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A Detailed Ecological Exploration of the Distribution Patterns of Wild Poaceae from the Jhelum District (Punjab), Pakistan

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Abstract: The purpose of this study was to investigate the taxonomic diversity, richness, and distribution patterns of Poaceae in relation to abiotic factors in the Jhelum district of the Pakistan Himalayas. We used a random sampling technique from 80 grids within 240 sites with a rich diversity of wild grasses and 720 quadrates in triplets from each site across the Jhelum district between 2019 and 2021 to collect data on grass species and the associated environmental factors and conditions. After evaluating the important value index for each plant taxa and for the environmental data, we analyzed the data using ordination and cluster analysis techniques. Fifty-two Poaceae taxa from twenty-nine genera were recorded within the study area. From a total of 52 recorded Poaceae species, 45 were native and 7 were invasive species. The life form (biological) showed the dominancy of 27 therophyte species, followed by 24 hemicryptophyte species, and 1 geophyte species. Microphyll had the leading leaf size spectra (27 species), followed by nanophyll (12 species), macrophyll (10 species), and leptophyll (3 species). The trend of the life cycle was the maximum (27 spp.) during the monsoon season, followed by spring (11 spp.), winter (8 spp.), and summer (6 spp.). The leading genera were *Setaria* with 9.61% of the species, followed by *Panicum*, *Cenchrus*, and *Brachiaria* with 7.69% of the species. *Aristida* and *Echinochloa* made up 5.76% of the species while *Chrysopogon*, *Digitaria*, *Eragrostis*, *Pennisetum*, and *Poa* made up 3.84% of the species. Other genera recorded single species. The leaf size spectra of grasses were dominated by microphylls (50%) followed by nanophylls (23.07%), macrophylls (19.23%), and leptophylls (7.69%). On the basis of the importance value index, the most dominant species was *Cynodon dactylon* (68), followed by *Dichanthium annulatum* (58), *Brachiaria ramose* (38), *Dactyloctenium aegyptium* (37), *Eleusine indica* (35), *Saccharum bengalense* (33), and *Cenchrus biflorus* (28). Two-way cluster analyses classified the grasses into three plant community associations based on the indicator plant species. Soil parameters as subsamples were tested for moisture, pH, EC, OM, macronutrients ($CaCO_3$, N, P, and K), and saturation while the ordination analysis revealed that they had a significant ($p \leq 0.002$) effect on vegetation associations. Overall, this study contributes to a better understanding of the influence of environmental factors on the composition and associations

of grass species and the development of scientifically informed management solutions for the ecological restoration of degraded habitats in this Himalayan region.

Keywords: Poaceae; environmental factors; ecological approaches; Pakistan Himalayas

1. Introduction

Vegetation compositional variations and the co-existence of species adequately represent the prevailing environment and/or environmental variables controlling the existence of a species in any region. Vegetation is defined as the classification, distribution pattern, structure, and composition of a plant species with respect to climatic, edaphic, and anthropogenic factors [1]. Vegetation represents the overall plant species in a certain habitat and environment with links to the physiognomic, synthetic, analytical, and quantitative features and is influenced by biotic and abiotic factors [2]. In the present study, the wild Poaceae flora and its ecological characteristics including habit, life cycle, life form, leaf size spectra, and flowering season were explored. Data about the life form and leaf size spectra can help us to understand the eco-physiological developments of plant communities [3,4], which show the climatic conditions. Little work has been completed on the life form of plant communities of alpine areas from Rudranath, Pakistan [5,6], and more detailed studies would be highly useful [7,8]. The major aim of the research was to record leaf size spectra, life cycle, life form, and other ecological aspects quantitatively [9] to clarify the distribution patterns of Poaceae.

Poaceae are the most successful Angiosperms on the planet, flourishing in every climate, accessible habitat, and phytogeographical zone. Poaceae account for about 15% of the diversity of the monocot species [10]. Members of the Poaceae family are on around 20% of the planet's land surface, making them ecological hegemons. Grasses are the principal source of nutrition for almost all living organisms. They are an essential part of many countries' urban and suburban environments, producing most human food and a variety of livestock feed. The majority of animals use forage grasses and natural pastures. Native Poaceae plant species provide a cost-effective source of nutrients for cattle while also helping to preserve soil integrity, water supply, and air quality.

Poaceae are the most crucial component of crops and livestock feed, as well as the primary source of income for many people in rural areas around the world [10]. Grasses are an essential ecological resource and a basic diet. They can be found in all climatic settings, including subalpine, xerophytic, and aquatic environments, and contribute to the production and maintenance of soil texture [3]. Grasses continually provide humus to the soil, meeting nutrient needs and increasing primary production [4].

In Pakistan, the Punjab province is divided into four regions: south, north, west, and center. The province is well-known for its dairy and meat production, as well as livestock management. This area is abundant in fodders, which include trees, shrubs, herbs, and grasses. However, wild grasses continue to be the most promising fodder resource. Grass is preferred over other fodders because it is more appealing to ruminants. As a result, grasses are the first choice for native people who manage livestock as fodder. Other benefits of grasses include their ability to grow vigorously regardless of the season and their ease of availability. Despite the fact that the scientific understanding of Poaceae is expanding, particularly the understanding of the link between grasses and animal health, [3,11,12] there are significant information gaps related to the ecological factors affecting the Poaceae family in the Pakistan Himalayas, particularly in the Punjab province. The Jhelum district has a diverse climate and topography [13] supporting a rich floral diversity. Nevertheless, it has attracted limited research attention until now. As a result, broad-scale ordination, and classification are useful for understanding the regional dynamics of grass species and associations, as well as for conservation, planning, and use. Keeping this in mind, the conservation of grasses is critical, and the current study was designed to address the

following research aims: (i) to document the taxonomic diversity of the Poaceae family in the study area; (ii) to understand the emerging trends within applied taxonomic diversity to document taxa and finally, (iii) to discover whether environmental factors influence the composition, diversity, and associations of species in the region.

Given the economic importance of grass species in the region under consideration, the findings of this study will guide sustainable grass management and habitat restoration, particularly in natural landscapes in this Himalayan region, with implications for the rest of the world.

2. Study Area

The Jhelum district in Pakistan is located to the north of the Jhelum River and is bordered to the north by Rawalpindi, to the south by Sargodha and Gujrat, to the east by Azad Kashmir, and to the west by the Chakwal district [14,15]. The district's climatic conditions are typical for a semi-arid, warm subtropical region with hot summers and harsh winters. Jhelum is a semi-mountainous range with an average annual rainfall of 880 mm and an average temperature of 23.6 °C [16]. The Jhelum River drainage area comprises almost 100,000 ha of the mainland of the plains. On the other hand, about 16,500 ha are covered by hills [13] (Figure 1). Jhelum is home to the world's second-largest salt mine (Khewra), spanning about 1000 ha. People in the Jhelum district have a broad range of life experiences, cultures, customs, and beliefs and have long used local plants for various purposes [12,17].

