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Plant species diversity and composition in Kanyabaha wetland in Rukiga District, Uganda

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ABSTRACT

Wetlands are ecologically and socioeconomically vital ecosystems, yet they remain highly vulnerable to human-induced disturbances. This study assessed plant species composition, diversity, and ecological dominance within Kanyabaha Wetland in Uganda to generate baseline ecological data that can inform sustainable management. Standard vegetation survey techniques and ecological indices, including Shannon-Wiener, Simpson's Diversity, and Importance Value Index (IVI), were employed across sites with varying disturbance levels. A total of 31 plant species belonging to 19 families were recorded, with notable variation in species richness and composition across sites. Less disturbed areas (e.g., Rutenje and Burime) exhibited higher native species richness and stronger ecological integrity, while highly disturbed sites like Kandago were dominated by introduced species, particularly Eucalyptus spp. Interestingly, Kandago recorded the highest diversity indices, suggesting that while disturbance may increase species evenness, it compromises ecological balance. The dominance of few species in disturbed areas indicated a shift in vegetation structure, potentially disrupting ecosystem functionality. To address these issues, the study recommends targeted conservation measures, such as the removal or control of invasive species, promotion of native species regeneration, and community-led restoration initiatives. These findings are crucial for wetland managers, conservation agencies, and policy-makers, offering a scientific basis for prioritizing conservation areas and designing context-specific management interventions. The study contributes to the broader understanding of plant community responses to disturbance, supporting ongoing ecological monitoring and evidence-based restoration planning.

1. Introduction

Wetlands are globally recognized for their ecological, economic, and socio-cultural value. They provide essential ecosystem services such as water purification, flood mitigation, carbon sequestration, and biodiversity conservation [1]. In Uganda, wetlands are a critical component of both ecological and livelihood systems. They are expected to play a significant role in achieving national and global development targets, including Uganda's Vision 2040, the National Development Plan (NDP) III, and the United Nations 2030 Agenda for Sustainable Development. These services directly support several Sustainable Development Goals (SDGs), notably SDG 6 (Clean Water and Sanitation), SDG 13 (Climate Action), and SDG 15 (Life on Land). Central to the functionality of wetlands is their vegetation, which is instrumental in regulating biogeochemical cycles, sustaining primary productivity, and providing habitats for diverse biological communities [2,3].

Despite their importance, Uganda's wetlands face increasing threats from human activities such as agriculture, settlement expansion, and resource extraction. Uganda has established comprehensive legal and policy frameworks to protect its wetlands. Key instruments include the 1995 Constitution, the amended National Environment Act (2019), the National Environment (Wetlands, Riverbanks and Lakeshores Management) Regulations (2000), the National Wetlands Policy (1995), the Land Act (1998), the Water Act (1995), and the Local Governments Act (1997). These regulations prohibit activities such as drainage, construction, pollution, and habitat conversion without prior approval, and mandate Environmental and Social Impact Assessments for proposed developments. However, despite the existence of this robust framework,

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enforcement and implementation remain weak [4], resulting in continued wetland degradation and biodiversity loss. Consequently, Uganda's wetlands have experienced declines in both area and ecological integrity. National wetland coverage fell from 15.6 % in the 1990 s to around 11 % by 2016 [5], including a 2.5 % decline between 1994 and 2017 [4]. While more recent data from the Ministry of Water and Environment (2023) indicate a modest increase in coverage from 13 % in 2015 to 13.9 % (33,762.6 km^2) in 2022, only 8.9 % (21,526 km^2) of this area remains ecologically intact. The remaining 4.1 % (9,885 km^2) is classified as degraded, reflecting persistent environmental pressures despite the apparent gains in total area.

The Rushebeya-Kanyabaha Wetland, located in south-western Uganda exemplifies the escalating challenges faced by ecologically sensitive ecosystems. This biodiversity-rich wetland serves as a critical breeding and nesting habitat for the endangered Grey Crowned Crane (*Balearica regulorum gibbericeps*), Uganda's national bird. However, the wetland has experienced substantial degradation in recent decades [6]. Key drivers of this degradation include agricultural expansion, largely fueled by persistent poverty and rapid population growth. These include unsustainable harvesting of wetland vegetation, dredging and drainage, burning, encroaching agricultural activities, and overfishing. Collectively, these pressures have degraded the ecological functionality and habitat quality of the wetland system, with significant repercussions for local livelihoods reliant on its resources for agriculture, fishing, water, and fuel. According to the Darwin Initiative [6], the wetland's extent declined by 33 % between 1986 and 2020. This ongoing degradation not only threatens biodiversity but also undermines critical ecosystem services and impedes progress toward Uganda's broader sustainable development goals.

Previous studies [7] have extensively characterized the ecological functions of wetlands, yet localized data on plant species diversity and the impacts of human-induced vegetation changes within specific systems such as Kanyabaha Wetland remain limited. This knowledge gap is critical given the wetland's importance to local communities, who rely on it for harvesting materials for crafts and construction, water collection, crop cultivation, and fishing for subsistence and income. Recent findings by Walakira et al. [8] reveal a significant decline in papyrus cover in Kanyabaha Wetland, highlighting the urgency for detailed ecological assessments. Consequently, understanding how anthropogenic disturbances influence plant species diversity and vegetation structure is essential, as these factors directly affect both ecosystem health and the sustainability of community livelihoods. However, the spatial distribution of plant species diversity and composition across disturbance gradients within this wetland, and their relationship to ecosystem resilience, remain poorly understood.

Kanyabaha Wetland was selected for this study due to its ecological significance and its critical role in supporting local livelihoods, exemplifying the broader national challenge of balancing wetland conservation with socio-economic demands in Uganda. This wetland serves as an ideal setting for investigating biodiversity dynamics under varying degrees of anthropogenic pressure. Current management initiatives remain fragmented, and the lack of comprehensive, site-specific ecological data hampers effective restoration efforts, risking interventions that are misaligned with local conditions. This study addresses these gaps by providing detailed insights into plant species composition, spatial distribution, diversity, and ecological dominance within Kanyabaha Wetland. Specifically, it seeks to answer three key questions: (i) What are the patterns of plant species composition and spatial distribution across the wetland? (ii) How does plant species diversity vary across disturbance gradients? and (iii) Which plant species exhibit the greatest ecological dominance? By generating evidence-based, ecosystem-centered knowledge, this research aims to inform sustainable management and restoration strategies, thereby supporting integrated wetland governance and contributing to the long-term sustainability of both the wetland ecosystem and the livelihoods that depend on it.

