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Herbaceous Species Diversity and Temporal Change in Biodiversity Heritage Site of GKVK, Bengaluru Campus

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***Abstract*:** The biodiversity heritage site of GKVK in Bengaluru was assessed for its herbaceous species composition, diversity and structure to better understand the seasonal vegetation dynamics and to provide baseline data for future conservation. A total of 600 quadrats (1 m x 1 m) in summer and winter season were established using random quadrat sampling method for vegetation sampling. A total of 59 species belonging to 55 genera and 25 families were recorded in winter and 39 species belonging to 36 genera and 14 families in summer season. The study site was dominated by the individuals of *Cynodon dactylon* (IVI=20.96) in summer season and *Panicum maximum* (IVI=26.25) in winter season. Shannon diversity index (3.12 and 3.30) and Simpson diversity index (0.94, 0.95) varied between summer and winter season, respectively. Herbaceous species diversity varied greatly between different seasons and different land use systems. Agricultural land use system had the greatest number of species with 35 and 39 species followed by planted Forest with 15 and 28 species in summer and winter season, respectively. Natural forest ecosystem had the least number of species compared to other land use systems. The present study hints at the influence of changes in land use pattern around the natural ecosystem and the work will provide baseline data for future conservation and management practices in the study area.

***Keywords*:** Biodiversity, Heritage site, Land use systems, Conservation

The global biodiversity crisis has given rise to a growing concern at the prospect of a rapidly accelerating loss of species, population, domesticated varieties, medicinal herbs and natural habitats (Shameem et al 2010). Herbaceous plants represent a significant proportion of the biodiversity, but they remain largely understudied despite their ecological relevance: they contribute to ecological processes, serve as ecological indicators of habitat quality and provide food and shelter for numerous wildlife species (Jones et al 2014, Willie et al 2014). Herbs can be classified as generalists which occur in all habitat types. The species diversity and composition of herbaceous plant communities can vary depending on habitat settings. Forest canopies either promote the growth of ground vegetation or hinder it by competition. Each landscape element is subjected to specific disturbances by management such as cultivation, trampling and mowing as well as abandonment (Kitazawa and Ohsawa 2001). Herbaceous vegetation can be affected by natural and anthropogenic disturbances including individual tree falls, catastrophic wind events, catastrophic fire, and timber harvesting that increase light and expose mineral soil (Elliott et al 2011, Belote et al 2012).

Various habitats can be regarded as spatially and temporally dynamic patches of vegetation being subjected to diverse human interference (Bhuju and Ohsawa 2001). Stability and vulnerability of ecosystems depend on species diversity that is defined by the spatio-temporal alteration in species composition and their distribution (Gillet et al 1999). Herbaceous plant species diversity and composition are affected by tree stand structure, tree species composition and topographic and environmental variables (Jones et al 2014, Akhtar and Bergmeier 2015). Tree canopies play a critical role in the spatio-temporal build-up of herbaceous species diversity and production (Sanchez-Jardon et al 2010). Understanding the composition, distribution, and diversity of herbaceous vegetation is basic to the understanding of dynamics of the forest ecosystem (Sagar et al 2012). Studies on herbaceous plant abundance, distribution, diversity and composition in forest stands at different successional stages can inform biodiversity conservation policy and forest management practices (Fraser et al 2014, Willie 2014).

Biodiversity heritage site of GKVK campus is a semi-natural and agricultural landscape which is one of the best sites to assess species diversity at a landscape level containing multiple type of habitats or ecosystems such as agricultural fields, plantations, natural forests etc. Floristic diversity of the campus is decreasing because of the increased anthropogenic activities such as agriculture and research in the campus. Therefore, it is necessary to study

and analyse the species richness and diversity to conserve and manage biodiversity in semi-natural ecosystems.The objectives of the present study are to analyse the floristic diversity of the herbaceous species under different land use systems and to find out the temporal change in the herbaceous species diversity and population structure.

MATERIAL AND METHODS

Description of the Study Area and Climate

Study area: The study was carried out in the biodiversity heritage site of Gandhi Krishi Vigyana Kendra (GKVK), UAS Bangalore. 167 hectares of the total area of the campus in 14 patches has been designated as biodiversity heritage site and these 14 patches are named as area A, B, C, D, E1, E2, E3, E4, E5, E6, E7, E8, E9 and E10 which are spread across the campus (Fig. 1). The study area consists of agricultural lands, Natural scrub forests and Planted forests.

