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Plant diversity in *terai* grassland vegetation: a landscape level assessment with special reference to north-eastern uttar pradesh, India

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The landscape level plant diversity was measured in *Terai* grassland of north-eastern Uttar Pradesh. The field assessment, based on random quadrats, was undertaken at 11 sites, sampling an area of 333.75 ha. The grassland vegetation was comprised of a greater species richness compared to old-field vegetation. The grassy landscape as a mosaic of grassland patches contained 287 species in the sampled quadrats, which represented 177 genera from 53 families. The species composition of sites varied significantly with an increase in species richness corresponding with landscape heterogeneity. The species richness of a few sites was significantly high due to mesic condition and topographic heterogeneity. The fully exposed sites had average moisture with moderate disturbance and showed greater diversity and lower dominance. However, the partially shaded locations had high moisture and low disturbance resulting in minimum diversity and maximum dominance. The presence of high levels of disturbance in the form of severe grazing, trampling and/or cutting favoured prostrate, perennial, herbaceous-grasses such as *Cynodon dactylon* and *Imperata cylindrica* as well as the forbs such as *Desmodium triflorum, Evolvulus nummularis,* and *Rungia repens.* The marked differences among grassland habitats and the intensity of various biotic processes within the grassy landscape of the adjoining forest result in an array of grassland patches with marked differences in their diversity. Due to changes in agricultural practices and grazing intensification, the *Terai* grassland has been significantly reduced and highly fragmented resulting into the rarefaction of species that were once common and widespread. The shrinkage of specialized habitat owing to intense cultural activities, severe grazing and recurrent trampling has pushed several medicinally important and other rare plant species towards local extinction. Therefore, we suggest that appropriate management guidelines be implemented in order to conserve at risk species from extinction on the *Terai* grassland.

Key words: Grassy landscape, Disturbance, Habitat fragmentation, Patch size, Species diversity.

INTRODUCTION

Grassland is one of the most widespread ecosystem types worldwide. It is closely related to agro-ecosystem

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and forms over 24% of the world's vegetation (Shantz, 1954). Species richness is currently the most widely used measure and easily interpretable indicator of biological diversity (Whittaker, 1977; Stirling and Wilsey, 2001). The number of species reflects the quantum of gene pool and adaptation potential of the plant community (Odum, 1963) and has long been used to characterize its taxonomic structure (Simpson, 1949; Margalef, 1958). Diversity is regarded as the result of species interaction or community adaptation to its environment over its evolutionary time (Whittaker, 1972; Rice and Westboy, 1982). Disturbance is a common and widespread phenomenon in nature. It is a distinct event that modifies population structure, community, ecosystem and landscape beside the passage of time and therefore, the role of disturbance in the dynamics of ecological system can be seen as one of the basic ideas in modern ecology (Pickett and Whyte, 1985). Disturbance contributes to long-term maintenance of ecological diversity (Huston, 1994). An understanding of the response of communities to both repeated and new disturbance regimes is, therefore, necessary.

In India, grasslands constitute one of the major biomes and form an important component of terrestrial vegetation. Indian grasslands are seral in nature but they tend to be stable under the constant influence of biotic disturbances (Pandeya, 1953). Grassland vegetation of different parts of India has been managed by a number of organisations [grassland vegetation of Bombay (Bharucha and Dave, 1944), Varanasi (Misra, 1972; Ambasht et al., 1972), Jodhpur (Gupta and Sharma, 1973) and Kurukshetra (Singh and Yadava, 1974)]. The grass-cover types recognized by Dabadghao and Shankarnarayan (1973) are not homogeneous.

There are two distinct eco-climatic zones parallel to sub-Himalayan in north India *viz*. *Bhabhar* and *Terai. Bhabhar* is a narrow, dry ecosystem in comparison to the *Terai* which is significantly larger and wetter ecosystem. The grassy landscape lies between the Sarju River and the foothills of the Himalayas, covering 11 districts of eastern Uttar Pradesh. A major part of this landscape is adjacent to the managed Sal forests of the eastern *Terai* and the region is known for its unique biodiversity and high productivity (Ansari et al., 2006; Krishnan et al., 2012). These grasslands consist of patches of natural herbaceous vegetation interspersed among agricultural fields. The region has undergone severe alterations due to the expansion of agriculture coinciding with urbanization, resulting in fragmentation and degradation of natural habitats (Johnsingh et al., 2002) which have adversely affected the *Terai* flora and fauna (Javed and Rahmani, 1998). Tripathi and Shukla (2007) undertook a comparison of species richness between the vegetation found in a natural grassland with those found in managed grassland. Shukla (2009) discussed the abundance and diversity patterns of plant species across different physiognomic units over a considerably large *Terai* landscape and found that natural sal and mixed forests had higher species diversity than plantations and other forest types. Most of the rare and threatened species were confined to forest edges and scrub vegetation. . Srivastava et al., (2014) observed changes in indigenous community composition due to invasive plant species.

The present study aimed, to create baseline data on *Terai* grassland vegetation with special reference to north-eastern Uttar Pradesh (U. P.), ecologically the least explored region of India. We measured plant diversity and analyzed the grassland floristic community of the region on a landscape scale. Our study is in contrast to other phytosociological studies which work out the distribution of species abundance in ecological assemblages of various sites as determined by natural as well as anthropogenic disturbances. The results found in this study will provide critical baseline data for management decisions.

MATERIALS AND METHODS

Study sites

The plains of north-eastern U.P. cover 16 districts of eastern U.P. The study was conducted in 11 of these districts (Figure. 1). The climax vegetation is forest. The natural forest has largely been converted into plantation forests and grassy landscapes; the major part is agricultural fields. The abandoned arable land has developed into grassland through secondary succession and may remain stable under the influence of biotic disturbances such as fire, grazing and cutting practices. The study area is bordered by Nepal in the north and Bihar state of India in the east. The regional plain slopes gently from north-west to south-east and is transversed by many rivers, rivulets, nullahs, lakes and ponds.

Climate

The climate of the region is typically tropical monsoonal with three distinct seasons, *viz.,* summer (March to mid-June), monsoon (mid-June to mid-October) and winter (mid-October to February). Average annual rainfall is 1814mm with 87% occurring during the wet summer and monsoon seasons. The number of rainy days per annum is 51±3.2 with average relative humidity ranging between 74 to 87%. The north -eastern plains of Uttar Pradesh receive more rainfall over a longer period and therefore, possess much richer plant biodiversity than western and southern districts of the state. Mean maximum and minimum temperature range during wet summer 26.2 to 35.2°C, winter 12.1 to 27°C and dry summer season 24.2 to 9.3°C respectively (Indian Metrological Department, 2000 to 2005).

Soil

The soil of this region is part of the trans-Sarju Plain and comprises Gangetic alluvium brought down by the rivers Ghaghara, Rapti, Rohin and Gandak from the Himalayas in the north. The texture is sandy loam and pH is near neutral. In the northern area there are a few elevated mounds, locally called *Dhus*, which range in size from a few hundred meters 4 to 5 km consisting of brown sandy soil.

Vegetation

The grassland vegetation presents a mosaic of plant communities.