2. Methods

2.1. Study area

The study was conducted in the Kanyabaha Wetland, located in Rukiga District, Uganda. This wetland spans an area of approximately 33 km^2 and is situated at latitude 1.1326°S and longitude 30.0434°E in the Kigezi Sub-region (Fig. 1).

The soils of the wetland exhibit a diverse mosaic of textures and compositions, ranging from nutrient-rich alluvial deposits to mineral-laden substrates. These soils support a dynamic vegetation profile, shaping the landscape into distinct patches of natural vegetation interspersed with open water bodies and agricultural fields. The wetland experiences a humid subtropical climate and features a variety of land use and cover types, including papyrus-dominated areas, small-scale farmlands, tree plantations, built-up zones, grasslands, and woodlands [8]. This diversity in land use reflects the wetland's ecological and socio-economic significance.

2.2. Data collection

A reconnaissance survey was conducted between January and February 2023 to stratify the wetland vegetation for subsequent inventory.

2.2.1. Transect establishment and plot layout

A total of 12 transects were established across six wetland sites (Rutenje, Kitanga, Kitojo, Kyerero, Kandago, and Burime), with two transects established at each site. A systematic transect sampling technique was employed to assess plant species diversity across the six wetland sites. At each site, two transect lines were established in a north–south orientation, each measuring 1 km in length (Fig. 2). The first transect was positioned randomly, while the second was laid parallel to it at a distance of 300 m. Along each transect, the first quadrat (20 m × 20 m) was randomly located, and subsequent quadrats were systematically placed at 100-meter intervals, offset by 5 m from the transect line to minimize edge effects.

2.2.2. Vegetation sampling

Vegetation sampling was conducted within 20 m × 20 m plots established across the study area. Within each plot, a nested quadrat approach was applied to assess woody vegetation based on diameter at breast height (DBH). Individuals with a DBH > 20 cm were recorded in the full 20 m × 20 m plot; those with a DBH of 10–20 cm in a 10 m × 10 m subplot; and stems <10 cm DBH in a 5 m × 5 m subplot. A total of 120 plots were surveyed across all wetland sites. All recorded woody individuals were identified to species level, measured for DBH, and documented using a standardized data collection sheet. Plant taxa were grouped into six life form categories: trees, shrubs, herbs, sedges, grasses, and ferns.

Non-woody vegetation was assessed within the 5 m × 5 m subplots. For each taxon, the number of individuals, percentage cover, and assigned life form were recorded. Life forms were classified based on shared morphological and structural characteristics [9]. Cover was estimated as the vertical projection of plant canopies onto the ground surface, expressed as a percentage of the quadrat area (Mueller-Dombois & Ellenberg, 1974). Coarse cover classes (<20 %, 20–80 %, >80 %) were used, and estimates were validated through consensus among multiple observers (Helm & Mead, 2004). Fig. 3 shows the sampling procedures in Kanyabaha Wetland.

2.3. Data analysis

The analysis encompassed the assessment of plant species composition, species diversity, and the calculation of Importance Value Indices (IVIs) to estimate the ecological significance of plant communities.

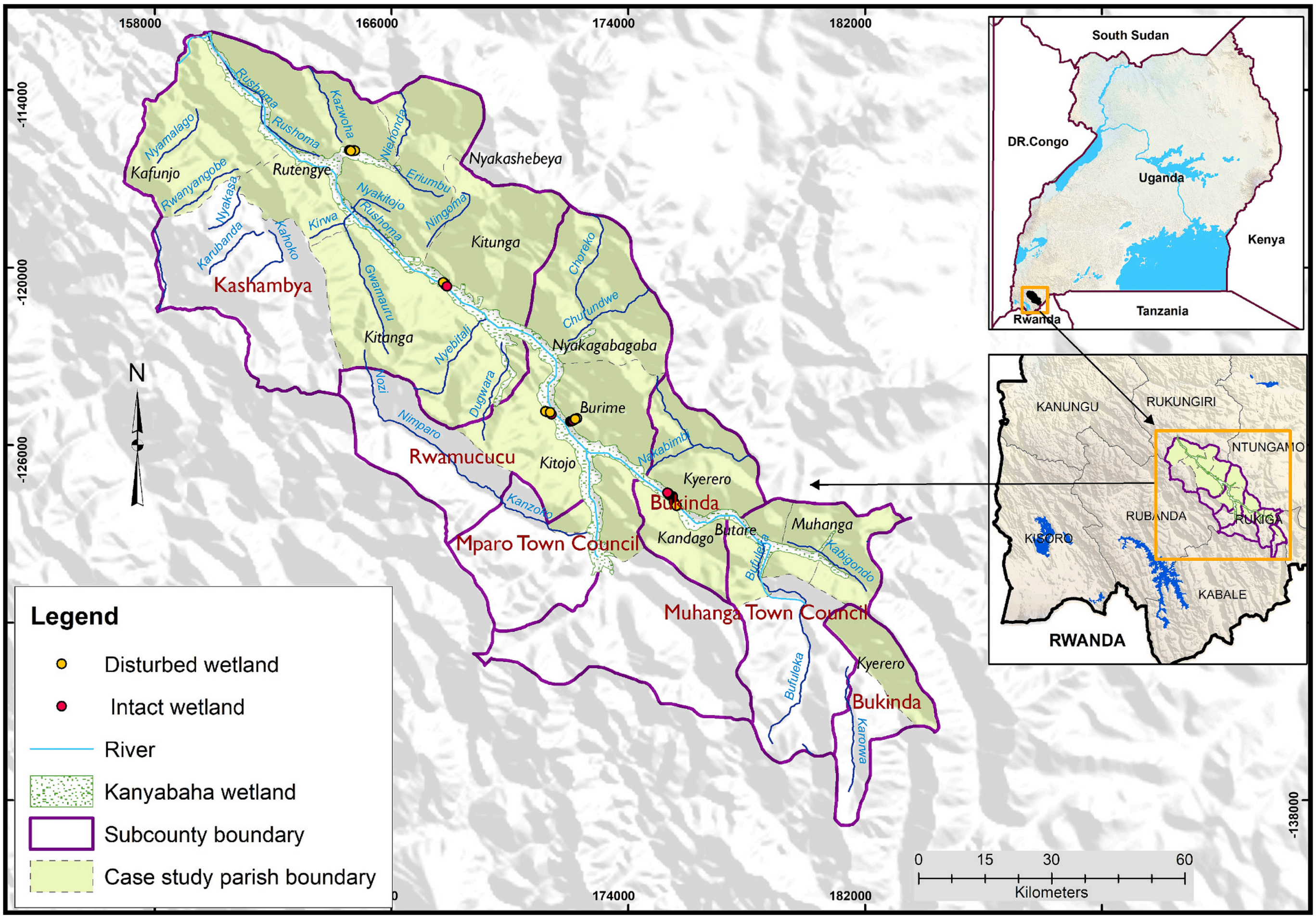

Fig. 1. Map of the study area showing the six wetland sites. software.
Source: Developed by the researchers using ArcMap 10.7.1

