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Hydrological influence on diversity and distribution of weedy grass species in the Hadejia-Nguru Wetland, Nigeria

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Abstract

Wetlands play a crucial role in supporting biodiversity, particularly in semi-arid regions like the Sahel, where they provide vital ecosystem services. This study investigates the taxonomic diversity and distribution of grasses (Poaceae) within the Hadejia-Nguru Wetland, a Ramsar site in northeastern Nigeria. Field surveys were conducted from October 2023 to December 2024 across 12 stratified sites in both flooded and irrigated habitats. Species diversity was analyzed using the Shannon-Wiener diversity index, Simpson's dominance index and Pielou's evenness index, while species composition was examined through Detrended Correspondence Analysis (DCA). A total of 46 grass species belonging to 25 genera and four subfamilies were recorded, with Panicoideae emerging as the dominant subfamily. Flooded habitats exhibited a higher Shannon-Wiener index (H′ = 3.52) and lower Simpson's dominance index (D = 0.036), indicating greater species evenness compared to irrigated fields (H′ = 3.07, D = 0.059). DCA results revealed distinct differences in species composition between habitat types, with hydrophytic species such as *Echinochloa stagnina* (Retz.) P. Beauv. and *Oryza barthii* A. Chev. & Roehr. dominating flooded areas. These findings emphasize the influence of hydrological conditions on species distribution and underscore the need for targeted conservation strategies that support both biodiversity and sustainable land use in wetland agroecosystems.

Keywords: conservation; flooding; grass diversity; Hadejia-Nguru; Poaceae; wetland biodiversity

Introduction

Wetlands are globally recognized as highly productive ecosystems that deliver essential services such as biodiversity conservation, carbon sequestration, nutrient cycling and water purification (1, 2). In Africa, these vital ecosystems underpin rural livelihoods through agriculture, fishing and grazing, while simultaneously maintaining ecological balance (3, 4). Nigeria, in particular, possesses extensive wetland coverage, estimated at over 30000 km^2, which includes diverse floodplain and riparian systems. These systems play critical roles in food security and climate regulation (5-7). Despite their ecological and socio-economic importance, these ecosystems face increasing threats from anthropogenic pressures, including irrigation development, dam construction, land conversion and climate variability, all contributing to biodiversity loss and ecosystem degradation (8, 9).

As primary producers, grass species (Poaceae) dominate wetland habitats and are instrumental in influencing ecosystem functioning. They achieve this by stabilizing soils, enhancing nutrient cycling and providing crucial fodder for livestock (10, 11). Studies across various African wetlands, such as those in East Africa (12) and Togo (13), have consistently documented the critical roles of grass communities in sustaining wetland structure and function. The hydrological regime is a key determinant of species composition, distribution and diversity in wetlands (14). Research from diverse regions, including the Yangtze River-connected floodplain in China (15), Egyptian floodplains (16) and Sahelian wetlands (17), consistently demonstrates that water availability, flooding frequency and depth profoundly shape grass community structures and facilitate niche differentiation. Similar global assessments have reported in previous studies that mapped Poaceae distribution and richness patterns across India, revealing that hydrological gradients and climatic conditions jointly determine grass diversity and dominance (18). This underlines the importance of integrating hydrological parameters when assessing grass community ecology in African wetlands.

In Nigeria, the Hadejia-Nguru Wetland Floodplain (HNW) is a Ramsar-designated site of international importance, recognized as a biodiversity hotspot supporting migratory birds, fisheries and agriculture (3, 19). However, hydrological alterations resulting from the Hadejia Valley Irrigation Project (HVIP) and upstream dams have significantly modified natural flooding patterns, thereby impacting wetland health and resource availability (6, 20). Over the past decades, the hydrology of the HNW has been profoundly altered by these upstream dam constructions and irrigation schemes, leading to reduced seasonal flooding, modified inundation patterns and significant ecological consequences for both biodiversity and local livelihoods (5, 6). Moreover, modeling studies in Sahelian river basins of northwestern Nigeria have demonstrated that land use changes significantly alter streamflow regimes and hydrological connectivity, with implications for downstream wetland ecosystems (17). In the West African context, previous findings have documented significant changes in the Senegal River flood regimes post-dam construction, demonstrating how modified hydrological patterns affect flood-dependent livelihoods, ecosystem productivity and agricultural practices, similar to observations in the Hadejia-Nguru Wetland (21). Despite these documented impacts, there remains limited empirical data on how these altered hydrological regimes specifically influence weedy grass species diversity and distribution within the crucial rice and wheat agroecosystems of the HNW.

