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Caption: Stripe-backed Weasel *Mustela strigidorsa*. Medium—digital, Software—procreate, Device—iPad + Apple pencil © Dhanush Shetty.

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ARTICLE

Grass species composition in tropical forest of southern India

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Abstract: Grass composition was assessed by plot method (1 m^2; n= 1,749) in three habitats (dry deciduous-DDF, moist deciduous-MDF, and thorn forest-TF) at Mudumalai Tiger Reserve, southern India across different seasons from Jan 2004 to Dec 2007. The grass species richness and availability (per cent composition) varied significantly with habitats. Seventy-four species of grasses and sedges were recorded in all three habitats, with a few species common in all habitats. Grass availability varied significantly in different habitats across seasons and was positively influenced by precipitation. Among biotic factors, regeneration and shrub density had a primary influence on grass availability, followed by herb, sedge and weed density. The principal coordinate analysis revealed seven major associations in the tropical forest. There were considerable changes in the composition and association of grasses when compared to the past. Fire resistant species such as *Themeda triandra*, *Heteropogon contortus* and *T. cymbaria* dominated in the DDF. Grass species *Aristida*/*Eragorstis* were recorded in the TF, which were considered as indicators of heavy grazing pressure. Grass species that were reported rare and sporadic in the earlier study were not recorded, which emphasizes better pasture management in the tropical forest. Grass species composition and availability was threatened by invasion of weeds.

Keywords: Graminae, Mudumalai Tiger Reserve, influence of fire on grass, *Themeda triandra*, *Heteropogon contortus*, *Themeda cymbaria*.

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Author contributions: MA developed the concept, formulated a hypothesis, and carried out data analysis. SS supported in receiving funds, field data collection and preliminary analysis. Dr. RN provided technical support and supervised the work. All the authors contributed to the preparation of the final manuscript.

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INTRODUCTION

Grasslands are highly dynamic ecosystems encompassing natural and semi-natural pastures, woodlands and scrubs dominated by grasses (Blair et al. 2014). Grasses are one of the important sources of biodiversity and the primary food source for many herbivores that support ecosystem function, agricultural sustainability, and livelihood for many pastoral communities (Sala & Paruelo 1997; White et al. 2000). In India, 1,506 species of grass belonging to 266 genera were reported (Kellogg et al. 2020). Peninsular India has maximum diversity and endemism (Karthikeyan 1989). The study of grass species is important since they are sensitive to global warming and altered precipitation patterns, and exhibit immediate response to climate change (Knapp & Smith 2001).

Grass species in the Western Ghats are threatened by domestic livestock, mining, wind-farms, plantations, canals and dams have led to degradation and loss of grassland habitats (Vanak 2013). The invasion of exotic species into tropical forest threatens grasslands (Srinivasan 2011; Ashokkumar et al. 2012). Invasions not only affect grass composition but also the foraging efficiency of herbivores (Wilson et al. 2013). Pasture management is essential in protected area management strategies to reduce the human-animal interactions. Although grasses have wide ecological amplitude and several adaptations to withstand trampling, grazing, fire, flood, and drought, they face severe competition for light and nutrients from aggressive wood species and invasive plants in tropical forests.

Mudumalai Tiger Reserve (MTR) is located in the Western Ghats, one of 34 global biodiversity hotspots (Myers et al. 2000). There were no earlier studies on the dynamics of grass species composition and diversity in similar tropical forest in Southern India. Though tree, herb and shrub species were studied in detail (Robert et al. 2002; Nath et al. 2006) information on grass species is lacking in the tropical ecosystem. In addition, the study area also has baseline data on grass species composition studied a decade before (Sivaganesan 1991), which enabled comparison with the present study. Sivaganesan (1991) studied grass composition in the study area in the year 1985, and he has studied grass species composition using strip transects of one kilometer length (n= 20) and laid 1 m^2 plots at every 250 m interval, resulting in sampling of five plots per transect and a total of 100 plots across different vegetation types.

Seasonal changes in the phenology of grass species influence herbivore movement, distribution and abundance (Sivaganesan 1991; Baskaran 1998). Cattle grazing and fire have major impacts on species composition of woody plants (Kodandapani et al. 2008) and grasses. The present study investigated the effect of environmental factors on grass availability (grass abundance) and grass association in tropical forests of Southern India. Studies on the grass association help to understand the grass communities in tropical forest and their dynamics due to climatic and anthropogenic factors.

STUDY AREA

Mudumalai Tiger Reserve (MTR) is located in the Nilgiris District of Tamil Nadu (11º 32´ and 11º 42´ N and 76º 20´ and 76º 45´ E). It extends over an area of 321 km^2 and forms a part of the Nilgiris Biosphere Reserve (Figure 1). It is part of a contiguous stretch of forest with Bandipur Tiger Reserve to the north, Segur Reserve forest to the east, Wayanad Wildlife Sanctuary to the west, and Gudalur forest division to the South. Altitude varies from 485 to 1,226 m with a general elevation of about 900 to 1,000 m. The annual rainfall varies from 1,001 mm to 1,648 mm. The sanctuary receives rain from both south-west (May to August) and north-east (September to December) monsoons. Based on climate seasons can be classified into dry season (January to April), first wet season (south-west monsoon) and second wet season (north-east monsoon). The three major forest types in the study area are tropical moist deciduous forest (MDF), dry deciduous forest (DDF) and tropical thorn forest (TF) (Champion & Seth 1968).

The major tree species association in MDF is *Lagerstoroemia-Terminalia-Tectona.* The ground flora mainly composed of *Helicteres isora*, *Desmodium* sp., and *Curcuma* sp. The dominant grass species are *Cyrtococcum accrescens*, *C. oxyphyllum*, *Bothriochloa pertusa*, *Oplismensus compositus* and *Oryza meyeriana* occur. Bamboo *Bambusa arundinacea* is very common along the perennial water sources. Swamp vegetation mainly consists of tall grass *Cenchrus hohenackeri*. Tree species in DDF is dominated by *Anogesis latifolia*, *Terminalia crenulata*, *Tectona grandis*, *Diospyros montana*, and *Gmelina arborea*. Shrubs include *Helicteres isora*, *Antidesma diandram*, and *Pavetta indica*. Grasses species is dominated by tall perennial rhizomatous grasses such as *Themeda cymbaria*, *Cymbopogon flexuosus*, and *Apluda mutica* in dry deciduous tall grass area. *T. triandra*, *Setaria intermedia*, and *Dicanthium caricosum* are common in short grass