2.3.1. Analysis of plant species composition and diversity

Plant species composition was defined as the assemblage of plant species characterizing the wetland vegetation. Plant species encountered in each plot were identified, enumerated, and recorded to describe their composition. Plant species diversity in the six Kanyabaha wetlands was assessed using three indices: Simpson's Diversity Index (D), Shannon-Wiener Diversity Index (H'), and Jaccard's Similarity Index (J) [10,11]. These indices were selected to capture both within-site diversity (richness and evenness) and between-site similarity. Species richness (total number of species) and species evenness (distribution of individuals among species) were analyzed. To test for significant differences in species diversity and composition among wetland sites, a one-way ANOVA was conducted. Where significant differences were found, Tukey's Honest Significant Difference (HSD) test was applied for post-hoc comparisons, as it controls for Type I error across multiple pairwise comparisons.

Shannon-Wiener diversity index

The Shannon-Wiener Diversity Index, an information statistic index, assumes that all species are represented in the sample and that sampling is random. The index was calculated using the formula (Eq. (1)):

$$H' = -\sum Pi \times (\ln Pi) \tag{1}$$

where H′ = is the Shannon Diversity index, Pi = is the proportion of individuals of the ith species (n_i/N), n_i is the number of individuals of the ith species, N is the total number of individuals across all species, ln = is the natural log, Σ = is the sum of the calculations.

Simpson's diversity index

Simpson's Diversity Index, a measure of diversity that accounts for both species richness and evenness, was calculated using the equation (Eq. (2)):

$$D = \frac{\sum_{i=1}^{s} n_i(n_i - 1)}{N(N-1)} \tag{2}$$

where D = Simpson Diversity Index, n_i is the number of individuals of ith species and N is the total number of individuals.

Jaccard's Similarity Index

Jaccard's Similarity Index was used to assess the similarity between wetlands based on the presence or absence of shared species and their uniqueness. The formula applied was (Eq. (3)):

$$C_j = a/(a + b + c) \tag{3}$$

where:

- a represents the number of species shared between two wetlands (e.g., Wetlands A and B),
- b represents the number of species unique to the first wetland (e.g., Wetland A),
- c represents the number of species unique to the second wetland (e.g., Wetland B).

2.3.2. Importance value index

The Importance Value Index (IVI) is a widely used ecological metric that quantifies the relative ecological significance of plant species within a community. It is calculated by summing up relative density, relative

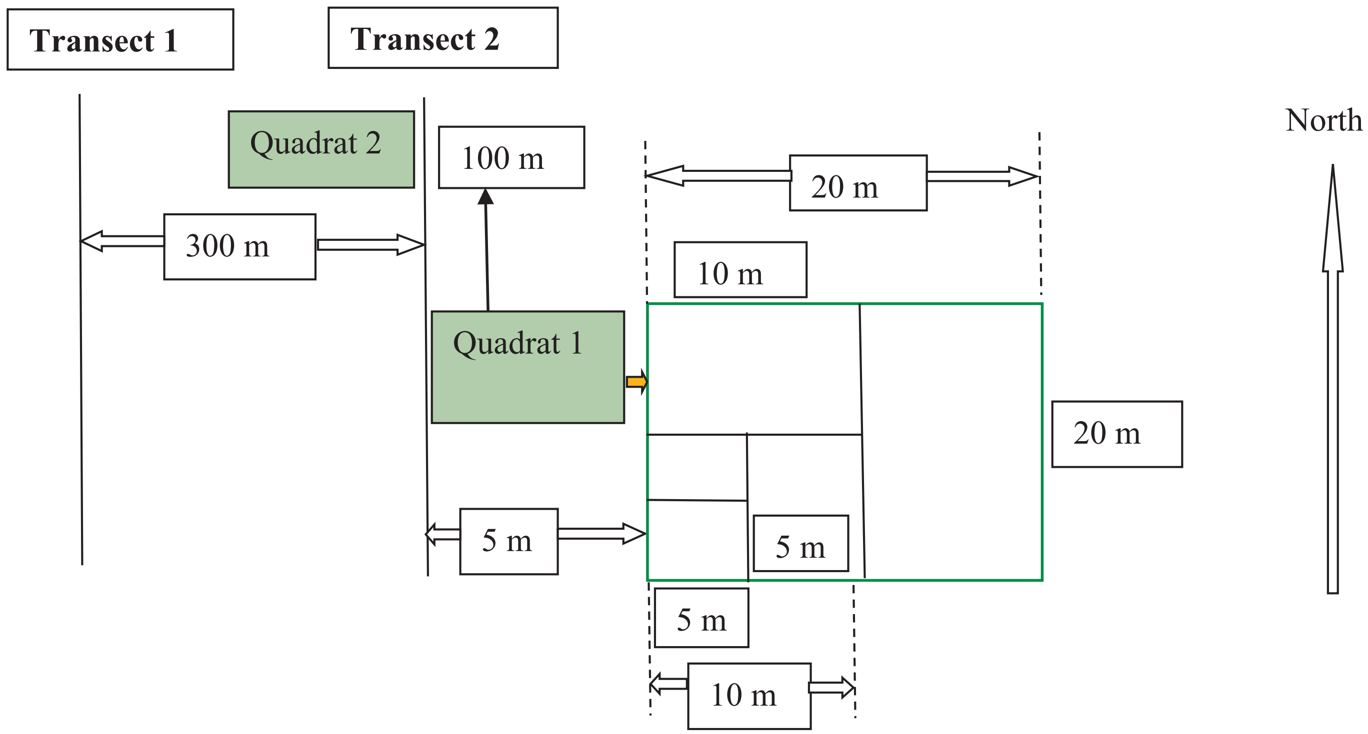

Fig. 2. Diagrammatic presentation of plot layout along transects.

Fig. 3. Field sampling procedures in Kanyabaha Wetland: (left) layout of a vegetation transect used to guide systematic quadrat placement; (right) a research assistant establishing a 5 m × 5 m quadrat for plant species identification and abundance assessment.

coverage, and relative distribution of every species. In this study, the IVI was calculated for both woody and non-woody (herbaceous) plant species using the following equation (eq. (4)):

$$IVI = Relative\,Density + Relative\,Dominance + Relative\,Frequency \quad (4)$$

where:

Relative Density = (density of individuals species / total density of all species) × 100.