Climate: GKVK is situated at an altitude of 924 meters above the mean sea level. The annual rainfall ranges from 528 mm to 1374.4 mm with the mean of 915.5 mm. The temperature and rainfall data will be collected between June 2020 to June 2021 from UAS Bangalore Agrometeorology climate database. The study area is characterized by an average temperature and rainfall of 23.32 °C and 973mm, respectively during the study period (Fig. 2).

Sampling design and vegetation data collection: Random quadrat sampling method was used to study the herbaceous species composition and species diversity. Quadrats of 1 m^2 ware laid in different locations of the study area. Each 1 m^2 quadrat was further divided into four 250 × 250 cm^2 sub-quadrats, as workable units for the study of the herbaceous vegetation. In each quadrat all the species present were identified and individuals counted. The study was carried out for two seasons i.e., summer and winter seasons. A total of 600 quadrats in two seasons were laid in the study site for recording the herbaceous species diversity. Identification of the species was done with the help of local floras and comparing the voucher specimen with the collection in the herbarium, Mahatma Gandhi Botanical Garden, UAS, GKVK, Bengaluru.

Data Analysis

Floristic composition and species diversity: Vegetation data were compiled and summarized using Microsoft Excel 2019. Shannon diversity index (*H´*) and Simpson diversity index (1-D) were determined using $H' = -\sum^{N}_{i=1} P_i \ln P_i$, $D=\sum n_i (ni-1)/N(N-1)$ (where, n_i= Number of individuals of the i^{th} species, N= Total number of individuals, $p_i = n_i/N$), respectively. The Shannon diversity index is a commonly used measure of diversity and it assumes individuals are randomly sampled from an infinitely large population and all the species from a community are included in the sample (Yemata and Haregewoien 2022).

The Hutcheson t-test is a modified version of the classic t-test that provides a way to compare two samples. The Hutcheson t-test was developed as a method to compare the diversity of two community samples using the Shannon diversity index (Hutcheson 1970). The basic formula is similar in appearance to the classic t-test formula, $t = H'_a - H'_b/\sqrt{\text{variance of } H'_a + \text{variance of } H'_b}$ (Where, *H'*=Shannon diversity index for each of the two samples (subscripted a and b). In the present study we used Hutcheson t-test to analyse and compare the diversity of different land use systems.

Population structure: The structure of the community was analysed in terms of density, frequency and importance value index of all herbaceous plant species. The analysis was carried out using Microsoft Excel 2019. Density refers to the number of all individual plants of a species per unit area and Frequency is the probability or the probability of finding a

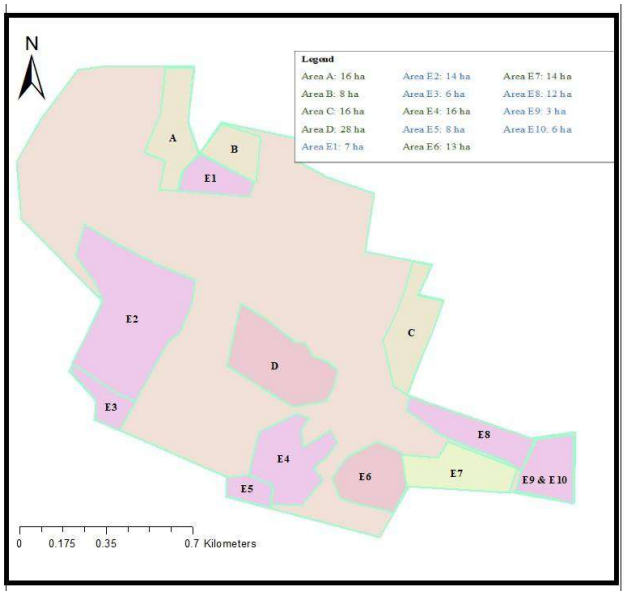

Fig. 1. Map of the study area

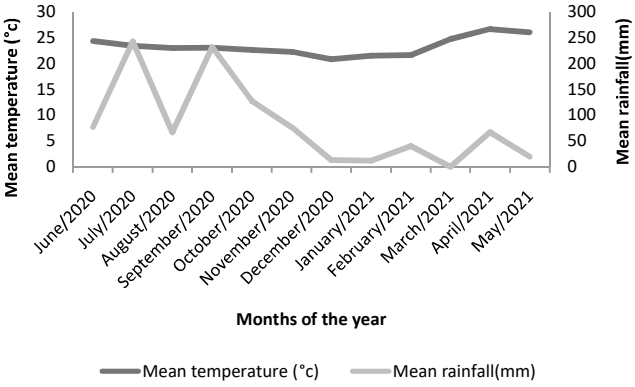

Fig. 2. Rainfall and temperature pattern in the study area during the study period

species in any given quadrat. The frequency value obtained reflects the pattern of distribution.