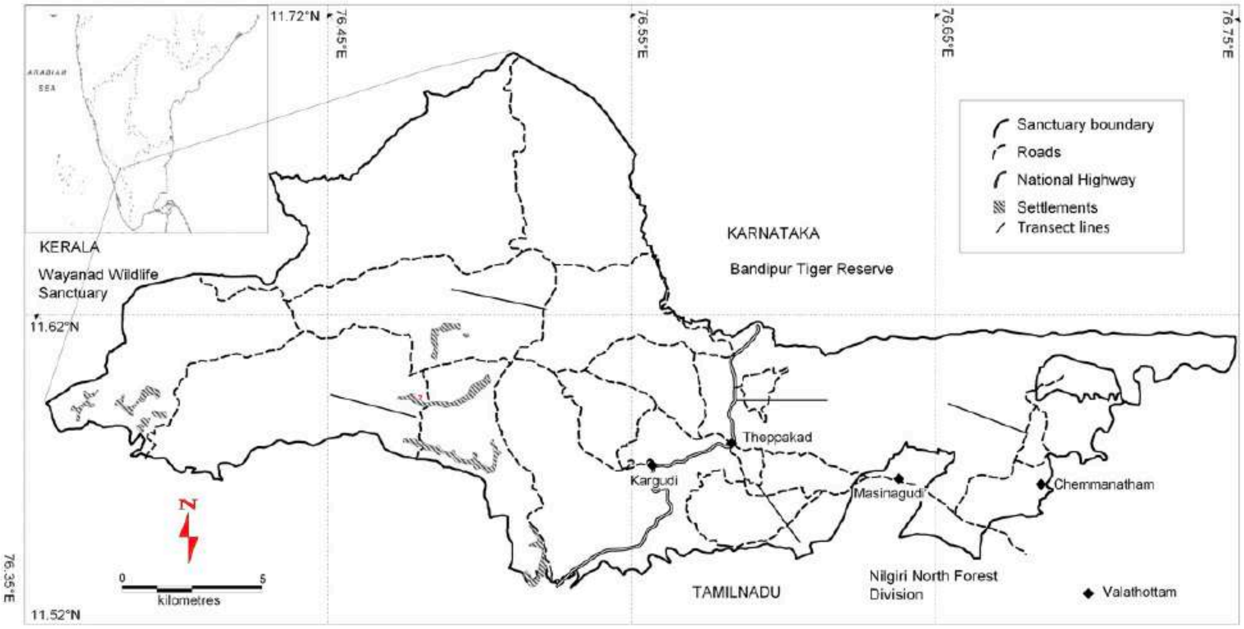

Figure 1. Map showing the location of transect lines used for vegetation sampling at Mudumalai Tiger Reserve.

area. TF is dominated tree species such as *Acacia* sp., *Albizia* sp., *Premna tomentosa*, *Dalbergia lanceolaria*, and *Ziziphus* sp. The shrub species includes *Acacia pinnata*, *Canthium parviflorum*, *Rhus mysorensis*, and *Mytenus emarginatus*. Grass species in TF includes *Aristida adscencsionis*, *Heteropogon contortus*, and *Tragus mongolorum*. The study area is threatened by habitat degradation from overgrazing and human disturbance.

METHODS

Five transects each of three-kilometre length were marked in three habitats (DDF 3; MDF 1, and TF 1; Figure 1). Two transects in Mudumalai range, two transects in Theppakad range and one in Masinagudi range were marked and sampled. The locations of transects were given in the georeferenced study area map (Figure 1). A total of 30 plots (1 m^2) were laid at an interval of 100m in each transect. Transects were sampled two times per season in alternate months. A total of 825 plots were laid in all three vegetation types (DDF 493, MDF 169, TF 103) in different seasons. In addition to this data, grass species composition, which was collected as part of Gaur *Bos gaurus* foraging ecology study was used. A total of 924 plots (DDF 669, MDF 110, TF 145) of 1 m^2 were laid in the Gaur foraged areas in different habitats, to assess the forage plant species including grass species and their consumption.

A herbarium of grass species that include both grass and sedges was made for confirmation of the species identity. All specimen vouchers were deposited in the Center for Ecological Sciences, Indian Institute of Sciences, Bangalore. Plant species were identified using Gamble (1935), Saldanha & Nicolson (1976), Saldanha (1984, 1996), Sharma et al. (1977), and Kellogg et al. (2020). Grass cover in each quadrat was visually estimated by giving a percent cover. Percent cover was given according to the proportion of area (within the quadrat) covered by grass (Giles 1971; Sivaganesan 1991). The other variables such as grass height, percent green grass, grass texture, and phenology were recorded (Jarman & Sinclair, 1979; Menaut and Cesar 1979; Sivaganesan 1991; Baskaran 1998).

Precipitation data was collected on monthly basis from weather stations located at the different habitats of the study area maintained by Center for Ecological Science, Indian Institute of Science. The information on extant and frequency of fire was collected from forest management plan and studies on fire in the study area (Kodandapani et al. 2008). Grass species richness, mean percent availability and grass height were tested using ANOVA.

The effect of environmental and biotic variable on grass availability was tested using multiple regressions. The relationship between the percent grass availability and environmental factors (habitat, season, precipitation and fire) and biotic factors (shrub, regeneration, herb, sedges, and weed) were investigated using multiple regression. The variations among the habitats, seasons and fire were controlled by entering these predictors as a dichotomous variable.

Grass species association was determined by principal co-ordinate analysis and species association was plotted in Euclidean space. The variables used in the analysis are percent composition of grass, height, habitat, elevation, fire, and spatial locations in the study area. Statistical analyses were performed by using Windows based statistical package *viz.* SPSS 21.0 (SPSS Inc., Chicago, IL, USA) and Past software 3.17 (Hammer et al. 2001).

RESULTS

A total of 74 species of grasses and sedges were recorded in the MTR with a maximum of species in DDF followed by TF and MDF (Table 1). MDF had lower grass species diversity (0.6) than other habitats. Though, species richness was high in TF (3.4), the mean percent availability of grass was less in TF (12.7%) than DDF (19%) and MDF (17%). The species richness and mean percent availability of grass varied significantly among habitats. The equitability of species was equal in all the habitats. While grass species diversity was higher in TF, the abundance of grass was higher in deciduous forests (MDF and DDF).