This study aligns with Nigeria's commitments under the Ramsar Convention to promote the wise use of wetlands. Its primary objective is to generate ecological knowledge for improved conservation and sustainable agricultural practices within the Hadejia-Nguru Ramsar site (3). Specifically, this research aims to assess the diversity and distribution of weedy grass species under different hydrological regimes in the Hadejia-Nguru Wetland Floodplain. It investigates how flooding and irrigation influence Poaceae community structure, identifies dominant and invasive species of management concern and provides evidence-based recommendations for integrated conservation and sustainable rice production within this critical Sahelian wetland landscape.

Materials and Methods

Study area

The Hadejia-Nguru Wetland Floodplain (HNW) is situated in northeastern Nigeria, encompassing approximately 200000 ha across Jigawa and Yobe States (19). It is formed by the confluence of the Hadejia and Jama'are Rivers, which converge to create the Komadugu Yobe River, ultimately draining into Lake Chad (5). The central portion of the wetland is geographically located between 12° 30′N to 13°00′N latitude and 10°15′E to 11°00′E longitude (19). Elevations within the study area range from 152 to 305 m above sea level. The regional climate is classified as semi-arid under the Köppen-Geiger system, characterized by mean annual temperatures of approximately 27 °C and a distinct wet season from May to September (5) (Fig. 1).

The hydrological system, estimated to encompass 350000 ha, includes the entire Hadejia-Jama'are river system and its associated floodplain environments (6). Hydrology is primarily driven by seasonal rainfall and upstream river discharge, with peak flooding typically occurring between July and September (22). The Hadejia Valley Irrigation Project (HVIP), an upstream development, diverts water for large-scale rice cultivation, thereby altering downstream flooding regimes, wetland inundation patterns and consequently, biodiversity (6, 20). Over the past decades, the hydrology of the Hadejia-Nguru Wetland has been significantly modified due to upstream dam constructions and irrigation schemes, leading to reduced seasonal flooding, altered inundation patterns and ecological consequences for biodiversity and local livelihoods (5, 6).

Vegetation sampling and data collection

Field surveys were conducted across twelve sites within the wetland, covering six local government areas: Auyo, Guri, Hadejia, Kafin Hausa, Kirikasamma and Mallam Madori. To ensure comprehensive coverage, sampling was stratified by habitat type, with six sites designated in flooded rice fields and six in irrigated rice fields. Within each site, 24 quadrats (1 m × 1 m) were sampled, resulting in a total of 288 quadrats across all habitats. This design facilitated systematic and robust coverage of ground layer plant diversity.

Samples from rice-cultivated fields were collected between April and October, corresponding to the wet season. Conversely, wheat fields, which are cultivated in the same paddy systems during the harmattan (dry season), were sampled between December and February. Quadrat plots were consistently laid at fixed distances of 10 m from central cross points along transects. This approach aimed to capture within-site variability and minimize sampling bias (23). The quadrat-based sampling method follows established protocols (23) suited to grass-dominated ecosystems by enabling the capture of both taxonomic and functional traits crucial for understanding community composition and structure in wetlands.