Relative Frequency and Relative Density were calculated using the formula,

$$\text{Relative Frequency (RF)} = \frac{\text{Frequency of a species}}{\text{Total frequency of all species}} \times 100$$

$$\text{Relative Density (RD)} = \frac{\text{Number of quadrats in which species is studied}}{\text{Total number of quadrats studied}} \times 100$$

Importance value index (IVI) is an important indicator for the ecological significance of a species. It often reflects the extent of dominance, occurrence and abundance of a given species in relation to other associated species in an area (Kent and Coker 1992). For calculating the IVI of herbaceous species, we use the formula, IVI = RD + RF.

RESULTS AND DISCUSSION

Vegetation composition: A total of 59 species belonging to 55 genera and 25 families were recorded in the winter season and 39 species belonging to 36 genera and 14 families were recorded in summer season (Table 1). Herbaceous species number in the present study was higher than the species richness reported by Mirza and Patil (2021) in Gautala Forest. The number herbaceous species recorded in the GKVK campus is lower than the number of species reported by Suresh and Harish (2000) in Indian Institute of Science, Bangalore campus. This may be attributed to the higher level of anthropogenic disturbance in the study area due to increasing agricultural activities. The occurrence of lower number of species in summer can be attributed to the less availability of the moisture and can also be attributed to ploughing activities which starts at the beginning of summer season. 74.36 and 59.32% of the total floristic composition in summer and winter season, respectively was represented by members of four families. In summer season, Poaceaehad 12 species (30.77%), Asteraceae had 9 species (23.08%), Fabaceae 5 species (12.82%) and Amaranthaceae 3 species (7.69%). In winter season Poaceae had species 16 (27.12%), Fabaceae had 8 species (13.56%), Asteraceae had 6 species (10.17%) and Asteraceae had 5 species (8.47%). This shows that Poaceae was the most dominant family in the study site irrespective of seasons. The success of the family might be result of the presence of a greater number of species and higher adaptation capabilities to varying climate and anthropogenic activities. Among the recorded plants, some are fodder species, such as *Panicum maximum* and *Digitaria ciliaris*. The presence of invasive weed species like *Parthenium hysterophorus* and *Cynodon dactylon* shows that the study ecosystem has been invaded and a further spread of these invaders should be prevented to protect other valuable medicinal and fodder species.

Species diversity: A diverse ecosystem has higher Shannon-Wiener index value, while an ecosystem with a low value will have low species diversity (Deka et al 2012). Shannon diversity index and Simpson diversity index values varied between summer and winter season. 3.12 and 0.94 in summer and 3.30 and 0.95 in winter season, respectively (Table 2) indicating that the study site is a biologically species diverse system with balanced species distribution. The outcomes of the present study show that the study site contains high diversity of herbaceous species both in terms of composition and life forms. The study results show that species diversity was higher in winter season compared to summer.

Different land use systems and floristic diversity: Herbaceous species diversity varied greatly between different seasons and different land use systems. Agricultural land use system had the greatest number of species with 35 and 39 species in summer and winter season, respectively followed by planted forest with 15 and 28 species in summer and winter season, respectively. Each landscape element is subjected to specific disturbances by management such as cultivation, trampling and mowing as well as abandonment: Various management regimes related to agricultural practice led to maintenance of diverse plant communities of different successional stages (Kitazawa and Ohsawa 2001). Natural forest ecosystem had least number of species compared to other land use systems with only 7 and 20 species in summer and winter season, respectively. The different land use systems led to the differences in herbaceous species composition and diversity. Most of the species in cultivated and managed sites were common seasonal weeds.