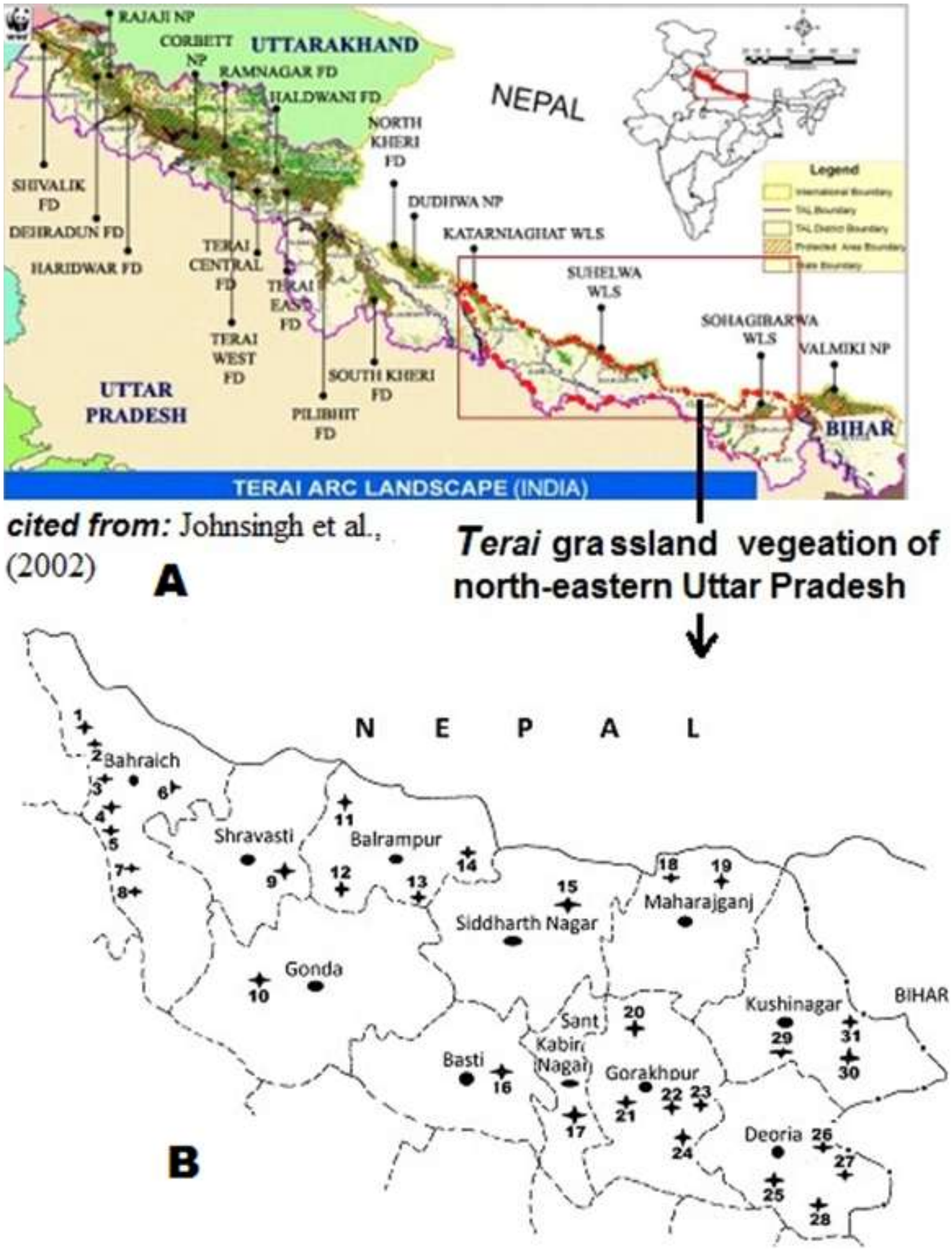

Figure 1. The red rectangle within the inset map shows the position of grassy landscape (A) and the sampled location (B) within different districts (study sites) are numbered from 1to 31.

These grasslands, developed and maintained by various cultural practices represent compositions which vary primarily according to the type of soil and available moisture within the upper layer. The growing season extends from mid-June to mid–September when most species flower and set seed. Many annuals are ephemerals and complete their life cycle before the end of October, while perennial species dry off in winter.

Sampling

This study commenced in June 2011. A general survey was conducted over a vast stretch of grassland vegetation of north-eastern Uttar Pradesh covering an approximate area of about 35, 48,000 ha encompassing 11 districts with marked differences in habitat conditions. Thirty – one sites were selected and sampled

Table 1. The combination of major factors determining habitat condition at different study sites, *Light:* o = open, ps = Partial shade; *Soil moisture*: Mh = High moisture, Ml = Low moisture, Ma = Average moisture; *Textural type*: S = Sandy, G = Gravel, C = Clay, L = loam and Disturbance: Dh = High disturbance, Dm = Moderate disturbance, Dl = Low disturbance.

Study sites	Habitat factors				Habitat condition
	Light	Moisture	Soil texture	Disturbance	
1.Bahraich	Lo	Ml	SL	Dh	Lo, Ml, SL, Dh
2. Balrampur	Lo	Mh	C	Dh	Lo, Mh, C, Dh
3. Basti	Lps	Ma	CL	Dm	Lps, Ma, CL, Dm
4. Deoria	Lps	Mh	CL	Dm	Lps, Mh, CL, Dm
5. Gonda	Lo	Ml	L	Dh	Lo, $M_{l,}$ L, Dh
6. Gorakhpur	Lps	Ma	CL	Dh	Lps, Ma, CL, Dh
7. Kushinagar	Lo	Ml	SL	Dm	Lo, $M_{l,}$ SL, Dm
8. Maharajganj	Lps	Ml	CL	Dm	Lps, $M_{l,}$ CL, Dm
9. Sant Kabir Nagar	Lo	Mh	C	Dh	Lo, Mh, C, Dh
10. Shrawasti	Lo	Ml	G	Dh	Lo, $M_{l,}$ G, Dh
11. Siddharth Nagar	Lo	Ma	C	Dm	Lo, Ma, C, Dm

Table 2a. Rare species categories based on geographic distribution, habitat specificity, and local population size (Rabinowitz 1981; Rabinowitz et al., 1986).

Geographic range	Wide		Narrow	
Habitat specificity	Broad	Restricted	Broad	Restricted
Abundance (large population)	Common	Predictable	Unlikely	Endemics
Abundance (small population)	Sparse		Non-existent	

from August, 2011 to March, 2014. Differences in habitat conditions appeared mainly in the degree of exposure, soil moisture and soil texture as related to topography and disturbance in the form of grazing and trampling (Table 1). Twenty 50 cm x 50 cm quadrats, were randomly laid at each sites i.e., with a total of 620 quadrats across the region. The occurrence and population density of species occupying each quadrat was recorded. The total basal area of individuals of each species was measured through chart-quadrat method (Mishra, 1972). Based on these values, various phytosociological and diversity indices were derived through conventional methods (Mueller-Dombois & Ellenberg 1974; Magurran, 2004). Predictor variables selected for analysis were; frequency, density, vegetal cover, their relative values and *Importance Value Index* (IVI). Several other indices like *Simpson's dominance index* ($Cd = \sum p_i^2$), *Shannon's diversity index* ($\bar{H} = -\sum p_i \ln p_i$), *Pielou's Evenness index* ($E = \bar{H}/\ln S$), *Abundance/ Frequency Ratio* (Whitford, 1948) and *Family Importance Value* (FIV) were derived. FIV was taken as the sum of relative density, relative diversity, and relative vegetal cover. The relative diversity of a family was evaluated as the number of species within the family expressed as percentage of total number of species within all the families represented in the community (Mori *et al*., 1983). The degree of similarity among communities at different study sites was computed through Jaccard's methods for Coefficient of Similarity (Jaccard, 1908). The Rabinowitz classification scheme was used to categorize each of threatened and endangered taxa into one of the seven types. They were defined on the basis of geographic range size (*wide vs. narrow*), habitat specificity (*broad vs. restricted*), and population size (*large, dominant vs. small, scattered*) (Table 2a). From the combination of these traits, eight categories were formed to decide commonness *vs*. rarity of a given species (Rabinowitz, 1981 and Rabinowitz et al., 1986) (Table 2b). The causes of threats to plant species may be natural or anthropogenic. All species were assigned to one or more threats as per the observations (Srivastava *et al.,* 2015). All the data was analysed by using PAST (Paleontological Statistics software) Version 2.17.