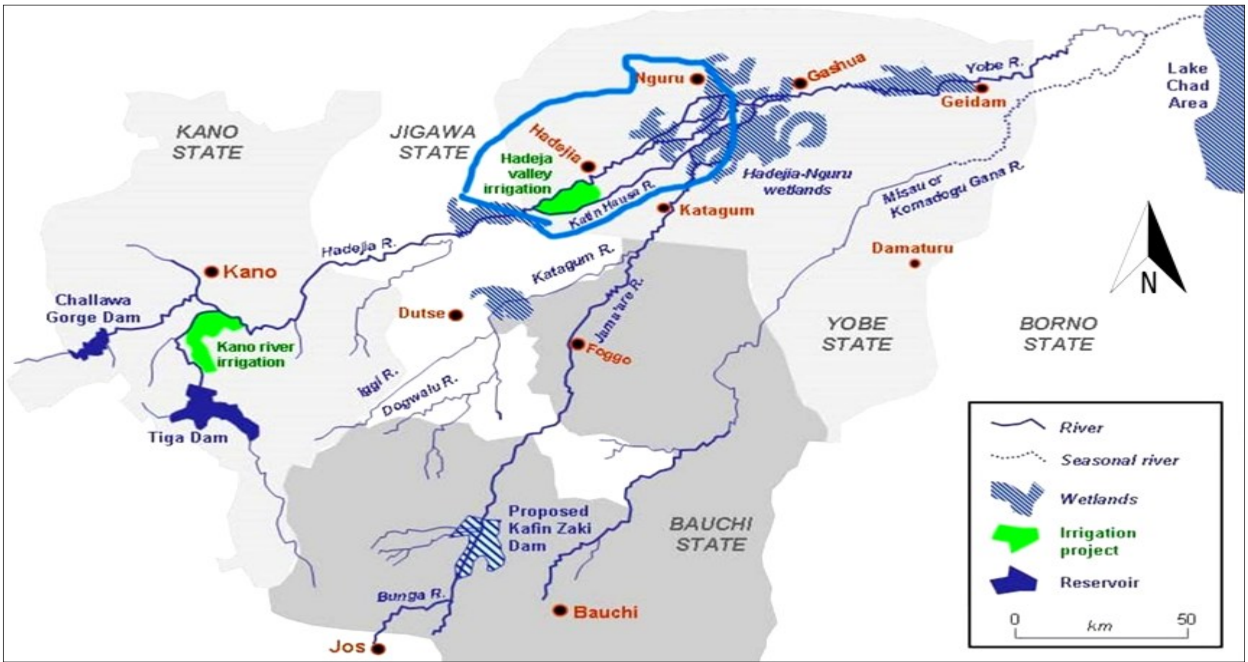

Fig. 1. Map of Hadejia-Nguru Wetland showing the study area.

Species identification

Plant specimens collected were identified using the Flora of West Tropical Africa (24) and subsequently verified at the Ahmadu Bello University Herbarium (ABU) and Umaru Musa Yar'adua University Herbarium (UMYU).

Data analysis

Species diversity indices, including Shannon-Wiener (H') and Simpson's dominance index (D), were calculated to quantify richness, evenness and dominance patterns within the communities. Detrended Correspondence Analysis (DCA) was performed using PAST version 4.17 (25). This robust software is widely recognized for multivariate ecological ordination and community analysis due to its user-friendly interface and suitability for exploratory ecological data analysis.

Community involvement

All habitats were surveyed with the informed consent of local landowners and stakeholders. Although traditional knowledge was not formally consulted, permission was obtained from community members, particularly farmers, to access and sample vegetation on their farmlands. This ensured ethical compliance and fostered goodwill, allowing uninterrupted fieldwork across the various habitat types. While no direct feedback or formal educational outreach was conducted during the study, findings relevant to local land use and species composition will be shared with interested community members in future awareness sessions or through local extension channels, fostering mutual understanding and potential application of research insights in sustainable land management.

Results

This study documented 46 Poaceae species across the Hadejia-Nguru Wetland Floodplain paddy fields (Table 1), encompassing diverse subfamilies, local names and habitat preferences. Of the 46 Poaceae species recorded, 32 were annuals (69.6 %) and 14 were perennials (30.4 %). Fig. 2 reflects adaptive strategies to the region's dynamic, seasonally fluctuating agroecosystems. Fig. 3 presents a heatmap depicting the spatial distribution of species richness and

Table 1. List of Poaceae species identified in the Hadejia-Nguru Wetland floodplain paddy fields, including subfamilies, local names and habitat preferences