Relative dominance

- **For woody species** = (basal area for a species / total basal area for all species) × 100
- **For non-woody species** = estimated using percent cover

Relative Frequency = (frequency of a species/sum of frequencies for all species) × 100.

2.4. Research flow chart

The research process for this study followed a structured and sequential framework comprising five interlinked phases: preparatory phase, tool development, field survey, data processing and analysis, and results interpretation (Fig. 4). The preparatory phase involved a comprehensive literature review, identification of knowledge gaps, refinement of research questions, stakeholder consultations, and logistical planning. This laid the foundation for tool development, customization of sampling protocols, and acquisition of relevant reference datasets. Subsequently, a systematic field survey was conducted across six sites within the Kanyabaha Wetland using established ecological methods to collect data on species composition, diversity, and environmental conditions. In the data processing and analysis phase, field data were cleaned, validated, and subjected to descriptive analysis. Key indices such as Shannon-Wiener diversity, Simpson's dominance, Jaccard similarity, and Importance Value Index (IVI) were computed.

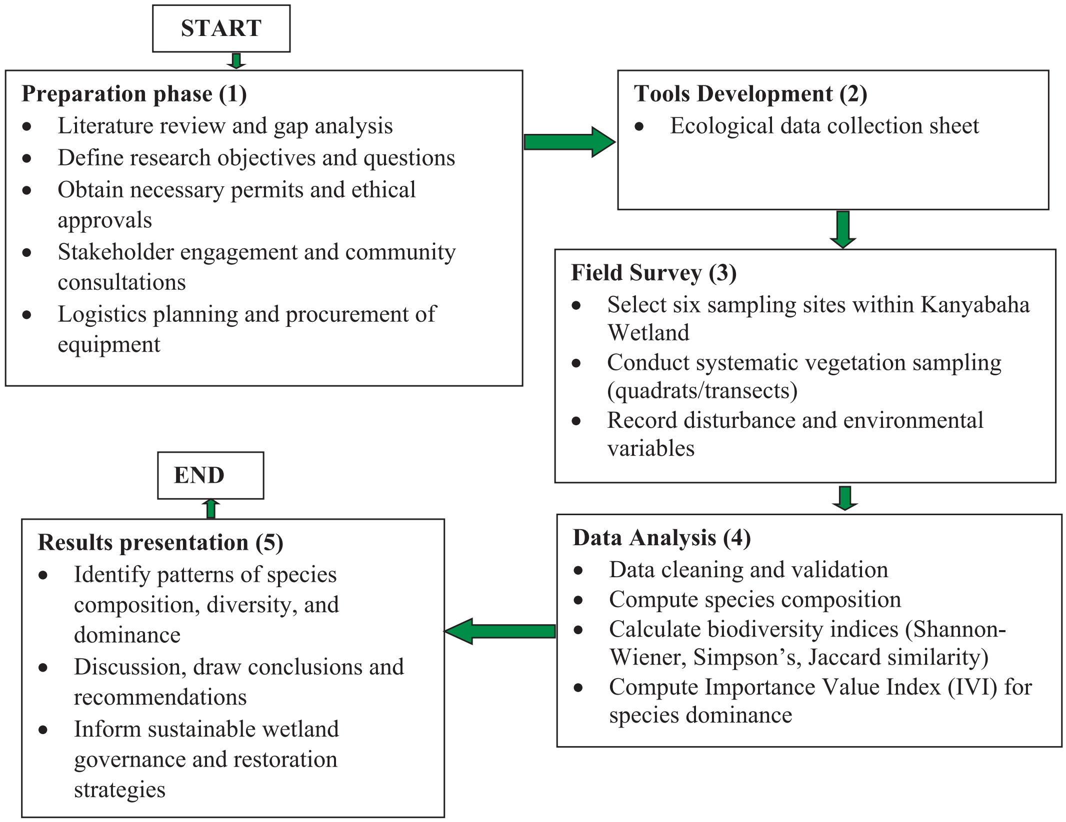

Fig. 4. Research flow chart illustrating the main phases: preparation, tool development, field survey, data analysis, and result interpretation.

Finally, the results interpretation phase synthesized the ecological patterns observed, assessed the influence of anthropogenic disturbances, and generated recommendations for ecosystem-centered wetland governance.

3. Results

This section presents findings from the study conducted in the Kanyabaha Wetland, Rukiga District, Uganda. The main objectives were to: i) document plant species composition; ii) assess species diversity; and iii) determine the ecological significance of individual species using the Importance Value Index (IVI). The results are organized around these objectives, beginning with an overview of species composition across the wetland sites, followed by diversity analyses using standard indices (Shannon-Wiener, Simpson, and Jaccard), and concluding with the calculated IVI values for both woody and non-woody species.

3.1. *Plant species composition*

A total of 31 plant species from 19 families were recorded in the Kanyabaha wetland (Table 1). These species encompassed a range of growth forms, including herbs (17), sedges (5), grasses (4), shrubs (4), trees (2), and a fern (1). Asteraceae and Polygonaceae were the most species-rich families, each contributing three species (9.7 %), while the remaining 17 families accounted for 80.6 % of species richness with one or two species each. In terms of abundance, vegetation was dominated by a few prolific species: *Eucalyptus* sp. (764 individuals), *Cyperus papyrus* (249), and *Vossia cuspidata* (200), which together comprised over 61 % of the total plant count (1,213 out of 1,986).

3.2. *Plant species diversity*

The assessment of plant species diversity utilized three biodiversity indices: the Shannon-Wiener Diversity Index (H'), Simpson's Diversity Index (D), and Jaccard Similarity Index (J). The results of these indices are presented below, providing a comprehensive evaluation of species richness, evenness, and similarity across sites.

Shannon-Wiener Diversity Index (H′)

The overall Shannon-Wiener diversity index (H′) for all six wetland sites combined was 3.05. At the site level, diversity values ranged from 2.39 to 2.66. Kandago recorded the highest H′ value (2.66), followed by Burime (2.61), Kitojo (2.55), Kyerero (2.48), and Rutengye (2.46). Kitanga exhibited the lowest diversity value ($H' = 2.39$). To assess whether the observed differences in diversity were statistically significant among the wetland sites, a one-way analysis of variance (ANOVA) was performed on plot-level Shannon indices. The results revealed a statistically significant effect of site on diversity ($F_{(5, 114)} = 12.88$, $p < 0.0001$), indicating that the diversity index varied meaningfully between sites. Post hoc comparisons using Tukey's Honest Significant Difference (HSD) test further identified that Kandago's mean plot-level H′ was significantly higher than those of Kitanga, Rutengye, and, to a lesser extent, Kyerero ($p < 0.05$).