RESULTS

Species richness and diversity

The landscape-level plant diversity assessment was made within 333.75ha of the grassy landscape. The details of each study site, sampled area and quadrats laid are shown in Table 3. A total of 287 plant species were encountered within the sampled quadrats, which represented 177 genera under 53 families. Dicotyledons made up 94.5% of the total families, 74.1% of genera and 69.7% of total species. The remaining species were monocots. The species: genus ratio was 1.62 and species: family ratio was 5.42. The site of Gorakhpur district which represented mostly intermediate upland topography and mesic habitat showed maximum species richness (147) of plant species and shared 51.2% of total species richness of the grassy landscape. The minimum species richness occurred at Sant Kabir Nagar (45 species). All other sites showed some intermediate value of species richness (Table 4). While *Cynodon dactylon* commonly occurred at all sites, species like *Aneilema nudiflorum, Desmodium triflorum, Launaea asplenifolia, Lindernia deccusata, Oldenlandia corymbosa, Rungia*

Table 2b. Seven form of rarity (2-8) of regional rare taxa. Each plant species was assigned to a rarity category based on their trait combinations. Category 1 is for common species. Our categorization has been compared with that of Rabinowitz's (1981).

	Trait combinations	According Rabinowitz's (1981)	Our observation (Srivastava et al., 2015)
1.	Large geographic range, wide habitat specificity, large population size	Common	Common
2.	Large geographic range, wide habitat specificity, small population size	Rare	Common
3.	Large geographic range, narrow habitat specificity, large population size	Rare	Rare
4.	Large geographic range, narrow habitat specificity, small population size	Rare	Rare
5.	Small geographic range, wide habitat specificity, large population size	Rare	Rare
6.	Small geographic range, wide habitat specificity, small population size	Rare	Rare
7.	Small geographic range, narrow habitat specificity, large population size	Rare	Rare
8.	Small geographic range, narrow habitat specificity, small population size	Rare	Rare

repens, Setaria glauca, Sida cordata and *Sida rhombifolia* were absent from quadrats sampled especially at sites in Sant Kabir Nagar.

The analysis of various phytosociological attributes shows that the erect annual herbs shared maximum values of various analytic indices (Table 5). The number of individuals/m^2 was also maximum for erect annuals (490.97) followed by prostrate perennials (39.87). The annual twiner climbers showed much less values (0.17). The erect annual herbs were much more abundant (1081.87) as compared to prostrate annuals (236.93). Shrubs were least abundant (6.12 to 6.52). Furthermore, erect annual herbs also showed much more basal area cover (30.27) as compared to twiner annuals. Overall, the landscape vegetation of *Terai* showed fairly high species diversity dominated by annual herbs (H=3.74) and quite low dominance (Cd = 0.058). The total vegetation density, however, was 811.5 individuals m^{-2}).

The life-span data of different grassland species showed that about 90% of species were annuals and the remainder perennials. There were a variety of different growth habits and dominant families within each study sites across the grassy landscape vegetation of *Terai* (Table 6). The maximum number of herbaceous plant species was encountered in Gorakhpur district (129) followed by Deoria (102) and Balrampur (103), with Sant Kabir Nagar having the minimum number of herbaceous plant species (40). Further, the number of shrubs and climbers was also much greater in Gorakhpur district as compared to Siddharth Nagar, Maharajganj, Basti and Gonda. No climbers were observed in Gonda district. At the landscape level, 250 species of herbs, 28 climbers and nine shrubs were found. Poaceae and Cyperaceae were the most *speciose* and ubiquitous families of the region.

Species richness and Importance value of different families

Six dominant families accounted for 56% of total species richness. Poaceae was the most common (17.2%), followed by Cyperaceae (11.2%), Papilionaceae (10.5%), Asteraceae (9.8%), Scrophulariceae (4.9%) and Euphorbiaceae (3.5%). The remaining 44% of species represented 47 families. Six families were represented by more than 10 species. Poaceae, Asteraceae and Papilionaceae showed maximum genera richness in that order with 38, 19 and 16 genera, respectively. In terms of individuals, two families, Scrophulariaceae and Poaceae were dominant with a total > 25,000 individuals within the sampled quadrats of the grassy landscape (Table 7).

The actual importance of a family within its community comes from FIV, an index which heavily depends upon the vegetal cover of component species in addition to the density values. Family Poaceae accounted for 17.4% of total species and 19.9% of total individuals of the landscape. They shared 18.49% of the total vegetal cover and contributed 18.6% to its FIV. Further, the other dominant families like Cyperaceae, Papilionaceae, Asteraceae, Scrophulariaceae and Euphorbiaceae shared 39.72% of total species richness and 52.37% of total individuals. These families together shared 47.49% of total vegetal cover and 52.37% of density (individual/m^2) sum and also contributed 46.52% to sum of FIV. The families, Scrophulariaceae, Poaceae, Papilionaceae and Acanthaceae accounted for >10,000 individuals within the sampled area. The 31 families were poorly represented in terms of the number of individuals. Of these families, Martyniaceae, Sphenocleaceae and Zygophyllaceae were monotypic and shared only 0.40; 0.38 and 0.36% FIV respectively across the *Terai* grassy landscape (Table 8).

Abundance distribution

The value of sum of frequency, density and abundance at 11 different sites across the grassy landscape were compared (Figure 2). The fluctuations in the sum of density were more conspicuous as compared to that of abundance and frequency. The sum of density was

Table 3. Details of study sites and sampling of grassy landscape.

S/N	Study sites (District)	Code	Latitude	Longitude	Altitude (Meter)	Geographical Area (ha)	Sampled Area (ha)	Number of quadrats
1.	Bahraich	BAH	27.34 N	81.38 E	126	469,680	97.94	160
2.	Balrampur	BLP	26.75 N	82.07 E	106	334,900	13.34	80
3.	Basti	BST	26.48 N	82.46 E	103	730,900	3.24	20
4.	Deoria	DEO	26.23 N	83.42 E	68	252,700	18.96	80
5.	Gorakhpur	GKP	26.46 N	83.22 E	69	348,380	40.88	100
6.	Gonda	GND	27.28 N	82.01 E	120	444,800	80.94	20
7.	Kushinagar	KHN	26.45 N	83.24 E	75	287,350	9.31	60
8.	Maharajganj	MRG	25.85 N	83.70 E	66	293,410	4.48	40
9.	Siddharth Nagar	SDN	27.30 N	83.09 E	88	275,200	38.45	20
10	Shravasti	SHW	27.70 N	81.93 E	122	194,820	12.14	20
11.	Sant Kabir Nagar	SKN	26.48 N	82.46 E	86	164,100	11.33	20
Total						3,796,240	333.01	620

Table 4. Richness of various plant taxa *viz.*, family, genera and species across grassy landscape.

Study sites	Family	Genera	Species	Species/Genera Ratio	Species/Family Ratio
BAH	29	66	98	1.48	3.38
DEO	28	85	109	1.28	3.89
GKP	38	101	147	1.45	3.87
GND	16	40	52	1.3	3.25
SKN	21	35	45	1.29	2.14
BLP	35	90	120	1.33	3.43
MRG	27	70	98	1.4	3.63
SDN	20	49	66	1.35	3.30
BST	20	48	55	1.15	2.75
KHN	27	72	98	1.36	3.63
SHW	25	60	69	1.15	2.76
North-Eastern U. P.	53	177	287	1.62	5.42

maximum in Gonda and Bahraich. Conversely it was low for both Sant Kabir Nagar and Kushinagar. The sum of abundance was higher only for Bahraich, Gorakhpur and Maharajganj as compared to other sites. Increase in abundance of species is a quantitative indication of its patchiness or hyper-dispersion. Several common herbaceous species showed hyper-dispersion across the landscape as evident from the

Table 5. Phytosociological indices for different habit group of species (summation values) across the grassy landscape. (No. of occur. = number of occurrence, ni = number of individuals, BA = Basal area, F = Frequency, D = Density, A= Abundance, A/F = Abundance /Frequency ratio, RF = Relative Frequency, RD = Relative density, RVC = Relative Vegetal Cover, IVI = Importance Value Index, Σ pi ln pi=Shannon's diversity index; Σ $(pi)^2$ = Dominance and E= Evenness).