Species composition and availability

Grass species composition varied among different habitats. Altogether, 66 grasses and eight species of sedges were recorded in three habitats. There were 21 species were common in all habitats, viz., *Themeda triandra, Oplismenus undulatifolius, Setaria intermedia, S. flavidum*, and *S. pumila* (Table 2). Among different grass species *Perotis indica, Cymbopogon* sp., *Cappillipedium assimile, E. spicatus*, and *Kyllinga* sp. were recorded only in DDF. Likewise, species such as *Cyrtococcum oxyphyllum, Paspalum conjugatum*, and *Cenchrus polystachios* in MDF and *Bothriochloa* sp. *Eragrostis atrovirens*, *Pseudanthistiria umbellata*, *P. tripheron*, and *Leersia hexandra* were recorded only in TF.

In DDF dominant grass species included both tall and short grass species. Tall grass species include *T. cymbaria* (30%), *I. cylindrica* (13%) and *S. fertilis* (13%) and short grasses were *T. triandra* (27%), *O. undulatifolius* (25%) and *S. intermedia* (22%). In MDF, the dominant species were *C. oxyphyllum, E. indica, C. patens, P. polystachion* and *A. compressus*. Swamp areas of both DDF and MDF were dominated by grass species such as *C. polystachyios*, *A. compressus, I. cylindrica*, and *E. indica*. Dominant grass species in TF were *D. bicornis, P. umbellata, D. caricosum*, and *A. mutica* (Table 2).

The percent grass composition varied significantly across season (F= 11.6; p <0.001) in different habitats (F= 13.92; p <0.001). Fire was not recorded in the TF area during the study period. Grass availability was higher in the MDF during dry season (27.7%). The mean percent available grass was highest in first wet season in the DDF (46 %) in the fire burnt areas (Figure 2). Grass availability was low in second wet season in TF. The three-way interaction among fire, habitats and seasons in ANOVA on grass availability was significant. The abundance of grass was higher in the DDF and MDF in wet seasons in the unburnt areas.

The influence of environmental variables on grass availability

The grass availability had a linear relationship with predictors. The model was highly significant and explained 23% variations in grass availability (%). Previous month precipitation positively influenced grass availability. All the other variables negatively influenced grass availability. From the Standardized Partial Regression Coefficients (SPRC), it was inferred that the shrubs had the primary influence on growth of grasses followed by sedges, regeneration, herbs, and weed (Table 3; Figure 3). Furthermore, the co-efficient of habitat and season indicated that the percent availability of grass reduced significantly among three habitats and seasons. Though, fire negatively influenced grass availability, it was not statistically significant in the model.

Grass species association

Principal coordinate analysis (multidimensional scaling) summarizes inter grass species association based on dissimilarity in a Euclidean space. There were seven distinct clusters formed. Among different variables elevation, height and percent composition collectively contributed 87% of the variance. There were four distinct clusters identified based on elevation and further separation was based on habitat and microhabitat (Figure 4). The first cluster consisted of grass species such as *Themeda triandra*, *Setaria intermedia*, *Enteropogon dolichostachyus* and *Oplismenus undulatifolius* in DDF. The second cluster consisted of *Axonopus* sp. (Image 1e) and *Bothriochloa bladhii* in riverine forest. The third cluster consisted of thorn forest species such as *Arthraxon, Chrysopogon, Psudanthistiria*, and *Cynodon*

Table 1. Mean percent grass available (±SD), species richness per plot, diversity and equitability of grass (and sedges) in different habitats of Mudumalai Tiger Reserve.

Habitat[a]		Total number of species	Species richness (S) / plot (±SD)	Mean percent (%) ± SD	Index value	
					Shannon Weiner Diversity (H')	Equitability (J')
DDF (n= 1,162)		61	2.9 ± 1.30	18.8 ± 22.45	0.65 ± 0.40	0.68 ± 0.22
MDF (n= 279)		33	2.7 ± 1.34	17.5 ± 21.67	0.60 ± 0.42	0.69 ± 0.21
TF (n= 248)		53	3.4 ± 1.79	12.7 ± 16.79	0.80 ± 0.45	0.72 ± 0.21
Overall (n= 1,749)		74	3.0 ± 1.42	17.3 ± 21.40	0.67 ± 0.42	0.69 ± 0.22
ANOVA	F		F_{1645}= 20.3	$F_{2,821}$= 14.04	F_{1645}= 20.5	F_{1432}= 5.18
	P		p <0.001	p <0.001	p <0.001	p <0.001

[a] DDF—Dry Deciduous Forest | MDF—Moist Deciduous Forest | TF—Thorn forest.

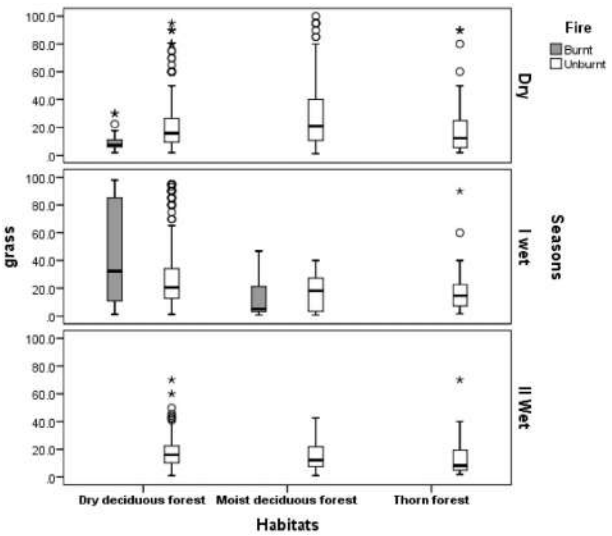

Figure 2. Grass composition (%) in different habitats, seasons, and fire (burnt/unburnt) in Mudumalai Tiger Reserve.

sp. Forth cluster consisted of *Cenchrus*, *Sporobolus, Centotheca*, and *Eragrostis* sp. in dry deciduous tall grass at 1,000 m elevation. Fifth cluster composed of *T. cymbaria, Ischaemum, Cyrtococcum*, and *Kyllinga* species in the moist deciduous forest. The sixth cluster composed of *Imperata*, *Echinochloa*, and *Cenchrus hohenackeri* in swamp areas of MDF. Dry deciduous higher elevation regions composed of *Arthraxon, Cappillipedium*, and *Setaria* species.

DISCUSSION

A total of 66 species of grasses and eight sedges were recorded in the Mudumalai Tiger Reserve. The number of species recorded was lower than earlier report (75 species) in the study area (Sivaganesan 1991). The marginal variation in the species composition could be

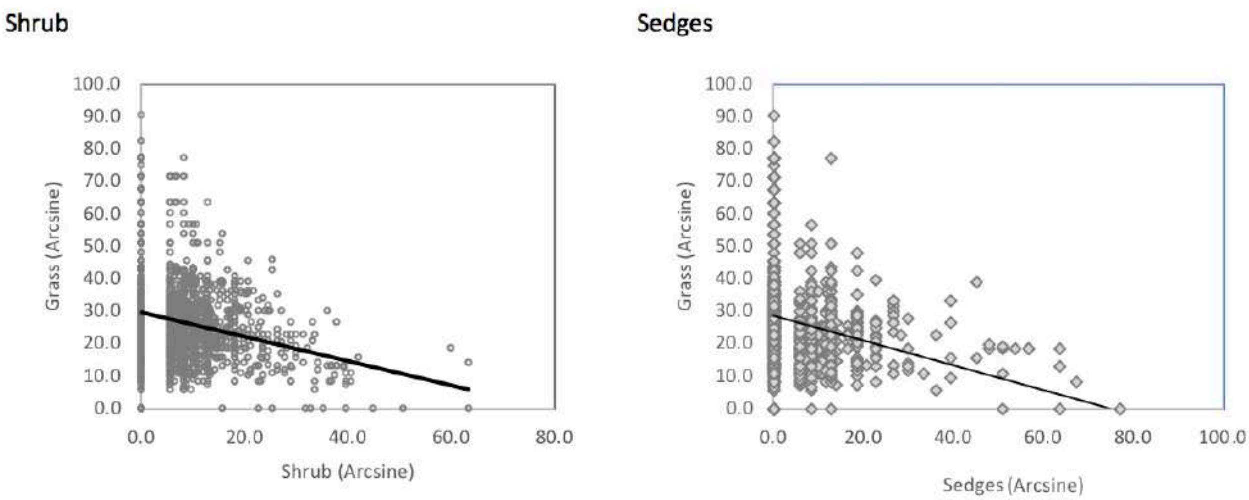

Figure 3. Relation between biotic factors and grass composition at Mudumalai Tiger Reserve.

Table 2. Percent grass (grass and sedges) available in different habitats of Mudumalai Tiger Reserve during the study period (Data sorted in descending order based on total percent).

	Species	Habitats			Total
		DDF	MDF	TF	
	Grass				
1	*Axonopus compressus*	45.7 ± 39	28.2 ± 31.67	-	33.4 ± 34.34
2	*Cyrtococcum oxyphyllum*	-	33.4 ± 22.19	-	33.1 ± 22.3
3	*Cenchrus hohenackeri*	27.4 ± 24.17	36.3 ± 33.65	-	33.1 ± 30.6
4	*Themeda cymbaria*	30.4 ± 22.45	25 ± 17.32	-	30.1 ± 22.15
5	*Themeda triandra*	27.2 ± 21.53	20.2 ± 20.17	23 ± 26.08	26.7 ± 21.68
6	*Oplismenus undulatifolius*	25.1 ± 24.99	4.3 ± 4.27	26.7 ± 24.9	25.3 ± 24.9
7	*Axonopus* sp.	28.4 ± 31.12		6.5 ± 5.58	23.9 ± 29.19
8	*Setaria intermedia*	22.3 ± 22.06	25 ± 7.07	31.4 ± 26.1	23.6 ± 22.78
9	*Pseudanthistiria umbellata*	-	-	23.4 ± 20.47	23.4 ± 20.47
10	*Centotheca lappacea*	-	-	40 ± 0.01	20.5 ± 27.58
11	*Setraria flavidum*	17.5 ± 18.03	2 ± 0.01	25.9 ± 16.92	18.9 ± 18.06
12	*Setaria pumila*	18.5 ± 21.39	28 ± 0.01	17.3 ± 16.38	18.5 ± 21
13	*Enteropogon dolichostachyus*	16.2 ± 18.84	14.1 ± 14.95	20.7 ± 24.35	16.6 ± 19.42
14	*Eleusine indica*	22.4 ± 31.09	14 ± 13.86	7.4 ± 7.16	16.3 ± 22.74
15	*Cenchrus polystachios*	-	15.6 ± 13.53	-	15.6 ± 13.53
16	*Heteropogon contortus*	19.2 ± 20.03	-	10 ± 13	15.3 ± 17.93
17	*Cyrtococcum accrescens*	8.7 ± 13.06	20.1 ± 21.69	-	15.1 ± 19.3
18	*Setaria verticillata*	-		15 ± 0.1	15 ± 0.1
19	*Imperata cylindrica*	13 ± 13.9	16.2 ± 28.06	-	13.9 ± 18.92
20	*Digitaria* sp.	11.6 ± 12.51	12.3 ± 15.37	16.9 ± 12.8	13.6 ± 12.82
21	*Bothriochloa* sp.	-	-	13.6 ± 7.47	13.6 ± 7.47
22	*Panicum* sp.	14.4 ± 8.46	-	1 ± 0.01	13.1 ± 9.04
23	*Digitaria bicornis*	13.8 ± 21.91	4 ± 1.73	9.8 ± 15.84	12.2 ± 19.82
24	*Digitaria griffithii*	11.9 ± 13.2	5 ± 0.01	12 ± 6.35	11.9 ± 12.65
25	*Perotis indica*	11.9 ± 17.94	-	-	11.9 ± 17.94
26	*Panicum tripheron*	7.8 ± 11.67	-	15.2 ± 14.85	11.8 ± 13.87
27	*Urochloa distachya*	12.2 ± 11.92	12.5 ± 10.61	10.6 ± 9.93	11.8 ± 11.23
28	*Apluda mutica*	9.4 ± 11.32	9.2 ± 13.09	18 ± 18.37	11.8 ± 14.16
29	*Dichanthium caricosum*	10 ± 0.01	5 ± 0.01	13 ± 9.08	11.4 ± 8.02
30	*Eragrostis tenuifolia*	15.8 ± 23.01	-	3.1 ± 2.77	11.4 ± 19.53
31	*Sporobolus fertilis*	13 ± 12.75	-	1 ± 0	11.4 ± 12.54
32	*Ischaemum ciliare*	10.2 ± 10.98	11 ± 15.25	-	10.9 ± 14.7
33	*Setaria palmifolia*	10.8 ± 12.59	1 ± 0.01	10 ± 0.01	10.5 ± 12.33
34	*Eragrosteilla* sp.	11.8 ± 8.67	-	8.2 ± 13.66	10.1 ± 11.39
35	*Eragrosits atrovirens*	-	-	10 ± 7.07	10 ± 7.07
36	*Oplismenus compositus*	6.3 ± 10.4	13.2 ± 13.87	-	9.9 ± 12.79
37	*Paspalum conjugatum*	-	9 ± 9.64	-	9 ± 9.64
38	*Aristida adscensionis*	8.4 ± 7.6	-	8.8 ± 10.18	8.7 ± 9.89
39	*Cynodon radiatus*	15 ± 0.1	-	2 ± 0.01	8.5 ± 9.19
40	*Echinochloa colona*	6.3 ± 7.51	15 ± 0.1	-	8.5 ± 7.51
41	*Themeda tremula*	7.2 ± 3.13	5 ± 0.1	20 ± 0.1	8.5 ± 5.4

	Species	Habitats			Total
		DDF	MDF	TF	
42	*Dactyloctenium aegyptium*	13.9 ± 16.5	-	5.3 ± 7.09	8.5 ± 11.8
43	*Sehima sp.*	7.3 ± 15.34	-	11.5 ± 15.73	8.2 ± 15.23
44	*Tragus mongolorum*	1 ± 0.01	-	8.1 ± 7.74	8 ± 7.73
45	*Sporobolus* sp.	7.8 ± 9.15	7.5 ± 11.22	4.2 ± 3.49	7.5 ± 9.01
46	*Alloteropsis cimicina*	5.4 ± 8.93		24.9 ± 25.6	7.5 ± 13.38
47	*Chrysopogon sp.*	-	-	7.5 ± 9.46	7.5 ± 9.46
48	*Cymbopogon sp.*	7.2 ± 5.18	-	-	7.2 ± 5.18
49	*Cappillipedium assimile*	6.8 ± 3.95	-	-	6.8 ± 3.95
50	*Cynodon dactylon*	7.1 ± 5.73	1 ± 0.01	3.3 ± 2.08	6.4 ± 5.54
51	*Eragrostis* sp.	1 ± 0.01	-	6.6 ± 12.56	6.3 ± 12.22
52	*Oryza meyeriana*	7.3 ± 10.01	4.7 ± 9.64	10 ± 0.1	5.8 ± 9.74
53	*Sporobolus diandrus*	4.8 ± 3.77	10 ± 0.1	-	5.8 ± 4.02
54	*Digitaria abludens*	20 ± 0.1	-	4.5 ± 4.96	5.1 ± 5.65
55	*Elytrophorus spicatus*	5 ± 0.1	-	-	5 ± 0.1
56	*Eragrosits abludens*	-	-	5 ± 0.1	5 ± 0.1
57	*Cenchrus purpureus*	5 ± 0.1		-	5 ± 0.1
58	*Bambusa arundinacea*	5.4 ± 2.88	4.5 ± 4.37	1.7 ± 0.58	4.3 ± 3.74
59	*Arthraxon* sp.	7.3 ± 8.62	-	2.5 ± 1.9	3.1 ± 3.58
60	*Panicum notatum*	-	-	3 ± 0.1	3 ± 0.1
61	*Bothriochloa bladhii*	2 ± 0.1	-	-	2 ± 0.1
62	*Isachne elegance*	2 ± 0	-	-	2 ± 0
63	*Leersia hexandra*	-	-	2 ± 0.1	2 ± 0.1
64	*Arthraxon lancifolia*	-	-	1.5 ± 0.58	1.5 ± 0.58
65	*Mnesithea granularis*	1 ± 0.1	-	1.5 ± 0.55	1.4 ± 0.53
66	*Chrysopogon lawsonii*	1 ± 0.1	-	-	1 ± 0.1
	Sedges				
67	*Kyllinga melanosperma*	15.2 ± 22.46	7.1 ± 7.22	6.2 ± 7.95	12 ± 18.59
68	*Mariscus madraspatanus*	6 ± 8.37	17.4 ± 26.83	2.5 ± 1.22	9.8 ± 17.98
69	*Fimbristylis aestivallis*	7.4 ± 5.87	-	6.2 ± 6.02	7 ± 5.73
70	*Cyperus distans*	4.2 ± 4.91	8.1 ± 13.59	5 ± 0	4.9 ± 7.42
71	*Cyperus rubicundus*	6.2 ± 5	-	3.2 ± 3.75	4.2 ± 4.41
72	*Fimbristylis* sp.	3.7 ± 2.36	-	2.6 ± 2.4	3 ± 2.41
73	*Kyllinga* sp.	2.6 ± 2.78	-	-	2.6 ± 2.78
74	*Kyllinga tenuifolia*	2 ± 0.1	-	1 ± 0	1.3 ± 0.58

DDF—Dry deciduous forest | MDF—Moist deciduous forest | TF—Thorn forest | ––Species were not recorded.

due to difference in the area of sampling, earlier study covered greater area of sampling. Sivaganesan (1991) divided the tiger reserve into five zones and did sampling in five transects with 30 plots in each transects with 250 m interval. The number of transect in Moist deciduous forest is less than earlier study. Further, there were invasion of exotic weed species such as *Lantana camera* and *Chromolena odorata* in the study area (Ashokkumar et al. 2012; Wilson et al. 2013), which were less and restricted to tourism zone in the study area. Whereas the growth of weeds was extensive and occupied all the grassland patches of DDF and MDF.

Grass species richness, composition varied among habitats, with maximum number of species recorded in DDF followed by TF. *Cymbopogon* sp. found in hill slopes of DDF in the elevation range of 2,000–3,000 m,

Table 3. Multiple regression equation to investigate the effect of environmental (habitat, fire and precipitation) and vegetation factors on the grass availability (%) in Mudumalai Tiger Reserve.

Independent variable	Predictor	Coefficients ± SE	SPRC*	t	p	Model (r^2)	Model (p)
Grass (%)	(Constant)	38.17 ± 2.535		15.059	<0.001	23.1	p<0.001
	Fire	-0.76 ± 1.100	-0.015	-.694	0.488		
	Habitat	-3.59 ± 0.414	-0.191	-8.653	<0.001		
	Season	-2.60 ± 0.598	-0.138	-4.353	<0.001		
	Previous month precipitation (mm)	2.82 ± 0.403	0.229	6.998	<0.001		
	Herb (%)	-0.31 ± 0.042	-0.161	-7.286	<0.001		
	Regeneration (%)	-0.52 ± 0.063	-0.179	-8.206	<0.001		
	Sedges (%)	-0.37 ± 0.039	-0.200	-9.341	<0.001		
	Shrub (%)	-0.46 ± 0.038	-0.268	-12.096	<0.001		
	Weed (%)	-0.23 ± 0.043	-0.112	-5.254	<0.001		

*—Standardized partial regression coefficient.

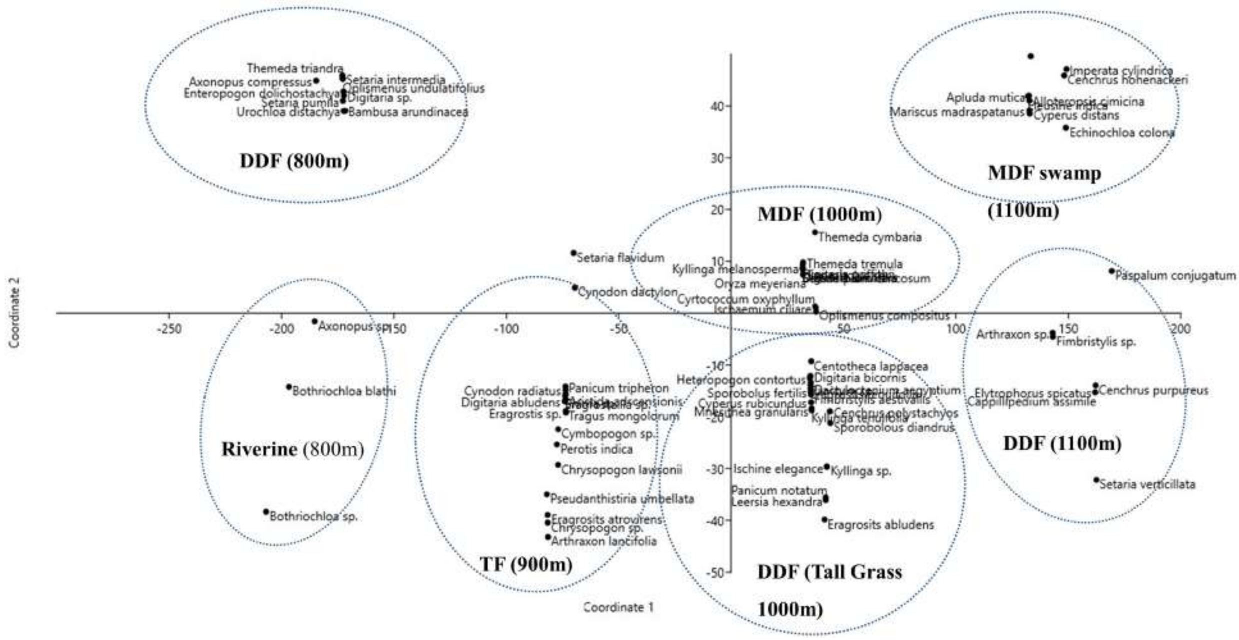

Figure 4. Principal coordinate (PCoA) analysis of grass species association based on dissimilarity in Mudumalai Tiger Reserve (Circles indicate distinct clusters).

P. polystachyon recorded in swamp areas of MDF in the elevation of above 1,000 m, and *A. adscensionis* found in TF in the elevation less than 600 m. Grass species such as *C. polystachios, L. hexandra*, and *I. cylindrica* were observed in the swamps of MDF and DDF in MTR. This might have been influenced by high moisture content and nutrients of the soil (Skerman & Riveros 1990). Amarasinghe & Pemadasa (1982) have also concluded that the complex interaction of edaphic factors, altitude, precipitation and human disturbance were responsible for a variation on Montane grasslands in Sri Lanka. Thus, the grass composition varied depending on altitudes and moisture content of the soil.

Factors influencing grass composition

Shrubs had the primary influence on the grass growth followed by sedges, regeneration, herbs and weeds. Studies done in Prairie grasslands in Canada indicated that shrubs strongly reduced available soil nitrogen and the secondary growth of shrubs allowed them to accumulate more biomass and height that eventually displaced the grass species (Kochy & Wilson 2000).

Image 1. Grass species composition in the selected habitats of Mudumalai Tiger Reserve: a—Dry deciduous tall grass (*Cymbopogon* sp.) | b—Dry deciduous tall grass (*Themeda- Cymbopogon-Imperata*) | c—MDF swamp areas with (*Cenchrus-Themeda-Imperata*) | d—*Setaria palmifolia* | e—*Axonopus compressus* | f—*Cyrtococcum oxyphyllum.* © M. Ashokkumar

The grass species *Axonopus* sp. was recorded only in *L. camara* invaded areas. This grass species was originated in United States and this species itself considered as weed (Skerman & Riveros 1990). Therefore, it competes well with weed species. In addition, both *L. camara* and *Axonopus* sp. grow well in humid areas and thus, they do have similar microhabitat preference. The microhabitat preference and weed resistance properties of *Axonopus* sp. enabled successful survival in *L. camara* invaded areas. Grass species that were recorded in *C. odorata* invaded areas (*Cenchrus*, *Setaria*, and *Chrysopogon*) seem to have high alkaline tolerance (Skerman & Riveros 1990). Thus, grass species had species-specific interaction with weed species. The percent availability of grass varied significantly among three habitats and seasons. The seasonal variation in grass availability was due to phenological changes of grass species due to senescence. The phenology of tropical grasses are moisture driven, with germination occurring shortly after the rains of first wet season. Grass senescence occurs in the end of the second wet season or in the early dry season. Both the reproduction and senescence have been influenced by multiple factors such as temperature, rainfall and photoperiod (Blair et al. 2014). Hence the availability of grass was higher in the wet seasons.

The percent grass available was significantly positively correlated with precipitation. Rainfall varied spatiotemporally across vegetation types in the study area. Such a rainfall pattern is ecologically significant and perhaps a boon to the dynamics of the study area. Elephant habitat preference was related to the rainfall in the study area (Sivaganesan 1991). In Africa, several ecologists (Leuthold & Sale 1973; Caughley & Goddard 1975; Leuthold 1976; Eltringham 1979; McNaughton 1985) documented the significance of the rainfall on the habitats and distribution pattern of the larger herbivores. The western part of the study area with MDF receives rainfall during south-west monsoon and eastern part (TF) during north-east monsoon. The grass growth and phenological changes can be seen depending on the precipitation.

Variation in grass composition in the study area

Comparison of grass species composition with earlier study Sivaganesan (1991) revealed that though, there were no changes in the dominant grass species there were considerable changes in the minor grass species composition. The principal coordinate analysis revealed seven distinct clusters of grass species association. Sivaganesan (1991) reported four distinct clusters of grass association in the study area: *Themeda-Cymbopogon-Imperata* in the dry deciduous tall grass area (Image 1a), *Cenchrus-Themeda-Imperata* in the swamp area (Image 1c), *Cyrtococcum-Apluda-Arthraxon* in MDF, and *Themeda-Heteropogon-Digitaria-Apluda* in the TF area. Changes occurred in the grass species composition in all habitats. The percent availability of grass was reduced when compared to past, possibly due to greater extent of invasion of exotic species.

Sivaganesan (1991) indicated that annual fire seems to influence the species association and succession of species at Mudumalai. He reported that fire-resistant species such as *T. triandra*, *H. contortus*, and *T. cymbaria* have survived and dominated the dry deciduous forest. This is unison with his finding that the above species also dominated in DDF based on the present study. The fire frequency was also high (22 incidences per annum), and more area was burnt in DDF (56%) than other habitats (Ashokkumar 2011). Grass species which were reported rare and sporadic in the earlier study were not reported in the present survey, for example *Chionachne koenigii* in DDF and *Oryza meyeriana* in MDF were not recorded. Similarly, percent composition of *Apluda* sp. and *Arthraxon* sp. were less in MDF. Fewer species were recorded in MDF, but the mean percent available grass was more in MDF. The dominant grasses in MDF were tall grass species in the swamp areas which grow up to 3 m, and thus their percent composition was higher. Earlier TF was dominated by *T. triandra* and *H. contortus* (Sivaganesan 1991) and these species were poorly represented during the present survey and TF is dominated by *Digitaria* sp., *Pseudanthistiria umbellata.* TFs facing severe pressure due to cattle grazing and removal of cattle dung from the forest floor had severely affected the forest regeneration and nutrient cycle. Earlier studies on livestock populations reported 7,248 cattle in the fringe areas (Silori & Mishra 2001) allowed to free graze in the reserve. Continued grazing affects grass availability and species composition.

Protection from cattle grazing

Grass species *Aristida-Eragrostis* were recorded in the TF which were considered as an indicator species of deteriorated grassland (Skerman & Riveros 1990). Grass species such as *Themeda-Heteropogon-Digitaria-Apluda* were dominant species in thorn forest reported in the past. At present, the quality of grass pastures was too poor to provide any grazing. Severe cattle grazing should be stopped for four or five years to allow the succession to progress towards fair condition represented by *Cynodon dactylon* as the first step toward improvement. Thus grasslands of TF required protection of pasture from cattle grazing or at least reduction of cattle pressure for at least four to five years to recover. Species reduced by overgrazing can recover if there were no change in the physical environment.

Influence of fire on grass availability

In the study area during the peak of dry season wildfire was common. These, wildfires were set by the villagers to get fresh fodder for their cattle and easy to move around in burnt areas. Fire in grass patches last only for a short time and high temperatures were maintained for only a few seconds. Temperatures at soil level rise steeply to 175–200 °C depending on wind, height and density, and usually return to ambient temperature within a few minutes (Mondal & Sukumar 2014). The soil temperature at a depth of about two centimeters changes little, varying at most by 14 C. The effect of subterranean portions of grasses is thus slight.

The study area as a whole had a fire-return interval of 3.3 years (Ashokkumar 2011). The vegetation type with the highest mean area burnt was at DDF (*Shorea* sp. dominant) with 56.6%, whereas, TF had the lowest mean area burnt with 14.6%. Forest fires burnt an average of 30% (98 km^2/year) of the forests in each year. Grass biomass was significantly low in burnt areas. Distance from the park boundary was reported as an important factor that predicts the fire-return interval in the study area (Kodandapani et al. 2008). Grass biomass was significantly low in the fire burnt areas of DDF and MDF. Sivaganesan (1991) indicated that the effect of annual fire seems to influence the grass species association and succession of species. On other hand, the annual fire plays an important role in the maintenance of forest stands at deciduous forest and seedling growth. The forest fire scorches the tree seeds of *Tectona grandis* and facilitates the growth by removing a portion of the seed coat (Seth & Kaul 1978). But overall tree species diversity, structure and regeneration were reduced by fire in tropical forest (Kodandapani et al. 2008), further, the results suggest both grass availability and composition altered by fire.

CONCLUSIONS

The present study provides baseline information on grass species composition in the tropical forest of southern India. There were considerable changes occurred in the grass species composition when compared to past. Grass association revealed seven major types of association in the tropical deciduous forest. Grasslands of TF were dominated by *Aristida-Eragrostis* indicators of heavy gazing and require protection of pasture from cattle grazing or at least reduction of cattle pressure to recover. Grass composition and availability was positively influenced by rainfall and reduced by fire in the tropical deciduous forest. Further grass availability and composition is threatened by invasion of weeds.

REFERENCES

Amarasinghe, L. & M.A. Pemadasa (1982). The ecology of Montane grassland in Sri Lanka, II- The pattern of four major species. *Journal of Ecology* 70: 17–23.

Ashokkumar, M. (2011). Population, foraging and activity pattern of Gaur (*Bos gaurus* H. Smith, 1827) in Mudumalai Tiger Reserve, Southern India. Ph.D. Thesis, Bharathidasan University, Tiruchirappalli, Tamil Nadu, India, 159pp.

Ashokkumar, M., R. Nagarajan, S. Ilayaraja, S. Swaminathan & A.A. Desai (2012). Impact of plant weeds on grass availability in Gaur (*Bos gaurus* H. Smith, 1827) foraging areas of Mudumalai Tiger Reserve, Southern India. *Indian Forester* 138(12): 1131–1140.

Baskaran, N. (1998). Ranging and Resource utilization by Asian elephant (*Elephas maximus* Linnaeus) in Nilgiri Biosphere Reserve, South India. Ph.D. Thesis, Bharathidasan University, Thiruchirappalli, India.

Blair, J., J. Nippert & J. Briggs (2014). Grassland Ecology. In: Monson, R.K. (ed). *Ecology and the Environment, The Plant Sciences*, 8. https://doi.org/10.1007/978-1-4614-7501-9_14

Caughley, G. & J. Goddard (1975). Abundance and distribution of elephants in Luangwa Valley, Zambia. *East African Wildlife Journal* 13: 39–48.

Champion, H.G. & S.K. Seth (1968). *Revised survey of forest types in India*, Manager of Publication, New Delhi. 404pp.

Eltringham, S.K. (1979). *The ecology and conservation of large African mammals*. University Park Press, Baltimore, 286pp.

Gamble, J.S. (1935). *The Flora of the Presidency of Madras.* Adlard and Son's Ltd., London, 143pp.

Giles, R.H. (1971). *Wildlife Management Techniques*. The Wildlife Society, Washington, 623pp.

Hammer, O., D.A.T. Harper & P.D. Ryan (2001). PAST: Paleontological Statistics software package for education and data analysis. *Palaeontol Electron* 4(1): 9

Jarman, P.J. & A.R.E. Sinclair (1979). Feeding strategy and the pattern of resource-partitioning in ungulates,pp. 130–163. In: Sinclair, A.R.E. & M. Norton-Griffiths (eds). *Serengeti: Dynamics of an ecosystem*, University of Chicago Press, Chicago, 397pp.

Karthikeyan, S., S.K. Jain, M.P. Nayar & M. Sanjappa (1989). *Florae Indicae Enumaratio: Monocotyledonae*. Botanical Survey of India, Calcutta, 435pp.

Kellogg, E.A., J.R. Abbott, K.S. Bawa, K.N. Gandhi, B.R. Kailash, K.N. Ganeshaiah, U.B. Shrestha & P. Raven (2020). Checklist of the grasses of India. *Check List* 163: 1–560.

Knapp, A.K. & M.D. Smith (2001). Variation among biomes in temporal dynamics of aboveground primary production. *Science* 291: 481–484.

Kodandapani, N., M.A. Cochrane & R. Sukumar (2008). A comparative analysis of spatial, temporal and ecological characteristics of forest fires in seasonally dry tropical ecosystem in the Western Ghats, India, *Forest Ecology and Management* 256: 607–617.

Kochy, M. & S.D. Wilson (2000). Competitive effects of shrubs and grasses in prairie. *Oikos* 91(2): 385–395. https://doi.org/10.1034/j.1600-0706.2000.910219.x

Leuthold, W. & J.B. Sale (1973). Movements and patterns of habitat utilization of elephants in Tsavo National Park, Kenya. *East African Wildlife Journal* 11: 369–384.

Leuthold, W. (1976). Group size in elephants of Tsavo National Park and possible factors influencing it. *Journal of Animal Ecology* 45(2): 425–439.

McNaughton, S.J. (1985). Ecology of a grazing ecosystem: The Serengeti. *Ecological Monograph* 55: 259–294.

Menaut, J.C. & J. Cesar (1979). Structure and primary productivity of Lamto savannas, Ivory Coast. *Ecology* 60(6): 1197–1210.

Mondal, N. & R. Sukumar (2014). Fire and soil temperatures during controlled burns in seasonally dry tropical forests of southern India. *Current Science* 107: 1590–1594.

Myers, N., R.A. Mittermeier, C.G. Mittermeier, G.A.B. Fonseca &

J. Kent (2000). Biodiversity hotspots for conservation priorities. *Nature* 403(6772): 853–858.

Nath, C.D., H.S. Dattaraja, H.S. Suresh, N.V. Joshi & R. Sukumar (2006). Patterns of tree growth in relation to environmental variability in the tropical dry deciduous forest at Mudumalai, Southern India. *Journal of Bioscience* 31(5): 651–669.

Robert, J., H.S. Dattaraja, H.S. Suresh & R. Sukumar (2002). Density-dependence in common tree species in a tropical dry forest in Mudumalai, southern India. *Journal of Vegetation Science* 13(1): 45–46.

Sala, O.E. & J.M. Paruelo (1997). Ecosystem services in grasslands, pp. 237–252. In: Daily, G.C. (ed.). *Nature's Services: Societal Dependence on Natural Ecosystem*. Island Press, Washington, DC, USA, 412pp.

Saldanha, C.J. & D.H. Nicolson (1976). *Flora of Hassan District*, Karnataka, India. Amerind Publishing Company, New Delhi, 915pp.

Saldanha, C.J. (1984, 1996). *Flora of Karnataka - Vol. (1 & 2)*. Oxford & IBH Publishing Company, New Delhi, 535pp.

Seth, S.K. & O.N. Kaul (1978). Tropical forest ecosystem of India: the teak forests (as a case study of silviculture and management),pp. 628–640. In: *Tropical Forest Ecosystem: A State of Knowledge*. Report by UNESCO/UNEP/FAO, Vendome, France, 683pp.

Sharma, B.D., B.V. Shetty, K. Vivekanathan & N.C. Rathakrishnan (1977). Flora of Mudumalai wildlife sanctuary, Tamil Nadu. *Journal of the Bombay Natural History Society* 75(1): 13-42.

Silori, C.S. & B.K. Mishra (2001). Assessment of livestock grazing pressure in and around the elephant corridors in Mudumalai Wildlife Sanctuary, South India. *Biodiversity and Conservation* 10: 2181–2195.

Sivaganesan, N. (1991). Ecology and conservation of Asian Elephant (*Elephas maximus*) with special reference to habitat utilization in Mudumalai Wildlife Sanctuary, Tamil Nadu, South India, Ph.D. Thesis, Bharathidasan University, Thiruchirappalli, Tamil Nadu, India, 115pp.

Skerman, P.J. & F. Riveros (1990). *Tropical Grasses*. Scientific Publishers, Jodhpur, India, 832pp.

Srinivasan, M.P. (2011). The Ecology of disturbances and global change in the montane grasslands of the Nilgiris, South India. PhD Thesis, Department of biology at the University of Kentucky, USA, 107pp.

Vanak, A.T. (2013). Conservation and sustainable use of the dry grassland ecosystem in Peninsular India: a quantitative framework for conservation and landscape planning. Report submitted to Ministry of Environment and forest, Government of India, Ashoka Trust for Research in Ecology and Environment, 40pp.

White, R.P., S. Murray & M. Rohweder (2000). *Pilot analysis of global ecosystems: Grassland ecosystems*, World Resources Institute, Washington, DC, 69pp.

Wilson, G., A.A. Desai, D. Sim & W.L. Linklater (2013). The influence of the invasive weed *Lantana camara* on elephant habitat use in Mudumalai Tiger Reserve, Southern India. *Journal of Tropical Ecology* 29(3): 199–207.

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