In summer season, Shannon diversity index and Simpson diversity index values varied between land use systems. According to diversity indices, agriculture land use system (H'=2.68, 1-D=0.90) was the most diverse system fallowed by planted forests (H' =2.27, 1-D=0.87). Least diverse was the natural forests (H'=1.65, 1-D=0.79). Herbaceous species diversity analysis showed a similar trend in winter season with Agriculture land use system (H'=2.76, 1-D=0.90) being the most diverse system fallowed by planted forests (H'=2.62, 1-D=0.89) and the natural forests (H'=1.87, 1-D=0.73). The higher diversity in the agricultural land use system may be attributed to the availability of more nutrients and moisture due to the agricultural operations carried out throughout the year in the study site. Diversity indices values in all type of land use systems were higher in winter season compared to summer in all the land use systems (Table 3). Hutcheson t-test analysis shows that there was significant

Table 1. Herbaceous species composition in the study site

Winter season		Summer season	
Name of the species	Family	Name of the species	Family
Acanthospermum australe (Loefl.) Kuntze.	Asteraceae	*Acanthospermum australe* (Loefl.) Kuntze	Asteraceae
Achyranthes aspera L.	Amaranthaceae	*Acanthospermum hispidum* DC.	Asteraceae
Ageratum conyzoides L.	Asteraceae	*Achyranthes aspera* L.	Amaranthaceae
Alternanthera brasiliana (L.) Kuntze	Amaranthaceae	*Ageratum conyzoides* L.	Asteraceae
Alternanthera sessilis (L.) R.Br. ex DC.	Amaranthaceae	*Alternanthera sessilis* (L.) R.Br. ex DC.	Amaranthaceae
Aristida setacea Retz	Poaceae	*Ammi majus* L.	Apiaceae
Bidens pilosa L.	Asteraceae	*Aristida hystrix* L.f.	Poaceae
Blepharis maderaspatensis (L.) B. Heyne ex Roth	Acanthaceae	*Bidens pilosa* L.	Asteraceae
Calyptocarpus vialis Less.	Asteraceae	*Blepharis maderaspatensis* (L.) B. Heyne ex Roth	Acanthaceae
Cardiospermum halicacabum L.	Sapindaceae	*Calyptocarpus vialis* Less.	Asteraceae
Cassia hirsuta L.	Fabaceae	*Cassia tora* L.	Fabaceae
Cassia tora (L.) Roxb.	Fabaceae	*Celastrus paniculatus* Willd.	Celastraceae
Celastrus paniculatus Willd.	Celastraceae	*elosia argentea* L.	Amaranthaceae
Centotheca lappacea (L.) Desv.	Poaceae	*Chloris barbata* Sw.	Poaceae
Centrosema pubescens Benth.	Fabaceae	*Chloris barbata* Sw.	Poaceae
Chenopodium vulvaria L.	Amaranthaceae	*Cocculus hirsutus* (L.) W. Theob.	Menispermaceae
Chloris barbata Sw.	Poaceae	*Crassocephalum crepidioides* (Benth.) S. Moore	Asteraceae
Chromolaena odorata (L.) R.M. King & H. Rob.	Asteraceae	*Crotalaria juncea* L.	Fabaceae
Commelina benghalensis L.	Commelinaceae	*Cynodon dactylon* (L.) Pers.	Poaceae
Crassocephalum crepidioides (Benth.) S. Moore	Asteraceae	*Cynoglossum furcatum* Wall.	Boraginaceae
Crotalaria juncea L.	Fabaceae	*Cyperus rotundus* L.	Cyperaceae
Curcuma longa L.	Zingiberaceae	*Dactyloctenium aegyptium* (L.) Willd.	Poaceae
Cynodon dactylon (L.) Pers.	Poaceae	*Desmodium paniculatum* (L.) DC.	Fabaceae
Cyperus rotundus L.	Cyperaceae	*Digitaria ciliaris* (Retz.) Koeler	Poaceae
Dactylis glomerata L.	Poaceae	*Euphorbia heterophylla* L.	Euphorbiaceae
Desmodium paniculatum (L.) DC.	Fabaceae	*Galinsoga parviflora* Cav.	Asteraceae
Digitaria ciliaris (Retz.) Koeler	Poaceae	*Ichnocarpus frutescens* (L.) W.T. Aiton	Apocynaceae
Hygrophila erecta (Burm.f.) Hochr.	Acanthaceae	*Ipomoea obscura* (L.) Ker Gawl.	Convolvulaceae
Eragrostis sp. L.	Poaceae	*Melinis repens* (Willd.) Zizka	Poaceae
Erigeron bonariensis L.	Asteraceae	*Mimosa pudica* L.	Fabaceae
Euphorbia heterophylla L.	Euphorbiaceae	*Panicum maximum* Jacq.	Poaceae
Heteropogon contortus (L.) P. Beauv. ex Roem. & Schult.	Poaceae	*Panicum virgatum* Roxb. ex Steud.	Poaceae
Ichnocarpus frutescens (L.) W.T. Aiton	Apocynaceae	*Parthenium hysterophorus* L.	Asteraceae
Indigofera hirsuta L.	Fabaceae	*Paspalum dilatatum* Poir.	Poaceae
Ipomoea staphylina Roem. & Schult.	Convolvulaceae	*Pennisetum polystachion* (L.) Schult.	Poaceae
Malvastrum coromandelianum (L.) Garcke	Malvaceae	*Richardia scabra* L.	Rubiaceae
Mimosa pudica L.	Fabaceae	*Stylosanthes fruticosa* (Retz.) Alston	Fabaceae
Panicum maximum Jacq.	Poaceae	*Themeda triandra* Forssk.	Poaceae
Panicum virgatum Roxb. ex Steud.	Poaceae	*Tridax procumbens* L.	Asteraceae

