

Wells, K. D. (2007). Book Reviews: Book Reviews. In Critical Sociology. https://doi.org/10.1177/0261018311403863

Wemmer, C., Kunz, T. H., Lundie-Jenkins, G., & McShea, W. J. (1996). Mammalian sign. Measuring and monitoring biological diversity: standard methods for mammals (W. Don E, C. F. Russell, J. I. Nichols., R. Rudran., & M. S. Foster (eds.)). Smithsonian Institution Press. https://pubs.er.usgs.gov/publication/5200145

Yager, G. O., Abete, M., & Chenge, I. B. (2019). Evaluation of Range Flora and Fauna Composition of a Community Forest in North-Central Nigeria Evaluación De La Flora De Área Y La Composición De Fauna De Un Bosque Comunitario En Norte-Central De. Sustainability, Agri, Food and Environmental Research, 7(1), 21–36. https://doi.org/http://dx.doi.org/10.7770/safer-V0N0-art1636

Zaghloul, A., Saber, M., Gadow, S., & Awad, F. (2020). Biological indicators for pollution detection in terrestrial and aquatic ecosystems. Bulletin of the National Research Centre, 44(1). https://doi.org/10.1186/s42269-020-00385-x

Zheng, H., Ying, H., Yin, Y., Wang, Y., He, G., Bian, Q., Cui, Z., & Yang, Q. (2019). Irrigation leads to greater maize yield at higher water productivity and lower environmental costs: a global meta-analysis. *Agriculture, Ecosystems and Environment*, *273*, 62–69. https://doi.org/10.1016/j.agee.2018.12.009