Species Groups	No. of occur.	Σ ni	Σ BA (cm^2)	Σ F	Σ D	Σ indivi./m^2	Σ A	Σ A/F	Σ%VC	Σ RF	Σ RD	ΣRVC	Σ IVI	Σpilnpi	$Σ(pi)^2$	E
Herbs																
Erect Annual	6757	76101	469206	1089.88	122.74	490.97	1081.87	522.69	30.27	60.09	60.50	49.63	170.22	2.31	0.040	0.41
Perennial	351	2119	16067	56.61	3.45	13.67	25.89	5.99	1.04	3.12	1.68	1.69	6.50	0.09	0.0001	0.02
Prostrate Annual	2133	22255	182611	344.03	35.89	143.58	236.93	101.45	11.78	18.97	17.69	19.31	55.98	0.69	0.007	0.12
Perennial	1618	24687	263047	260.97	39.87	159.27	85.22	3.04	16.97	14.39	19.63	27.82	61.84	0.61	0.01	0.11
Climbers																
Twiner Annual	65	107	2335	10.48	0.17	0.69	13.46	25.694	0.15	0.58	0.08	0.25	0.911	0.007	2.13E-07	0.001
Perennial	89	153	3787	14.35	0.25	0.99	13.28	20.334	0.24	0.79	0.12	0.40	1.32	0.010	4.26E-07	0.002
Tendril Annual	68	135	2819	10.97	0.22	0.87	14.56	12.024	0.18	0.60	0.11	0.30	1.01	0.009	2.48E-07	0.002
Shrubs																
Erect Annual	75	111	2425	12.10	0.18	0.72	6.12	5.254	0.16	0.66	0.09	0.26	1.01	0.007	4.22E-07	0.001
Perennial	89	112	3125	14.35	0.18	0.72	6.52	5.694	0.20	0.79	0.09	0.33	1.21	0.007	2.84E-07	0.001
Grassy landscape (Sum)	11245	125780	945422	1813.71	202.87	811.48	1483.88	702.16	66.99	100	100	100	300	3.74	0.058	0.661

Table 6. Species of different habit forms and dominant plant families (represented by >5 species) at different study sites.

Study sites	No. of Species under different Habit categories			Speciose Family (represented by >5 Species)	
	Herb	Shrubs	Climber		
BAH	90	3	5	Poaceae, Cyperaceae, Asteraceae, Euphorbiaceae,	Malavaceae Papilionaceae Scrophulariaceae
GKP	129	05	13	Cyperaceae, Poaceae, Papilionaceae, Asteraceae	Malavaceae, Scrophulariaceae, Euphorbiaceae, Caesalpiniaceae
GND	51	01	-	Poaceae	Papilionaceae,
SKN	40	02	03	Cyperaceae	Scrophulariaceae
DEO	102	02	05	Poaceae, Asteraceae, Cyperaceae,	Papilionaceae, Euphorbiaceae Malvaceae
BLP	103	04	13	Papilionaceae, Poaceae, Cyperaceae, Asteraceae,	Amaranthaceae, Euphorbiaceae Scrophulariaceae
MRG	93	01	04	Poaceae, Asteraceae, Papilionaceae,	Cyperaceae, Euphorbiaceae Malvaceae
SDN	63	01	02	Poaceae, Cyperaceae, Asteraceae,	Papilionaceae Scrophulariaceae
BST	52	02	01	Asteraceae, Poaceae	Scrophulariaceae
KHN	93	02	03	Poaceae, Asteraceae,	Papilionaceae Cyperaceae
SHW	61	03	05	Poaceae, Papilionaceae,	Asteraceae Malvaceae
Grassy landscape	250	09	28	Poaceae, Papilionaceae Scrophulariaceae	Cyperaceae, Asteraceae, Euphorbiaceae

Table 7. The number of plant genera, species and their individuals under different families as recorded within the sampled area.

S/N	Family	Genera	Species	Individual	S/No	Family	Genera	Species	Individual
1	Scrophulariaceae	6	14	32279	28	Primulaceae	1	1	71
2	Poaceae	38	50	25045	29	Unknown	5	5	65
3	Papilionaceae	16	30	15366	30	Portulacaceae	1	1	64
4	Acanthaceae	6	6	10004	31	Apocynaceae	1	1	62
5	Cyperaceae	4	32	8844	32	Molluginaceae	1	2	53
6	Convolvulaceae	4	7	8604	33	Solanaceae	2	4	34
7	Rubiaceae	4	5	6532	34	Cucurbitaceae	4	4	25
8	Asteraceae	19	28	5213	35	Chenopodiaceae	1	1	24
9	Euphorbiaceae	5	10	4165	36	Urticaceae	1	1	19
10	Boraginaceae	2	4	3065	37	Menispermaceae	3	3	18
11	Commelinace	3	4	1725	38	Apiaceae	1	1	17
12	Malvaceae	3	9	852	39	Vitaceae	1	1	16
13	Caesalpiniaceae	1	5	721	40	Martyniaceae	1	1	10
14	Amaranthaceae	6	9	542	41	Sphenocleaceae	1	1	10
15	Polygonaceae	2	4	503	42	Aizoaceae	1	1	8
16	Lamiaceae	5	7	341	43	Amaryllidaceae	1	1	8
17	Onagaraceae	1	4	196	44	Capparidaceae	1	1	7
18	Tiliaceae	2	4	189	45	Papaveraceae	1	1	7
19	Verbenaceae	4	4	154	46	Moraceae	1	1	5
20	Lobaliaceae	1	1	141	47	Zygophyllaceae	1	1	5
21	Violaceae	1	1	122	48	Cuscutaceae	1	2	4
22	Lytharaceae	1	2	120	49	Ranunculaceae	1	1	4
23	Nyctanginaceae	1	1	120	50	Basellaceae	1	1	3
24	Sterculiaceae	1	1	118	51	Bignoniaceae	1	1	3
25	Polygalaceae	1	1	94	52	Cannabinaceae	1	1	1
26	Oxalidaceae	1	1	92	53	Fumariaceae	1	1	1
27	Asclepidaceae	3	3	89	Total		177	287	125780

difference between their density and abundance values. *Lindernia decussata,* however, showed closely similar value of frequency and abundance resulting into A/F ratio near unity. Other distinctly dominant species like *Desmodium triflorum, Evolvulus nummularis, Imperata cylindrica, Lindernia ciliata* and *Rungia repens* showed abundance values of >20 and frequency value of > 40 (Table 9). The A/F ratio for these species was very low (< 1) with exception of *Imperata cylindrica.* Analysis of Jaccard coefficient of similarity showed that the Deoria and Kushinagar districts shared maximum similarity of 0.50 followed by Deoria and Maharajganj (0.44). The least similarity (0.09) was observed between sites at Siddharth Nagar and Sant Kabir Nagar. Over 70% of species were found to be common to all sites within the grassy landscape of north-eastern region (Figure 3).