Cont...

difference between herbaceous species diversity of different land use systems (Table 4, Fig. 3).

Population structure: In summer season *Cynodon dactylon, Alternanthera sessilis, Panicum maximum, Chromolaena odorata, Mimosa pudica* and *Parthenium hysterophorus* were the most frequently occurring species which occurred in 13.79, 9.72, 9.09, 7.52, 7.52 and 5.96% of the quadrats respectively. Similarly, in winter season *Panicum maximum, Chromolaena odorata, Mimosa pudica, Panicum virgatum, Alternanthera sessilis and Parthenium hysterophorus* occurred most frequently which occurred in 13.08, 9.13, 8.0, 7.71, 5.08 and 4.52 of the quadrats respectively. In the present study *Parthenium hysterophorus* occurred in both the season in higher frequency. This may be due to the vigorous growth and seed dispersal trait of the species. Most of the most frequently occurring species in the

Table 1. Herbaceous species composition in the study site

Winter season		Summer season	
Name of the species	Family	Name of the species	Family
Parthenium hysterophorus L.	Asteraceae		
Paspalum dilatatum Poir.	Poaceae		
Passiflora foetida L.	Passifloraceae		
Pennisetum polystachion (L.) Schult.	Poaceae		
Pennisetum setaceum (Forssk.) Chiov.	Poaceae		
Cenchrus stramineus (Peter) Morrone	Poaceae		
Peperomia magnoliifolia (Jacq.) A. Dietr.	Piperaceae		
Plumbago zeylanica L.	Plumbaginaceae		
Portulaca oleracea L.	Portulacaceae		
Richardia scabra L.	Rubiaceae		
Sida cordata (Burm.f.) Borss.Waalk.	Malvaceae		
Sida cordifolia L.	Malvaceae		
Solanum nigrum L.	Solanaceae		
Sorghum halepense (L.) Pers.	Poaceae		
Sphagneticola trilobata (L.) Pruski	Asteraceae		
Stylosanthes fruticosa (Retz.) Alston	Fabaceae		
Synedrella nodiflora (L.) Gaertn.	Asteraceae		
Urena lobata L.	Malvaceae		
Urochloa lachnantha (Hochst.) A.M. Torres & C.M. Morton	Poaceae		
Vernonia cinerea (L.) Less.	Asteraceae		

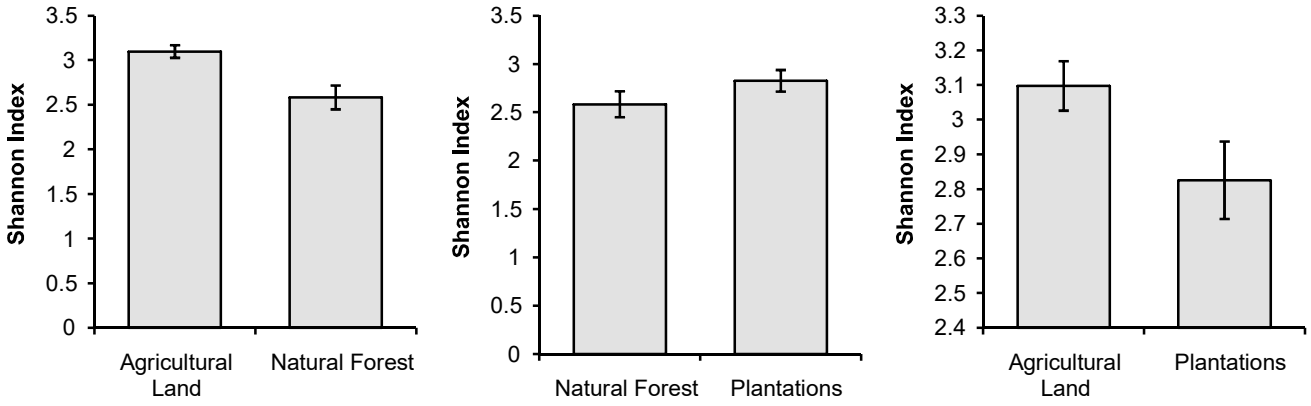

Fig. 3. Comparison of the Shannon diversities in different land use system

study site were observed to be the invading species. This is may be due to the intensive agricultural practices followed in the campus. Seasonal herb species were observed to be more frequent than that of perennials in the present investigation. The prevalence of seasonal herbaceous species as observed in this study could be largely due to seasonal variations in temperature and rainfall.