Pairwise Jaccard Similarity Index (J)

Table 2 presents the pairwise Jaccard Similarity Index (J) values for plant species composition among the six wetland sites. The comparisons revealed clear patterns of floristic overlap and differentiation. Kandago showed the highest similarity with Burime and Kitojo ($J > 0.75$), indicating a strong overlap in species assemblages. In contrast, Kitanga consistently exhibited the lowest similarity across all pairings (J approximately = 0.58–0.62). To statistically assess differences in plant community composition, a permutational multivariate analysis of variance (PERMANOVA) was performed using Jaccard dissimilarity matrices derived from species presence-absence data. The analysis revealed a statistically significant effect of wetland site on floristic composition ($F = 3.97$, $p = 0.001$), confirming that community structure varied significantly across the six wetlands.

Table 1
Plant species composition in Kanyabaha wetland system.

No	Plant Species	Life Form	Family	Village (corresponds to respective wetland)						Total
				Rutenje	Kitanga	Kitojo	Kyerero	Kandago	Burime	
1	*Eucalyptus* sp.	Tree	Myrtaceae	161	424	149			30	764
2	*Cyperus papyrus* L.	Sedge	Cyperaceae	89	87	29	9	8	27	249
3	Vossia cuspidata (Roxb.) Griff.	Grass	Poaceae	71	69	23	7	6	24	200
4	*Pycreus nitidus (Lam.)* J.Raynal	Sedge	Cyperaceae	47			15	66		128
5	*Rumex abyssinicus* Jacq.	Herb	Polygonaceae	113						113
6	*Crassocephalum montuosum* (S.Moore) Milne-Redh.	Herb	Asteraceae	63			5			68
7	*Impatiens burtonii* Hook.f.	Herb	Balsaminaceae	54						54
8	*Cyperus dives* Del.	Sedge	Cyperaceae	18	17	6	2	2	5	50
9	*Persicaria setosula* (A.Rich.) K.L.Wilson	Herb	Polygonaceae				15	25		40
10	*Digitaria scalarum* (Schweinf.) Chiov.	Grass	Poaceae	11	10	3	1	1	4	30
11	*Miscanthidium violaceum* (K.Schum.) Robyns	Grass	Poaceae	9	9	3	1	1	2	25
12	*Pennisetum purpureum* Schumach.	Grass	Poaceae	9	9	3	1	1	2	25
13	*Spathodea campanulata* Buch.-Ham. ex DC.	Tree	Bignoniaceae	2	8		5	7		22
14	*Ludwigia abyssinica A.Rich.*	Herb	Onagraceae	7	7	2	1	1	2	20
15	*Melanthera scandens* (Schumach. & Thonn.) Brenan	Herb	Asteraceae	7	7	2	1	1	2	20
16	*Nymphaea lotus* L.	Herb	Nymphaeaceae	7	7	2	1	1	2	20
17	*Typha capensis* (Rohrb.) N.E.Br.	Herb	Typhaceae	7	7	2	1	1	2	20
18	*Carex congolensis Turrill*	Sedge	Cyperaceae	7	7	2	1	1	2	20
19	*Cladium mariscus (L.) Pohl*	Sedge	Cyperaceae	7	7	2	1	1	2	20
20	*Myrica kandtiana Engl.*	Shrub	Myricaceae	5	5	2	1	1	1	15
21	*Rubus rigidus Sm.*	Shrub	Rosaceae	5	5	2	1	1	1	15
22	*Acalypha psilostachya* Hochst. ex A.Rich.	Shrub	Euphorbiaceae	4	4	1			1	10
23	*Achyranthes aspera* L.	Herb	Amaranthaceae	4	4	1			1	10
24	*Persicaria senegalensis* (Meisn.) Soják	Herb	Polygonaceae	4	4	1			1	10
25	*Phytolacca dodecandra* L'Hér.	Shrub	Phytolaccaceae	4	4	1			1	10
26	*Polygonum senegalense* Meisn.	Herb	Polygonaceae	4	4	1			1	10
27	*Crassocephalum vitellinum* S.Moore	Herb	Asteraceae						5	5
28	*Thelypteris confluens* (Thunb.) C.V.Morton	Fern	Thelypteridaceae	2	2				1	5
29	*Acacia mearnsii* De Wild.	Tree	Fabaceae	1		2			1	4
30	*Ocimum basilicum* L.	Herb	Lamiaceae						2	2
31	*Hibiscus diversifolius* subsp. *rivularis* (Bremek. & Oberm.) Exell	Shrub	Malvaceae	2						2
	Total			**724**	**707**	**239**	**69**	**125**	**122**	**1,986**

Values refer to number of individuals (abundance) of the species in each wetland.

Table 2
Pairwise Jaccard Similarity Index values between the six wetland sites.

Wetland	Burime	Kandago	Kitojo	Kyerero	Rutengye	Kitanga
Burime	*	0.77	0.74	0.71	0.68	0.62
Kandago		*	0.75	0.73	0.70	0.61
Kitojo			*	0.69	0.66	0.59
Kyerero				*	0.67	0.60
Rutengye					*	0.58
Kitanga						*

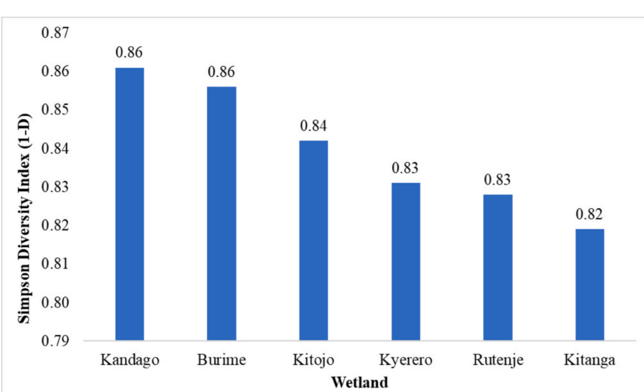

Fig. 5. Simpson diversity index (D) for the plant species in the Kanyabaha wetland system.

Simpson Diversity Index (1-D)

Simpson's Index of Diversity (1-D) ranged from 0.82 to 0.86 across the study sites (Fig. 5), indicating moderate to high species diversity. Kandago exhibited the highest diversity (0.861), while Kitanga recorded the lowest (0.819). A one-way ANOVA confirmed that these differences were statistically significant ($F (5, 114) = 6.21$, $p < 0.001$), highlighting meaningful variation in community structure among the wetlands.

3.3. Importance value index

3.3.1. Woody species

The woody plant community was dominated by *Eucalyptus* sp., with an IVI of 135.1 (Table 3). All other species had IVIs below 6, including

Table 3
Importance value index for woody species.

No.	Species	Relative coverage	Relative density	Relative frequency	IVI
1	*Eucalyptus* sp.	97.4	27.1	10.7	135.1
2	*Spathodea campanulata* Buch.-Ham. ex DC.	2.4	0.7	2	5.1
3	*Myrica kandtiana* Engl.	1.3	0.9	1.3	3.6
4	*Rubus rigidus* Sm.	1.3	0.9	1.3	3.6
5	*Acalypha psilostachya* Hochst. ex A.Rich.	1.3	0.6	0.9	2.8
6	*Phytolacca dodecandra* L'Hér.	1.3	0.6	0.9	2.8
7	*Hibiscus diversifolius* subsp. rivularis (Bremek. & Oberm.) Exell	1.3	0.1	0.2	1.6
8	*Acacia mearnsii* De Wild.	0.22	0.1	0.4	0.7

Spathodea campanulata (5.1), *Myrica kandtiana*, and *Rubus rigidus* (3.6 each).

3.3.2. Non-woody species

The IVI results for non-woody species revealed an uneven distribution of ecological importance (Table 4). *Cyperus papyrus* had the highest IVI (45.4), followed by *Vossia cuspidata* (38.6) and *Pycreus nitidus* (28.5). *Rumex abyssinicus* (25.8) and *Crassocephalum montuosum* (15.5) demonstrated moderate ecological significance. The majority of remaining species recorded IVI values below 10.

4. Discussion

4.1. Plant species composition

A total of 31 plant species belonging to 19 families were recorded across the six surveyed wetlands. Species richness varied among the sites. Rutenje and Burime wetlands, which are subject to moderate levels of human activity, recorded the highest richness with 18 and 17 species, respectively. In contrast, Kitojo, Kandago, and Kitanga wetlands exhibited the lowest richness, ranging from 10 to 12 species. These differences appear to reflect the intensity of human disturbance. Rutenje and Burime, with relatively intact sections alongside moderate human activities such as crop cultivation, settlements, fish farming, and selective harvesting of *Cyperus papyrus*, supported more diverse plant assemblages. In contrast, the higher levels of disturbance from agricultural expansion and settlement in Kitojo, Kandago, and Kitanga correspond with reduced species richness and simplified vegetation structure. These findings align with field-based assessments, which revealed that 57.1 % of the surveyed wetlands had been converted into farmland, while 25.0 % had been modified for agroforestry, primarily through the establishment of Eucalyptus plantations. Only 17.9 % of the wetlands remained relatively intact, with papyrus-dominated stands. This spatial pattern highlights the rapid rate of wetland transformation and reinforces growing concerns over biodiversity loss in Uganda's fragile wetland ecosystems [4,12]. Although these results support the commonly observed trend in which lower disturbance levels correlate with higher species richness, they differ from the findings of Takuwa et al. [13], who reported greater species diversity in highly disturbed wetland sites. Similarly, Mulatu et al. [14] observed higher richness in cultivated wetlands than in uncultivated sites in the South Bench District of southwest Ethiopia. Such discrepancies underscore the context-specific nature of disturbance-diversity relationships and highlight the need to account for multiple ecological and socio-economic variables.

Table 4
Importance value index for non-woody species.

No.	Species	Relative dominance	Relative density	Relative frequency	IVI
1	*Cyperus papyrus* L.	19.7	15.0	10.7	45.4
2	*Vossia cuspidata* (Roxb.) Griff.	15.9	12.1	10.7	38.6
3	*Pycreus nitidus* (Lam.) J.Raynal	10.1	7.7	10.7	28.5
4	*Rumex abyssinicus* Jacq.	8.9	6.8	10.0	25.8
5	*Crassocephalum montuosum* (S.Moore) Milne-Redh.	5.3	4.1	6.0	15.5
6	*Impatiens burtonii* Hook.f.	4.0	3.3	4.8	12.1
7	*Cyperus dives* Del.	3.9	3.0	4.4	11.3
8	*Persicaria setosula* (A. Rich.) K.L.Wilson	3.2	2.4	3.6	9.2
9	*Digitaria scalarum* (Schweinf.) Chiov.	2.4	1.8	2.7	6.9
10	*Miscanthidium violaceum* (K.Schum.) Robyns	2.0	1.5	2.2	5.7
11	*Pennisetum purpureum* Schumach.	1.6	1.5	2.2	5.3
12	*Ludwigia abyssinica* A. Rich.	1.6	1.2	1.8	4.6
13	*Melanthera scandens* (Schumach. & Thonn.) Brenan	1.3	1.2	1.8	4.3
14	*Nymphaea lotus* L.	1.3	1.2	1.8	4.3
15	*Typha capensis* (Rohrb.) N.E.Br.	1.3	1.2	1.8	4.3
16	*Carex congolensis* Turrill	1.3	1.2	1.8	4.3
17	*Cladium mariscus* (L.) Pohl	1.3	1.2	1.8	4.3
18	*Achyranthes aspera* L.	1.3	0.6	0.9	2.8
19	*Persicaria senegalensis* (Meisn.) Soják	1.3	0.6	0.9	2.8
20	*Polygonum senegalense* Meisn.	1.3	0.6	0.9	2.8
21	*Crassocephalum vitellinum* S.Moore	1.3	0.3	0.4	2.1
22	*Thelypteris confluens* (Thunb.) C.V.Morton	1.3	0.3	0.4	2.1
23	*Ocimum basilicum* L.	1.3	0.1	0.2	1.6

The variation in plant composition among wetlands likely reflects species-specific ecological traits, disturbance intensity, and landscape context. For example, Bullock et al. [15] emphasize the effective dispersal mechanisms of Asteraceae species, which facilitate their establishment in both disturbed and undisturbed areas. Likewise, Mamman et al. [16] attribute the dominance of certain families to their efficient seed dispersal strategies, while the limited presence of others may result from poor regeneration capacity or sensitivity to human pressure. Suding et al. [17] and Wang et al. [18] further argue that the resilience of plant communities depends on both the type and intensity of disturbance and the recolonization capacity of individual species. Gojamme et al. [19] also link wetland plant diversity to catchment-level variables such as hydrology, land-use patterns, and elevation.

These differences appear to reflect the intensity of human disturbance. Rutenje and Burime, with relatively intact sections alongside moderate human activities such as crop cultivation, settlements, fish farming, and selective harvesting of Cyperus papyrus, supported more diverse plant assemblages. In contrast, the higher levels of disturbance from agricultural expansion and settlement in Kitojo, Kandago, and Kitanga correspond with reduced species richness and simplified vegetation structure. It should be noted that the descriptors 'highly disturbed' and 'less disturbed' in this study are based on qualitative observations of human activity, land-use changes, and vegetation modification, rather than precise quantitative measurements. Consequently, these terms provide a general indication of anthropogenic influence, and interpretations regarding species richness, diversity, or dominance patterns should be made with caution. Future studies incorporating measurable disturbance metrics would strengthen understanding of the relationship between human activities and wetland plant communities. These findings align with field-based assessments, which revealed that 57.1 % of the surveyed wetlands had been converted into farmland, while 25.0 % had been modified for agroforestry, primarily through the establishment of Eucalyptus plantations.