Dominance- diversity relationship

The resource utilization and niche occupancy of the species within a community is frequently expressed by dominance-diversity curve. Only a few species pre-empted most of the niches at 11 different study sites (Figure 4). The pattern of niche pre-emption by *Lindernia decussata* was quite comparable for Bahraich and Kushinagar. The topography and soil type of the two sites were quite similar but the disturbance regime was different at Bahraich, the grazing intensity was higher as compared to Kushinagar. Further, the Gorakhpur and Shrawasti sites were similar in habitat conditions and disturbance regime. They showed quite similar niche occupancy pattern. The species such *as Desmodium triflorum, Evolvulus nummularis, Rungia repens* and *Cynodon dactylon* occupied maximum niche space of all other species in total. *Evolvulus nummularis* showed maximum number of individuals and occupied maximum niche space at sites of Balrampur, Gonda and Basti. Balrampur and Gonda sites were similar in light and disturbance regimes, grazing pressure and moisture regimes except for some marginal soil differences. Sant Kabir Nagar sites showed unique habitat conditions with fully open, high moisture and complex disturbance conditions and showed maximum niche occupancy by

Table 8. Species richness and Family Importance Value (FIV) of constituent families across grassy landscape of *Terai*.

Family	Species richness	FIV*	Family	Species richness	FIV
Poaceae	50	55.83	Cuscutaceae	2	0.72
Scrophulariaceae	14	42.17	Nyctanginaceae	1	0.66
Papilionaceae	30	41.18	Lobaliaceae	1	0.61
Cyperaceae	32	24.31	Apocynaceae	1	0.57
Asteraceae	28	20.51	Polygalaceae	1	0.57
Convolvulaceae	7	19.26	Violaceae	1	0.56
Acanthaceae	6	17.78	Oxalidaceae	1	0.55
Rubiaceae	5	11.39	Portulacaceae	1	0.49
Euphorbiaceae	10	11.39	Primulaceae	1	0.48
Boraginaceae	4	6.05	Vitaceae	1	0.41
Malvaceae	9	5.65	Chenopodiaceae	1	0.40
Amaranthaceae	9	4.36	Martyniaceae	1	0.40
Commelinaceae	4	3.99	Apiaceae	1	0.39
Lamiaceae	7	3.61	Urticaceae	1	0.38
Caesalpiniaceae	5	3.15	Sphenocleaceae	1	0.38
Polygonaceae	4	2.36	Capparidaceae	1	0.37
Tiliaceae	4	1.92	Aizoaceae	1	0.37
Unknown	5	1.89	Moraceae	1	0.37
Onagaraceae	4	1.86	Papaveraceae	1	0.37
Verbenaceae	4	1.78	Zygophyllaceae	1	0.36
Cucurbitaceae	4	1.59	Amaryllidaceae	1	0.36
Solanaceae	4	1.49	Basellaceae	1	0.36
Asclepiadaceae	3	1.33	Bignoniaceae	1	0.36
Menispermaceae	3	1.13	Ranunculaceae	1	0.36
Lythraceae	2	0.92	Cannabinaceae	1	0.35
Molluginaceae	2	0.84	Fumariaceae	1	0.35
Sterculiaceae	1	0.72	Total	287	300

*FIV = relative density + relative diversity + relative vegetal cover.

Medicago polymorpha.

The Siddharth Nagar site was quite similar to the former site except some degree of fire as disturbance factor. *Imperata cylindrica* occupied its maximum niche space. The fire, grazing and trampling together increased its occurrence and density. The expansion of the species is facilitated by its rhizomatous growth. Deoria and Maharajganj sites were quite similar in habitat condition with some difference in moisture regimes. The two moisture-loving species *Rungia repens* and *Phyllanthus urinaria* occupied their maximum niche spaces.

Rare species and its population

The total number of individuals or density, habit, posture categories, distribution, population status and the specific habitat conditions of rare species revealed that at the landscape level, only 31 species showed rare occurrence and occupied specific habitats (Table 10). They represented 27 genera under 18 families. The common species with large distribution range showed wide habitat specificity. The intense agricultural practices, mining, livestock grazing and trampling were found to be the major threats causing rarity of a great number of grassland herbs. A few species such as *Chyranthellum indicum* and *Spermacoce pusilla*, however, were encountered only at one of the eleven sites (Bahraich) but in the localized spots the individuals were much greater in number. These species occupied a habitat possessing sandy to sandy loam soils with average moisture and exposed condition. A few highly medicinal plant species such as *Astercantha longifolia, Bacopa monnieri, Centella asiatica, Chyranthellum indicum, Ionidium suffructicosum, Evolvulus alsinoides, Leucas aspera, L. cephalotus, Vernonia adscendens* and *Tribulus terrestris* have suffered seriously due to voracious harvesting for medicinal purpose from the wild. The very rare and poor occurrences of some lowland species such as *Cyperus niveus, Lobelia alsinoides and Sphenoclea zeylanica* may be attributed to severe grazing just before their full bloom or seed-setting stage.

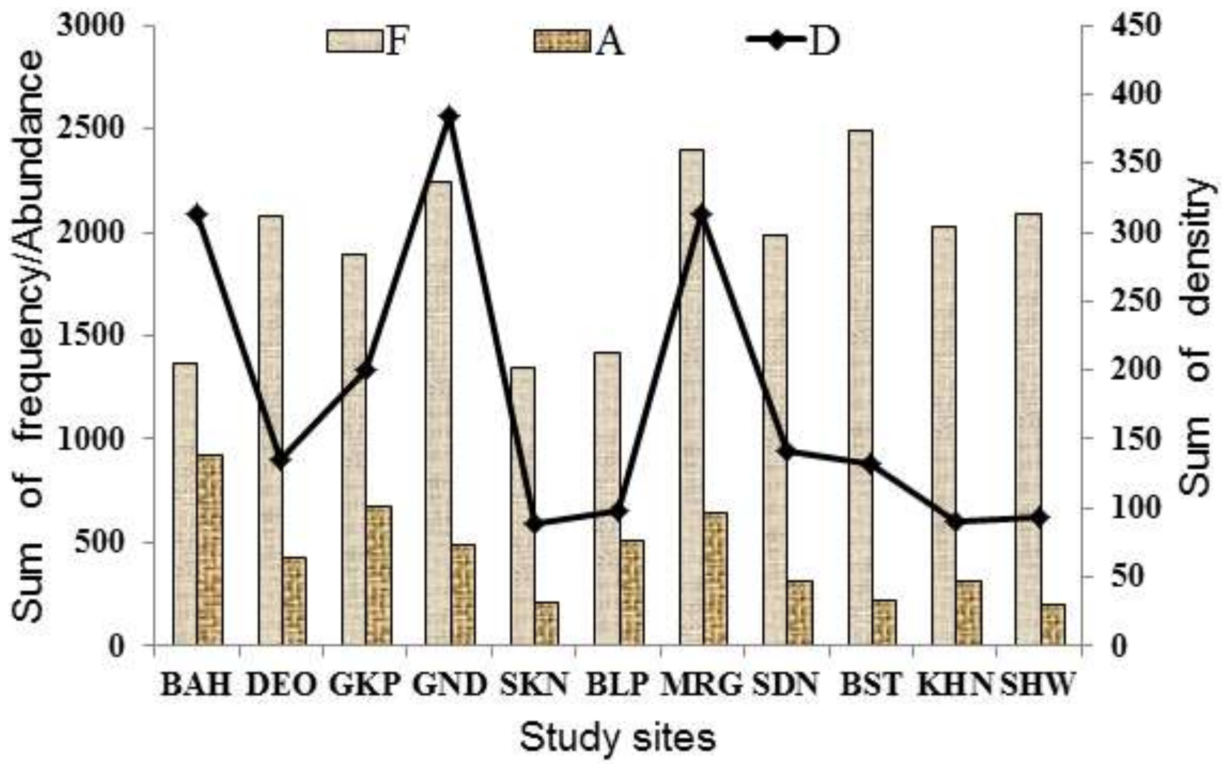

Figure 2. Sum values of frequency, density and of abundance of plant species at different study sites. (BAH = Bahraich, DEO = Deoria, GKP = Gorakhpur, GND = Gonda, SKN = Sant Kabir Nagar, BLP = Balrampur, MRG = Maharajganj, SDN =Sidharthnagar, BST = Basti, KHN = Kushinagar and SHW = Sharawasti

Table 9. Species showing most frequent and most prolific distribution across grassy landscape.