S/N	Name	Subfamily	Common Name	Location	Habitat preference
1	*Cenchrus ciliaris* L.	Panicoideae	African fox tail grass	Flooded/Irrigated	Terrestrial
2	*Chloris gayana* Kunth	Chloridoideae	Rhodes grass	Flooded/Irrigated	Amphibious
3	*Cenchrus pedicellatus* (Trin.) Morrone	Panicoideae	Sandbur	Flooded/Irrigated	Terrestrial
4	*Chrysopogon nigritanus* (Benth.) Veldkamp	Panicoideae	Black vetiver grass	Flooded/Irrigated	Amphibious
5	*Cynodon dactylon* (L.) Pers.	Chloridoideae	Bermuda grass	Flooded/Irrigated	Amphibious
6	*Dactyloctenium aegyptium* (L.) Willd	Chloridoideae	Crow foot grass	Flooded/Irrigated	Terrestrial
7	*Digitaria ciliaris* (Retz.) Koeler	Panicoideae	Southern crab grass	Flooded/Irrigated	Amphibious
8	*Digitaria debilis* (Desf.) Willd	Panicoideae	Finger grass	Flooded	Terrestrial
9	*Digitaria horizontalis* Willd	Panicoideae	Horizontal finger grass	Flooded/Irrigated	Terrestrial
10	*Dinebra retroflexa* (Vahl) Panz.	Chloridoideae	Viper grass	Flooded	Terrestrial
11	*Diplachne fusca* (L.) P. Beauv. ex Roem. & Schult.	Chloridoideae	Brown beetle grass	Flooded	Aquatic
12	*Echinochloa colonum* (L.) Link	Panicoideae	Jungle rice	Flooded/Irrigated	Amphibious
13	*Echinochloa pyramidalis* (Lam.) Hitchc. & Chase	Panicoideae	Antelope grass	Flooded/Irrigated	Amphibious
14	*Echinochloa stagnina* (Retz.) P. Beauv.	Panicoideae	Burgu grass	Flooded/Irrigated	Aquatic
15	*Eleusine indica* (L.) Gaertn	Chloridoideae	Indian goose grass	Flooded/Irrigated	Terrestrial
16	*Elytrophorus spicatus* (Willd.) A. Camus	Arundinoideae	Spike grass	Flooded	Aquatic
17	*Eragrostis cilianensis* (All.) Vignolo ex Janch.	Chloridoideae	Stink grass	Flooded	Terrestrial
18	*Eragrostis ciliaris* (L.) Link	Chloridoideae	Gophertail love grass	Flooded	Amphibious
19	*Eragrostis japonica* (Thunb.) Trin.	Chloridoideae	Japanese love grass	Flooded/Irrigated	Amphibious
20	*Eragrostis pilosa* (L.) P. Beauv.	Chloridoideae	Indian love grass	Flooded	Amphibious
21	*Eragrostis tenella* (L.) Beauv.	Chloridoideae	Love grass	Flooded	Terrestrial
22	*Eragrostis multiflora* Trin.	Chloridoideae		Irrigated	Terrestrial
23	*Eragrostis unioloides* (Retz.) Nees ex Steud.	Chloridoideae		Irrigated	Terrestrial
24	*Eriochloa barbatus* (Trin.) S. Yadav & M.R. Almeida	Panicoideae	Bearded eriochloa	Flooded/Irrigated	Amphibious
25	*Ischaemum rugosum* Salisb.	Panicoideae	Saramollagrass	Flooded/Irrigated	Amphibious
26	*Oryza barthii* A. Chev.	Oryzoideae	Barth's rice	Flooded/Irrigated	Aquatic
27	*Oryza glaberrima Steud.*	Oryzoideae	African rice	Irrigated	Aquatic
28	*Oryza longistaminata* A. Chev. & Roehr	Oryzoideae	Longstamen rice/Red	Flooded/Irrigated	Aquatic
29	*Panicum laetum* Kunth	Panicoideae	Panic grass	Flooded/Irrigated	Amphibious
30	*Panicum subalbidum* Kunth	Panicoideae	White panic grass	Flooded/Irrigated	Amphibious
31	*Paspalum scrobiculatum* L.	Panicoideae	Kodo millet	Flooded/Irrigated	Amphibious
32	*Paspalum vaginatum* Sw	Panicoideae	Water finger grass	Flooded/Irrigated	Amphibious
33	*Phragmites australis* (Cav.) Trin. ex Steud.	Arundinoideae	Common reed	Flooded/Irrigated	Aquatic
34	*Rottboellia cochinchinensis* (Lour.) Clayton	Panicoideae	Itch grass	Flooded/Irrigated	Amphibious
35	*Sacciolepis africana* C.E.Hubb. & Snowden	Panicoideae	Cupscale grass	Flooded/Irrigated	Aquatic
36	*Setaria geminata* (Forssk.) Veldkamp	Panicoideae	Water crown grass	Flooded	Amphibious
37	*Setaria pumila* (Poir.) Roem. & Schult	Panicoideae	Yellow foxtail	Flooded/Irrigated	Amphibious
38	*Setaria verticillata* (L.) P. Beauv.	Panicoideae	Hooked bristle grass	Flooded	Terrestrial
39	*Sporobolus pyramidalis* P. Beauv.	Chloridoideae	Giant rat's tail grass	Flooded	Terrestrial
40	*Sporobolus spicatus* (Vahl) Kunth	Chloridoideae	Salt grass	Flooded	Terrestrial
41	*Steinchisma laxum* (Sw.) Zuloaga	Panicoideae	Lax panic grass	Flooded	Terrestrial
42	*Urochloa deflexa* (Schumach.) H. Scholz	Panicoideae	Guinea millet	Flooded	Terrestrial
43	*Urochloa distachyoides* (Stapf) Sosef	Panicoideae	Signal grass	Flooded	Amphibious
44	*Urochloa mutica* (Forssk.) T.Q. Nguyen	Panicoideae	Para grass	Flooded/Irrigated	Amphibious
45	*Urochloa ramosa* (L.) T.Q. Nguyen	Panicoideae	Browntop millet	Flooded/Irrigated	Terrestrial
46	*Vossia cuspidata* (Roxb.) Griff.	Panicoideae	Hippo grass	Flooded/Irrigated	Aquatic