Floristically, the families Cyperaceae, Poaceae, Asteraceae, and Polygonaceae were the most represented across the study area. Among the species recorded, Eucalyptus sp., Cyperus papyrus, and Vossia cuspidata were the most abundant and widely distributed, though their dominance varied across sites. This variation in species composition reflects both ecological gradients and anthropogenic influence. The family-level patterns observed in this study are consistent with broader floristic trends in wetland ecosystems. Smith et al. [20], for instance, reported the dominance of a few key families in various wetland types, while Yuan et al. (2025) documented the prevalence of Cyperaceae, Polygonaceae, and Poaceae in marsh wetlands along the lower Tumen River in northeastern China. In East Africa, Ruto et al. [21] identified

Asteraceae as a dominant family in the riparian zones of Kenya's Mau Forest Complex, while Odull and Byaruhanga [22] noted the prevalence of Poaceae and Asteraceae in Ugandan wetlands. These patterns suggest that while some families such as Poaceae exhibit wide ecological amplitude, others are more indicative of local environmental conditions, hydrological dynamics, and disturbance regimes.

In summary, this study demonstrates that wetland plant composition is shaped by a combination of species-specific traits and human-induced pressures. Although moderate disturbance may support diverse assemblages in certain contexts, this relationship is not universal. Future research should explore how interactions among disturbance intensity, land-use history, and species traits affect the resilience and conservation status of wetland ecosystems. Such insights are essential for informing sustainable wetland management and biodiversity conservation in rapidly transforming landscapes.

4.2. Plant species diversity

Plant diversity plays a critical role in maintaining ecosystem stability and health [23], influencing primary productivity, nutrient cycling, and resilience to environmental changes [24]. In this study, multiple indices, Shannon-Wiener (H′), Simpson's Index (1-D), and Jaccard Similarity Index (J) were employed to assess plant diversity in the Kanyabaha wetland system. Together, they provide a multidimensional understanding of species richness, evenness, and compositional similarity across sites. The diversity indices revealed meaningful differences in plant community structure among the wetlands. While sites like Rutenje and Burime showed higher species richness, diversity indices such as Shannon-Wiener and Simpson's Index highlighted that Kandago, a site experiencing significant human disturbance exhibited the highest overall diversity. This counterintuitive result underscores the importance of evenness and species distribution, not just richness, in understanding biodiversity patterns. However, this pattern should be interpreted cautiously. Kandago's high diversity indices likely reflect greater species evenness, where individuals are more evenly distributed among species despite low overall richness. Such high diversity does not necessarily indicate ecological integrity, particularly in wetlands dominated by disturbance-tolerant or invasive species. Further analysis of species composition and functional traits in Kandago would help clarify how disturbance and evenness interact to shape observed diversity patterns.

These findings align with studies by Mulatu et al. [14] and Takuwa et al. [13], who reported high species diversity in cultivated or disturbed wetland areas. Such patterns may be attributed to increased habitat heterogeneity and colonization opportunities for disturbance-tolerant or invasive species [25,26]. The proliferation of species such as Eucalyptus in Kitanga, which exhibited both low richness and evenness, demonstrates how intense disturbance can simplify community structure and displace native flora, a trend also observed by Boru et al. [27], Turyasingura et al. [28], and Bentsi-Enchill et al. [29].

The low floristic similarity observed between sites, as indicated by the Jaccard Index, further suggests spatial heterogeneity in species composition, likely influenced by site-specific land-use practices, hydrological conditions, and disturbance histories [19]. Kitanga, in particular, emerged as ecologically distinct, potentially due to the dominance of exotic plantations and reduced understorey vegetation. From a conservation perspective, these findings highlight the dual role of disturbance in shaping plant communities. Moderate levels of disturbance may enhance diversity in the short term by creating niches for colonizers, but prolonged or intense disturbance especially through monoculture planting and wetland conversion can lead to biodiversity loss and functional degradation (Mulei et al., 2018) [30,31]. While some diversity may persist under disturbed conditions, the risk of long-term ecological instability increases due to invasive species dominance and native species displacement. Therefore, the relatively high diversity recorded in sites such as Kandago should not be interpreted as an indicator of ecological integrity, but rather as a signal of transitional or disturbed community dynamics. As observed in other tropical wetland systems (Ambebe et al., 2025) [32], floristic diversity must be interpreted in context, taking into account the processes driving it.

4.2.1. Factors influencing plant diversity

The observed variation in diversity across the study wetlands is shaped by the interplay of ecological traits, human activities, and environmental gradients. Dominance by fast-growing, disturbance-tolerant species like Eucalyptus and Cyperus papyrus in degraded sites suppresses understorey growth and reduces species richness [27,28]. Conversely, disturbances such as drainage, vegetation clearing, and cultivation may create heterogeneous microhabitats that support a wider array of colonizing species [25]. However, this temporary boost in diversity is often unsustainable and comes at the expense of sensitive native species. Anthropogenic factors including agricultural encroachment, settlement, biomass extraction, and tree planting continue to exert pressure on Uganda's wetlands, contributing to biodiversity decline [4,12]. Asongwe et al. [32] further warn that land-use changes and pollution reduce species diversity by favoring a few dominant taxa. This study confirms these trends: while certain wetlands may appear diverse, their community structure reflects stress-tolerant, often invasive assemblages.

4.3. Plant species dominance

The importance value index (IVI) measures the overall importance of a species in a given area, based on its relative dominance, density, and frequency. In this study, IVI values were computed separately for woody and non-woody plant species. The results showed considerable variation, with IVI scores ranging from 135.1 to 0.7 for woody species, and from 45.4 to 1.6 for non-woody species. Among the woody species, *Eucalyptus* sp. dominated the surveyed wetland areas, with a high IVI of 135.1. This dominance is primarily driven by its high relative coverage (97.4 %), coupled with a high relative density (27.1 %) and frequency (10.7 %). These values indicate that *Eucalyptus* sp. is not only the most widespread but also the most frequently encountered and densely populated woody species in the area. Its ecological dominance may reflect deliberate planting for agroforestry and commercial purposes. In the context of this study, such commercial use is reflected in the predominant cultivation of *Eucalyptus* for construction poles and timber, highlighting its economic importance to local livelihoods. This local pattern of widespread cultivation and economic reliance on *Eucalyptus* is supported by Iglesias-Carrasco et al. (2025), who note that *Eucalyptus species* are among the most widely used trees in global forestry due to their rapid growth and high profitability. Their versatility extends to a range of uses, including paper production, timber, firewood, and as ingredients in medicinal and cosmetic products (Prajapati et al., 2024). Other woody species exhibited markedly lower IVI values, with Spathodea campanulata (IVI = 5.1), Myrica kandtiana, and Rubus rigidus (each at 3.6) occurring at low frequencies and densities. This skewed distribution suggests a simplified woody plant community structure, likely shaped by extensive land-use change and species introductions.

