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Species Diversity and Distribution of Macrophytes in Different Wetland Ecosystems

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Abstract: Wetlands are vital and dynamic components of the global ecosystem, providing a wide range of ecosystem services such as water control and biodiversity. During 2015–2019, plant diversity and distribution of wetlands were studied in forty areas of the Mardan division, Khyber Pakhtunkhwa, Pakistan. A total of 282 vascular wetland plant species were identified, divided into 192 genera and 73 families. Poaceae, with 41 species, is the most diverse family of wetland plants, followed by Asteraceae, with 26 species. In the present study, wetland plants are classified based on the Cook classification system. It is interesting to note that all the life forms were present in the study area except Plankton. Helophyte life form was represented by the highest number of plants with 177 plants and 62.5 percent of total wetland plants, followed by Tenagophyte with 42 plant species (14.8%) and Hyperhydate with 27 plant species (9.5%). Based on the distribution pattern of 282 species in 40 wetland sites, the most common plant species found was *Euphorbia helioscopia*, recorded from 36 locations, followed by *Cynodon dactylon* which was found in 32 locations. In Mardan division, the Gulshan Abad Khuwar had the highest number of species occurrences (83 species) accounting for 32% of all species, followed by Alo Khwar (59 species, 23%) and Hathian Khwar (50 species, 19%). The current work presents a comprehensive and field-based detailed survey of wetland plant distribution in this region, filling knowledge gaps in the Himalayas in particular, and having broader implications for wetland management policy and practice. Unfortunately, wetlands of the research area are facing high pressure due to an increase in human population, overgrazing, deforestation, construction of buildings and roads. The filling up of these water bodies is resulting in the loss of hydrophytic species diversity. Therefore, these wetlands need proper attention and effective protection from anthropogenic disturbances.

Keywords: wetlands; plant diversity; Cook's classification; species distribution pattern; habitats; Khuwar

1. Introduction

Typically, those areas of land that are covered by water are considered wetlands [1]. Perennial bodies of water that are formed by underground sources of water and/or rainfall are categorized as wetlands [2–4]. These can be permanent or temporary [5]. Wetlands include different types of water bodies, such as ponds, boggy areas, floodplains and lagoons. Natural water bodies include rivers, lakes, streams, marshes, swamps, and bogs, while man-made water bodies include ponds, canals, fish farms, and paddy fields [6]. Among various types of aquatic ecosystems, wetlands are highly productive and resourceful ecosystems that provides direct as well as indirect services to human beings. Moreover, these wetland ecosystem services account for around half of total global ecosystem values, ranking first among all [7]. Wetlands cover almost 6% of the surface area of the world [8]. The Ramsar Convention use a wide-range and broader definitions of the many types of wetlands that were covered in its task, including lakes, rivers, swamplands, marshlands, peatland parcels, humid grasslands, deltas, tidal flats, estuaries, oases, mangroves, coral reefs, artificial sites, fish and many other aquaculture ponds, salt pans, reservoirs, dams, rice paddies, and irrigation culverts [9]. Wetlands reduce pollution and contamination by acting as natural filters, and by storing water during the rainy season, they acts as buffers and avoid floods [10].

Due to the speedy growth of the human population and the increase in anthropological activities, pressure on all types of resources has increased enormously [11]. The degradation of wetland ecosystems as a product of human actions is in fact damaging their functions [12]. Many actions of man are the most common causes of wetland damage [13]. Disturbance of the natural drainage system is harmful to ponds and lakes. Many natural events, such as floods and droughts, may cause serious threats to the wetlands. Wetlands perform like a sponge that can store water for a lengthy time. However, they cannot continue to play this role indefinitely. Many wetlands may dry up and overgrazing is an additional risk to wetlands [14].

Nearly half of the global wetlands that existed since 1900 have been lost [15,16]. The maximum loss occurred in the first half of the twentieth century. Since the 1950s, the wetlands of tropical and subtropical regions have been spoiled or vanished due to alteration for farming and land utilization for agriculture. It was found in 1985 that 56–65% of existing wetland areas were changed to agricultural fields in Europe and North America, 6% in South America, 2% in Africa, and 27% in Asia [15]. There are constant and ever-increasing demands for irrigation water and hydroelectricity. The flow of several rivers has been planned by constructing dams, headworks, and barrages. The resulting impacts on water bodies include receding underground aquifers, increasing salinity, diminishing fish stocks, and retreating biodiversity due to hindered migration and degraded habitation [17–19]. Many countries around the world are confronting the problem of sedimentation in their water reservoirs. According to [20], rising human populations and related developments are increasing the release of agricultural, domestic, industrial, and other contaminants into wetlands. There have been intermittent studies in many developing countries on pollutants and their harms [17]. About 58% of the reefs are at risk [21]. Moser et al. [12] detected that 84% of Ramsar listed wetlands are in danger due to ecological change. Similar threats to wetlands were considered for Asia [22] and tropical regions [23].

Plants found in wetlands can be classified into a variety of categories and groupings. Cook proposes one form of categorization [24]. Cook published "Aquatic and Wetland Plants of India," a reference book and identification handbook for vascular plants found in permanent or seasonal fresh water in India [24]. According to the classification system of hydrophytic plants by Cook [24], there are eight categories of life forms: Epihydates, Helophytes, Hyperhydates, Plankton, Pleustophytes, Rosulate, Tenagophytes, and Vittate. The aquatic flora of the West Dinajpur district was studied by Mitra and Mukherjee [25]. They classified the plants following Cook's classification system. The findings revealed various life forms, out of which Helophyte was the dominant class with 85 species (49.13%), followed by Hyperhydate with 22 species (12.71%) and Tenagophyte with 35 species (20.23%).

The significance of wetlands and the severity of threats were globally recognized and considered in the 1960s and later. At present, Pakistan's wetlands program is working to

safeguard and encourage the globally significant biodiversity of the country's wetlands. The current research area has important characteristics for the survival of all types of flora. However, except for a few short studies from the allied regions on specific plant characteristics, no substantial research has been carried out in the study area. Keeping these aims in mind, the present study was designed to investigate the diversity and distribution of wetland plants in different water bodies (habitats) of an unexplored area (Mardan division) of Pakistan.

2. Materials and Methods

2.1. Study Area

Mardan Division is a part of the Peshawar Valley. The geographic coordinates of division are latitude 34°12′0″ N and longitude 72°2′24″ E. The elevation range of the valley is 400–2056 m above sea level. Mardan Division is bounded on the north by Malakand and the Burner area, on the south by Nowshera district, on the east by Hazara division, and on the west by the Malakand protected zone and the Charsadda district. The total area of the Mardan division is 3046 km^2. The area is crossed by several khuwars, rivers, and nalas, among which the Sher Garhkhwar is the principal one. The main tributaries of the Sher Garhkhwar are Jalala Khwar and Jandaie khwar, with some minor nallas on the left and right. During the rainy season, all those small rivers flow with a sufficient volume of water, and during the hot season, they shrink to a narrow channel. As per the 1998 census report, the human population of the Mardan division was 2,486,904 [26]. Most of the people are farmers in villages. Mardan division may be divided into two parts: the southwestern plain and the northeastern hilly area. Alluvial deposits cover the entire region. The Swabi area is a part of an ancient lake. The summer season is very hot. In June, the temperature reaches 43.5 °C (110.3 °F) (Heat Index 69 on 7 July 2006). The coldest months are December and January. In January, the averages minimum temperature is 0.5 degrees °C (32.9 °F) [27]. The total precipitation noted for August, the rainiest month, is 125.85 mm [28]. The major crops of the area are wheat, sugar cane, rice, tobacco, maize, mustered and rape seed. Orange, apricot, plum, peach, pear, mango, leechi, and apple are the chief fruits. Irrigated canals are the main source of irrigation. Normally, the stream flows from north to south. Most streams drain into the Kabul River. Baghiari-Khawar, Muqam-Khawar, Naranji Khwar, Kundi, Polah, Wuch, Jammu, Gajai, Badah, Sargari, and Badri Khwars are important water bodies. The famous river Indus rises from the northeast mountains of the Gadoon area at Satkhaiter.

2.2. Field Survey and Data Collection

Detailed and extensive literature survey was first carried out on wetlands areas. Based on this information, extensive field investigations were conducted between 2015 and 2019. Habit, geographic range, habitat type, altitudinal range, distribution range, threats such as over-exploitation, grazing, and degradation of habitat were keenly observed in the natural environment.

Systematic exploration was conducted in the selected wetlands to survey the flora. Field trips were planned to study all forty selected areas to obtain all wetland plant species covering the wetland environments. These field excursions were planned and harmonized with the complete vegetation season. The wetland plant specimens were collected by standard procedures from the various wetland environments such as slow-flowing water, streams, stationary ponds, sewerage canals, paddy fields, and marshy habitats of the research area. The data collection included date of collection, collection number, flowering season, occurrence, and habitat. All the important information about wetland plants was documented in the field notebook on the spot. The wetland plant specimens collected in the field were pressed, dried out, and well preserved according to the standard technique as given by Krishnasamy et al. [29]. Voucher specimens of wetland plants were deposited in the herbarium of the department of botany at Hazara University, Mansehra, Pakistan on standard herbarium sheets is 28 × 11.5 cm.

2.3. Wetland Flora Identification

The Flora of Pakistan was used for taxonomic identification of the collected wetland plants [28,30–33] at the Herbarium of the Department of Botany, Hazara University, Mansehra, Pakistan. Four to five samples per species were examined under a microscope (Kyowa SZF, 0.75X–3.4X) to evaluate morphological characteristics such as vegetative and reproductive traits, and the results were compared to that of Flora of Pakistan [28,30–32].

2.4. Classification of Wetland Plants

Following the concept of Cook [24], aquatic and wetland vascular plants are classified into eight groups based on their growth forms. The various growth forms are as follows:

1. Plants with roots penetrating the substrate while leaves and/or stems are floating on but not rising above the water surface. species of this group have contact with soil, water, and air.
2. Helophyte: These plants are not physiologically bound to water but tolerate longer periods of submergence.
3. Hyperhydate: plants with roots penetrating the substrate but leaves and/or stems emerging above the water surface. Like Epihydate, these plants have contact with soil, water, and air.
4. Plankton: plants occupying the zone between the bottom and the lower surface of the water, i.e., free swimming below the water surface.
5. Pleustophyte: plants free-floating on the water surface, not attached to or penetrating the substrate.
6. Rosulate: plants submerged, rooted in the substrate, and leaves borne in a rosette.
7. Tenagophyte: plants with the juvenile stage submerged in or floating on water and the adult (flowering) stage terrestrial.
8. Plants submerged, rooted in the substrate, leaves arranged along elongated stems.

2.5. Data Analysis

The geographical positioning system (GPS) was used to determine the altitude, longitude, and latitude of all the wetland sites (40) in the Mardan division. ArcGIS software was used to create a map of the research area. All the wetland macrophytes that were collected were entered into a Microsoft Excel spreadsheet. Tables were prepared based on data collected during fieldwork about species distribution, habits, and life form classes in various wetland areas. In addition, the values from these tables were used to create graphical representations.

3. Results

3.1. Floristic Composition

To cover the distribution of vegetation of the wetlands in the research area, forty areas were selected for study (Figure 1, Table 1). The present study reveals that the study area possesses 282 species of wetland vascular plants belong to 192 genera and 73 families. Different growth forms were recorded in the study area dominated by herbs (254 species, 90%), followed by shrubs (19 species, 7%), and trees (9 species, 3%). Nonetheless, pteridophytes were recorded in lowest numbers. Previous wetland plant investigations in adjacent areas show a very low number of findings in respect of the number of plant species.

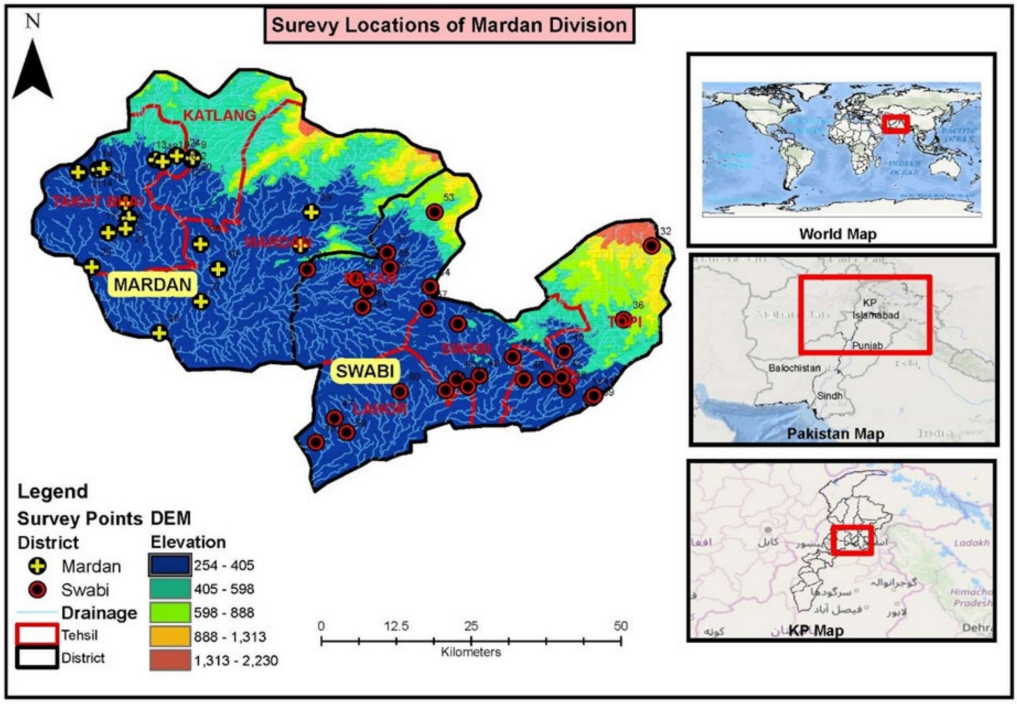


Figure 1. Map of the Mardan division showing research areas. The color variation is indicating to the altitudinal variation. The black and red lines indicate the district and tehsil boundaries, respectively. The symbols "plus" and "circles" show the investigational sites (water bodies).

Table 1. List of coordinates and altitude of different localities visited in Mardan division.

S.No	Names of Wetland Area	District	Latitude (N)	Longitude (E)	Altitude (m)
1	Gulshan Abad Khwar	Mardan	34°.38182	71°.92256	377
2	Alo Khwar	Mardan	34°.39713	72°.05485	400
3	Hathian Khwar	Mardan	34°.38080	71°.91491	375
4	Hathian Jaba	Mardan	34°.38081	71°.91492	372
5	Jalala Khwar	Mardan	34°.30491	71°.95894	311
6	Khat kale-Hosaie Jaba	Mardan	34°.30785	71°.96029	328
7	Sher Garh Jaba	Mardan	34°.37525	71°.88667	356
8	Sher Garh Khwar	Mardan	34°.37631	71°.88490	356
9	Deraie Leekpanee Khwar	Mardan	34°.39566	72°.05473	391
10	Par Hotee	Mardan	34°.08422	71°.10020	278
11	Chanonro	Mardan	34°.39713	72°.05485	400
12	Cheel. Near Redibaba	Mardan	34°.39513	72°.00086	375
13	Doawo khwar (Gulmera)	Mardan	34°.38185	71°.92289	379
14	Gulmera	Mardan	34°.38190	71°.92299	383
15	Koheebarmool	Mardan	34°.40117	72°.03210	711
16	Umarabad nehr Bazar	Mardan	34°.33015	71°.95572	358

Table 1. *Cont.*

S.No	Names of Wetland Area	District	Latitude (N)	Longitude (E)	Altitude (m)
17	Tordher	Mardan	34°.29222	71°.95602	378
18	Saro shah	Mardan	34.23483	71.90499	314
19	Katlang	Mardan	34°.39801	72°.05566	387
20	Garyala	Mardan	34.26666	72.21666	396
21	Ismaeela and Adeena Khwar	Swabi	34°.23078	72°.22725	311
22	Satketar (Menz khwar)-Utla	Swabi	34°.26617	72°.74049	1098
23	Maneraie Khwar	Swabi	34°.14958	72°.45179	329
24	Gohatee Neher	Swabi	34°.20464	72°.41009	359
25	Tarbela	Swabi	34°.03922	72°.65115	321
26	Bada Khwar (Gandaf)	Swabi	34°.15592	72°.69943	476
27	Shekh Jana khwar	Swabi	34°.25609	72°.34595	328
28	Batakare Nehr	Swabi	34°.05175	72°.61323	332
29	Gala Hemlet Tarbela	Swabi	34°.04260	72°.65526	330
30	Mainai Khwar	Swabi	34°.10819	72°.61026	365
31	Right Bank Canal Tarbela Dam	Swabi	34°.04231	72°.65503	328
32	Jehangira	Swabi	33°.97468	72°.20178	280
33	Jalbai	Swabi	34.008499	72.267498	301
34	Kunda	Swabi	34.049999	72.43333	332
35	Shah Mansoor	Swabi	34.066666	72.449998	294
36	Naranji	Swabi	34.316665	72.416665	345
37	Turlandi	Swabi	34.199999	72.316665	304
38	Shewa	Swabi	34.233332	72.349998	309
39	Dandoqa	Swabi	34.174999	72.309332	318
40	Lahore	Swabi	34.048472	72.365583	282

The most diverse family of wetland plants is Poaceae, with 41 taxa, followed by Asteraceae, with 26 species, and Cyperaceae with 23 species. Aside from that, there are 29 families with only one species, accounting for around 39 percent of the overall family composition in the region. There are 11 families with three species, eight families with two species, four families with four species, two families with five species, and one family each with seven and nine species. On the other hand, based on generic diversity, there are 135 genera (total 192 genera) with one species, accounting for 70 percent of the total genera recorded in the district.

3.2. Classification of Wetland Plants

Here, the wetland plants are classified based on Cook's system of classification. It is interesting to note that of all the eight life forms, namely, Epihydate, Helophyte, Hyperhydate, Plankton, Pleustophyte, Rosulate, Tenagophyte, and Vittate, as mentioned by the Cook classification system, seven life forms are reported from the Mardan division. Only the Plankton life form was absent. All recorded plant species along with their family name, growth form and life form are given in detail in Supplementary Table S1. The values noted for each life form, number of plants, and percentage (%) are: Epihydate—15.3%; Helophyte—

177.6%; Hyperhydate—27.5%; Plankton—0–0; Pleustophyte—13.4%; Rosulate—1–0.4%; Tenagophyte—2–14.8%; Vittate—8–2.8%. Table 2 and Figure 2 show the overall number and percentage of each life form.

Table 2. Values for each life form, number of plant species and percentage.

Life Forms	Number of Plant species	Percentage (%)
1. Epihydate	15	5.3%
2. Helophyte	177	62.5%
3. Hyperhydate	27	9.5%
4. Plankton	0	0
5. Pleustophyte	13	4.6%
6. Rosulate	1	0.4%
7. Tenagophyte	42	14.8%
8. Vittate	8	2.8%

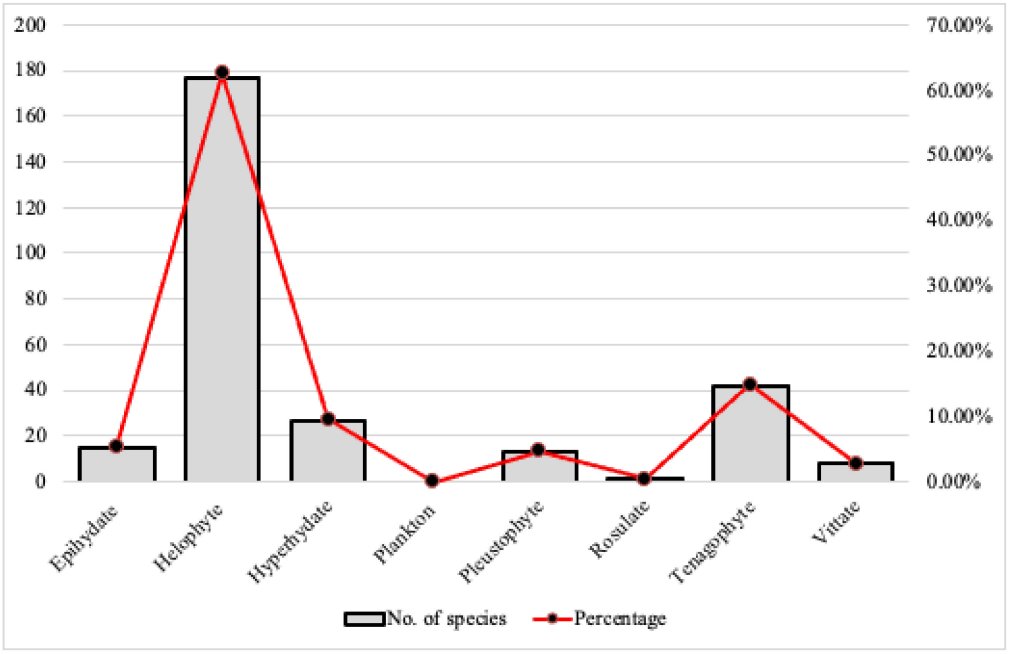


Figure 2. Cook ecological classification of wetland plants. Percentage of each life form.

3.3. Wetland Bodies of the Study Area

A study showed that the Mardan Division has both plains and mountainous areas. The whole area has plenty of fresh water. The atmosphere of the research area is suitable for a lot of wetland plant species. For these reasons, wetland plants are present everywhere. The study area possesses a rich flora, having all three types of plants: herb, shrub, and tree. The common habitats for the wetland plants of the research area are many natural ponds, diches, rivers, marshes, streams, springs, and canals. They maintain a rich hydrophyllus flora. However, unfortunately, these aquatic habitats of the research area are under a high threat at present. Some reasons are an increase in the human population and the construction of buildings and roads. Filling up of these water bodies thus causes a gradual loss of hydrophytic species diversity. Deforestation is a very common phenomenon in the study area. Plant resources as well as wetland areas are affected by various processes such as agriculture, wood collection, overgrazing, anthropogenic interaction, and building construction.

There is a vast difference in the number of plant species in different localities (Table 2). The highest number of species was recorded in Gulshan Abad Khwar (83 species, 32%), followed by Hathian Jaba (68 species, 26%), Sher Garh Jaba (61 species, 24%), Satketar (Menzkhwar)-Utla (60 species, 23%), Alo Khwar (59 species, 23%) and Chanonro (52 species, 20%). Moreover, Hathian Khwar had 50 species (19%), followed by Kohee barmool (46 species, 18%), Gala Hemlet Tarbela (39 species, 15%), Khat kale-Hosaie Jaba (34 species, 13%), and Maneraie Khwar (33 species, 13%). Furthermore, the remaining 29 sites had less than 13% of species (Figure 3 and Supplementary Table S2).

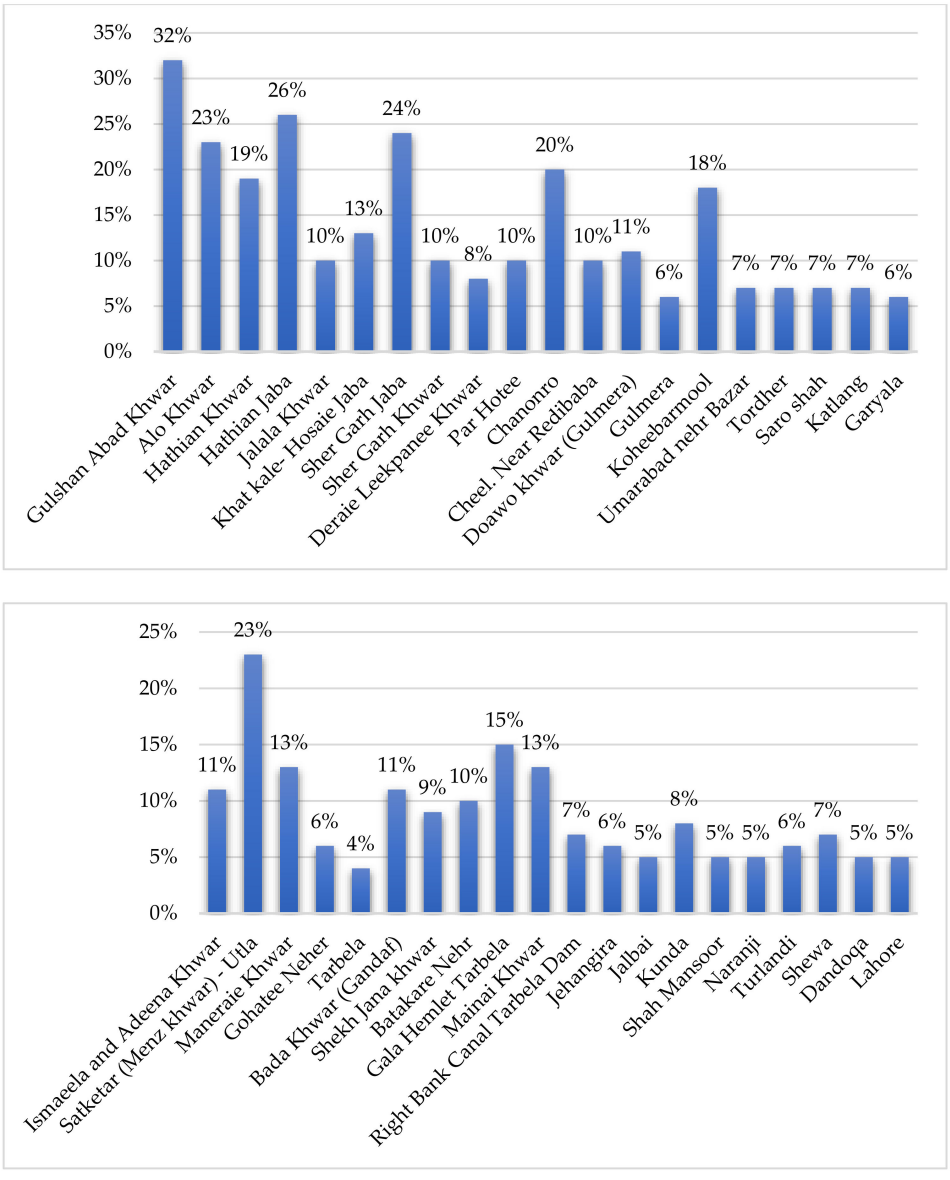


Figure 3. Number of species in different localities visited in Mardan division, KP, Pakistan.

3.4. Wetland Species Distribution in Different Water Bodies

Various localities visited in the research area were observed for the presence, absence, and abundance of all the explored wetland plant species (Supplementary Table S2). There is a large difference in the occurrence and distribution of a species in visited localities. For each wetland plant species, the presence was noted in different localities. For all the wetland flora the plant name and number of localities in which it was present listed as, *Euphorbia helioscopia* L.-36, *Cynodon dactylon* (L.) Pers.,-32, *Acrachne racemose* (Heyne ex Roem. & Schult.) Ohwi-32, *Adiantum capillus-veneris* L.-25, *Conyza canadensis* (Linn) Cronquest.-21,

Agrastis viridis (Gouan) Breistr.-19, *Taraxacum officinale* Webber.-19, *Mentha longifolia* (L.) L.,Fl.Monspel-19, *Rannuculus muricatus* L-16, *Coronopus didymus* (L.) Smith-16, *Fimbristylis bisumbellata* (Forssk.) Bubani.-14, *Paspalum paspalodes* (Michx.) Scribn.-14, *Agrostis exarata* Trin.-14, *Nasturtium officinale* R. Br.-12, *Verbena officinalis* L.-12, *Calendula arvensis* (Vaill.) L.-11, *Euphorbia prostrata* L.-11, *Alternanthera sessilis* (L.) R.Br. ex DC.-10, *Evolvulus alsinoides* (L.) L.-10, *Euphorbia hirta* Linn;-9, *Euphorbia granulate* L.-9, *Gerinium colinum* L.-9, *Oenanthe javanica* (Blume) DC.-9, *Origanum vulgare* L.-8, *Heteropogon contortus* (L.) P.Beauv. ex Roem. & Schult.-8, *Apium nodiflorum* Lag.-8, *Arundo donax* L.-8, *Asparagus gracilis* Royle ex Baker-8, *Cannabis sativa* L.-8, *Cnicus benedictus* L.-8, *Xanthium strumarium* L.-8, *Phragmites karka* (Retz.) Trin. ex Steud.-7, *Oxalis acetosella* L.-7, *Eryngium coeruleum* L.-7, *Hemarthria compressa* L.-7, *Bulboschoens affinis* (Roth) Drobov.-7, *Erigeron bonariensis* L.-7, *Coix lacryma-jobi* L.-7, *Cynoglossum lanceolatum* Forssk.-7, *Cyprus nutans* L.-7, *Marsilea crenata C. Presl.*-7, *Persicaria glabra* (Willd.) M. Gómes-7, *Ranunculus scleratus* L.-7, *Artemisia scoparia* Waldst. & Kit.-6, *Centaurea iberica* Trevir. ex Spreng.-6, *Brachiaria ramosa* (L.) Stapf.-6, *Centaurium centaurioides* (Roxb.) S.R.Rao & Hemadri.-6, *Cyperus brevifolius* (Rottb.)Endl. ex Hassk.-6, *Cyperus iria* L.-6, *Cyprus rotundans* L.-6, *Cyperus strigosus* L.-6, *Dicleptera bupleuroides* Nees in Wall.-6, *Liriope graminifolia* (L.) Baker-6, *Mazus japonicus* (Thunb.) Kuntze-6, *Chrozophora tinctoria* (L.) Raf., Chlor.-6, *Cirsium arvense* (Linnaeus) Scopoli-6, *Dicanthium annulatum* (Forssk.) Stapf.-, *Digeria muricate* (L.) Mart.-6, *Echinochloa colona* L.-6, *Launaea procumbens* (Roxburgh) Ramayya & Rajagopal.-6, *Persicaria lapathifolia* (L.) S. F. Gray.-6, *Verbascum thapsus* L.-6, *Veronica anagallis-aquatica* L.-6, *Misopates orontium* (L.) Raf.-6, *Artemisia vulgaris* L.-5, *Asplenium adiantum-nigraum* L.-5, *Bromus pifti* L.-5, *Canna indica* L.-5, *Clinopodium vulgare* L.-5, *Commelina benghalensis* L.-5, *Desmotachya bipinnata* (L.) Stapf in Thiselt.-5, *Eragrostis cilianensis* (All.) Vignolo ex Janch.-5, *Heliotropium strigosum* Willd.-5, *Mollugo nudicaulis* Lamk.-5, *Persicaria hydropiper* (L.) Spach.-5, *Phalaris minor* Retz;-5, and *Polygonum acumanatum* Kunth.-5.

4. Discussion

Wetlands are essential self-sustaining ecosystems that play an important part in the evolution of a diverse range of flora [34,35]. These aquatic and wetland plants are extremely important for long-term life support systems [36], including economic and aesthetic qualities, and have thus played a key role in the development of human settlements, agriculture, culture, and industrial progress [25]. Wetlands are regarded as the most valuable ecosystems for several reasons: (1) they are a significant source of food supply; (2) they are biological supermarkets because they are pools of animal and plant species; (3) they preserve biodiversity and are recognized as the kidneys of the landscape; (4) they stock nutrients and are considered the most productive ecosystems; (5) they are water reservoirs; (6). They provide beautiful tourist destinations; (7) Coastal areas provide protection from storms. Throughout the world, millions of people depend on wetland ecosystems. These people obtain the water, food, fuel, fiber, non-timber, and timber products required for their survival. Wetlands reduce pollution and contamination by acting as natural pollution filters and by storing the water content during substantial quantities of rain. This can avoid floods [10].

To cover the vegetation of wetlands in the research area, forty areas were selected for study. There was a vast difference in the number of plant species recorded in different localities. The highest percentage of plant diversity is recorded for Gulshan Abad Khwar, which shows the presence of 83 (32%) plant species at an elevation of 377m. Three species, i.e., *Euphorbia helioscopia*–36, *Acrachne racemos*–32, and *Cynodon dactylon*–32, show occurrences in most areas. Rehman et al. [37] also carried out a research study on aquatic plants in Bannu, KP, Pakistan, in which they showed the distribution of various aquatic plants in different habitats. Mulei et al. [38] studied the vegetation community structure and diversity in swamps undergoing anthropogenic impacts in Uasin Gishu County, Kenya. According to them, wetlands in Kenya faced continuous threats due to human activities.

For open areas, Poaceae, Asteraceae, and Cyperaceae are projected to be the most representative, as they provide excellent conditions for their establishment, such as high light intensity [39,40]. Both the Poaceae and Cyperaceae families stand out in the seasonal pond because some of their members are perennials with comparable ecological properties, reproducing quickly and dominating the habitat during floods and low water periods [41,42]. Furthermore, Cyperaceae species operate as monocot ridge mats, increasing environmental heterogeneity based on water and mechanical support availability thereby, encourages the next successional processes [43].

During the current study, no relationship between species richness and altitude was found. Despite the widely known concept that altitude reduces species richness due to decreased nutrient availability and slower rates of nitrogen mineralization and nitrification, studies on this topic are scarce in wetlands [44]. Despite its small size, the current study was able to demonstrate that there are altitudinal wetlands with significant richness, indicating to the importance of composition for conservation. It is possible to see a trend toward an increase in species number as the sampled area expands. These findings corroborated with those of Vestergaard and Sand-Jensen [45], where the authors discovered that species richness is more closely related to colonization of area than the total surface area.

Various studies have classified the wetland vascular plants diversity into many groups. In the present study, the wetland plants are classified based on the classification system adopted by Cook (1996). It is interesting to note that of all the eight life forms mentioned by Cook, all except the Plankton life form have been reported from the Mardan division. Moreover, the helophytic life form shows the highest number of plants with 177 plants and 62.5 percent of total wetland plants, followed by tenagophyte with 42 plant species (14.8%) and Hyperhydate with 27 plant species (9.5%). Bandyopadhyay and Mukherjee [46] have also classified the wetland plants of the Aquatic and Wetland Vascular Plants of Koch, Bihar District, West Bengal into different life form classes as given by Cook. It was also discovered that the helophyte life form is home to the greatest number of plants (83% of species). Similarly, the aquatic and wetland plants of west Dinajpur district, west Bengal with 85 (49%) plant species also show the highest frequency of helophyte (Hel) [25].

These species are crucial in maintaining stability and balance in various types of ecosystems. Therefore, it requires special attention, and these sties must be conserved. Unfortunately, these wetlands are declining at a faster rate and are under threats due to anthropologic activities around the world [47]. Urbanization, expansion of settlements, agriculture, drainage, pollution, and hunting are the top five threats in these areas [12]. In Pakistan, invasive aquatic weeds affected approximately 182,118 hectares of wetlands [17]. Scott [48] emphasized the use of new wetland inventories as a foundation for investigating wetlands loss; causes of wetland degradation are: (1) absence of effective guidelines and inefficient administration, coupled with alteration of wetland for farming practices; (2) changes in the flow of water system because of rapid population growth; (3) pollution and unsustainable wetlands utilization; (4) excessive use/extraction of wetland resources by humans; (5) off-site activities produce chemical and physical changes in wetlands. such as the addition of polluted water; (6) global warming, agriculture expansion, overharvesting of wild resources, roads and flood control infrastructure, industrial pollution, urban pollution, large-scale irrigation, forest cutting, and river canalization. These are the primary causes of wetland degradation in Pakistan [10].

5. Conclusions

The current research is the result of a comprehensive survey of the wetland flora of Mardan division. A total of 282 wetland plant species were recorded from different localities of the study area. These 282 vascular wetland plant species that belong to 192 genera and 73 families. The most diverse family of wetland plants is Poaceae, with 41 taxa, followed by Asteraceae, with 26 species, and Cyperaceae, with 23 species. Gulshan Abad Khwar was found with a maximum number of species (83 species, 32%) and having an altitude of 377 m, followed by Hathian Jaba (68 species, 26%). There is a vast difference in the

occurrence and distribution of wetland species in visited localities. For instance, *Euphorbia helioscopia* was recorded at 36 wetland areas and *Cynodon dactylon* and *Acrachne racemosa* at 32 sites. The study area has an important quality for the sustenance growth of all types of flora. Conservation of such wetlands is absolutely essential because they provide habitat for a wide range of plants and animals. Wetlands are critical to our survival because they filter pollution, recharge groundwater sources, and control floods. These aquatic habitats of the research area are under a high threat at present. Some reasons are an increase in the human population and the construction of buildings and roads. The filling up of these water bodies causes a gradual loss of hydrophytic species diversity. The wetlands area and their plant resources are severely affected by various anthropogenic factors such as agriculture, deforestation and wood collection, overgrazing, and building construction. Therefore, the wetlands should be given suitable and effective protection from anthropogenic disturbances such as harvesting, farming, and building infrastructures.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/app12094467/s1, Table S1: Cook ecological classification of the recorded macrophytes from different wetland ecosystems of the study area; Table S2: Distribution of wetland plant species in 40 different water bodies (wetland ecosystems).

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