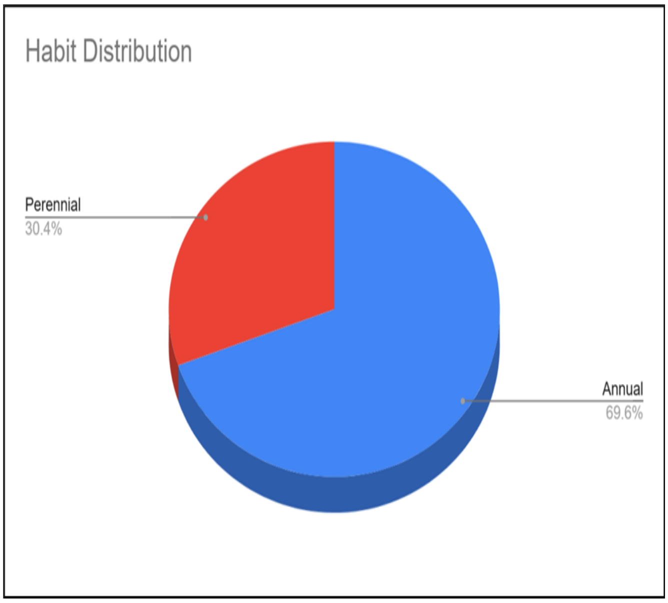

Fig. 2. Life cycle distribution.

accumulation across sampled plots. Fig. 4 illustrates diversity metrics-mean species richness and Shannon diversity index-across the two hydrological regimes. Flooded fields consistently supported significantly higher species richness and diversity than irrigated fields.

Hydrophytic grasses such as *Echinochloa stagnina* and *Oryza barthii* predominated in flooded habitats, while irrigated fields were dominated by disturbance-tolerant species including *Digitaria ciliaris*, *D. horizontalis* and *Echinochloa colona*.

Simpson's Diversity Index revealed the highest species diversity in flooded fields (0.966), followed by the combined dataset (0.964) and the lowest in irrigated fields (0.943). This gradient reflects lower dominance and greater species evenness in flooded habitats. The Simpson's Dominance Index (D) for the flooded fields was 0.034, indicating minimal dominance by any single species. These results suggest that hydrological variability in flooded fields supports a more balanced and ecologically stable plant community, in contrast to irrigated fields where dominance by a few disturbance-adapted species is more pronounced.

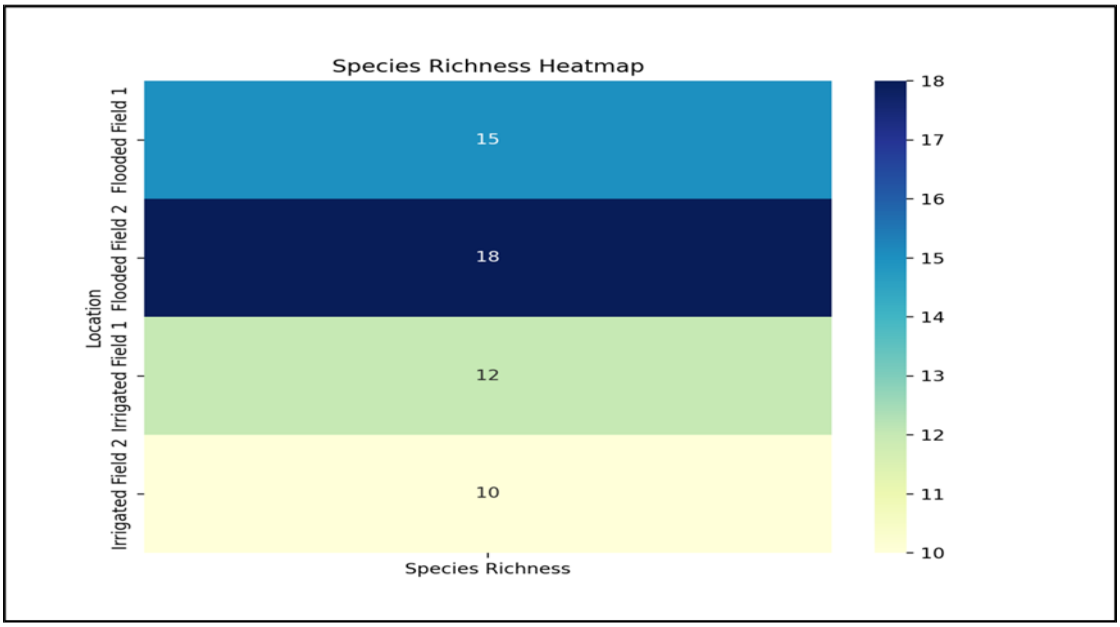

Fig. 3. Species richness heat map of the study area.

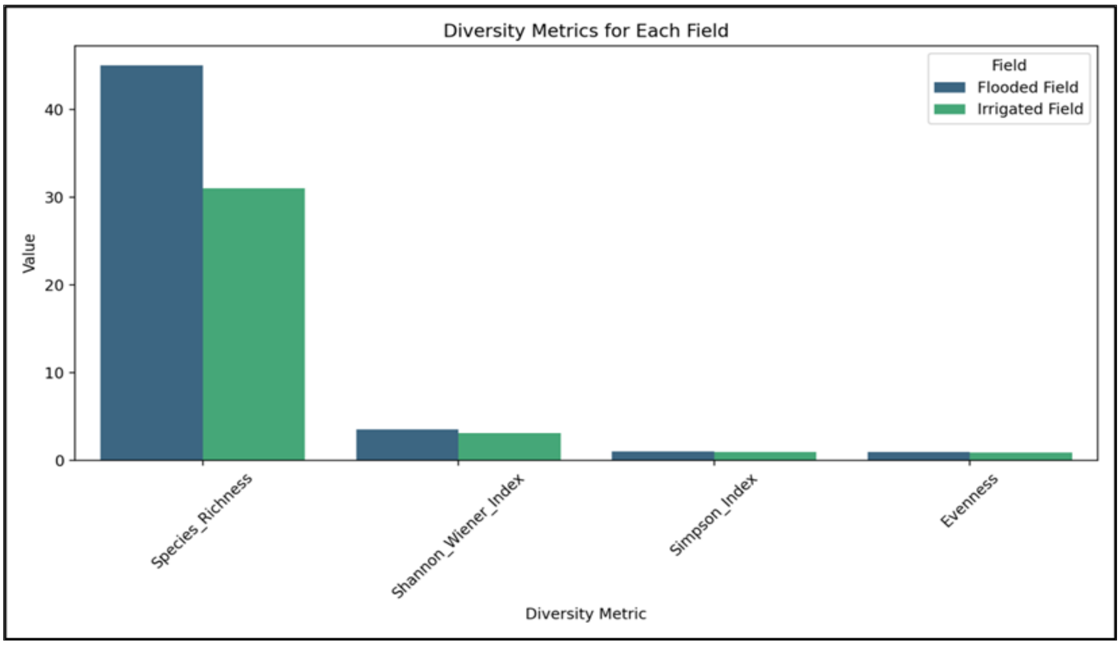

Fig. 4. Diversity metrics of the study area.

DCA further underscored this ecological differentiation. Axis 1 alone explained 100% of the total variance (eigenvalue = 3.54), clearly distinguishing flooded and irrigated field communities (Fig. 5). *Echinochloa stagnina* and *Dactyloctenium aegyptium* were key indicators of flooded plots, while *Cynodon dactylon* and *Paspalum vaginatum* characterized irrigated conditions. This dominant compositional gradient reflects moisture regime as the primary ecological filter shaping Poaceae assemblages in the Hadejia-Nguru Wetland.

Discussion

This study investigated the diversity and distribution of weedy grass species within flooded and irrigated rice fields in the Hadejia-Nguru Wetland Floodplain, Nigeria. Our findings consistently demonstrated that flooded habitats supported greater species richness and diversity compared to irrigated areas. This pattern aligns with observations from other African and Asian wetland ecosystems, reinforcing the critical role of natural hydrological regimes in maintaining biodiversity (11, 15, 26). The dominance and adaptability of Poaceae are ecologically significant, as these traits enable grasses to thrive under varying hydrological conditions, stabilize soils and influence nutrient cycling and competitive interactions within rice agroecosystems (9, 10).

The calculated Simpson's dominance index further highlighted a moderate dominance by hydrophytic species in flooded fields. In contrast, irrigated sites exhibited greater evenness, characterized by the prevalence of disturbance-tolerant species. As observed in our results, these included *Digitaria ciliaris*, *D. horizontalis* and *Echinochloa colona*. Here, disturbance-tolerant species refer to grasses that can thrive under frequent anthropogenic or environmental disruptions, such as land clearing, grazing, or soil disturbance, often dominating managed or degraded habitats (10). These results corroborate findings from studies in East African wetlands (12), Egyptian floodplains (16) and Ethiopian wetlands (26), all of which underscore how hydrological variability shapes plant community composition by creating heterogeneous microhabitats and promoting niche differentiation (14). These findings are particularly consistent with hydrological niche theory, as demonstrated by García-Baquero Moneo et al. (27), whose work on English floodplain meadows showed that spatial hydrological variability, influenced by microtopography and water availability gradients, significantly structures plant community diversity and drives ecological differentiation within grass-dominated wetland habitats.

Local farmers identified *Sacciolepis africana* as a particularly aggressive weed due to its intertwined root system with rice, which complicates manual removal and inhibits crop growth. Similar detrimental impacts were noted for *Paspalum vaginatum*, *Oryza longistaminata* and *Ischaemum rugosum*, all of which compete fiercely with rice for light, water and nutrients, potentially leading to reduced rice yield and quality. However, *Panicum laetum* was recognized for its positive contribution to soil stabilization and nutrient cycling, indirectly supporting rice cultivation (13).

Given the identified detrimental impacts of specific weed species and the varied habitat characteristics, the implementation of Integrated Weed Management (IWM) strategies is strongly recommended. These strategies should specifically target dominant competitor species (e.g., *Digitaria ciliaris*, *Eriochloa barbatus*, *Ischaemum rugosum*, *Echinochloa colona*, *Cynodon dactylon*, *Oryza longistaminata*, *Paspalum scrobiculatum*, *Sacciolepis africana*, *Paspalum vaginatum*) and invasive species (*Phragmites australis*). Recommended IWM approaches include manual removal, strategic flooding or drainage manipulation to suppress flood-sensitive weeds, crop rotation with competitive rice varieties and selective herbicide application tailored to specific wetland ecological conditions (1, 23). In support of integrated weed management strategies, Akpami (28) highlighted that adopting sustainable water management technologies in Nigerian rice paddies can enhance water use efficiency while promoting ecological stability.

Furthermore, the observed patterns in this study underscore ecological theories that posit hydrology as a primary driver of biodiversity, controlling carrying capacity, niche formation and dispersal processes (14). Previous studies (5, 6) further emphasize how upstream dam construction and irrigation projects critically alter downstream flooding regimes, biodiversity and livelihood dynamics within the broader Hadejia-Jama'are system. This reiterates the urgent need for integrated water governance and management.

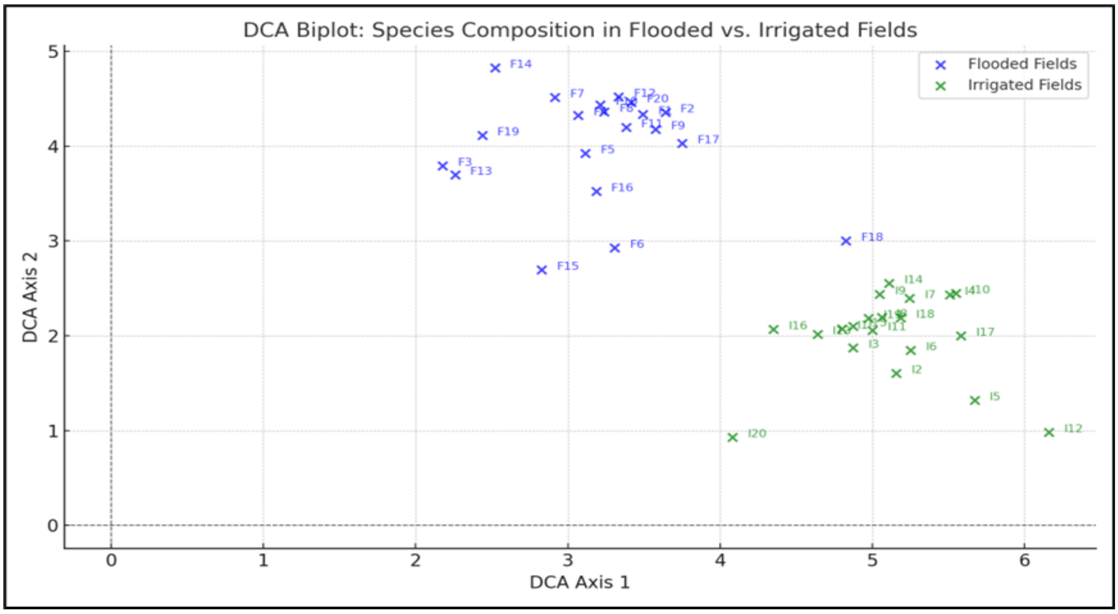

Fig. 5. DCA biplot of species composition within the study area.

Overall, this study significantly enhances the understanding of hydrology-species interactions in Sahelian wetlands. It provides robust, evidence-based recommendations crucial for guiding sustainable rice production, effective biodiversity conservation and comprehensive wetland management within this invaluable ecosystem.

Conclusion

This study documented and analyzed Poaceae diversity and distribution in the Hadejia-Nguru Wetland, emphasizing the impact of hydrological conditions on species composition. A total of 46 species were recorded, with greater diversity in flooded habitats, where Panicoideae dominated, highlighting seasonal flooding's role in species coexistence and ecological stability. DCA showed distinct species compositions, with hydrophytic species like *Echinochloa stagnina* and *Oryza barthii* thriving in flooded areas, while drought-tolerant species dominated irrigated fields. The study underscores the importance of hydrological variability in sustaining species diversity and provides insights for wetland conservation and sustainable land use planning. Future research should explore the long-term impacts of water regime modifications on species composition and weed-rice competition dynamics. It should also evaluate targeted Integrated Weed Management (IWM) strategies-such as selective removal, strategic flooding and crop rotation-tailored to control dominant competitors.

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Authors' contributions

AIT conducted the fieldwork, performed data analysis and drafted the manuscript. RR and BA revised the manuscript. MSV provided species identification and contributed to manuscript revision. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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