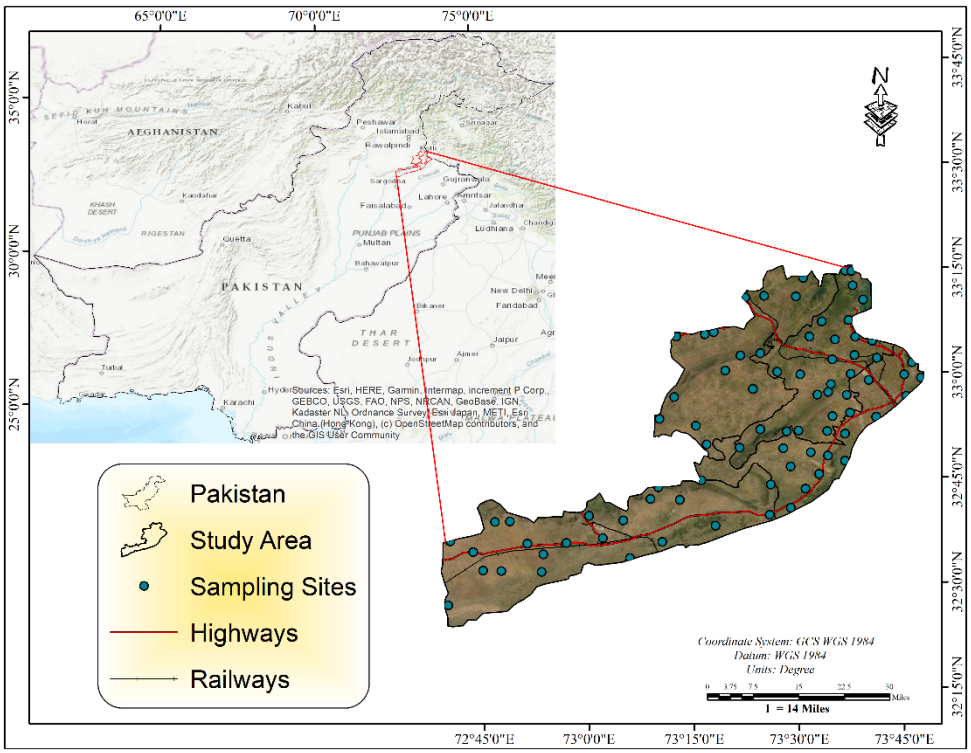

Figure 1. Description of study area with sampling sites.

3. Methodology

3.1. Vegetation Sampling

A comprehensive field survey was carried out to explore the botanical diversity in the Jhelum district (Punjab), Pakistan. The Jhelum district was separated into 80 sites based on the area's topography and climate and several visits were conducted throughout the early stages of the study from 2019 to 2021 to cover the variations in physiognomy and physiography. The entire district was divided into a total of 80 grids. Within each grid, a total of 3 sites/locations were randomly selected based on the heterogeneity and

physiognomy of the vegetation. Hence, a total of 240 sample sites were targeted and mapped. At each sample location a total of 9 plots (3 grasses per species) were studied. Similar plot sizes for herbs (1×1 m^2) were analyzed to collect the abundance data for each plant species. The density, frequency, and cover values of each plant species were recorded in the studied plots and the average values for each of the 720 sample quadrates were estimated. From each tehsil of the Jhelum district, sampling from each microhabitat viz. forest, arable land, dry land, grassland, mountain summits, roadsides, sandy places, scrubland, waste places, and wetlands were taken during field surveys. From each study site, triplet quadrates were selected. The size of the quadrates was 1×1 m^2 and they were laid out and randomly selected. Phytosociological measures such as frequency, density, plant cover, and the importance value index were calculated to evaluate the vegetation. The cultivation status, life form, seasons, and leaf size spectra of each species were recorded as essential and main components of the assessments. The quantitative vegetation measurements were calculated using the quadrate techniques. A GPS (Global Positioning System) called Garmin eTrex was used to determine the exact location of each site (latitude, longitude, and altitude).

Plants were collected and photographed during the field survey. Following identification using the Flora of Pakistan [18,19] (http://www.efloras.org/) (accessed on 25 September 2021), all samples were cross-referenced [6,20] with the floristic literature [21,22]. The collected plant specimens were marked with voucher numbers, pressed, properly dried, and lastly mounted on international standard-sized herbarium sheets. To avoid any taxonomic misinterpretation related to ordering and placement, the currently established binomials of each plant species and the family nomenclature followed the plant list ver. 1.1 (URL: http://www.theplantlist.org/) (accessed on 10 October 2021) (TPL, 2013), as proposed by [6,12,16] after the initial likely identification of specimens.

3.2. Soil Sampling

A handheld Global Positioning System (GPS) device was used to record the location data of the considered plots. The spatial distribution of vegetation communities is influenced by the physicochemical properties of the soil. Soil samples were collected in a polythene bag from each sampling site with the help of a spade at a depth of 6 to 10 cm. After thoroughly mixing the soil, it was air-dried, and then dry samples were sieved to remove particles larger than 2 mm (rock, rubbish, gravel). These subsamples were tested for moisture, pH, EC, OM, macronutrients ($CaCO_3$, N, P, and K), and saturation. A digital pH meter was used to determine the electrical conductivity (EC) and pH from the soil water extracts. The organic matter was determined using the Walkley–Black method, which was further refined, and the total nitrogen was determined using the Kjeldahl method [5]. The potassium (K) and phosphorus (P) contents were measured, and $CaCO_3$ was determined by acid–base neutralization. The moisture content in the soil samples was determined using a ScalTec Moisture analyzer set to 110 °C. The saturation percentage was estimated using the formula:

$$\% \text{ moisture} = \frac{\text{Wet soil} - \text{Dry soil}}{\text{Dry soil}} \times 100 \quad (1)$$

3.3. Ordination Analysis

Cluster analysis was performed to seek the relative contribution of each grass species in determined vegetation associations. This analysis also helped to identify the diagnostic as well as the rare plant species of each vegetation type, and their strength of affiliation with their respective groups. Ordination tools such as detrended correspondence analysis (DCA) were used to verify the results of the vegetation classification. Similarly, canonical correspondence analysis (CCA) was used to determine the role of environmental variables in the variations in the species data. The permutation test was used to evaluate the CCA model and in case of significant results, further CCA axes and predictors were tested for the order of importance. Both the simple and net effects of each variable were tested. The variance inflation factor (VIF)

of each variable was observed and a threshold value of ≤5 was used to include the variables in the final model. The ordination approach was applied to examine grass clusters and the influence of different environmental factors on these multivariate vegetation clusters. Three types of multivariate analysis were performed on the data sets relevant to grass vegetation as well as on edaphic factors i.e., Ward's method and Euclidean distances [6,23,24] were used to find the best pruning point for the dendrogram, DCA (Detrended Correspondence Analysis, and CCA (Canonical Correspondence Analysis).

3.4. Data Analysis

For further analysis, the species and environmental data were entered and arranged in Microsoft Excel 2016 according to CANOCO and PAST software specifications [25,26]. The importance value index of each grass species present in the 240 sampling sites was utilized as the basis for the cluster analysis. Ward's method and Euclidean distances were used to find the best pruning point for the dendrogram. The cluster analysis and diversity indices of each cluster group were calculated using PAST software (version 4.07). Canonical Correspondence Analysis (CCA) and Detrended Correspondence Analysis were performed using the CANOCO software, version 4.5 [7,23,27] to determine the impact of environmental gradients on the composition of the Poaceae species. The overall methodology used in this study is shown in Figure 2. A Two Way Cluster analysis (TWCA) was performed based on the presence and absence of the species (1/0).

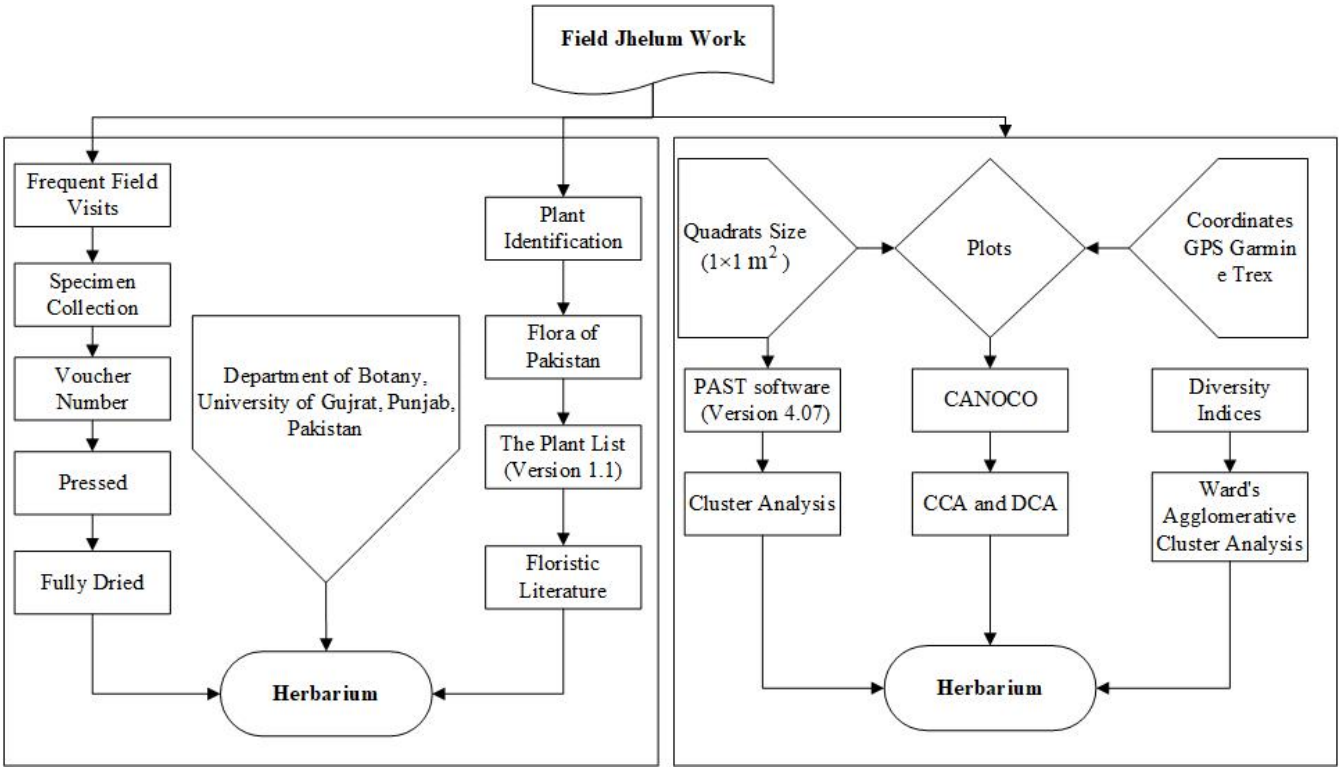

Figure 2. Flow chart of the methodology used in the current study.

4. Results

4.1. Species Composition and Functional Trait Diversity

The grass types and occurrence showed expected variations between and within the three associations of the study area. The data calculations focused on 52 wild species of Poacae which were recorded from all the sampled sites. From the Jhelum district, 52 grass species (Table 1) from 29 genera were recorded.

Table 1. Ecological characteristics of wild Poaceae from the study area.

Sr. No.	Cultivation Status	No. of Taxa	%	Sr. No.	Life Form	No. of Taxa	%
1.	Native	45	87	1.	Therophyte	27	52
2.	Invasive	7	13	2.	Hemicryptophyte	24	46
	Total	52	100	3.	Geophyte	1	2
					Total	52	100
Sr. No.	**Season**	**No. of Taxa**	**%**	**Sr. #**	**Leaf Size Spectra**	**No. of Taxa**	**%**
1.	Monsoon	27	52	1.	Microphyll	27	52
2.	Spring	11	21	2.	Nanophyll	12	23
3.	Summer	6	12	3.	Macrophyll	10	19
4.	Winter	8	15	4.	Leptophyll	3	6
	Total	52	100		Total	52	100

Overall, 45 native species (87%) and 7 invasive species (13%) were documented. The life form (biological) ordering results show the dominancy of the 27 therophyte species (52%), followed by 24 hemicryptophyte species (46%), and 1 geophyte species (2%) (Table 1).

The leaf size spectra of the wild Poaceae resulted in microphylls leading (27 species; 52%), followed by nanophylls (12 species, 23%), macrophylls (10 species; 19%), and leptophylls (3 species; 6%) (Table 1). The trend of the life cycle of wild Poaceae related to seasons shows that it is at a maximum during the monsoon season (27-spp., 52%), followed by spring (11 spp., 21%), winter (8 spp., 15%), and summer (6 spp., 12%) (Table 1).