Species	Average Density	Abundance	Frequency	A/F ratio
Lindernia deccusata	143.79	60.73	59.19	1.03
Rungia repens	62.59	28.77	54.35	0.53
Desmodium triflorum	58.16	20.49	70.97	0.29
Lindernia ciliata	56.52	31.74	44.52	0.71
Evolvulus nummularis	50.36	22.27	56.61	0.39
Cynodon dactylon	23.51	11.87	49.52	0.24
Zornia gibbosa	21	19.97	26.29	0.76
Imperata cylindrica	19.58	28.90	16.93	1.71
Phyllanthus urinaria	17.36	22.80	19.03	1.20

The dominant families also shared maximum number of rare species. For example, *Papilionaceae* and *Poaceae* had five rare species each, *Lamiaceae* three species and *Asteraceae, Boraginaceae* and *Caesalpinaceae* contained two rare species each. Another 12 families showed single rare species. The families *Apiaceae, Lobaliaceae, Martyniaceae, Sphenocleaceae* and *Zygophyllaceae* had single rare species under monotypic genera *viz*., *Lobalia alsinoides, Martynia annua, Sphenoclea zeylanica* and *Tribulus terrestris.*

DISCUSSION

The *Terai* grassland vegetation has considerable diversity represented by plant species of different habits. A landscape level approach addresses the changes in biodiversity due to anthropogenic activities and the effect of such changes in biodiversity on the functioning of biological system (Franklin 2001). Since humans play a key role in altering ecosystem level processes, its integration as part of the ecosystem is quite obvious.

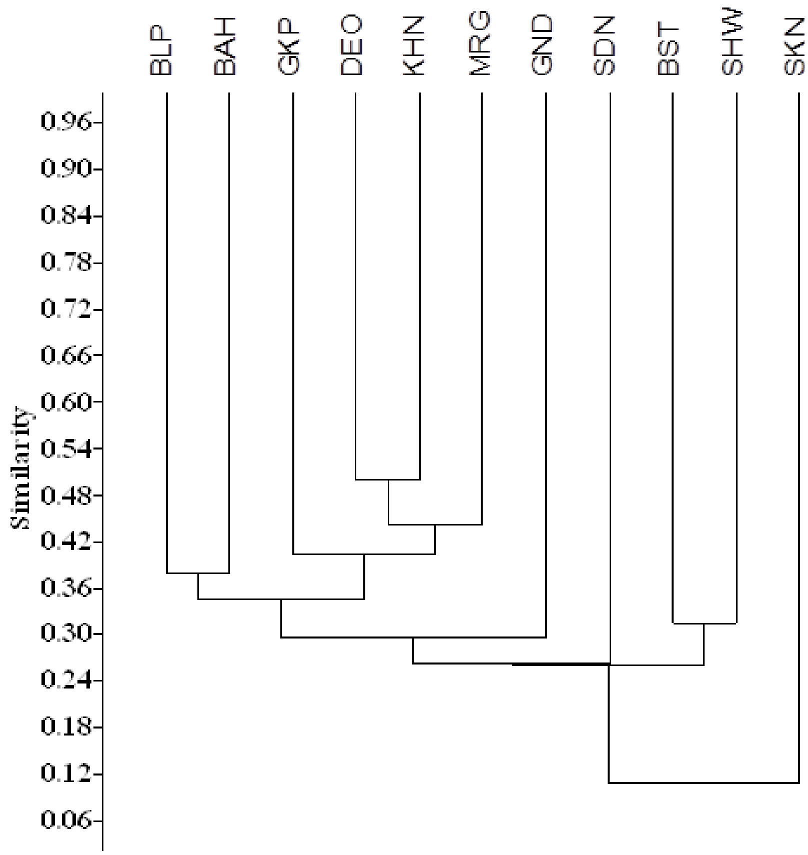

Figure 3. Dendrogram showing similarity among study sites (based on Jaccards coefficient).

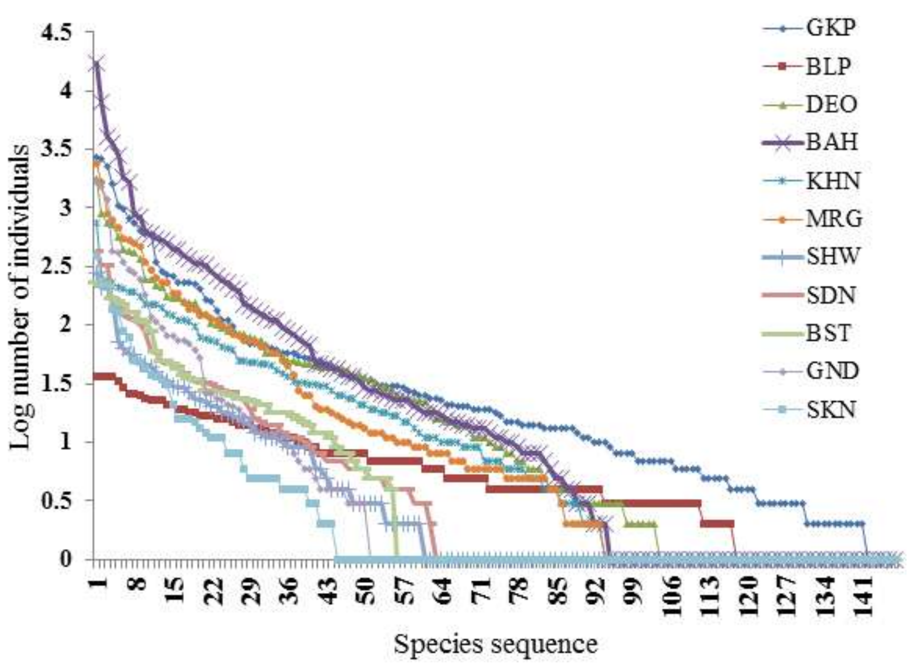

Figure 4. Rank-abundance model (dominance-diversity curve) for different study sites (based on Jaccards coefficient).

Table 10. The distribution and population status of rare species with their habit and posture categories. Abbreviation: *Light:* O= open, PS= Partial shade; *Soil moisture*: HM= High Moisture, LM= Low moisture, AS= Average moisture and Textural types: SS=Sandy soil, GS= Gravel soil, CL= Clayey soil, L= loam.