Cynodon dactylon (20.96), *Panicum maximum* (16.67) and *Parthenium hysterophorus* (16.03) had the highest IVI values (Table 4), respectively and ten dominant herbaceous speciescontributed 58% to the total IVI, in summer season. Similarly, in winter season *Panicum maximum* (26.25) *Chromolaena odorata* (18.28) and *Mimosa pudica* (15.94) showed the highest IVI (Table 4) and ten dominant herbaceous species contributed 61.86 % to the total IVI. Dominance of these species may be due to the environmental suitability and availability of optimum conditions for their growth and regeneration. Moreover, high IVI value by any individual species shows that most of the available resource are being utilized by that species and left over are being trapped by other species as the competitors and the associates (Shameem et al 2010). High importance value of a species indicates its dominance and ecological success, its good power of regeneration and greater ecological amplitude.

This study hints at the influence of changes in land use

Table 2. Species diversity indices of the study area for summer and winter season

Season/ Indices	Summer	Winter
Number of species	39	59
Shannon index	3.12	3.30
Simpson index	0.94	0.95
Evenness index	0.85	0.81

Table 3. Species diversity indices of the study area for different land use systems

Season	Summer			Winter		
Indices	Agricultural land	Forest	Planted forest	Agricultural land	Forest	Planted forest
Shannon	2.68	1.65	2.27	2.76	1.87	2.62
Simpson	0.90	0.79	0.87	0.90	0.73	0.90

Table 4. Comparison of the Shannon diversities of different land use systems using Hutcheson t-test

Land use system	Species richness	*H'*	Confidence interval	t-value	Degrees of freedom (df)	Critical value	p-value
Agricultural Land	46	3.10	0.07	6.78	430	1.97	<0.0001
Natural Forest	28	2.58	0.13				
Natural Forest	28	2.58	0.13	2.78	596.61	1.96	0.006
Plantations	39	2.83	0.11				
Agricultural Land	46	3.10	0.07	4.11	782.67	1.96	<0.0001
Plantations	39	2.83	0.11				

*Level of significance is 0.05

Table 5. Relative density, relative frequency, and IVI of the dominant herbaceous species in the study area

Species name	RD	RF	IVI	Species name	RD	RF	IVI
Summer				Winter			
Cynodon dactylon	17.13	3.82	20.96	*Panicum maximum*	13.18	13.08	26.25
Panicum maximum	12.45	4.22	16.67	*Chromolaena odorata*	9.16	9.13	18.28
Parthenium hysterophorus	10.60	5.43	16.03	*Mimosa pudica*	7.94	8.00	15.94
Alternanthera sessilis	9.23	2.93	12.16	*Panicum virgatum*	7.94	7.71	15.66
Chromolaena odorata	7.22	2.86	10.08	*Alternanthera sessilis*	5.05	5.08	10.13
Calyptocarpus vialis	4.10	4.55	8.65	*Parthenium hysterophorus*	4.49	4.52	9.00
Cyperus rotundus	2.73	5.37	8.10	*Cynodon dactylon*	4.11	4.14	8.25
Chloris barbata	0.73	7.16	7.89	*Cyperus rotundus*	3.93	3.95	7.88
Mimosa pudica	3.89	3.68	7.57	*Pennisetum polystachion*	3.08	3.10	6.19
Blepharis maderaspatensis	2.55	5.01	7.56	*Richardia scabra*	3.13	3.01	6.14

pattern around a semi-natural ecosystem. The results of the present study revealed high diversity of herbaceous in the biodiversity heritage site of GKVK campus. Herbaceous species diversity was highest in agricultural land use system compared to plantations and natural forests. Poaceae was represented by the highest number of species. The study site is dominated by the individuals of *Cynodon dactylon* in summer season and *Panicum maximum* in winter season. This study will provide baseline data for future conservation and management practices in the GKVK campus.

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