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Diversity and Dynamics of the *Terai* Grassland Communities of Valmiki Tiger Reserve, Bihar, India

Grasslands are important habitats since they support a high density of ungulates and increase the potential carrying capacity for carnivores within a protected area. An understanding of their community structure is essential for their management. Valmiki Tiger Reserve (VTR) has the only relic of the Terai grassland remaining in Bihar. By sampling 304 plots, the authors identified 60 plant species belonging to 54 genera classified into 32 families within the grasslands of VTR. Seven grassland communities, namely (i) Saccharum munja, (ii) Imperata - Vetiveria - Typha - S. spontaneum (iii) Typha - S. arundinaceum - S. spontaneum (iv) Scleostachya - S. ravennae - S. spontaneum - Carex (v) Phragmites - S. arundinaceum - Typha - Carex (vi) Phragmites karka and (vii) Phyllanthus - Carex - Ficus were identified by TWINSPAN. Unlike other Terai regions, relatively dry site associates comprising Narenga porphyrocoma and Themeda arundinacea, and hygrophilous Arundo donax were absent. A successional model of floodplain grassland communities is also provided, which will guide managers in managing the grasslands. Thus, the study findings will help in restoring the unbalanced prey - population which are dependent on the grassland's successional dynamics.

Key words: Community, Floodplain, Grassland, *Terai*, TWINSPAN

The study documents 60 plant species distributed among seven grassland communities identified within the Terai grasslands of Valmiki Tiger Reserve, Bihar.

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Introduction

Terai is the lowland region located in the upper and lower Gangetic plains of northern India and is characterized by a mosaic of tall grasslands, swamps, savannah, and tropical moist deciduous forests (Champion and Seth, 1968; Johnsingh *et al*., 2004). The grasslands are organized into several assemblages or associations, called communities, where a few dominating species impart a unique physiognomy to the vegetation (Chaturvedi *et al*., 1985). Grassland communities are site - specific (Singh and Joshi, 1979) and prone to change in structure and composition primarily due to natural (succession) and altered fluvial processes like construction of dam, bund, flood control spurs and dykes along the river banks (Subedi *et al*., 2013) and others like change in fire regime, intensity of thatch collection, and grazing (Lehmkuhl, 1989, 1994; Peet *et al*., 1999a, 1999b; Peet, 1997; Tripathi and Shukla, 2007). Owing to the dynamic nature as well as a threat to the survival of these grasslands, they are of global importance for conservation along with their associated fauna (Bell and Oliver, 1992; Peet *et al*., 1999a). The *Terai* grasslands are home to several grassland obligate endangered fauna such as greater one - horned rhinoceros (*Rhinoceros unicornis*, Linnaeus), swamp deer (*Cervus duvauceli*, Cuvier), hog deer (*Axis porcinus*, Zimmermann), hispid hare (*Caprolagus hispidus*, Pearson), and Bengal florican (*Eupodotis bengalensis*, Gmelin). These fauna associate with specific vegetation communities in managed as well as unmanaged grasslands (Kumar, 2002; Odden *et al*., 2005; Peet *et al*., 1999a; Rahmani *et al*., 1988 and Wegge *et al*., 2006). Therefore, classification becomes a prerequisite in all the grasslands to capture the floristic diversity,and successional relationship, and to provide an

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ecological basis for managing the grasslands (Lehmkuhl, 1989).

In most of the *Terai*, protected area managers manage (by cutting, burning, harrowing, and others) only a small portion of the grasslands, leaving the bulk unmanaged due to resource crunch and time. Consequently, associated fauna largely utilize the mosaic of vegetation communities in these unmanaged grasslands. Managers need to prioritize grassland patches to invest their limited resources efficiently by giving priority to the habitat of associated endangered fauna found through research studies. To begin this course of action, the authors classified the unmanaged *Terai* grasslands into various communities. The study was conducted during December - January (2016), describing current grassland communities, their structure and composition, distribution, and dynamics. Our findings set a baseline for grassland community dynamics and provide a successional model. The identification of these grassland communities and their successional dynamics, as shown in the model, will help in the active management of grasslands and deduce the policies for thatch and fodder grass collection, cattle grazing. This study will also provide baseline data to conduct a study to find the association of endangered wild fauna within these grassland communities.

Study Site

The study was conducted in Valmiki Tiger Reserve (VTR), India, situated along the Indo - Nepal border at the foothills of the Himalayan *Terai* in the West Champaran district of the state of Bihar, (Fig. 1). (27°10' - 27°03' N latitude to 83°50' - 84°10' E longitude), covering an area of 899.38 km^2. It represents one of the last patches of forests having the unique combination of *Terai-Bhabar* vegetation (Johnsingh *et al.*,2004; Murari *et al*., 2024). VTR, along with 100 km of shared boundary with Chitwan National Park in the north and Parsa Wildlife Sanctuary in the northeast. It also has an interrupted connectivity with the Sohagibarwa Wildlife Sanctuary from the west. The area comes under sub - tropical monsoonal climate and has three clearly defined seasons– summer (mid - March to mid - June), monsoon (mid - June to mid - October), and winter (mid - October to mid - March). Annual precipitation is 1106.23 mm, of which a major contribution comes from the monsoon. The altitude varies from 140 m above MSL to 874 m above MSL (Maurya and Borah, 2013). VTR has seven forest types - Bhabhar Dun Sal Forest, Dry Siwalik Sal Forest, West Gangetic Moist Mixed Deciduous Forest, Eastern Wet Alluvial Grassland, Khair - Sissoo Forest, Canebrakes, and Barringtonia Swamp Forest (Champion and Seth, 1968). Grassland comprises 5% (44.45 km^2) of the total reserve, out of which the largest portion (56.24%, 25 km^2) of the grassland is in the Madanpur block (Mathur *et al*., 2003; Sinha *et al*., 2016; Murari *et al*., 2024). Therefore, the research was conducted in the major southern portion of the Madanpur block of VTR, having the least elevated flat lands, covering an approximate area of 89.6 km^2, having various small and large - sized grassland patches. Madanpur block covers two ranges (Madanpur and Valmikinagar) out of eight in VTR. It is a linear stretch of land having unique ecosystem compared to the rest five blocks of reserve (having sal - dominated forest) owing

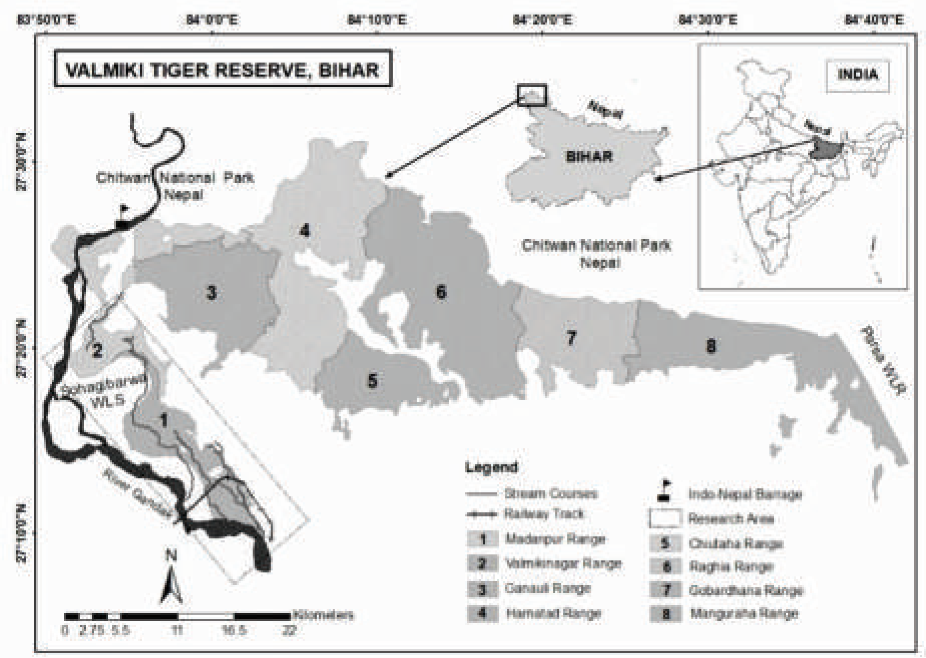

Fig. 1 : Map of Valmiki Tiger Reserve, Bihar, India

to its location in the fertile alluvial floodplain of the river Gandak and the presence of the last five forest types. Villages surround the block from all sides. Livestock grazing, human - induced uncontrolled fire, and thatch grass collection are common anthropogenic phenomena of these grasslands (Sinha *et al.,* 2016; Murari *et al*., 2024).

Methods

Vegetation sampling

The study area was stratified into forest and grassland patches. Then, systematic random sampling was followed, wherein transect lines were laid in grassland patches. Distance between the two transects was kept at 450 m. Circular plots of a two - meter radius were sampled on these transect lines. The distance between the two plots on the transect was 200 m. Observation was done in two - meter radius vegetation circular plots from a raised ladder platform. It ensured that the visibility would not impair ocular estimation of the per cent cover contribution of grasses (tall and short) and dicots within the plot. Grassland vegetation plots were laid in December–January when most of the grasses were in inflorescence. This helped in the identification of species in the field, as well as being the ideal time for the collection of herbarium specimens to verify their identity at the herbarium of the Wildlife Institute of India, Dehradun. A total of 304 plots were laid to cover almost all small and large grassland patches. Within each plot, data on landforms (upland or lowland), drainage (duration of standing water and presence of small stream courses or ditches), cutting, and burning were also recorded.

Grassland vegetation community analysis

Among several clustering techniques, TWINSPAN (Hill, 1979) was used in the software package PC - ORD. Cut values were 0, 3, 5, 10, 20, 30, 50, 70, and 100. Maximum numbers of indicators per division, as well as maximum levels of divisions, were chosen as three to avoid complexity while interpretation and to match visually estimated communities on the field. Non - metric dimensional scaling (NMDS; McCune *et al*., 2002) was used in software R using the similar name function “metaMDS” to visualize the clustering of species and samples along ordination gradients.

Results

Grassland vegetation diversity

Sampling from the grassland of the study area recorded 60 plant species belonging to 54 genera classified into 32 families. The major families contributing to plant diversity were Poaceae (14 species), Asteraceae (7 species), Cyperaceae, and Fabaceae with 3 species each; Mimosaceae, Moraceae, and Phyllanthaceae with 2 species each; while singletons from the rest other families. Out of 60 species, 18 were grasses and grass - like species, 16 herbs, 12 shrubs, 6 climbers, and 8 trees (Table 1) Grasslands of VTR were dominated by a few common species such as *Phragmites karka*, *Typha angustifolia*, *Vetiveria zizanioides*, *Imperata cylindrica*, *Saccharum arundinaceum*, *S. spontaneum,* and *Sclerostachya fusca*, while most others were rare (Fig. 2).

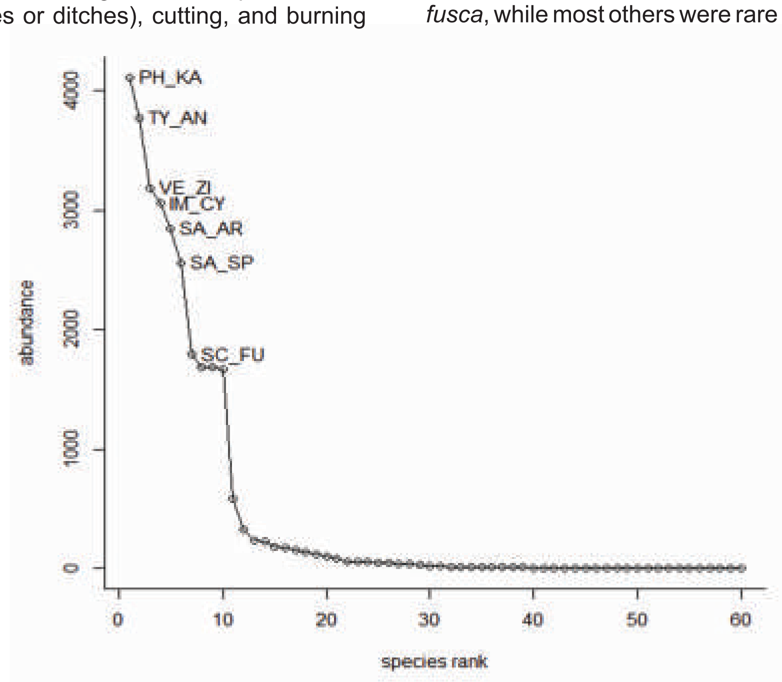

Fig. 2 : Rank abundance curve for the alluvial grassland of VTR.
PH_KA=*Phragmites karka*, TY_AN= *Typha angustifolia*, VE_ZI=*Vetiveria zizanioides*, IM_CY=*Imperata cylindrica*, SA_AR=*Saccharum arundinaceum*, SA_SP=*Saccharum spontaneum*, SC_FU=*Sclerostachya fusca*

Table 1: Checklist of plant species in the floodplain grassland of VTR.

S. No.	Scientific name	Family	Local name	Habit
1	*Phragmites karka* (Retz.) Trin. ex Steud.	Poaceae	Narkat	Grass
2	*Saccharum arundinaceum* Retz.	Poaceae	Kari / Dhamsar	Grass
3	*Imperata cylindrica* (L.) Raeusch.	Poaceae	Dabhi	Grass
4	*Saccharum munja* Roxb.*	Poaceae	Munj	Grass
5	*Saccharum ravennae* (L.) L.	Poaceae	Dhamsar	Grass
6	*Sclerostachya fusca* (Roxb.) A.Camus*	Poaceae	Ekra	Grass
7	*Vetiveria zizanioides* (L.) Nash*	Poaceae	Katra	Grass
8	*Saccharum spontaneum* L.	Poaceae	Kharai	Grass
9	*Desmostachya bipinnata* (L.) Stapf	Poaceae	Kush	Grass
10	*Cynodon dactylon* (L.) Pers.	Poaceae	Dubh	Grass
11	*Apluda mutica* L.	Poaceae	Basri	Grass
12	*Hemarthria compressa* (L.f.) R.Br.	Poaceae	Gadila	Grass
13	*Panicum antidotale* Retz.	Poaceae		Grass
14	*Paspalum scrobiculatum* L.	Poaceae	Kodwar	Grass
15	*Typha angustifolia* L.	Typhaceae	Pater	Grass
16	*Cyprus sp.*	Cyperaceae	Motha	Sedge
17	*Carex vesicaria* L.	Cyperaceae	Kewti	Sedge
18	*Fimbristylis sp.*	Cyperaceae	Motha	Sedge
19	*Ampilopteris sp.#*	Thelypteridaceae	Balya	Fern
20	*Curcuma spp.*	Zingiberaceae	Kachur	Herb
21	*Enhydra fluctuans* Lour	Asteraceae		Herb
22	*Polygonum hydropiper* L.*	Polygonaceae	Lirbiriya	Herb
23	*Cirsium arvense* (L.) Scop.	Asteraceae		Herb
24	*Rungia sp.*	Acanthaceae		Herb
25	*Aerva lanata* (L.) Juss.	Amaranthaceae	.	Herb
26	*Blumea sp.*	Asteraceae		Herb
27	*Spilanthes sp.*	Asteraceae		Herb
28	*Vicia sativa* L.	Fabaceae		Herb
29	*Lathyrus aphaca* L.	Fabaceae		Herb
30	*Curculigo sp.*	Hypoxidaceae		Herb
31	*Duchesnea indica* (Jacks.) Focke	Rosaceae		Herb
32	*Solanum nigrum* L.*	Solanaceae	Bhatkoi	Herb
33	*Pouzolzia sp.*	Urticaceae		Herb
34	*Gnaphalium luteoalbum* L.*	Asteraceae		Herb
35	*Ardisia solanacea* (Poir.) Roxb.	Primulaceae	Majargarwa	Shrub
36	*Murraya koenigii* (L.) Spreng.	Rutaceae	Kadhi patta	Shrub
37	*Ziziphus mauritiana* Lam.*	Rhamnaceae	Baer	Shrub
38	*Ageratum conyzoides* (L.) L.	Asteraceae	Bhant	Shrub
39	*Phyllanthus sp.*	Euphorbiaceae	Sikat	Shrub
40	*Callicarpa macrophylla* Vahl	Verbenaceae	Budhiya mai ka lawa	Shrub
41	*Randia dumetorum* (Retz.) Lam.*	Rubiaceae	Mauna	Shrub
42	*Urena lobata* L.	Malvaceae	Laptewa	Shrub
43	*Equisetum debile* Roxb. ex Vaucher*	Eqisetacea	Hadjodwa	Shrub
44	*Securinega virosa* (Roxb. ex Willd.) Baill.*	Phyllanthaceae		Shrub
45	*Flemingia semialata* Roxb.	Fabaceae	Banbariyar	Shrub
46	*Asparagus sp.*	Liliaceae	Santavar	Shrub
47	*Calamus tenuis* Roxb.	Arecaceae	Bet	Climber
48	*Mikania micrantha* Kunth	Asteraceae		Climber
49	*Acacia concinna* (Willd.) DC.	Mimosaceae	Tairi	Climber
50	*Smilax aspera* L.	Smilaceae	Gabnaha	Climber
51	Unidentified species 1^			Climber
52	Unidentified species 2^		Piliya latti	Climber
53	*Syzygium cumini* (L.) Skeels	Myrtaceae	Jamun	Tree
54	*Holarrhena pubescens* Wall. ex G.Don	Apocynaceae	Dudhkareya	Tree
55	*Ehretia laevis* Roxb.	Boraginaceae	Datranga	Tree
56	*Acacia catechu* (L.f.) Willd.	Mimosaceae	Khaira	Tree

S. No.	Scientific name	Family	Local name	Habit
57	*Trewia nudiflora* L.*	Euphorbiaceae	Bhilore	Tree
58	*Ficus hispida* L.f.	Moraceae	Kathdumar	Tree
59	*Bauhinia racemosa* Lam.	Caesalpiniaceae	Sahul	Tree
60	*Casearia tomentosa* Roxb.	Salicaceae		Tree

*Synonyms - *Saccharum munja* Roxb. Syn. *Saccharum bengalense* Retz., *Sclerostachya fusca* (Roxb.) A.Camus Syn. *Miscanthus fuscus* (Roxb.) Benth., *Vetiveria zizanioides* (L.) Nash Syn. *Chrysopogon zizanioides* (L.) Roberty, *Polygonum hydropiper* L. Syn. *Persicaria hydropiper* (L.) Delarbre, *Solanum nigrum* L. Syn. *Solanum americanum* Mill., *Gnaphalium luteoalbum* L. Syn. *Laphangium luteoalbum (L.) Tzvelev, Ziziphus mauritiana* Lam. Syn. *Ziziphus jujuba* Mill., *Randia dumetorum* (Retz.) Lam. Syn. *Catunaregam spinosa* (Thunb.) Tirveng., *Equisetum debile* Roxb. ex Vaucher Syn. *Hippochaete debilis* (Roxb. ex Vaucher) Ching, *Securinega virosa* (Roxb. ex Willd.) Baill. Syn. *Flueggea virosa* (Roxb. ex Willd.) Royle, *Trewia nudiflora* L. Syn. *Mallotus repandus* (Willd.) Müll.Arg.; # *Ampilopteris spp.* along with *Christella dentata* (Forssk.) Brownsey and Jermy and *Diplazium esculentum* (Retz.) Sw. were clubbed as fern during sampling; ^ found in dried stage.

Grassland vegetation communities

TWINSPAN analysis classified 304 plots into seven different grassland communities based on indicator species (Fig. 3a). All seven communities of VTR were dominated by a few abundant species, while most other species had low abundance and low frequency (Fig. 3b).

Division of 304 plots separated hygrophilous communities from mesophilic communities in subsequent dichotomies till the last division, where non - grassy indicator species separated from the majority of grassy indicator species. NMDS showed segregation of all seven grassland communities along the ordination gradient with little overlap at the ecotone. Since NMDS collapses information from multi - dimensions (multi communities/sites) to just a few axes (typically set to 2), therefore, communities appearing to be overlapping segregate in ordination space when plotted separately from the rest of the other communities (Fig. 4 (a) and 4 (b)).

Physiognomy of grassland vegetation communities

TWINSPAN analysis classified *Terai* grasslands of VTR into seven major communities based on species

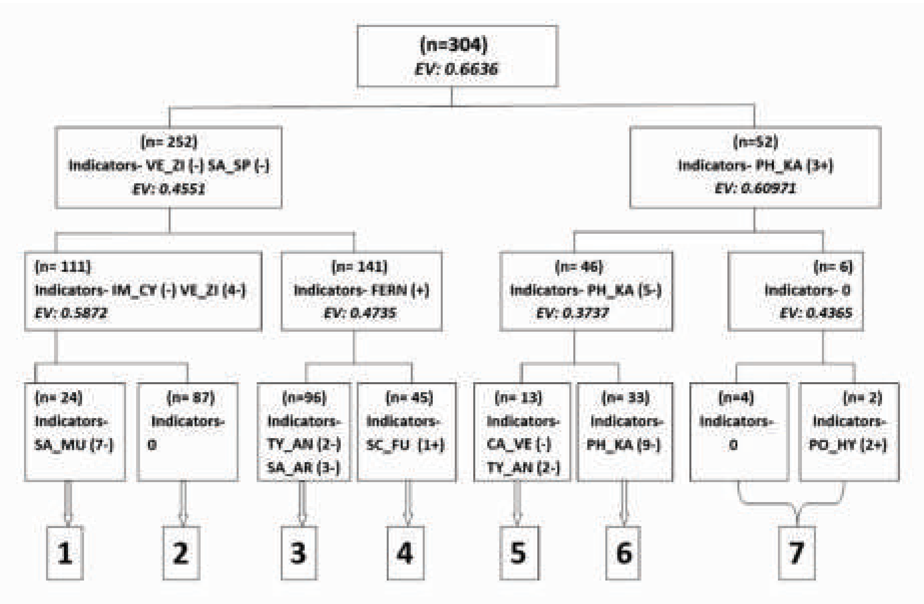

Fig. 3a : Dendrogram showing seven grassland communities as inferred from the ordered two - way table obtained from the result of TWINSPAN analysis;
n=sample plot, EV=eigen value, VE_ZI= *Vetiveria zizanioides*, PH_KA=*Phragmites karka*, IM_CY is *Imperata cylindrica*, SA_MU=*Saccharum munja*, TY_AN=*Typha angustifolia*, SA_AR=*Saccharum arundinaceum*, SC_FU=*Sclerostachya fusca*, CA_VE=*Carex vesicaria*, PO_HY=*Polygonum hydropiper*;1= *Saccharum munja*(SAMU) association, 2=*Imperata cylindrica - Vetiveria zizanioides - Typha angustifolia - Saccharum spontaneum* (IMCY - VEZI - TYAN - SASP) association, 3= *Typha angustifolia - Saccharum arundinaceum - Saccharum spontaneum*(TYAN - SAAR - SASP) association, 4= *Sclerostachya fusca - Saccharum ravennae - Saccharum spontaneum - Carex vesicaria*(SCFU - SARA - SASP - CAVE) association, 5= *Phragmites karka - Saccharum arundinaceum - Typha angustifolia - Carex vesicaria*(PHKA - SAAR - TYAN - CAVE) association, 6= *Phragmites karka* (PHKA) association, 7=*Phyllanthus sp. – Carex vesicaria - Ficus heterophylla* (PHYL - CAVE - FIHE) association.

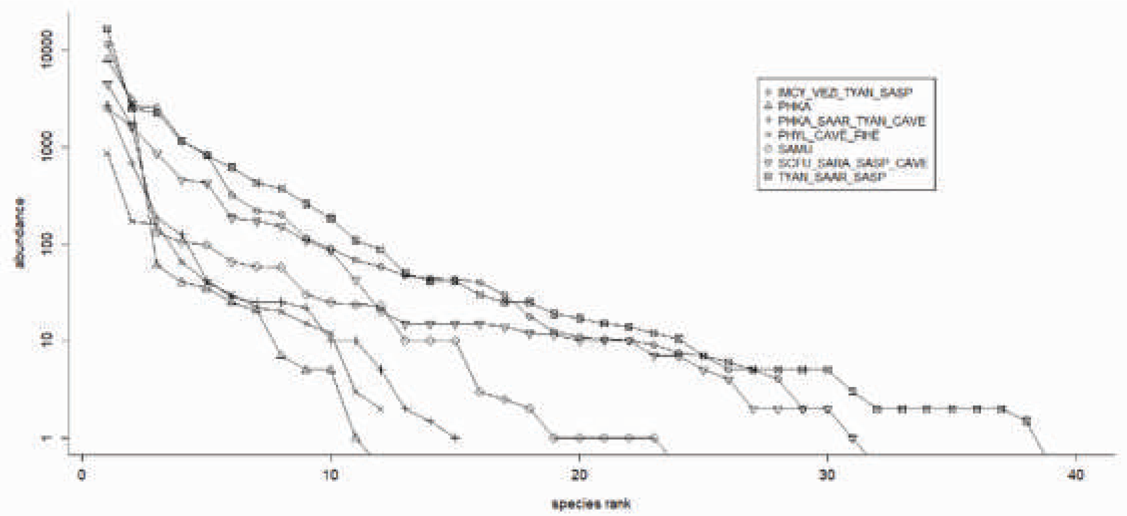

Fig 3b: Rank abundance curve of all seven grassland communities in VTR.

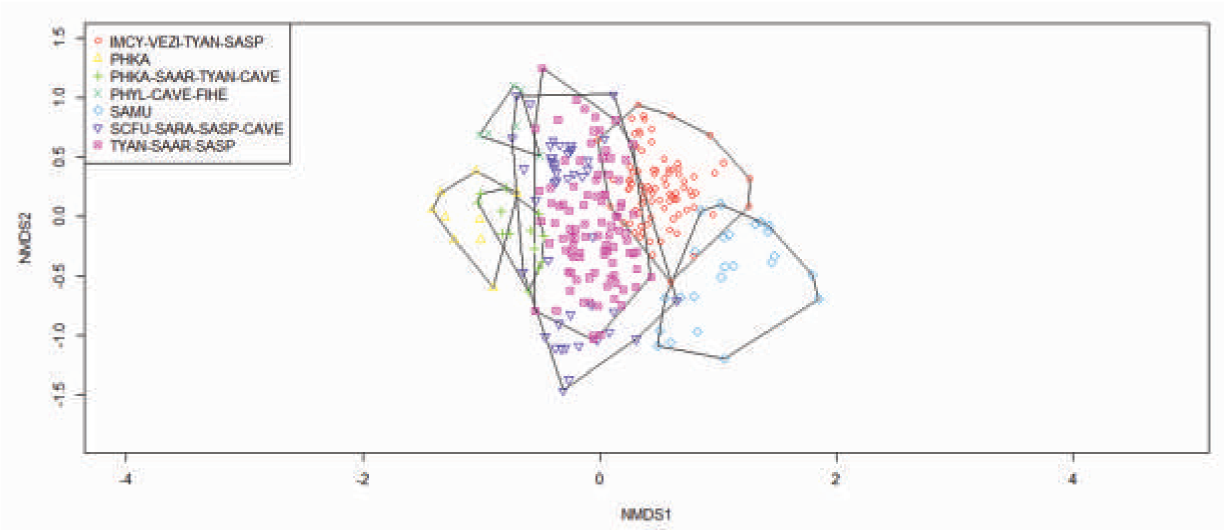

Fig. 4a : Distribution of all the grassland associations along the ordination gradient as depicted by output of NMDS. Upland dry community of *S. munja* clustered far right on x - axis while wettest marshy community of *P. karka* clustered far left on x - axis. Rest other communities with intermediate affinity to moisture occupied the ordination space in between.

composition and indicator species. These were as follows -

***Saccharum munja* association :** This is a monospecific dominant community. Out of 21 species occurring in the association, *S. munja* alone contributed 67.5 (± SE 4.79)% of the total mean per cent cover. *S. munja* was the sole indicator of the association, wherein *I. cylindrica* was frequently associated, followed by *Ziziphus mauritiana* and *Desmostachya bipinnata.* Each of the other species contributed <5% to the total mean per cent ground cover. This community was found in dry upland areas and is in the late seral stage of succession among all grasses. Sward height ranges from 1.8 m to 3 m on well - drained old alluvial clayey soil.

***Imperata cylindrica - Vetiveria zizanioides - Typha angustifolia - Saccharum spontaneum* association :** In this association, *I. cylindrica* with 30.49 (± SE 2.91)% mean cover co - dominated with *V. zizanioides* with 29 (± SE 4.6)% mean cover. *T. angustifolia* with 13.38 (± SE 1.91)% mean cover and *S. spontaneum* with 9.6 (± SE 1.3)% mean cover are frequently associated with co - dominants. Out of 30 plant species occurring in varied proportions within this association, the above four species together constituted 72.47% of the total mean per cent cover. However, in some places, *T. angustifolia* was absent from this association. *Hemarthria compressa* is locally associated, sometimes at moist sites. This community was second in abundance (29%) and was found in lowland areas, where moisture is

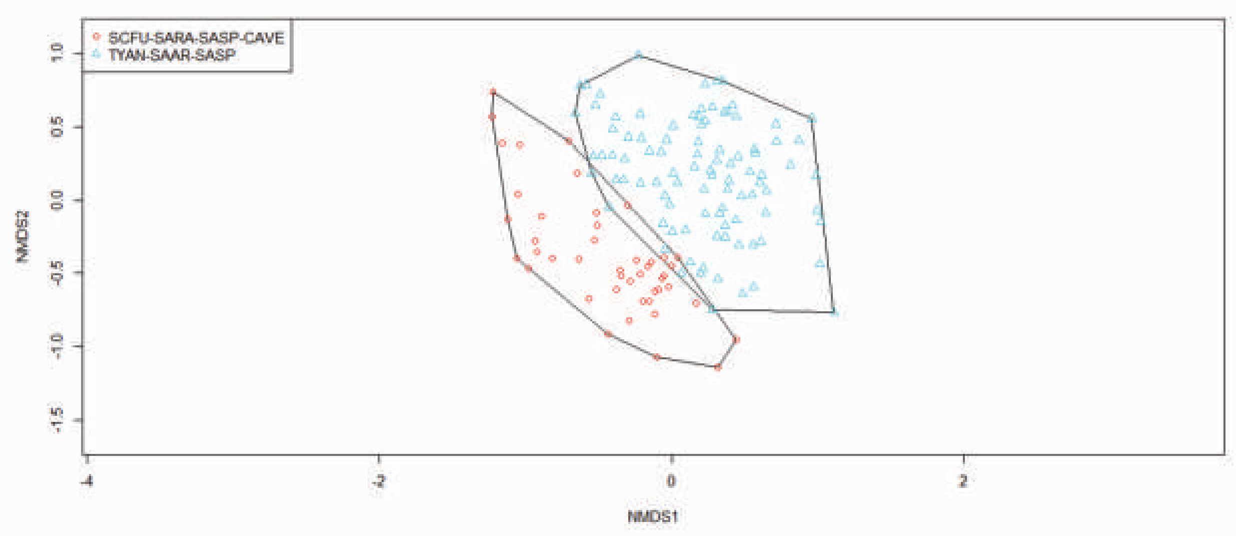

Fig. 4b : Two grassland communities (SCFU - SARA - SASP - CAVE and TYAN - SAAR - SASP) which seemed to be overlapping in Fig 4a, separate when plotted separately in NMDS.

present throughout the year and water inundates the area for a few monsoon and post - monsoon months. Visually community has two storeys - upper with structurally dominant species of *T. angustifolia* and *S. spontaneum* with heights ranging from 1.5 to 3.5 m, and secondly, the lower storey of *I. cylindrica* and *V. zizanioides*, mostly at outer and sun - exposed patches, with sward height 0.7 - 1.2 m.

Furthermore, one early successional phase of this association was also identified. *Saccharum spontaneum - Phragmites karka* phase with *S. spontaneum* contributing 60 to 80% cover and *P. karka* as a sub - dominant on recently developed alluvium, lying longitudinally along stream courses.

***Typha angustifolia - Saccharum arundinaceum - Saccharum spontaneum* association :** Within this association, *T. angustifolia* with 25.69 (± SE 2.86)% mean cover, co - dominated by *S. arundinaceum* with a mean per cent cover of 23.32 (± SE 2.85)%. Both *T. angustifolia* and *S. arundinaceum* are indicators of the association. *S. spontaneum* sub - dominated the association with a mean per cent cover of 12.06% (± SE 1.96). *Carex vesicaria* and fern species are frequently associated with co - dominants and sub - dominants. *Apluda mutica* is sometimes associated with relatively drier sites. Out of 36 plant species occurring in varied proportions within this association, only three species (co - dominants together with sub - dominants) comprised 61.07% of the total mean per cent cover. This community is most abundant (31%) and was found in poorly drained low - lying areas where water stagnates for 4 - 5 months (July – November). Sward height in the lower storey of fern and *C. vesicaria* varies from 0.7 m to 1 m, and 2.5 m to 4 m in the top storey, comprises *T. angustifolia* and *Saccharum* species.

Additionally, three phases that eventually culminate in this association were also identified. First, *Typha angustifolia* phase, on waterlogged marshy patches having recent silt deposits, in which *T. angustifolia* alone comprises 60 to 90% cover. Second, *Typha angustifolia - Saccharum arundinaceum* phase, in which *T. angustifolia* and *S. arundinaceum* were codominants in very wet places. Third, *Saccharum arundinaceum - Saccharum spontaneum* phase with *S. spontaneum* as sub - dominant to *S. arundinaceum* on the peripheral edge of this association.

***Sclerostachya fusca - Saccharum ravennae - Saccharum spontaneum - Carex vesicaria* association :** *Sclerostachya fusca* is the indicator as well as dominant species of the association, with a mean per cent cover of 36.95 (± SE 4.59)%. The sub - dominants of this association are *S. ravennae* with 19.24 (± SE 4.50)% mean cover and *S. spontaneum* with 10.24 (± SE 2.38)% mean cover. *C. vesicaria* and fern species are frequently associated with the dominant and sub - dominant. Out of 30 plant species occurring in varied proportions within this association, *S. fusca,* together with *S. ravennae* and *S. spontaneum* alone, comprised 66.43% of the total mean per cent cover. This community occurred in the low - lying areas where seasonal inundation happens for 5 - 8 months (July – December). Sward height in the upper storey of *S. fusca*, *Saccharum* species varied from 1.8 m to 4.5 m, whereas *C. vesicaria* and fern in the lower layer rose to 1.2 m.

Moreover, three phases that ultimately culminate in this association were also identified. Firstly, *Sclerostachya fusca - Saccharum spontaneum* phase on long - inundated lowland. In this, *S. fusca* constitutes 40 to 90% of the cover (sometimes a pure patch) along with *S. spontaneum* as codominant. Secondly, *Sclerostachya fusca - Saccharum ravennae* phase with

S. fusca and *S. ravennae* usually as co - dominants on the banks of stream courses, but sometimes *S. ravennae* in purity. Thirdly, *Sclerostachya fusca - Carex vesicaria* phase with *S. fusca* and *C. vesicaria* as co - dominants on heavily trampled lowland inundating areas.

***Phragmites karka - Saccharum arundinaceum - Typha angustifolia - Carex vesicaria* association :** In this association, *P. karka* was the dominant plant species with a mean per cent cover of 52.92 (± SE 5.21)%. *T. angustiolia* with a mean per cent cover of 9.61 (± SE 2.96)%, and *C. vesicaria* with a mean per cent cover of 3.23 (± SE 1.18)% were the indicators of the association. *S. arundinaceum* with a mean per cent cover of 14.34 (± SE 5.90)% is frequently associated with *P. karka*. Out of 14 plant species occurring in varied proportions within this association, above mentioned four species alone comprised 80.1% of the total mean cover. This community occurred along pools (locally called *nari*) and stream courses (locally called *nala*). Sward height varies from 2 m to 3.5 m with *C. vesicaria* rising to 0.75 m above ground.

***Phragmites karka* association :** This is a monospecific dominant community. *P. karka* is the sole indicator of the association, which alone comprised a mean per cent cover of 92.36 (± SE 3.01)%. This community was found in water - logged swampy areas around pools and ditches or stream courses, especially on the old watercourse of river Gandak in compartment M19. On average, water stands up to knee height in the dry season with above - water sward height up to 5 m.

***Phyllanthus* sp. *- Carex vesicaria - Ficus heterophylla* association :** This is the only dicot - dominant association out of the seven associations in the study area. *Phyllanhus sp*., a dicot with a mean per cent cover of 28.33 (± SE 8.23)%, co - dominated the association with *C. vesicaria*, a sedge, with a mean per cent cover of 26.33%. *Ficus heterophylla,* another dominant dicot, sub - dominated the association with a mean per cent cover of 10.83%. Out of 11 plant species occurring in varied proportions within this association, the above three species together comprised 65.49% of the total mean cover. *Urena lobata*, another dicot frequently associated with co - dominants and sub - dominants. This community occurred along pools and stream courses with above - ground height ranging from 1.6 m to 2m.

Discussion

Grassland diversity

Sampling done in the cool dry season (December - January; post - monsoon) recorded 60 species, of which 18 species belonged to grasses and grass - like species. However, some grass species – *Themeda arundinacea*, *Bothriochloa intermedia*, *Dichanthium annulatum*, *Setaria sp*., *Arundo donax*, *Chrysopogon fulvus* were encountered randomly at a few places, but outside the sampling plot. It indicates their rarity in the *Terai* grasslands of VTR. Like the *Terai* grasslands of Nepal (Peet *et al*., 1999a), few common species in VTR – *P. karka*, *T. angustifolia*, *V. zizanioides*, *I. cylindrica*, *S. arundinaceum*, *S. spontaneum,* and *S. fusca* dominated the grasslands (Fig. 2).

Grassland communities: distribution and dynamics

From the floodplain of VTR, seven grassland communities with three phases in two communities each and one phase in one of the communities were identified. A model of *Terai* grassland community dynamics and hypothetical successional trend in VTR is given in Fig. 5 and explained below. Like the communities reported from different parts of *Terai*, all seven communities of VTR were dominated by a few abundant species, with five or fewer species constituting more than 70% of the total mean per cent cover in each community (Peet *et al.,* 1999a; Fig. 3b). Fluvial processes (natural as well as altered), fire, cutting, and grazing have shaped the dynamics of VTR grasslands as in other *Terai* regions (Tripathi and Shukla, 2007; Murari *et al*., 2024). The natural path of succession causes the hydrophytic communities (*Phragmites* and *Typha*) to change into the mesophytic communities (such as one with *S. spontaneum*, *Imperata*, *S. arundinaceum,* etc.) and ultimately to xerophytic communities (*S. munja*, *D. bipinnata*) at the edge of sal forest via the riverine forest, with the soil textural development (Fig. 5). Sand constitutes the recent alluvium formed mainly by physical weathering and is deposited along rivers (Vishwanath and Ukil, 1943). *P. karka* association on the undisturbed waterlogged swampy place with silt deposits at the old watercourse of the river Gandak represents the stable edaphic association less responsive to the floodplain ecosystem (Lehmkuhl, 1994). *T. angustifolia* phase on marsh with recent silt (Lahkar, 2008), *Phragmites - S. arundinaceum - Typha - carex* association on marshy lowland, and *Phyllanthus - Carex - F. heterophylla* association along stream courses and marshes in lowlands has close edaphic similarity. The grassland pioneer *S. spontaneum - P. karka* phase on recent alluvial sands along stream courses and rivers (Dinerstein, 2003) step up to form successional *Imperata - Vetiveria - Typha - S. spontaneum* association on lowlands which are heavily grazed and cut and burned. While, mid seral tall wet association of *Sclerostachya - S. ravennae - S. spontaneum - Carex* on seasonally inundated long waterlogged place (Kumar, 2002; Sreenivasan and Sreenivasan, 1984) gives way to next seral association of *Typha - S. arundinaceum - S. spontaneum* with subsequent soil development. Grazing, cutting and burning restricts the succession into *S. munja* association, flourishing on well - developed clayey upland soil mostly at forest edges (Lehmkuhl, 1994; Peet *et al.,* 1999a). *S. munja,* along with *D. bipinnata* and *Z. mauritiana,* indicates the culmination into riverine forest with *Acacia catechu* and *Dalbergia sisoo* on sandy

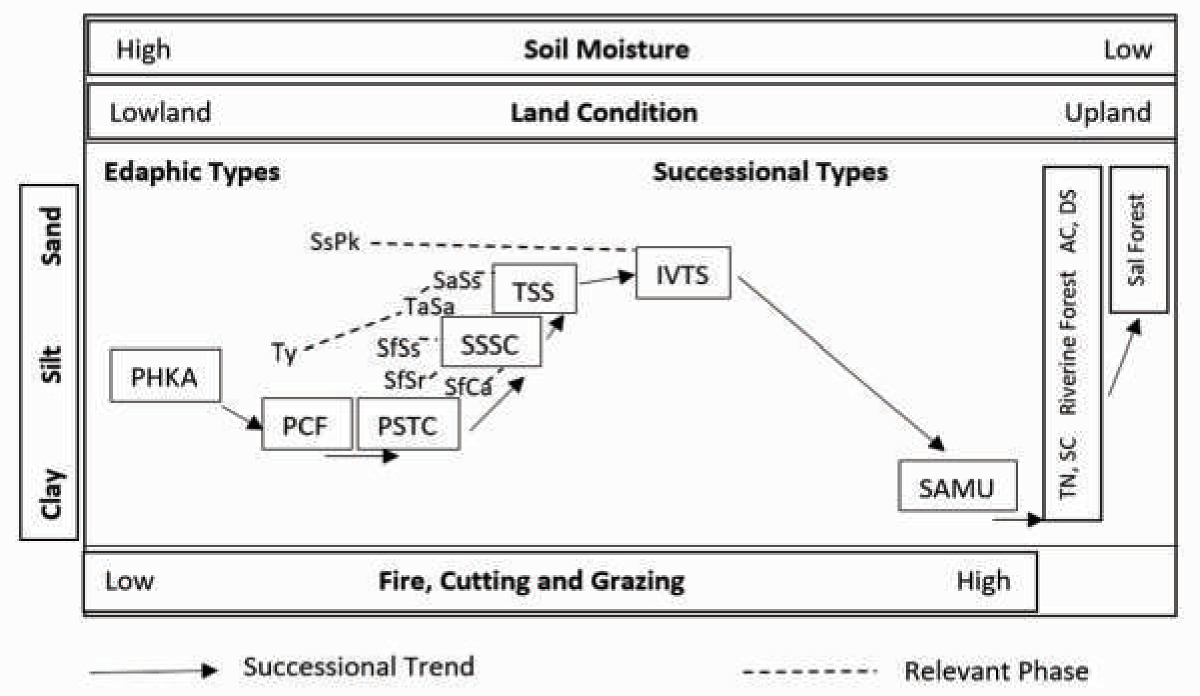

Fig. 5 : A model of riverine grassland community dynamics and hypothetical successional trend in VTR.
SAMU= *Saccharum munja* association, IVTS= *Imperata cylindrica - Vetiveria zizanioides - Typha angustifolia - Saccharum spontaneum* association, TSS= *Typha angustifolia - Saccharum arundinaceum - Saccharum spontaneum* association, SSSC= *Sclerostachya fusca - Saccharum ravennae - Saccharum spontaneum - Carex vesicaria* association, PSTC= *Phragmites karka - Saccharum arundinaceum - Typha angustifolia - Carex vesicaria* association, PHKA= *Phragmites karka* association, PCF= *Phyllanthus sp. – Carex vesicaria - Ficus heterophylla* association; SsPk= *S. spontaneum* - P. karka phase, Ty= Typha anguistifolia phase, TaSa= *T. angustifolia - S. arundinaceum* phase, SaSs= *S. arundinaceum - S. spontaneum* phase, SfSs= *S. fusca - S. spontaneum* phase, SfSr= *S. fusca - S. ravennae* phase, SfCa= *S. fusca - C. vesicaria* phase; TN= *Trewia nudiflora*, SC= *Syzygium cumini*, AC= *Acacia catechu*, DS= *Dalbergia sissoo*

alluvial soil along rivers and *Trewia nudiflora* and *Syzygium cumini* on well - developed clayey soil. This stage ultimately culminates in the climatic climax of the sal forest (Champion and Seth, 1968). Low occurrence of pure patches of early colonizer *S. spontaneum* in VTR indicates altered fluvial processes by the past activities of the Indo - Nepal barrage and railway track construction, which have changed the ecology of grasslands and forests of Madanpur by reducing the siltation load into the grassland and alteration in the drainage pattern (Murari, 2017; Tiwari, 1999). It has promoted growth and domination of *S. fusca* association, majorly avoided by ungulates due to dense clumps formation as a result of high tillering and waterlogging resistance ability (Sreenivasan and Sreenivasan, 1984). Altered fluvial flow prevents inherent fast succession by *S. spontaneum*, an important food plant of ungulates, and promotes inherent slow succession of *S. spontaneum* into tall mixed wet associations (Dinerstein, 2003; Kumar, 2002; Lehmkuhl, 1994; Peet *et al.,* 1999a; Subedi *et al.,* 2013). This is evident from the high dominance of three medium to tall wet associations (75%) of *Typha - S. arundinaceum - S. spontaneum* (31%) and *Imperata - Vetiveria - Typha - S. spontaneum* (29%) and *S. fusca* dominated the association (15%) in the study area. It also suggests that a large portion of the floodplain grassland of VTR is in a transition phase, viz., from hydrophilic to mesic phase.

The Floodplain grassland of VTR had similarity to Nepal *Terai* and Terai Conservation Area (TCA; Kumar, 2002; Murari, 2017), in having wet associations dominated by *P. karka*, *T. angustifolia*, *S. spontaneum* and *S. arundinaceum*, *S. fusca* (only in TCA), but different due to the absence of relatively dry site associates dominated by *N. porphyrocoma* and *T. arundinacea* (Lehmkuhl, 1994; Peet *et al*., 1999a).

Conservation and management implications

This study recognizes seven grassland communities that exhibit unique ecological characteristics that influence their conservation and management. Understanding their classification is crucial, as each type supports distinct plant and animal species and responds differently to environmental pressures (Peet *et al*., 1999a). Succesional dynamics, the natural progression of plant communities over time, play a vital role in shaping grassland structure and biodiversity. Human activities such as agriculture, overgrazing, thatch collection, and fire suppression disrupt these natural successional processes, often leading to degradation or conversion into shrubland or forest. The villagers sought after *S. spontaneum* (locally called *kharai*), *I. cylindrica* (locally called *dabhi*), *V. zizanioides* (locally called *katra*) for building fine thatch walls and roofs, and *S. munja* (locally called *muj*) for rope and traditional basket making. Similarly, construction of barrages (such as Indo - Nepal barrage in VTR) and dams, checks, dykes alters the fluvial process hindering colonization of *S. spontaneum* patches while promoting tall wet mixed associations (Lehmkuhl, 1994; Peet *et al*., 1999a). Waterlogging due to blockage of perennial rivulets (such as Rohua and Kotraha in the study area by the construction of the railway track (Tiwari, 1999)) led to the growth and abundance of *S. fusca* association. Clearing the water blockage will bring back natural fluvial dynamics and may result in more proliferation of *S. spontaneum*, a preferred plant association of ungulates. Therefore, mapping these associations as a first step (Lehmkuhl, 1994) and subsequent development of control grazing policy, thatch collection policy, and departmental controlled burning policies as practiced in Chitwan by managers will lead to the conservation of the deteriorating *Terai,* preferably through community participation (Pokharel, 1993). During treatments, management strategies must consider the specific grassland type, which isthe habitat of grassland obligate animals (Moe and Wegge, 1997; Odden *et al*., 2005), and its stage in succession to maintain ecological balance. Protecting early - successional species, which are often outcompeted in later stages, is especially important in maintaining biodiversity. Grassland restoration efforts should aim to re-establish native species and natural disturbance regimes that support healthy succession. Monitoring changes in community composition over time helps guide adaptive management practices. Overall, integrating grassland classification and successional dynamics into conservation planning ensures more targeted and sustainable outcomes.

वाल्मिकी टाइगर रिजर्व, बिहार, भारत के तराई घास के मैदान समुदायों की विविधता और गतिशीलता

कृष्ण मुरारी, गौतम तालुकदार, यादवेन्द्रादेव वी. झाला, बिवाश पांडव, कमर कुरैशी और गोपाल सिंह रावत

सारांश

घास के मैदान महत्वपूर्ण आवास हैं क्योंकि वे खुर वाले जानवरों के उच्च घनत्व का समर्थन करते हैं और संरक्षित क्षेत्र के भीतर मांसाहारियों की संभावित वहन क्षमता को बढ़ाते हैं। उनके प्रबंधन के लिए उनकी सामुदायिक संरचना की समझ आवश्यक है। वाल्मीकि टाइगर रिजर्व (वी. टी.आर.) में बिहार का एक मात्र तराई घास के मैदान का अवशेष है। 304 भूखंडों के नमूने लेकर, लेखकों ने वीटीआर के घास के मैदानों के भीतर 32 परिवारों में वर्गीकृत 54 पीढ़ी से संबंधित 60 पौधों की प्रजातियों की पहचान की। सात घास के मैदान समुदाय, अर्थात् (i) *सैकरम मुंजा,* (ii) *इम्पेराटा – वेटिवेरिया – टाइफा – एस. स्पोंटेनियम* (iii) *टाइफा – एस. अरुंडिनेसियम – एस. स्पोंटेनियम* (iv) *स्क्लेओस्टैचिया – एस. रेवेना – एस. स्पोंटेनियम – केरेक्स ट्विनस्पैन द्वारा अरुंडिनेसियम – टाइफा – कैरेक्स* (vi) *फ्राग्माइट्स करका* और (vii) *फिलांथस – कैरेक्स – फिकस* की पहचान की गई। अन्य तराई क्षेत्रों के विपरीत, *नारेंगा पोर्फिरोकोमा* और *थीमेडा अरुंडिनेशिया* और *हाइग्रोफिलस अरूण्डों डोनैक्स* सहित अपेक्षाकृत शुष्क साइट सहयोगी अनुपस्थित थे। बाढ़ के मैदान के घास के मैदान समुदायों का एक उत्तराधिकार मॉडल भी प्रदान किया गया है, जो घास के मैदानों के प्रबंधन में प्रबंधकों का मार्गदर्शन करेगा। इस प्रकार, अध्ययन के निष्कर्ष असंतुलित शिकार – आबादी को बहाल करने में मदद करेंगे जो घास के मैदान की उत्तराधिकार गतिशीलता पर निर्भर हैं।

References

Champion H. and Seth S. (1968). *A revised study of the forest types of India*. Government of India Press, New Delhi. 404 pp

Dinerstein E. (2003). *The return of the unicornis - the natural history and conservation of the greater one - horned rhinoceros*. Biology and Resource Management Series. World Wildlife Fund, Washington DC, 320pp

Hill M.O. (1979). *TWINSPAN, a FORTRAN program for two - way - indicator - species - analysis.* Cornell University, Ithaca, New York.

Kumar H. (2002). *An ecological assessment of forest spatial heterogenity species diversity and grassland burning practices in terai conservation area*. Doctor of Philospy Thesis. Saurashtra University, Rajkot, Gujrat. 72pp

Lahkar B.P. (2008). Ecology and management of grassland with special reference to grassand bird communities in Manas National Park. Ph.D. Thesis Assam: Gauhati University, Guwahati.

Lehmkuhl J.F. (1989). *The ecology of a South Asian tall - grass community*. Ph.D. Dissertation., University of Washington, Seattle.

Lehmkuhl J.F. (1994). A classification of subtropical riverine grassland and forest in Chitwan National Park, Nepal. *Vegetation,* **111**: 29–43.

Mathur P.K., Kumar H. and Lehmkuhl J.F. (2003). Terai grasslands – diversity, management, and conservation perspective. *ENVIS Bulletin. Grassland Ecosystems and Agro forestry*. Indian Institute of Forest Management, Bhopal. **1**(1): 1 - 28.

Maurya K.K. and Borah J. (2013). *Status of tigers in Valmiki Tiger Reserve, Terai Arc Landscape, Bihar, India.* WWF - India.

Mccune B., Grace J.B. and Urban D.L. (2002). *Analysis of ecological communities* (Vol. 28). Gleneden Beach, OR: MjM software design.

Moe S.R. and Wegge P. (1997). The effects of cutting and burning on grass quality and axis deer (*Axis axis*) use of grassland in lowland Nepal. *Journal of Tropical Ecology*, **13**(2) : 279-292.

Murari K. (2017). *Assessment of grassland communities, its use by mammals, and mapping the potential habitat of Rhinoceros unicornis in Valmiki Tiger Reserve, Bihar*. Master of Science Thesis. Saurashtra University, Gujrat.

Murari K., Talukdar G., Pandav B., Jhala Y.V. and Rawat G.S. (2024). Fate by Food: Planning for reintroduction and designating refugium for Indo - Nepal migratory Rhinoceros unicornis Linn. in Valmiki Tiger Reserve, Bihar, India. *The Indian*

Forester, **150**(10): 940 - 949

Odden M., Wegge P. and Storaas T. (2005). Hog deer *Axis porcinus* need threatened tallgrass floodplains: a study of habitat selection in lowland Nepal. *Animal Conservation*, **8**(1): 99 - 104.

Peet N.B. (1997). *Biodiversity and management of tall grasslands in Nepal*. Ph.D. Thesis, University of East Anglia, Norwich.

Peet N.B., Watkinson A.R., Bell D.J. and Kattel B.J. (1999a). Plant diversity in the threatened sub - tropical grasslands of Nepal. *Biological Conservation*, **88**:193–206.

Peet N.B., Watkinson A.R., Bell D.J. and Sharma U.R. (1999b). The conservation management of *Imperata cylindrica* grassland in Nepal with fire and cutting: an experimental approach. *Journal of Applied Ecology*, **36**(3): 374 - 387.

Pokharel S.K. (1993). *Floristic composition, biomass production and biomass harvest in the grassland of the Royal Bardia National Park, Nepal*. Doctoral dissertation, *MSc Thesis*, Agricultural University of Norway, As, Norway.

Rahmani A.R., Narayan G., Rosalind L. and Sankaran R. (1988). Bengal florican *Houbaropsis bengalensis*. status and ecology. *Bombay Natural History Society,* Bombay (India).

Rahmani A.R., Bhargava R. and De R. (2015). *Avifaunal Studies at Sohagibarwa Wildlife Sanctuary*: Final Report. Bombay Natural History Society, Mumbai. Pp. 77

Sawarkar V.B. and Hussain S.A. (1995). *Conservation Status of Tarai Grasslands in Valmiki Tiger Reserve. Project. Integral land use approach for the conservation of biological diversity of Tarai grasslands*. Wildlife Institute of India.

Singh J.S. and Joshi M.C. (1979). Primary production. In: R.T. Coupland (ed.) *Grassland Ecosystems of the World*. IBP, Cambridge University Press, London, pp.197 - 218.

Sinha S., Bahera S.K., Bodhankar S., Chaudhary B.C. and Kaul R. (2016). Ecology and management of grasslands in Valmiki Tiger Reserve in the himalayan foothills, India. In Rawat G.S. and Adhikari B.S. (Eds.) *Ecology and management of grassland habitats in India*. Envis Bulletin: Wildlife and protected areas, Wildlife Institute of India, Dehradun - 248001, India, Vol. **17**: 240pp

Sreenivasan J. and Sreenivasan T.V. (1984). In vitro propagation of a *Saccharum officinarum* (L.) and *Sclerostachya fusca* (Roxb.) A. *Camus Hybrid*. Theor Appl Genet. 67:171 - 174.

Subedi N., Jnawali S.R., Dhakal M., Pradhan N.M., Lamichhane B.R., Malla S., Amin R. and Jhala Y.V. (2013). Population status, structure and distribution of the greater one - horned rhinoceros *Rhinoceros unicornis* in Nepal. *Oryx*, *47*(3), pp.352 - 360.

Tiwari (1999). Trouble in tiger territory. *Sulabh India*.

Tripathi S. and Shukla R.P. (2007). Effect of clipping and grazing on various vegetational parameters of grassland communities of Gorakhpur, UP. *Tropical Ecology*, *48*(1), pp.61 - 70.

Vishwanath B. and Ukil A.C. (1943). Soil map of India. *Indian Agricultural Research Institute, New Delhi*.

Wegge P., Shrestha A.K. and Moe S.R. (2006). Dry season diets of sympatric ungulates in lowland Nepal: competition and facilitation in alluvial tall grasslands.

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