The most dominant genera were *Setaria* with 9.61% of the species followed by *Panicum*, *Cenchrus*, and *Brachiaria* with 7.69% of the species, *Aristida* and *Echinochloa* with 5.76% of the species, and *Chrysopogon*, *Digitaria*, *Eragrostis*, *Pennisetum*, and *Poa* with 3.84% of the species each (Figure 3), while other genera represented single species. From these, 86.53% of the species were native, and 13.46% were introduced. The life form classification results revealed that the dominant life form was therophytes (53.84%), followed by hemicryptophytes with 4 species (4.23%), and geophytes with 1 species (1.92%) species. The leaf size spectra of grasses were dominated by microphylls (50%) followed by nanophylls (23.07%), macrophylls (19.23%), and leptophylls (7.69%) (Table 1). The collected data revealed that *Setaria* had the most species (5), followed by *Brachiaria*, *Cenchrus*, and *Panicum* (4 each), while the other leading genera were *Aristida* and *Echinochloa* (3 each).

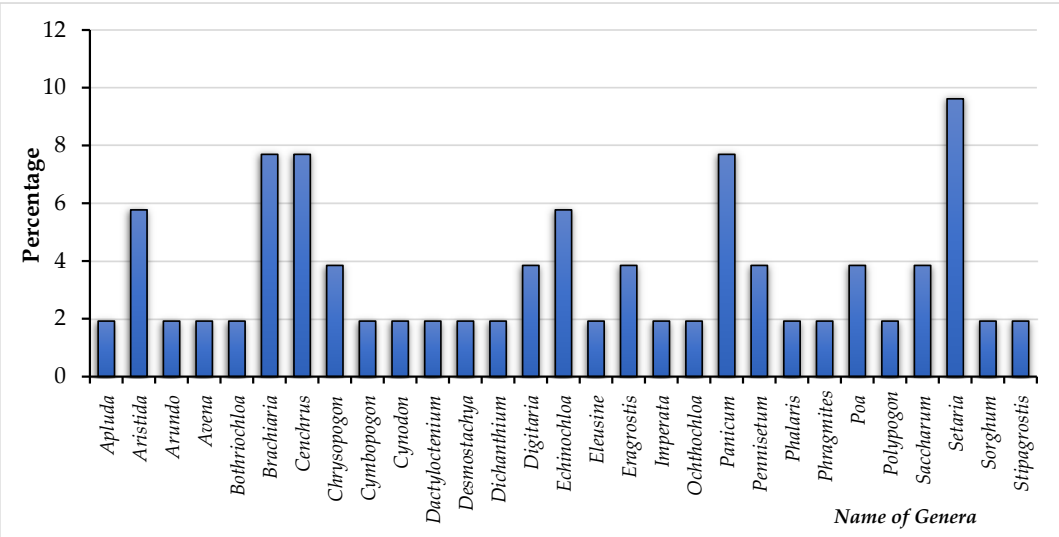

Figure 3. Percentage of species in the different genera.

4.2. Vegetation Classification of the Documented Species

Cluster Analysis of Grasses

The data were interpreted using the collected sampling from 80 grids on 240 sites with 720 quadrates in three significant associations using Ward's agglomerative cluster analysis (Figure 4). The cluster analysis revealed three associations of the sampling transect in the studied area. The species data matrix had 80 sampling grids with 240 sites in three associations (Figure 5). The species number and diversity indices of the three associations are given in (Table 2).

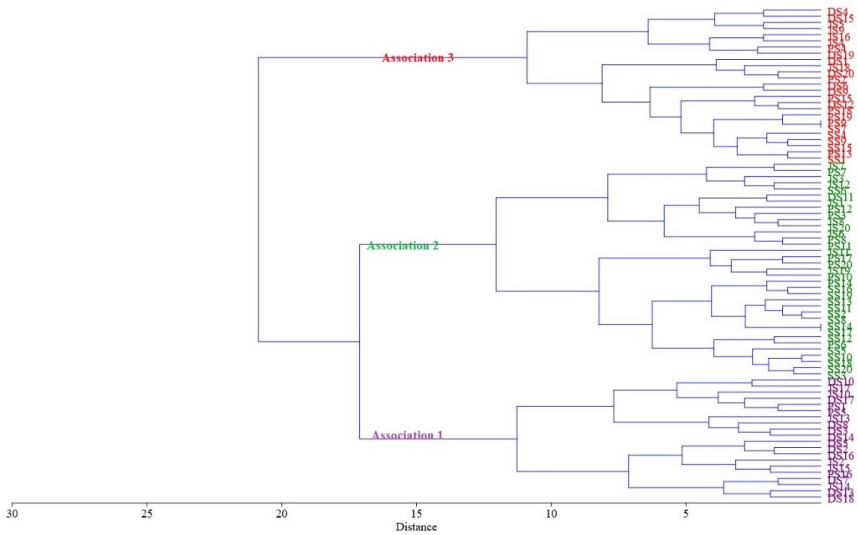

Figure 4. Three major associations of the sampling sites based on Ward's agglomerative cluster analysis.

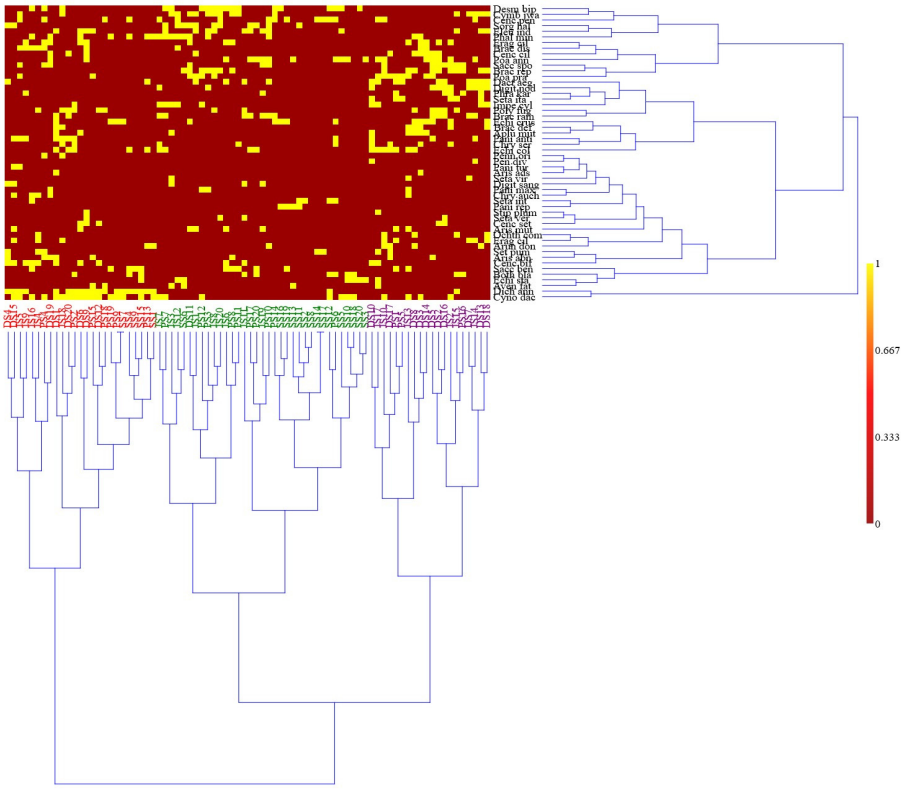

Figure 5. Two-way cluster dendrogram showing the distribution of 52 species and 80 sites. The red color represents the absence of a species while the yellow color represents the presence of a species.

