DOI: 10.17138/TGFT(4)8-18

Floristic diversity and effect of anthropogenic activities on human-dominated grasslands in subtropical regions of Peninsular India

MANDAR N. DATAR

Biodiversity and Paleobiology, MACS-Agharkar Research Institute, Pune, India. www.aripune.org

Keywords: Burning, community protection, grazing, palatable species, pastures.

Abstract

Indian subtropical grasslands are secondary habitats formed due to anthropogenic activities resulting in degradation of deciduous forests. Spread throughout Peninsular and Central India, they are important from economic and ecological points of view and are the prime source of fodder for the large population of livestock in this region. Pastures are either exposed to open grazing or protected and harvested periodically for fodder. In the present investigation floristic diversity of 21 sites from Western Ghats and Central India was studied, along with the effects of anthropogenic activities like burning and grazing on floristic composition in general and palatable species in particular. Over-grazing and burning were found to result in dominance of unpalatable species, making the grasslands less useful for livestock production. High rainfall and protection by local communities seem to play important roles in the dominance of palatable species in grasslands. Our results suggest that periodic harvesting and protection from burning and over-grazing should be encouraged and implemented in order to increase the potential of these grasslands for livestock production. Detailed studies are warranted to confirm these findings.

Resumen

En las regiones subtropicales de la India, los pastizales son hábitats secundarios que se formaron como consecuencia de la degradación de bosques deciduos debido a actividades antropogénicas. Estos pastizales se extienden por toda la India Peninsular y Central y son importantes desde los puntos de vista económico y ecológico; constituyen la principal fuente de forraje para la alta población de ganado en esta región. Su uso es mediante pastoreo no controlado o son protegidos para cosechas periódicas. En el estudio se determinó la diversidad florística en 21 sitios de las regiones Western Ghats y Central India. Además se evaluaron los efectos que actividades antropogénicas como la quema y el pastoreo tienen en la composición de especies en general y de especies palatables en particular. Se encontró que el sobrepastoreo y la quema condujeron a la dominancia de especies no-palatables, reduciendo el potencial de los pastizales como fuente de forraje. La alta pluviosidad y la protección de los pastizales por parte de las comunidades locales aparentemente tienen un papel importante en la dominancia de las especies palatables. Los resultados sugieren que se deben estimular cosechas periódicas de los pastizales y su protección contra la quema y el pastoreo excesivo con el fin de aumentar su potencial para producción animal. Se requieren estudios detallados para confirmar estos resultados.

Introduction

Grasslands are productive biomes of the Earth, covering approximately 36% of terrestrial landscapes, similar to forest covers (Shantz 1954). Tropical grasslands of the Indian subcontinent are widespread, though they are not climax grasslands, being continuously exposed to anthropogenic pressures like lopping, shifting cultivation, burning and over-grazing (Dabadghao and Shankarnarayan 1973). Except for *shola* forests, which are the only natural communities, these grasslands are treated as secondary as they are formed as a result of human activities. Indian grasslands are important for their biodiversity values, cultural heritage and effects on the economy as a fodder source.

Pioneering work on ecology and biodiversity of Indian grasslands was done by Dabadghao and Shankarnarayan (1973). Various community aspects of grassland vegetation in India have been examined by a number of workers mostly focusing on species diversity, dominance and the

Correspondence: M.N. Datar, Biodiversity and Paleobiology, MACS-Agharkar Research Institute, Gopal Ganesh Agharkar Road, Pune 411 004, India.
E-mail: mndatar@aripune.org

effects of anthropogenic pressures on grasslands from various parts of the subcontinent, such as Tarai region (Shukla 2009), Northeast India (Ramakrishnan and Ram 1988; Yadava 1990; Shankar et al. 1993), Northern India (Singh 1973; Misra and Misra 1981; Tripathi and Shukla 2007) and Western Ghats (Bharucha and Shankarnarayan 1958; Jose et al. 1994; Ramesh et al. 1997; Rawat et al. 2003). In spite of these efforts, the grassland communities of Peninsular India have largely been ignored by science, except for a few broad studies, e.g. classification of Indian grasslands (Oke 1972) and a few local studies like the synecological studies of grasslands of Marathwada University campus (Naik and Patunkar 1979). Oke (1972) classified Indian grasslands into 7 major habitat patterns and 24 minor sub-patterns based on various agro-climatic and habitat zones. The grasslands of Peninsular India are generally *Dichanthium-Sehima* type (Dabadghao and Shankarnarayan 1973) and occur along with other vegetation like evergreen forests, semi-evergreen forests, moist deciduous forests, dry deciduous forests, and thorny scrub forests, and along rocky outcrops (Puri 1960). These diverse and threatened habitats have received little attention when compared with other vegetation types like forests and cultivated landscapes.

In Peninsular India, many grassland patches are protected as community grasslands called '*Kuran'* or *'gairan'* and are used as large-scale fodder collection sites, where grasses and legumes are harvested. Many exclusively cattle-rearing nomadic communities like *Gavali dhangar* depend on these habitats (Gadgil and Malhotra 1982) and grasslands play, for example, a substantial role in total milk production in the State of Maharashtra. In addition, many grasslands serve as State Government wildlife sanctuaries for the conservation of endemic animal species like Black Buck (*Antilope cervicapra*), Chinkara (*Gazella bennettii*) and threatened bird species like Lesser Florican (*Sypheotides indica*) and Indian Bustard (*Ardeotis nigriceps*).

In the present work, the grasslands of human-dominated landscapes of Maharashtra State were studied for their floristic diversity, uniqueness and effects of degradation due to burning and grazing on overall grassland diversity and fodder potential. This is the first attempt to understand the grassland communities of human-dominated landscapes in northern parts of Peninsular India (15.63–21.14° N, 72.71–80.59° E) in recent times.

Materials and Methods

Twenty-one study sites (Figure 1) were selected from the list of grasslands of Maharashtra State catalogued in Dabadghao and Shankarnarayan (1973) and Oke (1972). Study sites fall into 2 major biogeographic zones of India, namely Central India and Western Ghats. Central India is characterized by low rainfall (annual mean 700–1,500 mm) and high temperature in summer (mean 45 °C), while the Western Ghats is one of the 35 biodiversity hotspots of the world (Myers et al. 2000) with abundant rainfall of 3,000–4,000 mm.

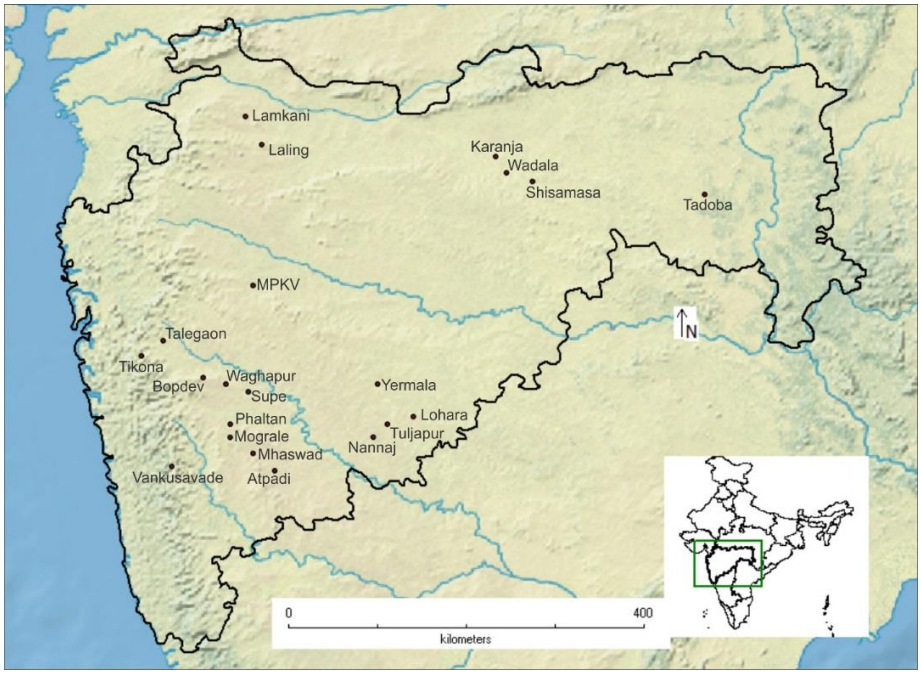

Figure 1. Study sites (Map was prepared using DIVA GIS, version 2).

Table 1. Summary of study sites with geographic and environmental variables. Weather data were obtained from nearest weather observation station of the Indian Meteorological Department.

Location	Latitude (North)	Longitude (East)	Mean annual rainfall (mm)	Max. temp. (°C)	Min. temp. (°C)	Protection status
Atpadi	17.40	74.93	571	38.1	13.3	Government protected
Bopdev ghat	18.40	73.91	623	38.9	13	Unprotected
Karanja-Sohol	20.42	77.50	965	40.8	16.0	Government protected
Laling	20.80	74.73	614	40.3	15.4	Government protected
Lamkani	21.08	74.57	728	40.3	15.4	Community protected
Lohara	18.02	76.29	677	40.2	16.1	Community protected
Mhaswad	17.65	74.65	597	30.2	13.1	Unprotected
Mogarale ghat	17.55	74.52	488	35.2	13.1	Unprotected
MPKV	19.36	74.64	550	41	11	Unprotected
Nannaj	17.81	75.88	723	40.2	16.1	Government protected
Phaltan	17.94	74.42	499	35.2	13.6	Community protected
Shisamasa	20.69	77.13	866	40.8	16.0	Community protected
Supe	18.33	74.37	300	38.9	13	Government protected
Tadoba	20.30	79.27	1,337	42.3	13.1	Government protected
Talegaon	18.80	73.72	1,297	37.9	12	Unprotected
Tikona	18.65	73.50	1,500	37.9	12	Unprotected
Tuljapur	17.95	76.02	723	40.2	16.1	Unprotected
Vankusavade	17.51	73.82	2,000	36	9	Community protected
Wadala	20.51	77.23	965	40.8	16.0	Community protected
Waghapur	18.41	74.10	500	40.3	15.4	Unprotected
Yermala	18.36	75.92	723	40.2	16.1	Unprotected

Among the 21 sites, 3 locations are from Western Ghats (Vankusavade, Tikona and Talegaon) and the remainder from Central India. Study sites were shortlisted to cover spatial and environmental variations such as rainfall, latitude-longitude and protection status of the locality. Table 1 summarizes the spatial and climatic variables of the study sites.

Sites were surveyed in the post-monsoon months September and October, that is, the peak flowering time, during 2011–2014. Community enumeration was done using quadrats (2 x 2 m) laid in the areas of continuous grass growth using standard ecological techniques (Magurran 2004; Sutherland 2006). The number of quadrats per location was decided based on size and heterogeneity of the area. Number of quadrats per study site was determined by species area curve. A total of 67 quadrats were laid in these locations to document the grassland community. For tufted grasses, 1 tiller was recorded as 1 individual. Plants were grouped as very palatable (fodder) species, moderately palatable species, legumes and other herbs based on field observations, interviews with local stockowners and literature (Blatter and McCann 1935; Bor 1960; Patunkar 1980; Gorade and Datar 2014). Plant samples were collected and processed using standard herbarium methods (Jain and Rao 1977) and identified with the help of regional floras (Cooke 1901–08; Lakshminarasimhan 1996; Potdar et al. 2012). Identity of a species was confirmed by comparing it with authentic specimens deposited in the herbaria of Agharkar Research Institute, Pune (AHMA) and Botanical Survey of India, Western Regional Center, Pune (BSI). Specimens were deposited in AHMA. Data on the distribution, endemism and ecology of taxa encountered in this study are based on relevant literature (Lakshminarasimhan 1996).

Statistical analysis of the data was performed in PAST (Hammer et al. 2001). The diversity was determined by Shannon's index with the log base 2 calculated using PAST. Canonical correspondence analysis (CCA) was performed to understand the effects of spatial and environmental parameters on plant species of the grasslands. Environmental variables considered for statistical analyses included latitude-longitude, rainfall, maximum temperature, minimum temperature and variables indicating levels of grazing, burning, community protection and wildlife protection. Wildlife protection status was considered for areas which are protected and managed by the State Government, while community protection was considered for areas which are conserved and managed by local communities. Rankings were assigned for burning and grazing in the grasslands based on personal observations.

Cluster analysis was performed using PAST to understand the floristic uniqueness and similarities amongst the studied sites. Sample rarefaction (Colwell et al. 2004) was also conducted to understand whether the number of sites selected for the study was adequate or not.

Results

A total of 83 species belonging to 69 genera and 28 families was documented (Annex table). In addition to grasses and legumes, in high rainfall areas like Vankusavde, Tikona and Tadoba, growth of other herbs was also significant. The maximum number of species was found in Tadoba (S = 20) and the minimum number in Mhaswad and Nannaj (6 each). Grasslands like Atpadi, Yermala, Tuljapur and Mhaswad showed lowest diversity and tended to show the highest dominance of species belonging to the genus *Aristida* and of *Heteropogon contortus*. Tikona, which is located in a high rainfall region (4,000 mm), also recorded low diversity. Grasslands in Wadala, Shisamasa, Tadoba, Talegaon and Lamkani were characterized by high diversity and low dominance. Of these, Wadala, Shisamasa and Lamkani were community-protected grasslands, while Tadoba was a government-protected area. *Heteropogon contortus*, *Indigofera cordifolia* and *Aristida funiculata* were the most common species, occurring in 16, 10 and 9 of the 21 assessed sites, respectively. Apart from the cosmopolitan taxa, these grasslands also harbor few endemic grass species like *Ischaemum afrum*, *Sehima sulcatum* and *Lophopogon tridentatus*. *Lophopogon tridentatus*, an indicator of exposed and degraded grassland, was observed at 5 sites with high dominance due to its unpalatable nature. *Sehima sulcatum*, a good fodder species and sensitive to disturbance, was recorded from 4 sites (Lamkani, Atpadi, Tuljapur and Nannaj), which are protected by government or local communities. *Ischaemum travancorense*, an endemic and threatened species, which was earlier distributed in Western Ghats, was found in Central Indian grasslands (Tadoba) for the first time. *Ischaemum afrum*, a perennial grass, is known to occur in agricultural landscapes and is recorded only in Shisamasa grassland, which is a mosaic of natural grasslands and agricultural fields. Apart from grasses, an endemic and threatened ground orchid, *Habenaria longicorniculata*, was observed in community-protected Vankusavade grassland (Western Ghats).

Sample rarefaction as per Colwell et al. (2004) suggests that 20 samples were adequate for the study as the curve reached asymptote and most of the diversity in the grassland patches was covered (Figure 2).

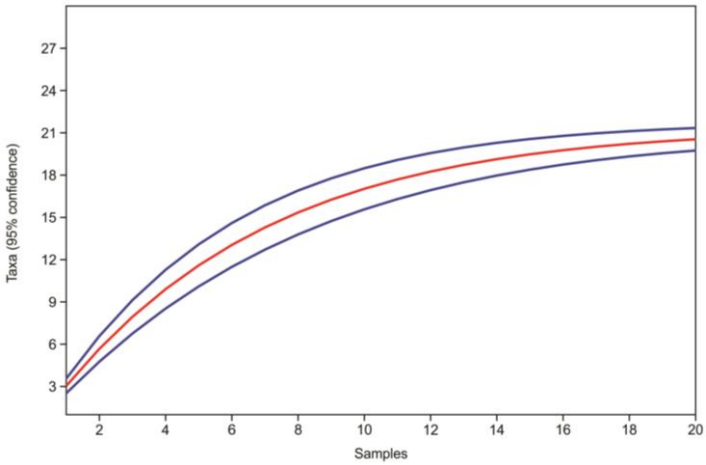

Figure 2. Sample rarefaction curve with 95% confidence.

Table 2. Total taxa, dominance and diversity (Shannon index) of studied sites.

Location	Taxa_S	Dominance_D	Shannon_H
Atpadi	10	0.777	0.600
Bopdev ghat	9	0.415	1.133
Karanja	8	0.352	1.248
Laling	18	0.216	1.821
Lamkani	11	0.213	1.792
Lohara	8	0.300	1.424
Mhaswad	6	0.459	1.034
Mogarale ghat	8	0.282	1.446
MPKV	11	0.466	1.203
Nannaj	6	0.290	1.416
Phaltan	9	0.490	1.060
Shisamasa	12	0.178	1.930
Supe	16	0.364	1.487
Tadoba	20	0.236	1.912
Talegaon	15	0.171	1.931
Tikona	10	0.826	0.428
Tuljapur	7	0.523	0.973
Vankusavade	11	0.353	1.403
Wadala	11	0.204	1.888
Waghapur	13	0.309	1.422
Yermala	9	0.537	0.752

Diversity indices (Shannon H) (Table 2) in all these 20 sites were compared and the range was 0.4 to 1.93 with highest H value in Talegaon and Shisamasa (H = 1.93) followed by Tadoba (H = 1.91). Talegaon, Shisamasa and Tadoba receive more precipitation than other sites (850–1,350 mm), which might have resulted in higher species diversity. The fact that Tadoba grassland is part of Tadoba Tiger Reserve and Shisamasa is community-protected could be another reason for higher diversity. On the other hand Tikona, though receiving higher rainfall (1,500 mm) than Tadoba, recorded the lowest diversity due to high dominance (D = 0.826) of *Themeda triandra*. Though

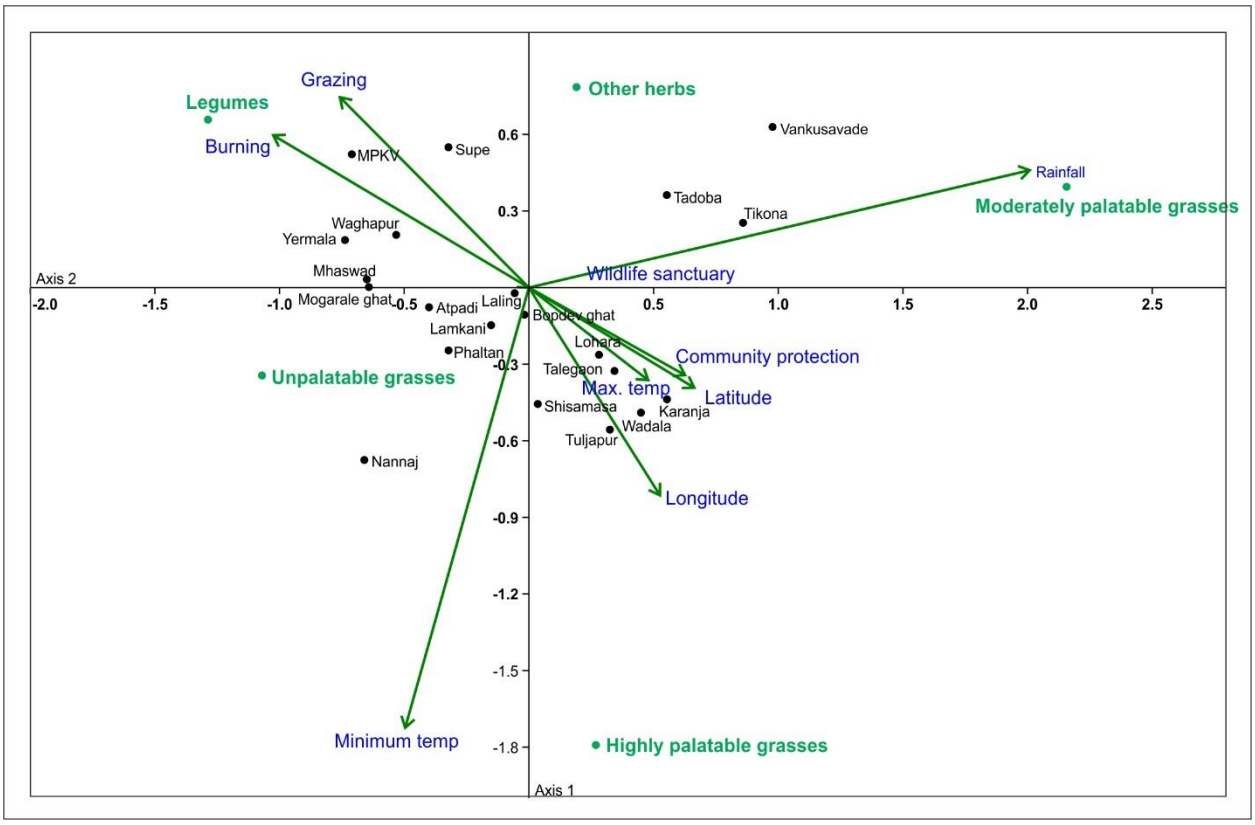

Figure 3. Canonical correspondence analysis showing effects of environmental variables. (Axis 1 explains 56.2%, while Axis 2 explains 25.4% of the total variation of data.)

Table 3. Summary of Canonical correspondence analysis.

Axis	Eigenvalue	%
1	0.19	56.2
2	0.09	25.4
3	0.05	14.5
4	0.01	3.9

Tikona supports 10 species, 90% of the total individuals belong to *T. triandra*, which is characterized by profuse growth of tillers. Tikona recorded highest dominance of 0.825, followed by Atpadi (0.777) (dominated by *Aristida* sp.).

Canonical correspondence analysis, performed to understand the effect of environmental variables on grass communities (Figure 3; Table 3), revealed that the first 2 axes explained a total of 81% of the variation among communities.

Discussion

Floristic diversity

The grasslands were dominated by grasses and legumes, where Poaceae was the dominant family representing 27 (39%) species, while legumes were represented by 11 (15%) species. Grasslands with low diversity were frequently dominated by members of the genus *Aristida* and by *Heteropogon contortus*, which are dominant in grasslands frequently subjected to fire (Dabadghao and Shankarnarayan 1973). Tikona grassland in the high rainfall zone is dominated by the widespread grass species *Themeda triandra*, which is gregarious in growth and gives a characteristic appearance to hill slopes (Dabadghao and Shankarnarayan 1973). *Themeda triandra* is adapted to overcome competition from other grasses and herbs, especially during the seedling stage (Hagon 1977), which might be a reason for dominance of this species. Both community-protected and government-protected grasslands showed high diversity and low dominance. However, Talegaon, an unprotected grassland, possessed high diversity, mostly due to its geographical location that receives more rainfall (900 mm) than other sites (Table 1).

The current study highlights the presence of *Ischaemum travancorense* outside Western Ghats for the first time (Datar et al. 2014). This species was earlier thought to be endemic to Western Ghats and classified as a *Least Concern* species in the IUCN redlist (Rehel 2013).

However, the scattered distribution and availability of this species in various habitats from coastal salty marsh to dry inlands suggests that taxonomic enumeration of this species needs further attention, as well as reassessment of its IUCN status.

The mosaic of natural grasslands and agricultural fields in Shisamasa supports *Ischaemum afrum*, which is the primary breeding habitat of the endangered bird Lesser Florican (*Sypheotides indica*). The grass patches amidst crops are preferred by this bird (Sankaran 1997). In Shisamasa, it lays eggs in the culms of *Ischaemum afrum*, thus making this grass important in the conservation program of the bird. Another taxon with conservation concerns encountered in this study was the ground orchid *Habenaria longicorniculata*, from Vankusavade grassland. This species is endemic to Peninsular India and is listed as *Near Threatened* in threat category (Kumar et al. 2000). Three sites were severely invaded by weedy species like *Xanthium strumarium* and *Alternanthera sessilis* (Singh and Karthikeyan 2000). These species must be eradicated from grasslands in order to control their further spread, thereby facilitating the conservation of grassland habitats.

Floristic uniqueness

When a dendrogram was drawn using Cluster analysis (Figure 4), floristic similarities amongst grasslands showed groupings based on the species assemblage and environmental parameters. Vankusavade is distinct from all other grasslands, as it is located in a high rainfall area in Western Ghats and characterized by dominance of the rainfall-associated taxon *Eulalia trispicata*, a typical member of the grass association of Western Ghats (Bharucha and Dave 1952). The bottom branch of the cluster groups, Waghapur, Supe and MPKV grasslands, is highly degraded by annual burning and over-grazing. In unprotected grasslands, over-grazing is responsible for dominance of non-palatable species over time (Naik and Patunkar 1979).

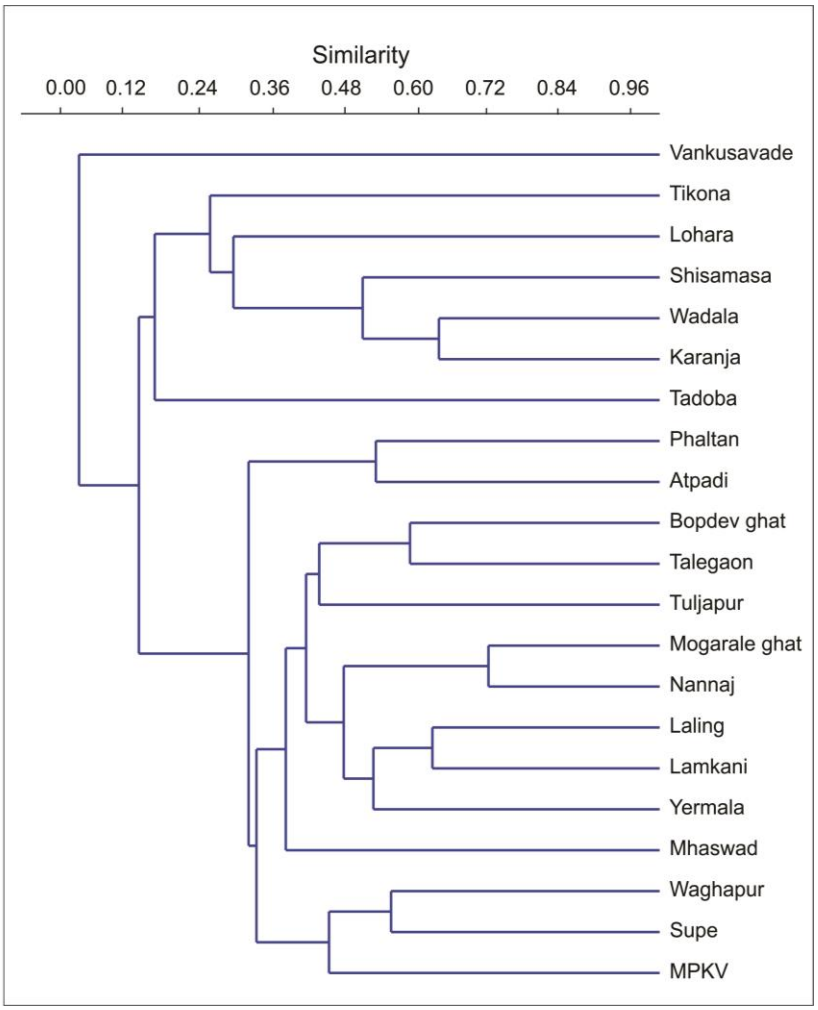

Figure 4. Floristic similarity based on Jaccard's index (Paired group UPGMA).

One cluster contains Shisamasa, Wadala and Karanjasohol, i.e. sites from a high rainfall region (800–1,000 mm) displaying a combination of palatable and non-palatable species. These 3 sites are under community or government protection, which prevents the grazing-associated plant community shift. Community-protected grasslands are characterized by strict bans on grazing and periodic harvesting of fodder during the post-monsoon (September–October), when the community gets enough fodder to overcome rainless summer months until the next monsoon (June–July). This periodic harvesting has advantages over direct grazing. By preventing the disturbance caused by cattle grazing, these grasslands provide higher yields of fodder. In grasslands, which are grazed regularly, the grasses are consumed by grazing cattle well before flowering. On the other hand in grasslands, which are not grazed and are periodically harvested, seed setting is achieved and seed is dispersed before harvesting, leading to regeneration of good quality fodder species during the monsoon in the next year. In contrast to community-protected grasslands, government-protected grasslands are accessible to wild animals throughout the year and are not harvested by humans. Protection from domestic cattle helps them to maintain good grass growth and diversity. This practice, which is beneficial for improving productivity of grasslands, should be implemented in other openly grazed grasslands.

Cluster analysis has grouped sites like Phaltan-Atpadi, Laling-Lamkani and Bopdev ghat-Talegaon, which may be based on the close proximity of these sites. The maximum similarity between any 2 grassland patches was 55%, highlighting the need for conservation of each site.

Effects of physical parameters on diversity and fodder potential of grasslands

The CCA plot showed strong correlation between rainfall and moderately palatable grasses. Locations like Tadoba, Tikona and Vankusavade, which show high rainfall, are dominated by palatable grasses. Unpalatable grasses are more prolific in locations like Phaltan, Lamkani, Atpadi and Laling, which are located in low rainfall sites. High rainfall also showed positive correlation with growth of other herbs. In areas with less rainfall the sturdy grasses grow abundantly but higher rainfall gives herbaceous species other than grasses a chance to establish, which is evident in the CCA plot. Anthropogenic activities like burning and grazing showed strong association with the presence of legumes. Sites that are repeatedly burnt have soils with low or poor nitrogen levels that prevent the growth of most of the grass taxa, as fire is reported to reduce soil nutrients by burning the top layer and destroying humus (Pivello et al. 2010). However, legumes sprout and dominate in the early stages of succession due to their nitrogen-fixing root nodules (Towne and Knapp 1996). Grasses become dominant subsequently as they take advantage of the nitrogen availability in the soil. This phenomenon can be observed in locations like Mhaswad, Mograle ghat, MPKV, Yermala and Waghapur and is clearly depicted in the plot.

Good patterns were evident between community protection and highly palatable grasses. According to Dabadghao and Shankarnarayan (1973), protecting an *Aristida-Heteropogon* community produced a slow shift to *Apluda mutica-Chrysopogon fulvus* and *Dichanthium pertusum*, which are progressively replaced by *Sehima nervosum* and *S. sulcata* and ultimately by *Themeda quadrivalvis*. Presently, Lamkani, where *Sehima* is dominant, can be treated as the penultimate stage of this succession. Lamkani has been protected by local communities for the past 10 years, which has resulted in the community shift towards more palatable species. As sites like Wadala and Shisamasa are protected by local communities from burning and grazing and are not harvested before seed-set, the seeds of palatable species are dispersed and germinate in the next monsoon. In contrast to this situation, in over-grazed grasslands the palatable species are consumed by cattle much before they reach the reproductive stage, resulting in reduction in their population in subsequent years. Unpalatable fodder species on the other hand are not consumed by cattle and their chances of survival are much higher, thus making them dominant in the community.

Conclusion

Subtropical grasslands of India are situated in human-dominated landscapes and are affected by livestock grazing and associated anthropocentric pressures on them. The present study covering 21 sites with varying levels of protection and utilization from Western Ghats and Central India indicated that grasslands protected by local communities with periodic harvesting show high growth of preferred palatable species. Most of the grasslands in this region are unprotected and/or over-grazed, hence the dominance of unpalatable species is evident. The majority of the livestock of the region depends exclusively on these degraded grasslands for fodder, so further degradation is unavoidable, and regaining of the original composition with species like *Dichanthium-Sehima* seems difficult with current management practices. However, protection and periodic harvesting of selected species can prevent further degradation. Future grassland management plans should consider and implement seasonal harvesting

practices. Seasonal harvesting should lead to better yield of fodder species even in protected areas and eventually decrease the dependence of domestic livestock on grasslands inside protected areas. However, a blanket management plan for the entire state would be difficult to implement due to highly varying rainfall and temperature patterns and magnitude of human disturbance across the state. Management plans for each site or group of sites in an ecoregion need to be developed with emphasis on wildlife conservation, as some of the grasslands also harbor highly threatened bird species. Protection of grasslands will not only provide fodder but also increase ground water level of the area by allowing rainwater to percolate into soil and avoid soil erosion during monsoon rains. The present study also documented invasion by many non-native weed species and future research work should focus on interaction of invasive species with native grass species and its implications for long-term conservation. Moreover, these fragile grasslands are present in the human-dominated landscape and community participation in conservation is essential, so interaction of scientists and managers with local people will be vital if proper conservation and management are to be achieved.

Acknowledgments

The author is thankful to: the Director MACS-Agharkar Research Institute, Pune for providing necessary facilities and encouragement; Dr. Dhananjay Newadkar, Shri. Kaustubh Pandharipande, Shri. Jayaji Paikrao, Madhavi Gandhi, Ketaki Ghate, Manasi Karandikar and authorities of Maharashtra Forest Department for their help and support in field work; and Dr. Aparna Watve and Dr. Karthick Balasubramanian for providing comments and advice on the manuscript. Thanks are also due to Maharashtra State Biodiversity Board for their permission (MSBB/desk-5/NOC/84/714-15/797). This research was supported by ARI vide grant no. BOT-18.

References

Bharucha FR; Shankarnarayan KA. 1958. Studies on the grasslands of the Western Ghats, India. The Journal of Ecology 45:681–705. DOI: 10.2307/2257545

Bharucha FR; Dave RN. 1952. The grasslands of Raita, Bombay. Grass and Forage Science 7:55–63. DOI: 10.1111/j.1365-2494.1952.tb01303.x

Blatter E; McCann C. 1935. The Bombay grasses. Scientific Monograph No. 5, Imperial Council of Agricultural Research (ICAR), New Delhi, India.

Bor NL. 1960. The grasses of Burma, Ceylon, India and Pakistan. Pergamon Press, Oxford, London, New York, Paris.

Colwell RK; Mao CX; Chang J. 2004. Interpolating, extrapolating, and comparing incidence-based species accumulation curves. Ecology 85:2717–2727. http://goo.gl/2XXim7

Cooke T. 1901–08. The flora of the presidency of Bombay. Vols. 1 and 2. Taylor and Francis, London, UK. http://goo.gl/LHlo39

Dabadghao PM; Shankarnarayan KA. 1973. The grass cover of India. Indian Council of Agricultural Research (ICAR), New Delhi, India.

Datar MN; Gorade PD; Nadgir P; Bayani A. 2014. Extended distribution of endemic Travancore Murainagrass *Ischaemum travancorense* Stapf ex C.E.C. Fisch. (Poaceae) to Central India. Journal of Threatened Taxa 6:6733–6736. DOI: 10.11609/JoTT.o4125.6733-6

Gadgil M; Malhotra, KC. 1982. Ecology of a pastoral caste: Gavli Dhangars of peninsular India. Human Ecology 10:107–143. DOI: 10.1007/bf01531107

Gorade PD; Datar MN. 2014. Checklist of palatable grass species from peninsular India. Notulae Scientia Biologicae 6:441–447. DOI: 10.15835/nsb.6.4.9376

Hagon MW. 1977. Effects of competition, herbicides and activated carbon on establishment of Australian grasses. Weed Research 17:297–301. DOI: 10.1111/j.1365-3180.1977.tb00482.x

Hammer O; Harper DAT; Ryan PD. 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. Palaeontologia Electronica 4(1):1–9. http://palaeo-electronica.org/2001_1/past/past.pdf

Jain SK; Rao RR. 1977. A handbook of field and herbarium methods. Today and Tomorrow's Printers and Publishers, New Delhi, India.

Jose S; Sreepathy A; Mohan Kumar B; Venugopal VK. 1994. Structural, floristic and edaphic attributes of the grassland-shola forests of Eravikulam in peninsular India. Forest Ecology and Management 65:279–291. DOI: 10.1016/0378-1127(94)90176-7

Kumar S; Shetty BV; Bennet D; Molur S. 2000. Report of the Conservation Assessment and Management Plan Workshop on Endemic Orchids of the Western Ghats. Zoo Outreach, Organization and CBSG South Asia, Coimbatore, India.

Lakshminarasimhan P. 1996. Monocotyledones. Vol. 1 of: Sharma BD; Karthikeyan S; Singh NP, eds. Flora of Maharashtra state. Flora of India Series 2. Botanical Survey of India, Calcutta, India.

Magurran AE. 2004. Measuring Biological Diversity. Blackwell Publishing, Oxford, UK.

Misra MK; Misra BN. 1981. Species diversity and dominance in a tropical grassland community. Folia Geobotanica 16:309–316. DOI: 10.1007/bf02851900

Myers N; Mittermeier RA; Mittermeier CG; Fonseca GAB da; Kent J. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853–858. DOI: 10.1038/35002501

Naik VN; Patunkar BW. 1979. Synecological studies in grasslands of Marathwada. Indian Journal of Forestry 2:372–377.

Oke JG. 1972. Studies in grassland ecology of the Maharashtra State. Ecological classification of grassland patterns found

in different ecological habitats and their botanical characterization. Indian Forester 86:86–106.

Patunkar BW. 1980. Grasses of Marathwada. Scientific Publishers, Jodhpur, India.

Pivello VR; Oliveras I; Miranda HS; Haridasan M; Sato MN; Meirelles ST. 2010. Effect of fires on soil nutrient availability in an open savanna in Central Brazil. Plant and Soil 337:111–123. DOI: 10.1007/s11104-010-0508-x

Potdar GG; Salunke CB; Yadav SR. 2012. Grasses of Maharashtra. Shivaji University, Kolhapur, India.

Puri GS. 1960. Indian forest ecology. Oxford Book and Stationery Co., New Delhi and Calcutta, India.

Ramakrishnan PS; Ram SC. 1988. Vegetation, biomass and productivity of seral grasslands of Cherrapunji in north-east India. Vegetation 74:47–53. DOI: 10.1007/bf00045613

Ramesh BR; Menon S; Bawa KS. 1997. A vegetation based approach to biodiversity gap analysis in the Agastyamalai region, Western Ghats, India. Ambio 26:529–536.

Rawat GS; Karunakaran PV; Uniyal VK. 2003. Shola grasslands of Western Ghats – Conservation status and management needs. ENVIS Bulletin on Grassland Ecosystem and Agroforestry 1:57–64.

Rehel S. 2013. *Ischaemum travancorense*. The IUCN Red List of Threatened Species. Version 2014.2. www.iucnredlist.org/details/177174/0

Sankaran R. 1997. Habitat use by the Lesser Florican in a mosaic of grassland and cropland: The influence of grazing and rainfall. Journal of the Bombay Natural History Society 94:40–47.

Shankar U; Pandey HN; Tripathi RS. 1993. Phytomass dynamics and primary productivity in humid grasslands along altitudinal and rainfall gradients. Acta Oecologica 14:197–209.

Shantz H. 1954. The place of grasslands in the earth's cover of vegetation. Ecology 35:143–145. DOI: 10.2307/1931110

Shukla RP. 2009. Patterns of plant species diversity across Terai landscape in northeastern Uttar Pradesh, India. Tropical Ecology 50:111–123.

Singh JS. 1973. A compartment model of herbage dynamics for Indian tropical grasslands. Oikos 24:367–372. DOI: 10.2307/3543812

Singh NP; Karthikeyan S, eds. 2000. Flora of Maharashtra State. Dicotyledons. Vol. 1. Botanical Survey of India, Calcutta, India.

Sutherland WJ, ed. 2006. Ecological census techniques: A handbook. Cambridge University Press, Cambridge, UK.

Towne EG; Knapp AK. 1996. Biomass and density responses in tallgrass prairie legumes to annual fire and topographic position. American Journal of Botany 83:175–179. DOI: 10.2307/2445935

Tripathi S; Shukla RP. 2007. Effect of clipping and grazing on various vegetational parameters of grassland communities of Gorakhpur, U.P. Tropical Ecology 48:61–70. http://goo.gl/z2J6CF

Yadava PS. 1990. Savannas of north-east India. Journal of Biogeography 17:385–394. DOI: 10.2307/2845367

Annex table: List of species.
Habit: H = herb; RP = Root parasite; C = climber. Plant names are as per The Plant List (www.theplantlist.org)

No.	Species	Family	Habit	Native/Non-Native/Endemic
1	*Alternanthera sessilis* (L.) R.Br. ex DC.	Amaranthaceae	H	Non-Native
2	*Alysicarpus longifolius* (Spreng.) Wight & Arn.	Leguminosae	H	Native
3	*Alysicarpus pubescens* J.S.Law	Leguminosae	H	Native
4	*Andropogon pumilus* Roxb.	Poaceae	H	Native
5	*Apluda mutica* L.	Poaceae	H	Native
6	*Aristida adscensionis* L.	Poaceae	H	Native
7	*Aristida funiculata* Trin. & Rupr.	Poaceae	H	Native
8	*Aristida* sp.	Poaceae	H	Native
9	*Arundinella* sp.	Poaceae	H	Native
10	*Arthraxon* sp.	Poaceae	H	Native
11	*Blainvillea acmella* (L.) Philipson	Asteraceae	H	Non-Native
12	*Blumea* sp.	Asteraceae	H	Native
13	*Boerhavia diffusa* L.	Nyctaginaceae	H	Native
14	*Boerhavia repens* L.	Nyctaginaceae	H	Native
15	*Buchnera hispida* Buch.-Ham. ex D.Don	Orobanchaceae	RP	Native
16	*Celosia argentea* L.	Amaranthaceae	H	Native
17	*Chrysopogon fulvus* (Spreng.) Chiov.	Poaceae	H	Native
18	*Cleome viscosa* L.	Cleomaceae	H	Native
19	*Commelina benghalensis* L.	Commelinaceae	H	Native
20	*Crotalaria hebecarpa* (DC.) Rudd	Leguminosae	H	Native
21	*Cymbopogon citratus* (DC.) Stapf	Poaceae	H	Native
22	*Cyanotis fasciculata* (B.Heyne ex Roth) Schult. & Schult.f.	Commelinaceae	H	Native
23	*Dichanthium annulatum* (Forssk.) Stapf	Poaceae	H	Native
24	*Dichanthium caricosum* (L.) A.Camus	Poaceae	H	Native
25	*Digitaria ciliaris* (Retz.) