Journal of Ecosystem Science and Eco-Governance (JESEG)

Vol. 6, No. 1 | June 2024
PRINT ISSN 2704 4394 | ONLINE ISSN 2782 8522
DOI: 10.54610/jeseg.v6i1.85

Floristic Inventory, Diversity, and Community Structure of the Riparian and Coastal Sand Dune Landscapes in the Lower Padsan River Basin, Laoag City, Ilocos Norte, Philippines

Archie A. Along, Dawn Rosarie F. Orboc, and Laurence B. Calagui*

Department of Biology, College of Mathematics and Natural Sciences, Caraga State University, Ampayon, Butuan City 8600, Agusan del Norte, Philippines

*Corresponding Author
*Email: aaalong@carsu.edu.ph

Received: February 2, 2024
Revised: May 24, 2024
Accepted: June 26, 2024
Available Online: June 30, 2024

Cite this article: Along, A.A, Orboc, D.R.F., & Calagui, L.B. (2024). Floristic Inventory, Diversity, and Community Structure of the Riparian and Coastal Sand Dune Landscapes in the Lower Padsan River Basin, Laoag City, Ilocos Norte, Philippines, *Journal of Ecosystem Science and Eco-Governance*, **6**(1):20-33.

ABSTRACT

Padsan River basin, the largest river system in Laoag City, Ilocos Norte, encompasses two vital ecological landscapes: coastal sand dunes and riparian areas. Despite its ecological importance, the floristic diversity of these landscapes still needs to be better understood and documented. A vegetation assessment was conducted to characterize the composition, diversity, and community structure of plants in the lower Padsan River landscapes. Eighteen 10 m x 10 m nested quadrats were established across six sampling stations. The study recorded 82 species of vascular plants from 80 genera and 41 families. Fifty-two percent are introduced species, 48% are native species, and 27% are invasive species. The plant life forms are composed of trees (34 spp.), herbs (17 spp.), vines (13 spp.) and grasses (9 spp.). Fabaceae and poaceae were the most species-rich plant families. *Prosopis juliflora* (Candaroma) was the most dominant tree species, comprising 29% of the entire population. The lower Padsan River basin landscapes exhibits moderate tree diversity (H' = 2.7), with Shannon diversity indices ranging from 0.89 to 2.43 across sampling locations. The riparian areas showed higher tree Shannon diversity, richness, and evenness, while the coastal sand dune areas had higher tree dominance but lower Shannon diversity. The plant community structure varies between the two types of ecological landscapes (ANOSIM Global R=0.7, $p<0.05$). *P. juliflora* dominates the coastal sand dune, while a mix of the *Leucaena-Pithecellobium-Terminalia* community characterizes the riparian area. This study provides essential baseline information on the floristic diversity and community structure, serving as a foundation for developing an integrated river management plan and strategies for conserving important ecological landscapes in the downstream section of the Padsan River Basin.

Keywords: *Downstream, Ecological landscapes, Laoag River, Northwestern Luzon, Plants, Vegetation*

1 Introduction

The Padsan River Basin, also known as the Laoag River or Sarrat River, is the largest river system in the province of Ilocos Norte, with a total length of 73.1 kilometers and a drainage basin of 1,320 km² (DENR EMB 2021). Its main channel and bodies of water bisect and run through the eastern towns in Ilocos Norte down to Laoag City, the province's capital city. The watershed and significant tributaries of the Padsan River originate from the central portion of the Cordillera Mountains, the most extensive mountain range running north and south in the Northern Part of Luzon Island (JICA 1997). This mountain range is also an important site for floristic studies. It is considered the last frontier of contiguous old-growth forests in the Ilocos Region and the northwestern portion of the country (Batuyong et al. 2021). The river basin provides various ecosystem services in Ilocos Norte, such as food sources, protection from storms, habitat for flora and fauna, and maintenance of water quality, among others (DENR EMB 2021).

The riparian and coastal sand dunes are the two significant ecological landscapes that dominate the lower Padsan River basin. The riparian zones occur along riverbanks and floodplain areas. Meanwhile, the river mouth comprises coastal sand dunes, which are composed of loose, well-sorted, fine-grained sub-angular to subrounded sand, with a thickness varying from 0 to 50 meters (JICA 1997). This is part of the more enormous La Paz sand dune, the only significant dune field development located on the northwest coast of the Philippines (Hesp 2004). These coastal flats and beachfront areas are known for recreational activities such as sandboarding in Laoag City. Despite its ecological significance, more studies are needed to understand these important landscapes' floristic diversity, composition, and status in the lower Padsan River Basin.

Coastal sand dunes are fragile and globally threatened ecosystems that serve as a natural barrier against waves and windy storms and are generally generated by the interaction of tides, waves, and sand particle size (Kutiel et al. 2000; Šilc et al. 2017; Anbarashan et al. 2022). Plant and animal communities in the sand dunes ecosystem have particular ecological requirements, which determine their position along the environmental gradients from the seashore (Carboni et al. 2010; Anbarashan et al. 2022). The coastal sand dune vegetation has been extensively studied in other areas of the tropics (Tordoni et al. 2021; Anbarashan et al. 2022,); however, biodiversity studies and information, particularly flora, of such important and only sand dune ecosystem in the Philippines is lacking and remains poorly understood.

The riparian areas constitute a small part of a watershed that contributes to rivers' overall diversity and functioning (Goebel et al. 2003; Pasion et al. 2021). Riparian zones, riverbanks, riversides, and floodplains are distinct terrestrial landscapes, serving as ecotones that bridge the river's aquatic ecosystem with the adjacent land ecosystem. (Nilsson and Svedmark 2002; Pasion et al. 2021). These ecosystems provide important services such as protecting water quality and reducing stream bank erosion, which act as natural protection areas from frequent flood and flow pulse events and provide a habitat for a diverse group of organisms (Pasion et al. 2021). The vegetation of the riparian ecosystem is characterized by a continuum of species dispersed from the higher slope to the active river channel. This ecosystem supports multiple life forms, including trees, shrubs, herbs, and grasses.

Rapid urbanization, human encroachment, and industrial development activities are among the major environmental disturbances in the lower Padsan River. For instance, dredging activities are conducted in the lower Padsan River to reduce siltation and flooding, gain economic benefits, and create local livelihoods (DENR EMB 2021). Human economic activities can interfere with river structure and function in varying forms and intensity, affecting plant communities' character, diversity, and species richness (Myśliwy 2010; Stępień et al. 2019).

This study provides an inventory of plants in the less explored coastal sand dune and riparian landscapes, including their diversity and community structure, in the Lower Padsan River Basin, Ilocos Norte. The information is a foundation for policymakers and local government units to develop integrated river management strategies and conservation efforts for these ecologically important landscapes, which are subject to multiple uses and environmental disturbances.

2 Materials and Methods

Study Area and Entry Protocol

The study was conducted in the Lower Padsan River Basin, Laoag City, Ilocos Norte, Northwestern Luzon, Philippines, in November 2019 (Fig. 1). North-western Luzon experiences a monsoon climate characterized by a dry season in the lowlands spanning from November to April and a wet season from May to October (Stevenson et al. 2010). Laoag City has an annual rainfall of 2187 millimeters, a mean annual temperature of 27.6°, and a mean relative humidity of 79% (PAGASA-CADS 2024). Notably, during the wet season, rainfall shortages linked to the ENSO phenomenon can occur (Stevenson et al. 2010).

All research activities were conducted following an approved entry protocol established in collaboration with the Provincial Government

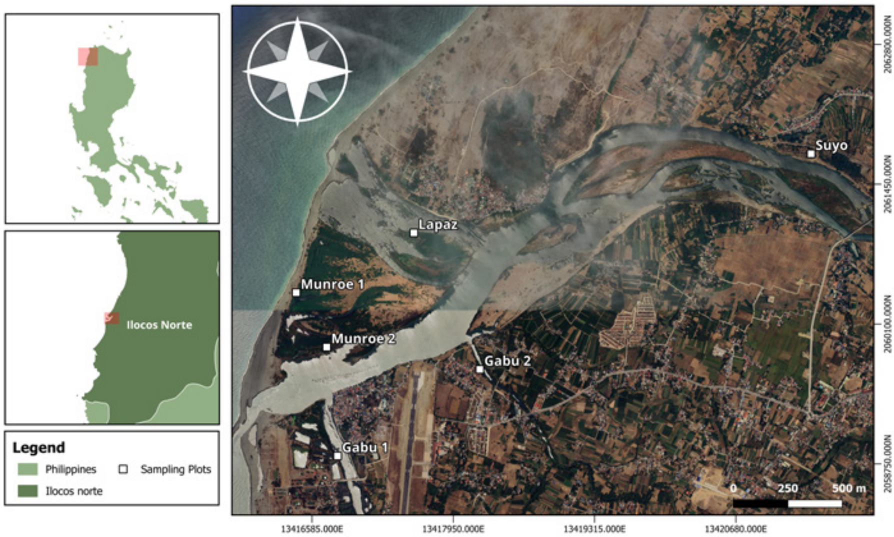

Figure 1. The map of sampling stations along Padsan River, Laoag City, Ilocos Norte, Philippines. The map was generated using QGIS version 3.36.2

of Ilocos Norte (PGIN). Permissions and necessary approvals were obtained from the appropriate authorities before commencing the study, and all research practices adhered to guidelines for ethical conduct in the field.

Vegetation Sampling

Two dominant ecological landscapes, riparian and coastal sand dunes, in the lower Padsan River basin were selected, each with three sampling stations for vegetation sampling. The selection of sampling stations was based on the observable characteristics of each identified landscape, including the type of substrate, zonation, and presence of vegetation. The coastal dune areas are located towards the seaward zone, while riparian areas are in the riverbanks towards the landward zone and river tributaries.

Three sites were selected in the coastal dune: Munroe 1, Munroe 2, and La Paz. Munroe 1 and 2 sites are located on the beachfront and side of Munroe Island, respectively (Fig. 2a, 2b). Munroe Island is a small coastal landform forming into a delta in the river mouth of Padsan. This island lies between the Lapaz and Gabu sites fronting the West Philippine Sea and splits the river into two small channels. Small ponds were also observed in Munroe. Moreover, the Lapaz site is in Brgy. Lapaz, adjacent to Munroe Island and west of Brgy. Suyo (Fig. 2c). The construction of a small port (known as "Free port" to locals) serves as access to the sea for locals and a docking area for boats. A dike was also constructed on this site to prevent severe flooding. Munroe and Lapaz sites are part of the LaPaz coastal dune in Laoag City, which is dominated by sandy substrate (Hesp 2004). Thorn bushes, herbs, grasses, and patches of beach forest trees characterize coastal dune vegetation. Additionally, multiple sandbars formation is dominated by mats of grass and sedge vegetation. In the riparian area, three sites were established: Suyo, Gabu 1, and Gabu 2. The Suyo site is located inwardly near the bypass bridge of Laoag City (Fig. 2d). Gabu 1 and 2 are small tributaries of the lower Padsan River in Brgy. Gabu Norte and Gabu Sur (Gabu 1) and Brgy. Cavit (Gabu 2) (Fig. 2e, 2f). For the uniformity of site coding, the small tributary in Brgy. Cavit is referred to as "Gabu 2". These sites are characterized by sandy-muddy to clay substrate and dominated by landward forest trees, grasses, and sedges thriving along riverbanks. In Gabu 1, planted mangroves such as *Rhizophora* spp., human settlers, and fish cages were observed. The Riparian area is converted into residential areas with houses interspersed between remnants of vegetation.

A nested quadrat was used for vegetation sampling to inventory the plant species and determine its composition, diversity, and vegetation structure in the two landscapes. Quadrats were

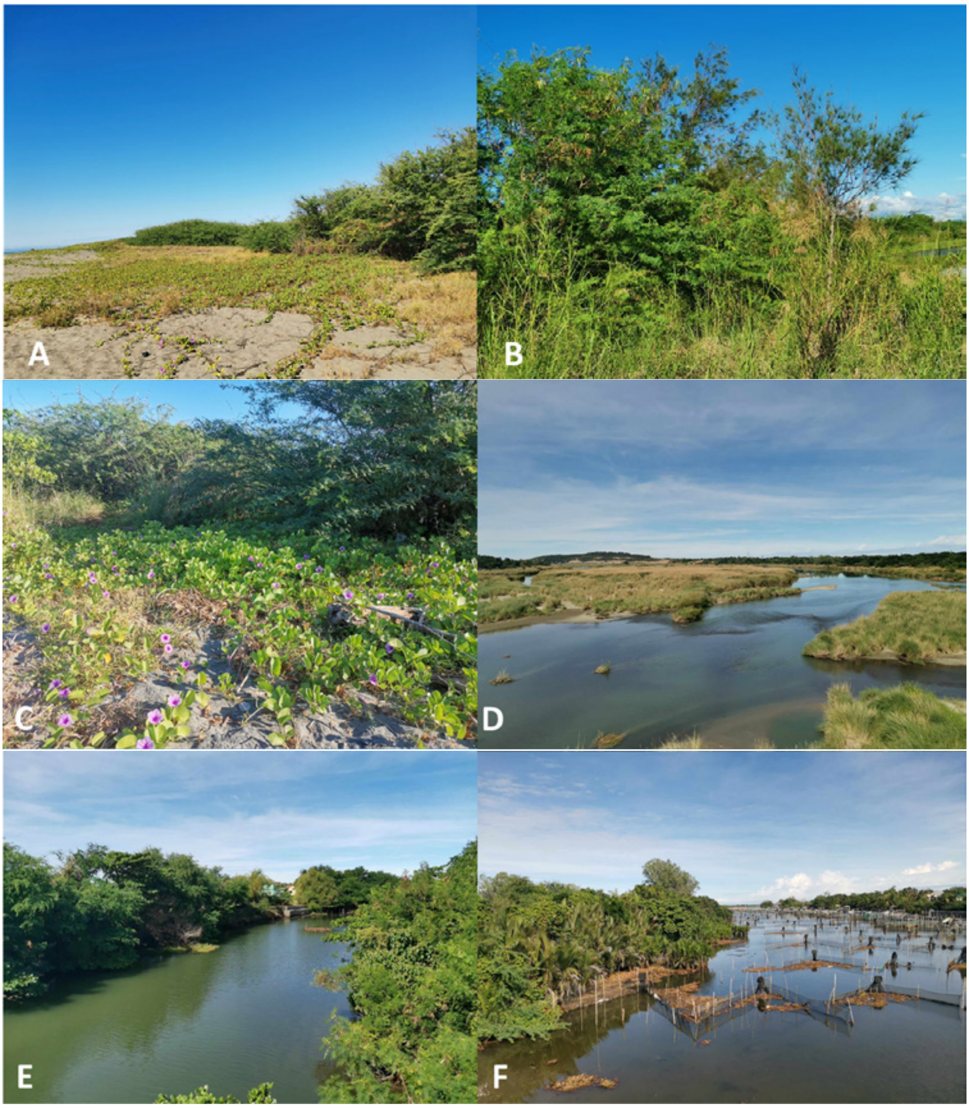

Figure 2. The sampling sites in the lower Padsan River basin a) Munroe 1 and b) Munroe 2 sites in Munroe Island, c) Lapaz, d) Suyo, e) Gabu 1 in Gabu Sur/Norte and f) Gabu 2 in Brgy. Cavit

randomly established in areas with sufficient vegetation cover. In each station, three (3) 10 m x 10 m fixed area nested quadrats were established for trees with a diameter at breast height (DBH) ≥10cm. Smaller quadrats measuring 5 x 5 m were established for shrubs, saplings, and poles, while 1 m x 1 m for herbaceous plants <1 cm tall. All species of flora inside the plot were identified, counted, and measured. Vegetation parameters such as diameter at breast height (DBH), basal area (BA), and tree height were recorded. The DBH taken 1.3 m above the ground was measured using tape. The DBH and BA were calculated based on the formulae given by English et al. (1997). A Global Positioning System device (Garmin GPSMAP 64sc) was used to determine the location of each plot. Random meander sampling was also done between plots to enrich the data on species richness and create a comprehensive list of species accounts in the lower river basin.

Documentation and Identification of Plants

Plant species were identified to the lowest taxon possible using the taxonomic keys, protologues, comparison of types, and publications from floras and monographs (Merrill 1926; Brummitt 1992; Madulid 2000; Regrario et al. 2017; Giesen et al. 2006; Primavera et al. 2004; Melana and Gonzales 2000; and Primavera and Sadaba 2012). Websites such as philippineplants.org (Pelser et al. 2011) and Plants of the World Online (POWO 2022) were also utilized. Documentation of diagnostic features (i.e., flowers, fruits, leaves, and roots) was conducted. Residency status, invasiveness, and conservation status were determined using the Global Invasive Species Database (Invasive Species Specialist Group 2015), IUCN Red List of Threatened Species (IUCN 2023), and list of Philippine threatened plant species by the Department of Environment and Natural Resources (DENR) Administrative Order 2017-11 (DENR 2017).

Data Analysis

The biodiversity indices used in the study are species richness, abundance, Shannon diversity, Pielou's evenness, and species dominance index. The abundance of trees was used to compute the biodiversity attributes of flora in the sampling sites. Paleontological Statistics Software package (PAST) version 4 was used to calculate the biodiversity indices in this study (Hammer et al. 2001).

Data ordination techniques using non-metric multidimensional scaling (nMDS) and cluster analyses were used to visualize the community structure of plants based on the tree abundance. The analysis generated dendrogram and nMDS plots for visualization. Analysis of similarities (ANOSIM) was done to test similarities and differences in plant community structure between the two landscapes. This procedure supports the generated dendrogram and ordination of the plant community structure evaluation. A similarity percentages (SIMPER) analysis was used to determine the significant contributions of plants to the dissimilarity of community structure. PRIMER 6 software was used to analyze the community structure of trees (Clarke and Warwick 2001; Clarke and Gorley 2006).

3 Results and Discussion

Composition of Plants

The study revealed 82 plant species from 41 families and 80 genera in the riparian and coastal sand dune landscapes of Lower Padsan River, Ilocos Norte (Table 1). Of these, 79 species were angiosperms, two pteridophytes, and only one gymnosperm. In the coastal sand dune, the common trees include *Prosopis juliflora* (Candaroma), *Casuarina equisetifolia* (Agoho), *Terminalia cattapa* (Talisay), *Acacia mangium* (Mangium), and *Leucaena leucocephala* (Ipil-Ipil). The dominant herbaceous plants were *Spinifex littoreus, Panicum repens, Ipomoea pes-caprae,* and *Canavalia maritima*. These species colonize open areas, sandbars, coastal flats, bushland, and thickets in the mouth of the Padsan River basin.

The riparian vegetation consists of mixed tree species growing along riverbanks, such as *Gmelina arborea* (Gmelina), *Samanea saman* (Acacia), *Eucalyptus globulus* (Bagras), *Calophyllum inophyllum* (Bitaog), and *P. juliflora*. Five mangrove species are found in Gabu 1 and 2, the small tributaries of the lower Padsan River, including *Rhizophora mucronata, Rhizophora apiculata, Nypa fruticans, Acrostichum aureum,* and *Acrostichum speciosum*. Mats of grass and sedges also thrive in the sandbars along river floodplains, including *Arundo donax, Cyperus compactus,* and *Saccharum spontaneum*.

The plant species richness in riparian areas is generally higher than in coastal dune landscapes. Across sampling locations, Gabu 2, one of the tributaries of the Padsan River, contains the highest number of species (n=37), followed by Suyo (n=35) and Lapaz (n=33). Both sites in Munroe Island had the lowest number of species, particularly on the beachfront (Munroe 1; 18 species). As to plant life forms, results revealed that trees dominate the riparian and coastal dune areas with a total of 34 species, followed by herbs (17 species), vines (13 species), and grasses (9 species; Fig. 3). These growth habits are present in all sampling sites in Padsan River.

The Padsan River holds much lower species richness and diversity compared to other river basins in the country (Malabrigo et al. 2014; Lubos et al. 2016; Sarmiento et al. 2017; Sarmiento et al. 2022), and forest ecosystems found in higher elevations of the Cordillera Mountains in

Table 1. The species richness, residency status, and occurrences of flora in the riparian and coastal sand dune habitats of the lower Padsan River basin

Family	Species	Residency Status	Common Name	Riparian			Coastal Sand Dune		
				G1	G2	SY	M1	M2	LP
Acanthaceae	*Ruellia tuberosa* L.	IT			/	/			
Amaranthaceae	*Amaranthus spinosus* L.	IT / IV	Kalunai	/				/	/
	Celosia argentea L.	IT		/					
	Buchanania arborescens (Blume) Blume	NT	Balinghasai			/			
	Mangifera indica L.	IT	Manga	/	/				
Apiaceae	*Centella asiatica* (L.) Urb.	NT							/
Apocynaceae	*Tabernaemontana pandacaqui* Lam.	NT					/		
Araceae	*Colocasia esculenta* (L.) Schott	NT							/
Arecaceae	*Cocos nucifera* L.	NT	Niyog	/	/	/			/
	Nypa fruticans Wurmb	NT / IV	Nipa	/	/		/		
Asteraceae	*Chromolaena odorata* (L.) R.M.King & H.Rob.	IT / IV	Hagonoy	/		/			
	Elephantopus tomentosus L.	IT	Elepante		/				
	Mikania micrantha Kunth	IT / IV	Mote mote		/	/		/	/
	Sphagneticola trilobata (L.) Pruski	IT / IV						/	
	Synedrella nodiflora (L.) Gaertn.	IT			/	/			/
Bignoniaceae	*Dolichandrone spathacea* (L.f.) Seem.	NT	Tiwi	/					
Calophyllaceae	*Calophyllum inophyllum* L.	NT	Bitaog	/	/				
Cannabaceae	*Trema orientale* (L.) Blume	NT	Hanabiong		/				
Caricaceae	*Carica papaya* L.	IT	Papaya			/			
Casuarinaceae	*Casuarina equisetifolia* L.	NT / IV	Agoho					/	/
Combretaceae	*Combretum indicum* (L.) DeFilipps	NT					/		/
	Terminalia catappa L.	NT	Talisay	/	/	/	/	/	/
Convolvulaceae	*Ipomoea pes-caprae* (L.) R.Br.	IT					/	/	/
Cucurbitaceae	*Luffa cylindrica* (L.) M.Roem.	IT	Wild upo	/	/	/	/		/
	Melothria pendula L.	IT					/	/	/
Cyperaceae	*Cyperus compactus* Retz.	NT							/
Ebenaceae	*Diopyros* sp.	NT		/					
Euphorbiaceae	*Euphorbia pulcherrima* Willd. ex Klotzsch	IT	Poinsettia		/				
	Jatropha gossypiifolia L.	IT / IV		/			/		/
	Macaranga tanarius (L.) Müll.Arg.	NT	Binunga			/			
	Melanolepis multiglandulosa (Reinw. ex Blume) Rchb. & Zoll.	NT	Alum		/	/			
	Ricinus communis L.	IT / IV	Tangan tangan			/			
Fabaceae	*Acacia mangium* Willd.	IT / IV	Mangium	/		/		/	
	Canavalia maritima Thouars	NT	Pataning dagat					/	
	Centrosema pubescens Benth.	IT				/			
	Clitorea ternatea L.	IT	Blue ternate		/				
	Derris trifoliata Lour.	NT			/			/	
	Gliricidia sepium (Jacq.) Kunth	IT	Mansanitas			/			/
	Leucaena leucocephala (Lam.) de Wit	IT / IV	Ipil ipil	/	/	/	/	/	/
	Mimosa pudica L.	IT / IV	Makahiya		/				
	Pithecellobium dulce (Roxb.) Benth.	IT	Kamatsili	/	/	/			

Notes: Sampling sites (G1=Gabu 1, G= Gabu 2, M1=Munroe 1, M2=Munroe 2, LP=Lapaz, SY=Suyo); / =presence of species; Residency Status (IT=Introduced Species, NT=Native Species, IV=Invasive Species)

Table 1. The species richness, residency status, and occurrences of flora in the riparian and coastal sand dune habitats of the lower Padsan River basin (continuation)

Family	Species	Residency Status	Common Name	Riparian			Coastal Sand Dune		
				G1	G2	SY	M1	M2	LP
	Pongamia pinnata (L.) Pierre	NT	Bayok	/	/	/		/	
	Prosopis juliflora (Sw.) DC.	IT / IV	Candaroma	/	/		/	/	/
	Pterocarpus indicus Willd.	NT	Narra			/			
	Samanea saman (Jacq.) Merr.	IT / IV			/	/			
	Sesbania grandiflora (L.) Poir.	IT	Katurai						/
Flagellariaceae	*Flagellaria indica* L.	NT	Uwag		/				
Lamiaceae	*Gmelina arborea* Roxb. ex Sm.	IT	Gmelina			/			
Lecythidaceae	*Barringtonia acutangula* (L.) Gaertn.	NT	Potat	/	/				
Malvaceae	*Kleinhovia hospita* L.	NT	Bitan ag	/		/		/	/
	Sida acuta Burm.fil.	IT	Wireweed		/	/		/	/
	Sterculia foetida L.	NT					/		
	Hibiscus tiliaceus L.	NT	Malibago		/				/
Meliaceae	*Azadirachta indica* A.Juss.	IT	Neem tree	/	/	/			
	Swietenia macrophylla G.King	IT	Mahogany	/					
Moraceae	*Ficus septica* Burm.fil.	NT				/			
Moringaceae	*Moringa oleifera* Lam.	IT	Malunggay						/
Myrtaceae	*Eucalyptus globulus* Labill.	IT	Bagras	/		/			
Passifloraceae	*Passiflora foetida* L.	IT / IV						/	
Petiveriaceae	*Rivina humilis* L.	IT			/				
Phyllantaceae	*Breynia cernua* (Poir.) Müll.Arg.	NT	Turog	/	/	/			
	Glochidion lutescens Blume	NT		/			/		
Piperaceae	*Piper aduncum* L.	IT / IV	Buyo buyo						/
Poaceae	*Arundo donax* L.	IT / IV	Talahib	/	/	/		/	/
	Bambusa vulgaris Schrad. ex J.C.Wendl.	IT / IV	Kawayan		/	/		/	/
	Dactyloctenium aegyptium (L.) Willd.	NT	Crowfoot grass				/	/	/
	Eleusine indica L.	IT		/		/	/		
	Imperata cylindrica (L.) Raeusch.	IT	Cogon		/	/		/	/
	Panicum repens L.	IT / IV		/				/	
	Saccharum spontaneum L.	NT		/	/	/	/	/	/
	Spinifex littoreus (Burm.f.) Merr.	NT		/		/	/		/
Pontederiaceae	*Eichhornia crassipes* (Mart.) Solms	IT / IV	Water hyacinth		/				
Pteridaceae	*Acrostichum aureum* L.	NT	Palaypay		/				
	Acrostichum speciosum Willd.	NT	Palaypay	/					
Rhamnaceae	*Ziziphus jujuba* Mill.	IT / IV							/
Rhizophoraceae	*Rhizophora apiculata* Blume	NT	Bakhaw lalaki	/					
	Rhizophora mucronata Poir.	NT	Bakhaw babae	/					
Rubiaceae	*Morinda citrifolia* L.	NT	Apatot	/	/		/	/	
	Nauclea orientalis (L.) L.	NT	Bangkal			/			
Taccaceae	*Tacca leontopetaloides* (L.) Kuntze	NT							/
Verbenaceae	*Lantana camara* L.	IT / IV	Baho baho		/	/			
	Vitex rotundifolia L.f.	NT / IV	Beach vitex		/		/		
No. of Species	**82**			**33**	**37**	**35**	**18**	**23**	**33**

Notes: Sampling sites (G1=Gabu 1, G= Gabu 2, M1=Munroe 1, M2=Munroe 2, LP=Lapaz, SY=Suyo); / =presence of species; Residency Status (IT=Introduced Species, NT=Native Species, IV=Invasive Species)

Northern Luzon, Philippines (Malabrigo 2013; Batuyong et al. 2020; and Napaldet 2023). Plant richness is associated with ecological and growth limiting factors such as species-specific habitat requirements, type of substrate, physicochemical properties, and other habitat characteristics of dune and riparian ecosystems (Carboni et al. 2010; Šilc et al. 2017; Pielech and Czortek 2021; Peilech 2021; and Anbarashan et al. 2022).

Riparian ecosystems are recognized for their high plant species richness and diversity (Naiman and Décamps 1997; Peilech 2021). Riparian diversity is not evenly distributed in rivers but responds to the spatial gradients in the riparian zone from the springs towards river mouths (Ward 1989; Peilech 2021), with the highest diversity in middle river reaches than in river mouths (Nilsson et al. 1989). Several factors can affect riparian diversity and richness, including hydrological and disturbance regimes, light availability, habitat productivity, water flow, soil moisture, erosion, accumulation rates, and other factors (Larsen et al. 2019; Pielech and Czortek 2021; and Peilech 2021).

In coastal sand dune landscapes, the plant species documented in this study were also found in other areas in the tropics (Miththapala 2008; Anbarashan et al. 2022). Sand dune plants thrive in regions characterized by high temperatures, strong winds, and intense waves. These conditions often result in unstable anchorage for the plants, leading to the desiccation of plant tissues and breakage (Packham and Willis 1997; Miththapala 2008). The sand remains loose and porous in this environment, constantly altering the substrate. As an adaptation, plants near the shoreline develop sideways-growing roots and shoots that lie close to the ground. This growth pattern results in a dense mat on the surface, as seen in species like *I. pes-caprae* and *S. littoreus*. As one moves further inland to more stable dunes, plants adopt a more upright growth posture. Also, due to temperatures rising to 50°C, sand dune plants tend to exhibit xeromorphic characteristics by having a very thick outer layer of leaves and often reduced leaves to spiny projections like *S. littoreus* (Packham and Willis 1997; Miththapala 2008).

Family Fabaceae is the most represented plant family with 14 species (17%), followed by Poaceae (10%), Asteraceae (6%), Malvaceae (6%) and Euphorbiaceae (5%) (Table 1). The rest of the plant families comprise ≤ 2% species each. Fabaceae, commonly known as legumes, bean, or pea family, is the third-largest plant family of terrestrial plants with various growth habits, can fix nitrogen, and can adapt to adverse habitat conditions. The Poaceae, or the grass families, include bamboo, perennials, and annual plants. These families have been considered pioneer species with a wide range of ecological amplitude and can adapt to denuded and newly formed sandy habitats. Several studies have also found dominance of Poaceae, Fabaceae, and Asteraceae families in sand dune vegetation in the tropics (Rao and Sherieff 2002; Rodriguez et al. 2011; and Anbarashan et al. 2022) and lowland tropical rivers and riparian ecosystems (Mligo 2017, Sarmiento et al. 2017; and Sarmiento et al. 2022). In the study area, representative species of Poaceae and Fabaceae often form homogenous cover along with the riparian and coastal areas.

Prosopis juliflora (Candorama) is the most dominant tree species, comprising 29% of the entire tree population (Fig. 4). This species is present in five sampling stations and is most abundant in Munroe Island and Lapaz and grows along with specialized sand dune plants, *I. pes caprae* and *S. littoreus*. It forms dense thornbushes and thickets on dry coastal dune habitats. The species are also encroaching and mixing with the riparian forest

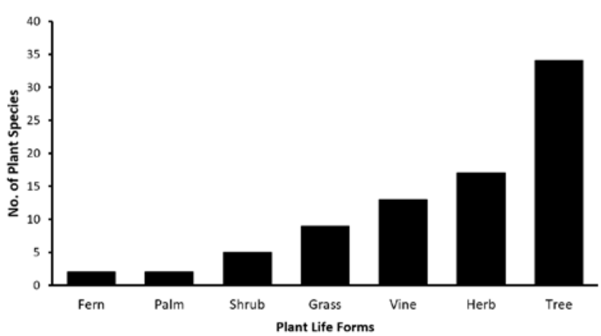

Figure 3. The species richness of plant life forms in the Lower Padsan River Basin

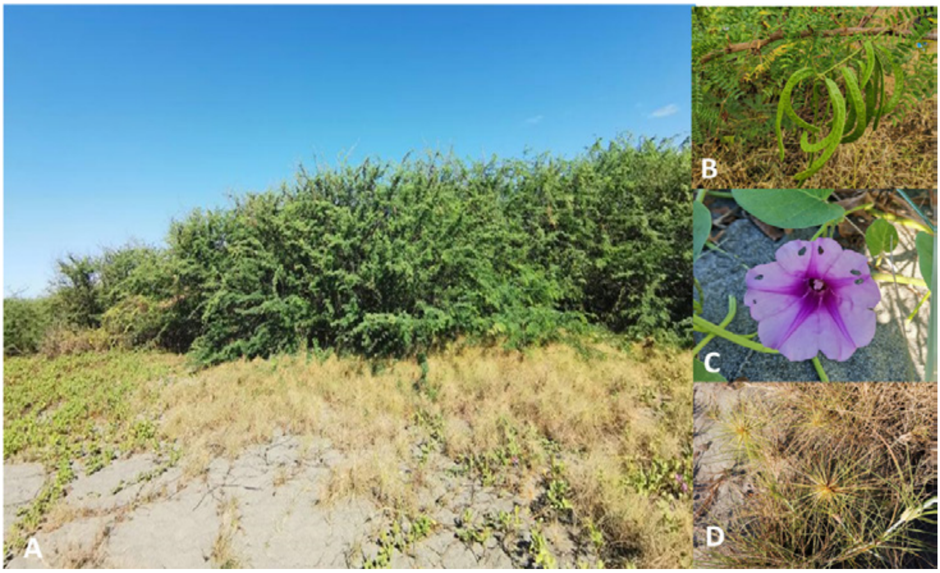

Figure 4. The coastal sand dune areas of Munroe Island are dominated by invasive b) *Prosopis juliflora* and specialized sand dune plants, c) *Ipomoaea pes caprae* , and d) S*pinifex littoreus*

in the tributaries of the Padsan River. *P. juliflora* is a salt-tolerant, nitrogen-fixing small tree or shrub plant reaching 3-8 m tall and native to the Neotropics; however, it is widely spread and thoroughly naturalized in the Philippines (Primavera and Sadaba 2011). It is considered one of the world's worst invasive species due to its aggressive behavior, broad ecological amplitude, and ability to outcompete native vegetation rapidly, which needs to be eradicated (Invasive Species Specialist Group 2015).

Ecological status

As to residency status, 52% of plants are introduced species, 48% are native species, and 27% are invasive species (Fig. 5). Of the invasive species, 23% are both introduced and invasive, and only 4% are both native and invasive species. The higher percentage of introduced species and occurrence of invasive species are associated with ecological and disturbance factors in sand dunes and riparian habitats of the Lower Padsan River.

Different kinds and degrees of disturbances are found to increase alien species and decrease native species in dune areas (Salgado et al. 2022) and riparian landscapes (Renöfält et al. 2005; Stępień et al. 2019). In the downstream of Padsan River, several observed anthropogenic disturbances are likely linked to the increase in introduced and invasive species, like *P. juliflora*. In some studies, the dominance of *P. juliflora* is linked with human activities and failed conservation strategies, which in turn replace native species in dune habitats of Cuddalore, India (Anrabashan et al. 2022).

Tree diversity and structure

The lower Padsan River basin exhibits moderate tree diversity (H' = 2.7), with Shannon diversity indices ranging from 0.89 to 2.43 across different sites. Specifically, the riparian areas located inwardly (Gabu 1 and 2 and Suyo) contain higher tree diversity, richness, abundance, and evenness. Moreover, the coastal dune areas (Lapaz, Munroe 1 and 2) showed higher tree dominance but lower diversity, species richness, abundance, and evenness (Table 2). Among the sampling sites, Suyo, located near the Laoag bypass bridge, has the highest tree diversity (H'=2.43) and species richness (n=15) and lowest dominance (0.11). Conversely, Munroe 1, located on the beachfront of Munroe Island, has the lowest diversity of trees (H'=0.89) attributed to its higher dominance (0.60) and lower species richness (n=6). The homogenous stands of *P. juliflora* contributed to the high dominance of the site. The diversity trend across sites from highest to lowest is as follows: Suyo>Gabu 2>Gabu 1>Lapaz>Munroe 2>Munroe 1.

The structural features of trees in the study area were calculated and presented in Table 3.

The total stand basal area was 18 $m^2\ ha^{-1}$, a mean DBH of 13 cm, and a mean height of 8.6 m. Among the sampling sites, riparian areas in Gabu 1 and 2 and Suyo had the highest mean DBH, stand basal area, and mean height. The largest trees in the sites with the highest DBH are *S. saman, E. globulus, G. arborea, Pithecellobium dulce, Sterculia foetida, C. inophyllum* (Fig. 6a). The tallest trees with highest mean height are *E. globulus, S. saman, G. arborea, A. mangium, T. catapa and C. inophyllum* (Fig. 6b).

Results suggest that the riparian areas had bigger and taller trees, located mainly in the landward and small tributaries of the river. Landward riparian areas are favorable for tree growth, likely due to high freshwater and nutrient inputs, various substrate types (muddy, clay, and sandy), and protection from wave and wind actions. The presence of trees in riparian ecosystems is essential, as they plays a vital role in maintaining river health by reducing sediment transport and channel degradation, strengthening riverbank stability, regulating flood, and sequestering significant amounts of carbon (Pasion et al. 2021).

Community Structure of Trees

The Bray-Curtis cluster analysis and non-metric multidimensional scaling showed two major grouping patterns at 30% similarity based on tree abundance (Fig. 7). The sampling sites of Gabu 1, 2, and Suyo formed a single cluster, while Munroe 1, 2, and Lapaz as another cluster. This grouping pattern showed that plant community composition varies significantly between coastal dunes and riparian landscapes. The clustering of sampling

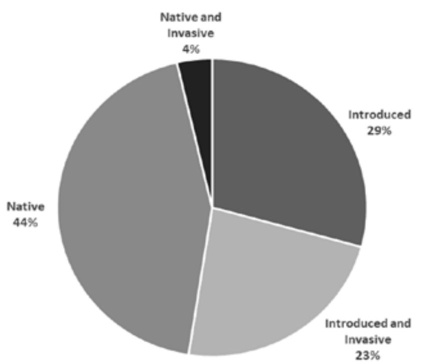

Figure 5. Residency status of plant species in the Lower Padsan River Basin

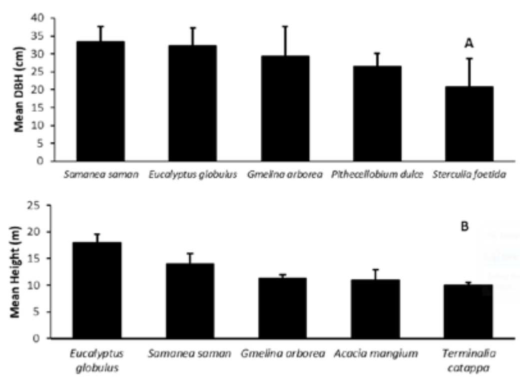

Figure 6. The top five trees with the highest a) mean diameter at breast height (DBH; cm) and b) mean total height (m). Error bars indicate the standard error of the mean (SEM)

Table 2. The plant diversity indices in the sampling sites of the Lower Padsan River

Diversity Indices	Riparian			Coastal Sand Dune			Overall
	Gabu 1	Gabu 2	Suyo	Lapaz	Munroe 1	Munroe 2	
Species Richness	10	12	15	10	6	4	33
Abundance	52	47	43	34	39	39	255
Species dominance	0.16	0.15	0.11	0.27	0.60	0.38	0.12
Shannon Weinner Index	2.01	2.11	2.43	1.68	0.89	1.10	2.7
Pielou's Evenness	0.74	0.69	0.76	0.54	0.41	0.75	0.43

Table 3. The tree diameter at breast height (DBH), height, and stand basal area in the Lower Padsan River Basin. The mean ± standard error of the mean (SEM) for height and DBH are shown

Tree Structural Features	Riparian			Coastal Sand Dune		
	Gabu 1	Gabu 2	Suyo	Lapaz	Munroe 1	Munroe 2
Mean DBH (cm)	14.1±2.5	16.1±2.7	15.3±2.5	4.19±1.7	10.6±0.9	12±2.0
Mean Height (m)	9.3±0.7	8.7±0.3	11.2±0.7	6.2±0.2	6.1±0.2	8.2±0.3
Stand Basal Area ($m^2\ ha^{-1}$)	3.36	5.82	5.77	0.29	1.47	1.33

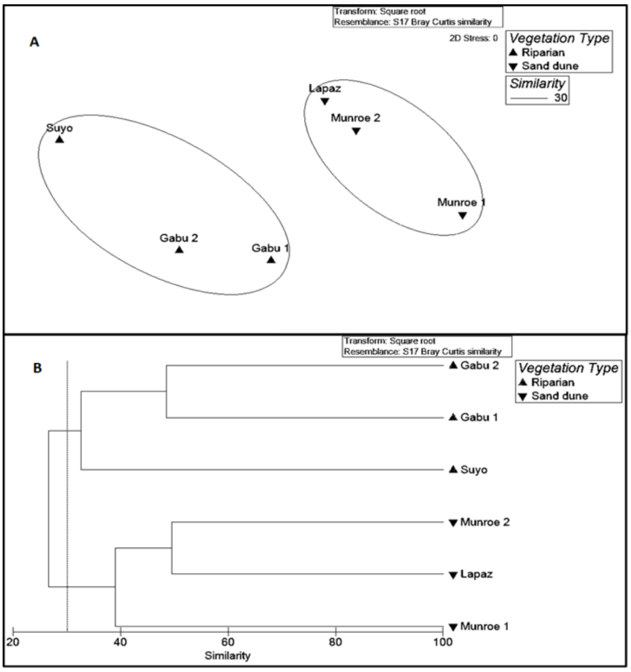

Figure 7. The multivariate exploratory analysis shows the a) nMDS plot and b) cluster dendrogram of sampling sites constructed based on the Bray Curtis Similarity Index

sites within a group indicates a higher similarity of plant communities sharing similar species composition. Conversely, clustering of sampling sites in between groups indicates lower species similarity.

Analysis of similarities (ANOSIM) test indicated significant dissimilarity (ANOSIM Global R=0.7, $p<0.05$) of tree communities between riparian and coastal dune environments in the Padsan River, supporting the grouping patterns found in cluster analysis and nMDS. ANOSIM pairwise comparison showed higher dissimilarity (Anosim R closer to 1) of plant communities between Suyo vs Munroe Island and Gabu 2 vs Munroe Island. In contrast, the comparison between Gabu 1 vs 2 and Gabu 2 vs Suyo showed higher similarities in plant communities (ANOSIM R closer to 0).

Similarity percentages (SIMPER) analysis showed that coastal dune is characterized by the dominance of *P. juliflora* with 68% contribution, while the riparian zone is a mixed tree community with the highest percentage contributions of *L. leucocephala* (24%), *P. dulce* (17%) and *T. catappa* (15%). In each site, the species with the highest contributions are the following: Suyo (*Kleinhovia hospita*), Gabu 1 (*C. inophyllum*), Gabu 2 (*Pongamia pinnata*), Lapaz (*P. juliflora*), Munroe 1 (*P. juliflora*), Munroe 2 (*P. juliflora*). Moreover, *P. juliflora* contributed the highest percentage contributions (10%) to the dissimilarity between riparian and coastal dune vegetation. The higher percentage of contributions indicates the dominance of species, thereby shaping the community similarity or dissimilarity and structure of plants in the lower Padsan river basin.

The spatial heterogeneity of plant communities in the ecological landscapes of the lower Padsan River basin is likely associated with environmental factors such as the type of substrate, topography, and water flow. Previous studies showed that factors such as water flow, soil characteristics, topography, groundwater fluctuations, and landscape type influence the distribution and composition of plants in riparian areas (Fu et al. 2021; Zu et al. 2022). Soil conditions and topography are crucial in shaping plant community distributions and characteristics, influencing riparian vegetation's type, quantity, and quality (Zhao et al. 2020).

4 Conclusion and Recommendations

The coastal sand dune and riparian landscapes of the lower Padsan River basin are home to 82 plant species belonging to 80 genera and 41 families. Of these, 52% of plants are introduced species, 48% are native species, and 27% are invasive species. Riparian zones in landward areas contain higher diversity.

Given the scarcity of published data and the existing threats to important landscapes in the Padsan River basin, our data provide crucial baseline information for science-based interventions such as the development of management and conservation strategies and long-term monitoring of the anthropogenic impacts on biodiversity and ecosystem health of the river. These efforts are essential for maintaining the vital functioning of the river ecosystem as human economic activities, such as dredging, progress downstream in the Padsan River, Ilocos Norte. In-depth studies investigating the effects of environmental factors on the distribution and abundance of coastal sand dunes and riparian plants in the Padsan River Basin are recommended.

5 Acknowledgement

The authors would like to express their appreciation to the Provincial Government of Ilocos Norte (PGIN) for providing logistical support for the study. The team also extends their gratitude to Ms. Merle M. Ravelo and the local guides for their technical assistance during fieldwork and data collection, and to Mr. Nick Burias for generating the map used in this paper.

Statement of Conflict of Interest

The authors declare no conflict of interest associated with the submission and publication of this manuscript.

Author Contribution

AA Along spearheaded the conceptualization of the study, data curation, formal analysis, and the writing and editing of the manuscript. DRF Orboc and LB Calagui provided technical inputs for the writing and revision of the manuscript. All authors participated in the data collection and approved the final version of the article.

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