Table 2. Various diversity indices applied for the wild Poaceae within the three major associations of sampling in the study area.

Diversity Indices	Association 1	Association 2	Association 3
Species number	44	44	38
Dominance_D	0.04	0.06	0.04
Simpson_1-D	0.95	0.93	0.95
Shannon_H	3.43	3.25	3.34
Evenness_eˆH/S	0.71	0.58	0.74
Brillouin	2.83	2.65	2.93
Menhinick	2.38	2.34	1.79
Margalef	7.45	7.41	6.09

a. Association 1

Association 1 included 19 sample sites and 44 species. The most dominant species in association 1 was *Dactyloctenium aegyptium*, which had a 30.6 importance value index, followed by *Brachiaria ramosa*, which had a 25.8 importance value index, *Digitaria nodosa*, which had a 21.8 importance value index, *Echinochloa crus-galli*, which had a 20.98 importance value index, and *Poa pratensis*, which had a 17.57 importance value index. *Cenchrus ciliaris*, *Saccharum spontaneum*, and *Phragmites karka* were prominent in association 1. Association 1 showed a species richness of 2.38 and a species evenness of 0.70. The Simpson and Shannon diversity values were 0.95 and 3.43, respectively.

b. Association 2

Association 2 included 25 sample sites and 44 species. *Dichanthium annulatum* ranked first with an importance value index of 55.2, followed by *Cynodon dactylon* with an importance value index of 51, *Saccharum bengalense* with an importance value index of 20.89, and *Eleusine indica* with an important value index of 13.2. The other most common species were *Aristida abnormis, Bothriochloa bladhii*, *Echinochloa crus-galli*, and *Eragrostis ciliaris*. The species richness of Association 2 was 2.34, while the species evenness was 0.58. The Simpson and Shannon diversity values were 0.93 and 3.25, respectively.

c. Association 3

Association 3 included 36 sample sites and 38 species. *Desmostachya bipinnata* had the highest importance value index of 44.83, followed by *Eleusine indica* which had an importance value index of 37.03, *Sorghum halepense* which had an importance value index of 31.74, and *Poa annua* which had an importance value index of 22.39. *Brachiaria reptans*, *Cynodon dactylon*, *Brachiaria ramosa*, and *Phalaris minor* were the other most prevalent species. Association 3 had a richness of 1.79 species and an evenness of 0.74 species. The Simpson and Shannon diversity values were 0.95 and 3.34, respectively.

4.3. DCA Ordination of Poaceae

A DCA scattered diagram of the species displayed the location of diverse species along the two axes and their connection with the gradients (based on the species score) (Figure 6). The extreme top left side of the DCA diagram contains the species *Setaria pumila*, *Cenchrus pennisetiformis*, *Pennisetum orientale*, *Brachiaria distachya*, *Eragrostis ciliaris*, and *Ochthochloa compressa* which suggests a low score on axis 1 and a high score on axis 2. These species favor arid environments, and low-elevation habitats. The diagram's top right-side position shows that *Panicum repens*, *Setaria intermedia*, *Saccharum bengalense*, *Chrysopogon aucheri*, and *Panicum turgidum* have high scores on axes 1 and 2. These high scores indicate that these species like typically dry habitats found at high elevations. The species were separated by microclimatic variations. On the bottom left side, *Digitaria nodosa*, *Dactyloctenium aegyptium*, *Setaria viridis*, *Cenchrus setiger*, *Setaria verticillata*, *Phragmites karka*, and *Setaria italica* represent the species of a semi-arid habitat. The species depicted in the center of the diagram, *Cynodon dactylon*, *Brachiaria deflexa*, *Dichanthium annulatum*, *Avena fatua*, *Poa annua*, *Imperata cylindrica*, *Panicum*

antidotale, *Cenchrus biflorus*, and *Apluda mutica*, show that these species have no apparent preference for particular habitats and are common in nature in numerous communities. The DCA diagram reveals scattered vegetation types at low elevations with the first and second associations, while association three was found at a high elevation (Figure 6). In the DCA ordination for 52 species and 80 sampling sites, the maximum gradient length recorded for axis 1 was 4.637 with an Eigenvalue of 0.487. Axis 2 had a gradient length of 4.964 and an Eigenvalue of 0.421 (Figure 6). The plant grasses plant had a total inertia of 7.46 (Table 3).

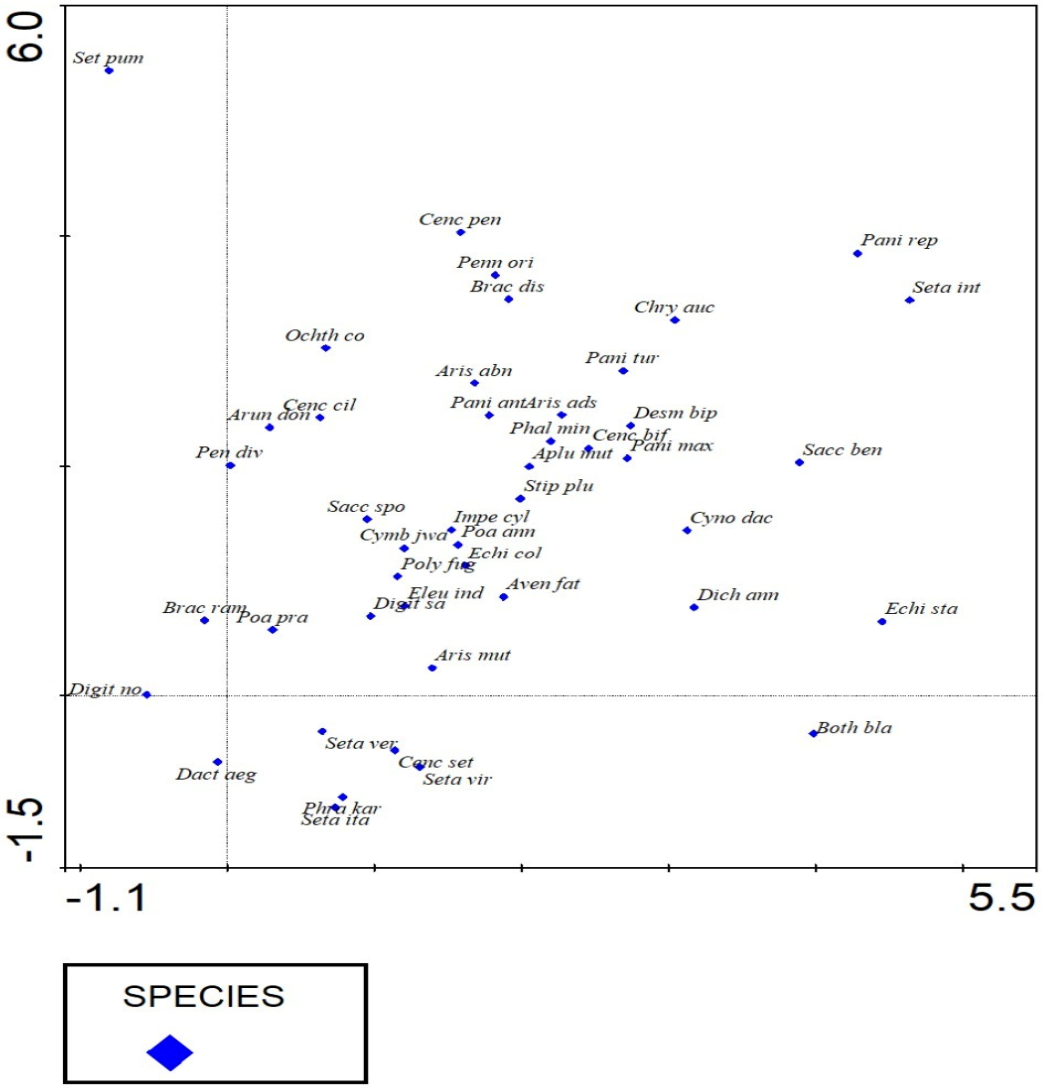

Figure 6. DCA showing the distribution of the grass species.

Table 3. Summary of the DCA analysis.

Summary					
Axes	1	2	3	4	Total inertia
Eigenvalues	0.487	0.421	0.355	0.285	7.46
Lengths of gradient	4.637	4.964	3.96	4.091	
Cumulative percentage variance of species data	6.5	12.2	16.9	20.8	
Sum of all eigenvalues					7.46

4.4. CCA Ordination of Grasses

The CCA ordination findings differed considerably from those of the DCA. The majority of the sample locations are located on the top left side of the CCA diagram. The slope, slope aspect, altitude, soil moisture, soil pH, soil saturation, calcium carbonate ($CaCO_3$), potassium (K), phosphorus (P), nitrogen (N), and organic matter percentages all had an influence on grass distribution. The species that were sensitive to organic matter (OM), altitude, N and K included *Echinochloa stagnina*, *Avena fatua*, *Echinochloa crus-galli*, *Desmostachya bipinnata*, *Eleusine indica*, *Poa annua*, and *Pennisetum divisum*. Other factors such as P, pH, and electric conductivity (EC) also influenced the species distribution, and the grass species that positively correlated with their value included *Bothriochloa bladhii*, *Chrysopogon aucheri*, *Saccharum bengalense*, *Dichanthium annulatum*, *Ochthochloa compressa*, and *Setaria viridis*. The species affected by other factors (e.g., $CaCO_3$ and soil moisture) included *Panicum turgidum*, *Panicum antidotale Dactyloctenium aegyptium*, and *Brachiaria ramose* (Figure 7).

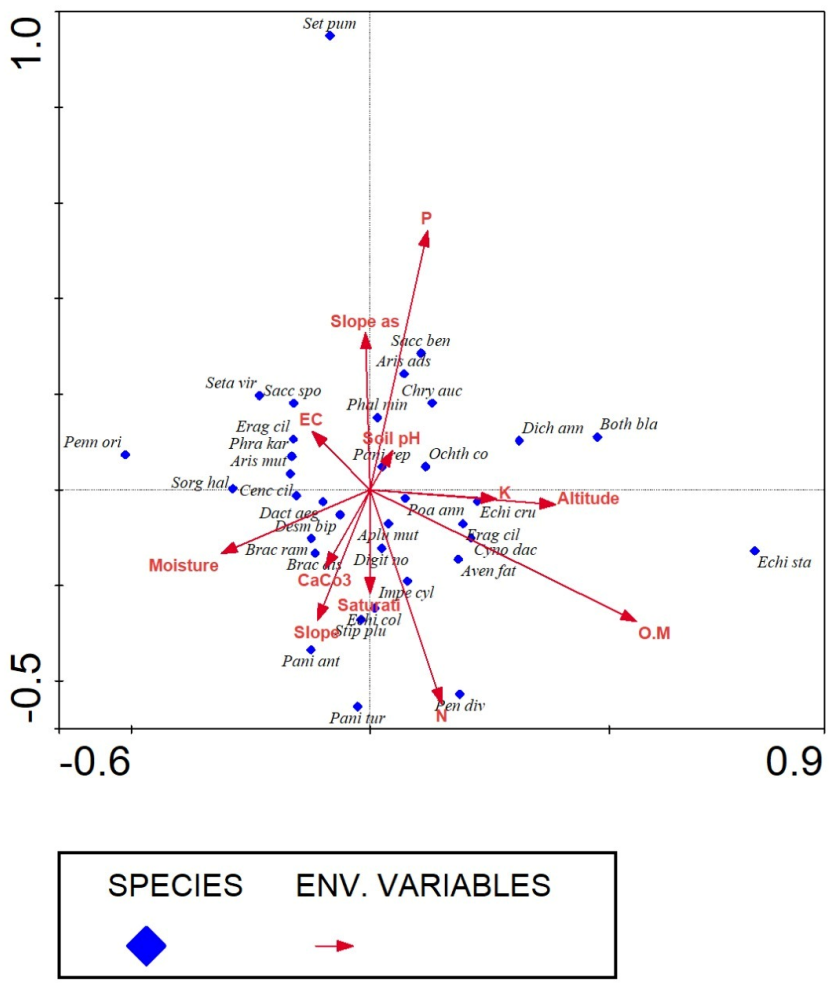

Figure 7. CCA bi−plot diagram of grass species and abiotic variables.

Each triangle from Figure 8 shows a separate species of grass, with the distance between them showing the index of similarity and difference. Grasses were affected by soil pH and phosphate in the first quadrant of the CCA. At the same time, the grasses in the second quadrant were influenced by electrical conductivity and slope characteristics. Calcium carbonate, saturation, slope, and soil moisture affected plants in the third quadrant. The CCA diagram demonstrates that the grasses in the fourth quadrant were affected by potassium, nitrogen, altitude, and the proportion of organic matter (Figure 8).

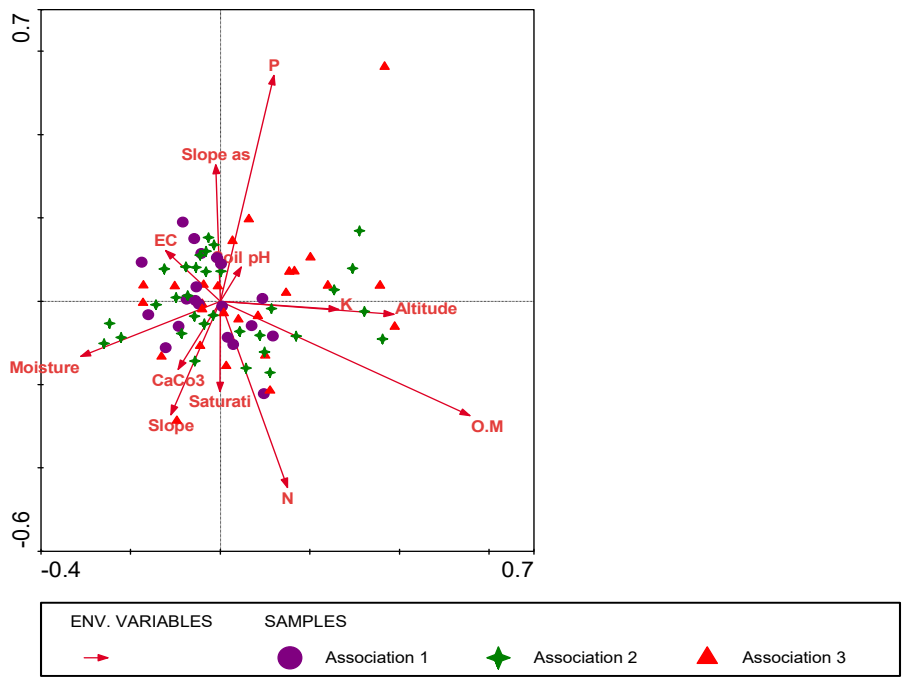

Figure 8. CCA bi−plot diagram of transect and abiotic variables.

The first CCA axis explains 3.2 of the variation, whereas the second accounts for 5.7. The third and fourth axes of CCA explain 8–10.3 of the accumulative variation in grass data, indicating that soil moisture and the percentage of organic matter had the principal relationship with the third and fourth axes, which might have had a substantial influence on the distribution patterns of the grass species. According to the CCA findings, some species were found at all elevations, while some other, distinct species arose at specific elevations. (Table 4).

Table 4. Summary of the CCA analysis.

Summary					
Axes	1	2	3	4	Total inertia
Eigenvalues:	0.241	0.185	0.173	0.168	7.46
Species–environment correlations:	0.773	0.759	0.752	0.695	
Cumulative percentage variance of species data:	3.2	5.7	8	10.3	
Cumulative percentage of species–environment relation:	18.6	32.9	46.3	59.2	
Sum of all Eigenvalues					7.46
Sum of all canonical Eigenvalues					1.295
Summary of Monte Carlo test					
Test of significance of the first canonical axis: Eigenvalue = 0.241					
F-ratio = 2.204					
p-value = 0.0960					
Test of significance of all canonical axes: Trace = 1.295					
F-ratio = 1.155					
p-value = 0.0460					

5. Discussion

Environmental and edaphic factors have long been known to play a role in determining the composition, diversity, and dispersion of species [27]. It is important to understand the assemblage of the plant community associations for grass species, as well as to disentangle the role of abiotic factors in vegetation patterns. As a result, our research represents the most comprehensive assessment of plant species–environmental relationships in Poaceae, as it examines a large geographical region of the Jhelum district in depth. A total of 52 grass species were identified in the study region. The study found a floristic composition similar to the one in the Cholistan Desert Rangelands, Pakistan [28], where the genus *Eragrostis* was the most representative with five species (18.5 percent), followed by *Aristida* and *Cenchrus* with four species (14.8 percent) each, and *Panicum* with two species (7.4 percent). Similar data were presented from Pakistan's salt range region [29], where 62 species of grasses were recorded belonging to 11 different tribes. The Paniceae tribe had the most species with 18, while the Andropogoneae and Eragrastoideae tribes had 12 and 10 species, respectively. *Brachiaria distachya*, *Pennisetum orienttale*, *Cenchrus ciliaris*, *Digitaria nodosa*, and *Setaria glauca* are all members of the Panicoideae (Table S1 in Supplementary Material).

A community is a group of plant species that share the same environment and ecological tolerances. Only a few dominating species in a community affect the habitat and influence the growth of other species; these species are known as dominants [30]. Many countries recognize the advantage of having communities with such knowledge and information to document data about forage and fodder. Local communities around the world that manage and supervise livestock have substantial knowledge of forage [2]. Aitchison, 1881–1882, was the first to recode roadside flora from the Kurram Valley in Pakistan [3].

Anthropogenic, environmental, and biotic pressures [31,32] may alter an ecosystem's floristic structure and composition [33], such as frequency, density, and cover [34,35]. The structure of a community results from habitat [36], ecological conditions, and existing plant species [37,38]. Our findings on phytosociological parameters (density, frequency, and cover) from the Jhelum district agree with prior ecological studies [30,39,40]. A wide variety of studies worldwide have reported that the distribution patterns, composition, and community structures of species are considerably influenced by an altitudinal gradient [26,41]. A similar tendency prevailed in the Jhelum district, especially at higher elevations.

Trait-based techniques, in which physical distinctions are linked to performance, fitness, and ecological impacts, allow for the standardized categorization of plant variation while they simultaneously account for the eco-evolutionary dynamics that build communities [42]. To comprehend the relationship between vegetation and its environment, the life form is a fundamental physiognomic trait [43], indicating plant adaptation to micro- and macro-climates. Our results revealed that the vegetation was dominated by therophytes, which made up 53.84% of the species, followed by hemicryptophytes with four (4.23%) species. The dominance of therophytes in Poaceae has been earlier reported, e.g., from Libya and Senegal [44]. The high percentage of therophytes as the dominating life form is an indicator of the high degree of disturbances in our study area. Therophytes are frequently associated with dry environmental conditions [45]. Low precipitation and short vegetative growth seasons are common features with which therophytes are generally associated [46]. Hemicryptophytes were the second most common life form in the study area. The plausible reason for the predominance of hemicryptophytes is the association of this life form with cold and mountainous climates [42]. Our results showed that the majority of plant species found in the vegetation were microphylls (50%) followed by nanophylls (23.07%). These findings are supported by the authors od [47,48], who found that environmental factors influence leaf size evolution because moisture retention is critical when the root system is sensitive to low temperatures, resulting in a decrease in water and nutrient absorption from the soil, which is predicted to favor the leaves of microphylls. The current study's findings are also supported by the authors of [45], who conducted their research in the Northwestern Himalayas. Our results indicated that 13.46% of the grass species found were introduced. Due to their greater phenotypic plasticity and frequently superior fitness

attributes compared to native plants, alien plant species invade damaged areas more successfully and outcompete native species, regardless of their life history strategy [49]. As a result, native grass species should be preferred over invasive grass species for habitat restoration.

The capacity of species to survive environmental obstacles can be linked to their vast dispersion [50]. Lower altitude species differed from higher altitude species in terms of structure, distributional range, and contribution to community structure [49]. *Apluda mutica*, *Chrysopogon serrulatus*, *Cymbopogon jwarancusa*, *Ochthochloa compressa*, *Panicum turgidum*, *Polypogon fugax*, and *Stipagrostis plumosa* were restricted at high elevations. These findings are similar to [51], who studied the grasses in the Potohar region. Elevation variation significantly impacted the abundance, association, and distributional pattern of grass species in the Jhelum. The richness was at a maximum at an intermediate altitude. *Cynodon dactylon*, *Dichanthium annulatum*, *Brachiaria ramose*, *Dactyloctenium aegyptium*, *Eleusine indica*, *Saccharum bengalense*, and *Cenchrus biflorus* all appeared well-adapted to the Jhelum district (Table S1). The richness of the species decreased dramatically at higher elevations as the climatic conditions become more severe [52]. Temperature, air pressure, rainfall, and nutrient availability are dramatically altered at altitude [34,53,54]. This transition caused a complete shift in the structure of the grass community, with xeric species being replaced by high altitude plants that could endure lower temperatures. Changes in global climate conditions can also be connected to the upward migration of species [51]. The altitudinal variation, slop, aspects, and abiotic gradients were shown to impact the diversity, richness, and distribution of grass species. Even at a short geographical scale and within a restricted altitudinal range, altitude was the most critical environmental factor, negatively influencing the diversity and abundance of grasses. Climbers were also discovered to find ideal locations with high soil moisture, nitrogen contents, a low pH, and a low altitude needed for growth [25,55]. This is similar to other research [30,51,56,57].

Multivariate analyses (Cluster and Two-Way Cluster Analyses; DCA and CCA) revealed that environmental variables had a strong influence on community associations. Using statistical analyses, the Poaceae family of the Jhelum district was sorted into three plant community associations, based on a combination of environmental (slope, slope aspect, altitude) and edaphic (soil moisture, pH, saturation, $CaCO_3$, K, P, N, and organic matter) parameters. Floristic zonation is generally found to be related to micro-topography, soil parameters, altitude, and environmental gradients [58]. Similar classifications for the species found in diverse habitats of Poaceae family have been reported by many investigators. Similar approaches have been applied to the analysis of the classification and ordination of the Poaceae family by Brazilian researchers [59]. According to the authors of [60], environmental factors correlate with the richness, abundance, and functional features of grass species to define the spatial patterns of grass species from West Africa. Grasses with different photosynthetic strategies thrive in a variety of climatic conditions. According to the ordination analyses (CCA and DCA), different levels of environmental parameters had a significant ($p \leq 0.002$) effect on vegetation association. A strong association with certain plant communities was found e.g., for grasses such as *Dactyloctenium aegyptium* and *Brachiaria ramosa* in plant community 1. Soil moisture and $CaCO_3$ appeared to have a strong influence on the distribution of these species. The presence of *Dichanthium annulatum* and *Saccharum bengalense* in plant community 2 was most likely influenced by the P, pH, and Ec. *Desmostachya bipinnata*, *Eleusine indica*, and *Echinochloa crus-galli* were strongly associated with OM, altitude, N, and K. The indicator species can be associated with a variety of environmental factors as well as morphological and functional traits [61]. According to the authors of [62], environmental variables are important factors in shaping the composition of plant species. Plant distributions are frequently reported to be correlated with topographical features and ecological interactions. These patterns vary greatly and are linked to the species' various soil adaption techniques. As a result, it is possible to conclude that soil variables were not only key drivers of species distribution across habitats, but they are also important drivers of species distribution within habitats. The combined effect of

soil structure and composition, soil moisture, available nutrients, and other environmental factors are responsible for the distribution of grass species.

6. Conclusions

We investigated the taxonomic composition, diversity, and distribution patterns of grasses in relation to abiotic factors in Pakistan's Himalayan district of Jhelum. In total, 52 grass species were identified in the study area, indicating that the district has a diverse vegetation due to topography and climatic variation. The cultivation status of grasses indicated the native species (87%) and invasive (13%) species. The life form (biological) ordering results showed the dominancy of therophytes (52%), followed by hemicryptophytes (46%), and geophytes (2%). The leaf size spectra of the wild Poaceae resulted in microphylls dominating (52%), followed by nanophylls (23%), macrophylls (19%), and leptophylls (6%). The trend of the life cycle of wild Poaceae related to the seasons showed that the species was at the maximum during the monsoon season (52% of the species), followed by spring (21% of the species), winter (15% of the species), and summer (12% of the species). *Setaria* was the most dominant genus, accounting for 9.61 percent of all the species, followed by *Panicum*, *Cenchrus*, and *Brachiaria*, each accounting for 7.69 percent of all the species. The life form classification results revealed that the dominant life form was therophytes, followed by hemicryptophytes. The results indicate the relationship between environmental factors and species based on multiple-factor classification and multivariate analyses. Species diversity and species richness differed across spatial scales. According to the findings of the current study, edaphic factors play a key role in determining the pattern of vegetation dynamics. Employing a functional diversity approach to investigate species traits might help to better predict the function of an ecosystem, which can sequentially contribute to the assessment of ecosystem services. In addition, this information might be useful in designing management plans to development of scientifically informed management solutions for the ecological restoration of degraded habitats in this Himalayan region.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su14073786/s1, Table S1: Taxonomical and ecological diversity of wild Poaceae in district Jhelum.

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