For non-woody plant species recorded, *Cyperus papyrus* emerged as the most ecologically significant, with an IVI of 45.4, attributed to relatively high dominance (19.7 %), density (15.0 %), and frequency (10.7 %). *Vossia cuspidata* followed closely, with an IVI of 38.6, supported by strong dominance (15.9 %) and density (12.1 %). *Pycreus nitidus* ranked third, with a relatively lower IVI of 28.5, although it exhibited the same frequency (10.7 %) as the top two species. These results suggest that *C. papyrus* and *V. cuspidata* are the most ecologically influential non-woody species in the surveyed wetlands. This study affirms that human-induced disturbances such as farming, brick-making, and vegetation clearance can drive shifts in wetland plant communities by displacing native species and facilitating the proliferation of secondary or ruderal vegetation. These processes likely explain the elevated IVIs of generalist species such as *Vossia cuspidata* and *Pycreus nitidus*, particularly in more disturbed wetland sites. Blaser-Hart et al. [33] further link the expansion of *V. cuspidata* to hydrological alterations such as fluctuating water levels and retention times, which create favorable microhabitats for colonization. Therefore, while high IVI scores may indicate ecological dominance, they should not be interpreted uncritically as markers of ecological integrity, especially when such dominance arises under anthropogenically altered conditions.

4.4. Implications for management and policy

This study highlights the need for integrated wetland management strategies informed by ecological data. Variation in species composition and dominance across Kanyabaha Wetland reflects differing levels of anthropogenic disturbance, with implications for biodiversity and ecosystem resilience. First, management interventions should go beyond species richness metrics and incorporate species dominance patterns, especially where exotic or disturbance-tolerant species (e.g., Eucalyptus, Vossia cuspidata) prevail. Restoration efforts should be site-specific, targeting areas where ecological integrity is compromised. Second, findings support the integration of biodiversity assessments into land-use planning and enforcement of wetland protection policies. The widespread conversion of wetland areas to farmland and settlements underscores the need for stronger governance and coordination among stakeholders. Third, community-based conservation should be prioritized. Sustainable use models, including incentives and alternative livelihoods, can reduce pressure on wetland ecosystems. Lastly, regular monitoring using ecological indices is essential to track changes and inform adaptive management. Aligning local actions with national wetland policies and international frameworks, such as the Ramsar Convention, will strengthen long-term conservation outcomes.

5. Conclusions and recommendations

5.1. Conclusions

This study assessed plant species composition, diversity, and ecological dominance in Kanyabaha Wetland to generate baseline ecological data for conservation and sustainable management. Using standard vegetation survey techniques and ecological indices, it revealed that human disturbance significantly influences wetland plant communities. Highly disturbed sites, such as Kandago, exhibited reduced native species richness and a dominance of introduced species like Eucalyptus spp., as reflected in their high Importance Value Index (IVI) scores. In contrast, less disturbed sites such as Rutenje and Burime supported greater native species richness and stronger ecological integrity. Notably, Kandago recorded the highest diversity based on Shannon-Wiener and Simpson's indices, despite its high disturbance levels, highlighting the role of species evenness in shaping diversity metrics. This paradox suggests that while disturbance may increase diversity under certain conditions, it often signals underlying shifts in community composition that could impair ecosystem function.

The study's findings are relevant to conservation practitioners, wetland managers, and local authorities by providing baseline data to guide site-specific restoration and management interventions. Areas with high ecological integrity should be prioritized for protection, while degraded sites require targeted restoration. However, the study was limited by single-season sampling, absence of quantitative disturbance metrics, and occasional challenges in species identification. The reliance on single-season sampling constrains interpretation of the results, as wetlands are dynamic ecosystems where species composition and abundance fluctuate with hydrological and seasonal changes. Consequently, the observed patterns may only represent a snapshot in time rather than the full ecological variability across wet and dry periods. In addition, the absence of quantitative disturbance metrics limited the precision of our analysis of human pressures. Disturbance was assessed qualitatively through observed land-use activities, but incorporating measurable indicators such as frequency of harvesting, extent of cultivation, or hydrological modification would have strengthened the links between disturbance intensity and vegetation responses. Future studies incorporating multi-seasonal sampling and standardized disturbance metrics will provide a more comprehensive understanding of the drivers of wetland vegetation dynamics and enhance the robustness of ecological and management recommendations. These limitations highlight the need for long-term ecological monitoring, experimental studies on species interactions under varying disturbance regimes, and interdisciplinary research incorporating soil, hydrological, and socio-economic factors. Addressing these gaps will enhance the development of integrated, ecologically sound, and community-responsive wetland management strategies.

Based on the study's findings, it is recommended that ecologically intact areas such as Rutenje and Burime be prioritized for protection due to their higher native species richness and stronger ecological integrity. In contrast, degraded sites like Kandago require targeted restoration interventions, including the control or removal of invasive species such as Eucalyptus spp. and the reintroduction of native wetland flora to restore ecological balance. To sustain conservation outcomes, active involvement of local communities in wetland management is essential. Community-led restoration initiatives, coupled with awareness campaigns and incentives for sustainable land use, can enhance long-term stewardship. Given the limitations of single-season sampling, the establishment of long-term ecological monitoring programs is also recommended. These should include regular assessments of plant diversity, disturbance levels, and ecosystem health to support adaptive management. Furthermore, future research should adopt interdisciplinary approaches that integrate soil properties, hydrological data, and socio-economic drivers of disturbance to better understand the ecological dynamics of the wetland. Finally, the study's findings should inform local and regional land-use planning and wetland policy, providing a scientific basis for evidence-based conservation and sustainable resource management.

CRediT authorship contribution statement

Paul Walakira: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Investigation, Conceptualization. **Cecilia Gichuki:** Validation, Supervision. **John Muriuki:** Validation, Supervision. **Ezekiel Ndunda:** Validation, Supervision. **Peter B. Olanya:** Validation, Formal analysis, Data curation. **Pantaleon M.B. Kasoma:** Validation, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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