Plant species	Family	Habit	Posture	Total number Individuals	Density (m²)	Habitat factors			Population Size	Habitat Specialization	Geographical Range
						Light	*Moisture*	*Soil*			
Alternanthera pungens	Amaranthaceae	H	PA	9	0.06	O	LM	GS	Large	Narrow	Narrow
Alysicarpus bupleurifolius. Dc.	Papilionaceae	H	EA	33	0.21	O	AM	CS/CLS	Large	Narrow	Narrow
Astercantha longifolia	Lamiaceae	H	EA	13	0.08	O	HM	CS	Large	Broad	Narrow
Bacopa monnieri Linn.	Scrophulariaceae	H	EA	8	0.05	O	HM	CS	Small	Narrow	Narrow
Cassia absus Linn.	Caesalpiniaceae	H	EA	7	0.05	PS	AM	CLS	Small	Narrow	Narrow
Cassia pumila Lamk. WG	Caesalpiniaceae	H	PA	13	0.08	PS	AM	CLS	Large	Narrow	Narrow
Centella asiatica Linn.	Apiaceae	H	PA	17	0.11	O	HM	CS	large	Narrow	Wide
Chrysanthellum indicum Dc. Prod.	Asteraceae	H	PA	595	3.84	O	AM	SS/SLS	Large	Narrow	Narrow
Crotalaria calycina Linn.	Papilionaceae	H	EA	15	0.10	O	LM	SLS	Large	Narrow	Narrow
Crotalaria palida	Papilionaceae	H	PA	1	0.01	O	LM,	SLS	Small	Broad	Wide
Cynoglossum lanceolatum Forsk.	Boraginaceae	H	EA	123	0.79	O	LM	SLS	Large	Narrow	Narrow
Cyperus niveus	Cyperaceae	H	EA	2	0.01	O	AM	SLS	Small	Narrow	Narrow
Eragrostis capensis	Poaceae	H	EA	45	0.29	O	AM	SLS	Small	Narrow	Narrow
Eragrostis cilianensis	Poaceae	H	EA	29	0.19	O	AM	CS/CLS	Small	Narrow	Narrow
Evolvulus alsinoides Linn.	Convolvulaceae	H	PPer	763	4.92	O	AM	SLS /SL	large	Narrow	Wide
Heliotropium ovalifolium	Boraginaceae	H	EA	12	0.08	O	HM	CS	Small	Narrow	Narrow
Hemarthria compressa	Poaceae	H	EA	47	0.30	O	HM	CS	Large	Narrow	Narrow
Hetropogon contortus Linn	Poaceae	H	EA	25	0.16	O	LM	SLS	Large	Narrow	Narrow
Ionidum suffructicosum Roe&She	Violaceae	H	EA	122	0.79	O/PS	AM	SLS/CLS	Small	Narrow	Wide
Leucas aspera Willd. Spreng.	Lamiaceae	H	EA	19	0.12	O	LM	SLS	Small	Broad	Narrow
Leucas cephalotus	Lamiaceae	H	EA	51	0.33	O	AM	SLS	Small	Broad	Narrow
Lobelia alsinoides	Lobaliaceae	H	EA	141	0.91	PS	HM	CLS	Small	Narrow	Narrow
Martynia annua Linn.	Martyniaceae	H	EA	10	0.06	O	LM	CLS	Small	Narrow	Narrow
Perotis indica Linn.	Poaceae	H	PA	174	1.12	O	LM/AM	SLS	Large	Narrow	Narrow
Psoralea corylifolia	Papilionaceae	H	EA	191	1.23	PS	AM	SLS	Small	Narrow	Narrow
Spermacoce pusilla	Rubiaceae	H	EA	4076	26.30	O	AM,	SLS	Large	Narrow	Narrow
Sphenoclea zeylanica	Sphenocleaceae	H	EA	10	0.06	O	HM	CS	Small	Narrow	Narrow
Teramnus labialis	Papilionaceae	C	PerTw	8	0.05	PS	AM	GS	Small	Narrow	Narrow
Tribulus terrestris Linn.	Zygophyllaceae	H	PA	5	0.03	O	LM	SS	Small	Narrow	Narrow
Vernonia adscendens	Asteraceae	H	EA	9	0.06	O	LM	SLS	Small	Narrow	Narrow
Zephyranthes citrina Baker	Amaryllidaceae	H	EA	8	0.05	O/PS	AM	GS & CS	Small	Narrow	Narrow

Table 11. The number of rare species (decreasing order) and their % share against total species within different families.

Family	Total species	Rare species	Percentage (%) share of rare species
Papilionaceae	30	5	(16.7%)
Poaceae	50	5	(10 %)
Lamiaceae	7	3	(43%)
Asteraceae	28	2	(7.1%)
Boraginaceae	4	2	(50%)
Caesalpiniaceae	5	2	(40%)
Zygophyllaceae	1	1	(100%)
Scrophulariaceae	14	1	(7.1%)
Rubiaceae	5	1	(20 %)
Amaranthaceae	9	1	(11 %)
Sphenocleaceae	1	1	(100%)
Martyniaceae	1	1	(100%)
Apiaceae	1	1	(100%)
Amaryllidaceae	1	1	(100%)
Violaceae	1	1	(100 %)
Cyperaceae	32	1	(3%)
Convolvulaceae	7	1	(14.3 %)
Lobaliaceae	1	1	(100%)

Habitat modifications and management practices that change functional diversity and functional composition are likely to have large impacts on ecosystem processes (Tilman et al., 1997). Societies, by their activities also affect landscape function (Ramakrishnan, 1992). The developmental stage of community is complicated by disturbance types and their intensity. Disturbance may increase species richness by lowering the dominance of a few species, freeing resources for early successional plants, and providing opportunities for herbaceous species to spread rapidly (Tripathi, 1999; Sood et al., 2011).

The landscape of north-eastern Uttar Pradesh forms an interrupted regional community of grassland which is quite heterogeneous due to small-scale changes in topography, soil and light conditions and, therefore, may be easily recognized on the basis of species composition, habitat characters and patch size. The different patch type characterise different habitats and species composition, and the total number of species in a landscape increases with increase in heterogeneity of landscape (Sluis et al., 2014). Our result showed clear difference in species richness of patch sizes at different study sites. The total number of species of two sites such as Gorakhpur and Balrampur were fairly high. At Gorakhpur, 147 species were encountered within 40.88 ha area; with 120 species recorded within 13.34 ha at Balrampur. Further, Sant Kabir Nagar recorded only 45 species within 11.33ha area. These results indicated that the sizes of patches are significantly related neither to species richness nor species composition as also evident from the Bisteau and Mahy (2005). Other studies have however, reported that size is the main factor affecting species richness in fragmented grasslands (Krauss et al., 2004) and isolation may also be a significant factor (Piessens et al., 2005). Low species richness may result from the dominance of a few competitors and ruderals. Both, a reduction in species richness and increased dominance of a few species are common phenomenon in highly fertilized grasslands (Berendse and Elberse, 1990).

The density and abundance distribution of individual species are measurable indicators of plant diversity (Wattenberg and Breckle, 1995). The importance of natural and anthropogenic disturbance in maintaining species richness and diversity have been pointed out by many authors including Grime (1979), Pickett et al., (1989) and van der Maarel (1993). Variation in disturbance intensity exerts profound influence on the pattern of diversity and species richness; the ever-increasing biotic pressure often leads to a mosaic of patches with various degrees of ecological maturity (Rescia et al., 1994). Increased diversity and reduced dominance has been found in case of fully exposed locations having average moisture and facing moderate disturbance. It was minimum in case of partially shaded locations having high moisture and facing low disturbance. It has been shown to be associated with increased stability (McNaughton, 1967). Bahraich and Gonda showed low diversity and high dominance in comparison to other sites. This may be due to the presence of severe disturbances in the form of grazing, trampling and cutting. The disturbance in the form of periodic clipping caused greater dominance and low diversity, and the species of prostrate habit dominated the localities. It has already been established that diversity is lower in absence of disturbance as well as in presence of too much of disturbance (Srivastava et al., 2015). The moderate level of anthropogenic disturbance, therefore, are compatible with maintenance of high biodiversity of landscape (Gentry, 1991).

The annual herbaceous species have been reported to respond more positively to disturbance (Belsky, 1986). The prostrate perennial herbaceous grasses like *Cynodon dactylon* and *Imperata cylindrica* and few forbs such as *Desmodium triflorum, Evolvulus nummularis,* and *Rungia repens* had maximum dominance due to multiple reproductive strategies (Patrica et al., 2002) and rapidly occupied the horizontal space created by disturbance especially by severe trampling and grazing. Annual and perennial species showed maximum seed and ramet proliferation even in regularly trampled habitat. The abundance of a species in an area depends on the ability of its propagule and tolerates features of the environment (Harper, 1967). *Lindernia decussata* exhibited the greatest density, abundance and A/F ratio of all other species. The species is ephemeral, moisture loving and produces numerous seeds where discrimination is favoured by grazing. The species such as *Cynodon dactylon, Desmodium triflorum, Evolvulus nummularis* and *Rungia repens,* showed overall maximum occurrence in the region. *R. repens* also exhibited maximum density and abundance but its A/F ratio was low in comparison to annual species. The high importance value of these species may be attributed to efficient mode of seed production and ramet growth. Relatively, privileged number of species can be attributed to moderate grazing and grazing may develop mutualism between the grazers and grazed species. The saliva and dung of grazers may also promote the growth of some species (Grace and Jutila, 1999).

The sum of frequency value changed notably from one to other study sites which may be attributed to the sudden increase in the number and abundance of a few more opportunistic weeds in response to increased exposure. Low value of both abundance and frequency showed rare occurrence of species while very high value indicated their dominance quite often in the form of extensive patches. Hubbell and Foster (1986) found that most rare species were specialist either in habitat utilization (topography or edaphic condition) or in regeneration niche (regenerative condition in gap openings) which implies that a high heterogeneity of environmental condition is necessary to accommodate so many specialist species. The sum of frequency may be much lower in highly disturbed sites because of much greater abundance of a few adaptive species (Stachurska, 1994, Pandey and Shukla, 2003, 2005).

The ability of large, fast-growing perennial herbs suppressed the growth of smaller species. A nearly non-random species distribution within the community in the form of widely distributed dominant species and locally distributed subordinate species is quite common (Kolasa et al., 1989). The pattern of species abundance may be related to habitat factors and growth pattern of the species which specialize the niche (Brown et al., 1995). Our results are consistent with the prediction that, as generalists use various habitat types in the landscape, they should be less affected by habitat fragmentation than specialists, which are more dependent on one or few habitat types (Brouat et al., 2004). Specialist's plant species are also expected to be adversely affected by landscape disturbance (Kithahara et al., 2000, Kassen, 2002). Our observations are also consistent with the empirical findings that the human induced landscape degradation cause decline of specialist species (Krauss et al., 2003, Devictor et al., 2007a,). We found little support for the hypothesis that common species are competitive dominants and rare species are weak competitors (Whittaker 1965; McNaughton and Wolf 1970). Our results indicate that response to competition may be important for coexistence. We found that rare species were relatively tolerant of competition which allowed them to persist at low abundances and coexist with common species (Rabinowitz et al., 1984). The rare forbs suffered weak competition from common species because they started growing and flowering earlier in the spring allowing them to get a head-start before competition from other species was established.

Severe change in habitat conditions resulted in fall of specialist species and rise of opportunist species. The population of some grassland species such as *Chrysanthellum indicum* and *Spermacoce pusilla* showed least tolerance to these disturbances and were found limited to one site having sandy to loamy soils. On the other hand, species such as *Baccopa monnieri, Cassia absus, Cyperus niveus, Eragrostis capensis, Eragrostis cilianensis, Heliotropium ovalifolium, Leucas cephalotus, Leucas aspera, Lobalia alsinoides, Martynia annua, Psoralea corylifolia, Sphenoclea zeylanica, Atylosia scarabaeoides, Teramnus labialis, Tribulus terrestris, Vernonia adscendens* and *Zephyranthes citrina* generally occupied quite specialized habitats and had a small population size within a narrow distributional range. Due to their medicinal importance they have been over-exploited, their natural habitat is almost destroyed and they are at the verge of local extinction. Voracious and unmanaged harvesting is another major threat to the existence of several minor but valuable plant species of the region (Shukla, 2009).

The recent urbanisation and associated disturbances have caused a much greater loss to specialized niches of the region. For example, *Crotolaria calycina,* and *Ionidium suffruticosum* happen to be rare and their population size has reduced significantly during the last decade. Considerably shaded and damp habitats within village forests or orchards are preferred. The species have suffered seriously, due to the fast reduction of such habitats mainly by increased urbanization and agricultural expansion. It has been established that the shade tolerant species are more sensitive to habitat fragmentation than shade intolerant species (Metzger, 2000). Species like *Astercantha longifolia, Bacopa monnieri, Centella asiatica* and *Heliotropium ovalifolium* mostly grew in areas facing some degree of water-logging on clayey soil and most often show aggregation.

Currently, they have become infrequent across water-logged or lowland regions despite their two-pronged regeneration strategy that is, through seeds as well as through sprout and ramets. Thus, not only upland but also the marginally lowland habitats of the region are severely disturbed. The highly specialized species in nature have significant positive associations and they cannot survive outside of their natural habitat (Hubbell and Foster, 1986). Bruun (2000), identified numerous functional groups including specialist grassland species which were positively correlated with habitat area. With the small population size and restricted habitats more species will be prone to localized extinction (Menges, 1998; Butaye et al., 2005).

The resource sharing and occupancy of niche space are frequently expressed by dominance-diversity curve (Whittaker, 1975). As evident from these curves, generally fewer species in the landscape preempted most of the niches. The conditions like moderate grazing and lesser clipping and trampling allowed relatively greater number of species to share community resources, thus reducing the degree of dominance at community level, as evident from the less steeper and more flattened curve (Raizada et al., 1998). Disturbance has positive effects on the grassland vegetation as reported earlier by some workers (Sundriyal et al., 1987). Further, disturbance caused by herbivores may reduce the negative effect of competition (Nautiyal et al., 2004). In comparison to other species of exposed community, erect herbaceous component was dominant especially in condition of low moisture and moderate disturbance. *Lindernia decussata* was more frequent, highly dominant and occupied maximum niche space (Bahraich and Kushinagar). *Desmodium triflorum, Evolvulus nummularis, Rungia repens* and *Cynodon dactylon* showed high dominance and occupied maximum niche space at two other study sites (Gorakhpur and Shrawasti). The latter two sites showed slight differences in habitat conditions but their disturbance regime was quite similar. On the contrary, almost uniform and periodic clipping inhibited the establishment of most of the upper strata species and promoted dominance of only a few prostrate species like *Rungia repens* and *Desmodium triflorum* which occurred most frequently within low disturbance zone (Dwivedi, 1978).

Habitat modification or fragmentation due to persisting disturbance (grazing and other anthropogenic pressure), creates a platform for the onset of biological invasion by species such as *Hyptis suaveolens*, *Parthenium hysterophorus* and *Solanum sisymbriifolium* (Srivastava et al., 2015). The replacement of many endemic species by a few widespread species could, by itself, promote large-scale homogenization especially in open habitats with reduced competition, often created by grazing and man-made disturbance (Wu et al., 2004; Huang et al., 2009). The survival and growth of small population into large population of several plant species indicated that the habitat quality was not always worse for all species especially invaders. They can easily colonize and fruitfully outcompete the native species. So, the invasive alien species form one of the major threats after fragmentation, against the survival and growth of several native species (CBD, 2005). They have potential to damage or eliminate already small populations of rare taxa (Menges, 1991a).

The anthropogenic disturbance is an important factor in determining the vegetation pattern across different habitat and often more dominating as compared to other (Angassa & Oba 2010; Dargie & Demerdash 1991; Gunaga et al. 2013, Körner, 1995). The human induced changes have caused, major changes in vegetation composition of *Terai* and a vast area of grasslands is converted into agro-ecosystem. Currently anthropogenic disturbance has affected the structural variability of these grasslands at local scale.

Conclusion

The present study explores the species composition and diversity pattern of *Terai* grassland vegetation with special reference to north-eastern Uttar Pradesh. This analysis emphasizes that for conservation of species, their habitat priority should be given to the maintenance of large grassland patches. The common species often show intraspecific competition and rare species show interspecific competition. The strong competitive effects for common species and weak effects for rare species suggest that competition promotes, rather than inhibits diversity. The land use change and agricultural intensification have led to the loss of habitat heterogeneity. Our analysis showed that generally, the moderate level of disturbance specially, grazing, trampling and cutting play a major role in maintaining optimum species diversity of the landscape but habitat condition such as marginal differences in soil, light condition and moisture regime also affect the level of species richness and overall biodiversity.

During the first phase of restoration it is important to focus on improvement of immigration. Connectivity between different sites is better as the main management tool because animals transport propagules and thus increase the speed of formation of field layer.

Conflict of Interests

The authors have not declared any conflict of interests.

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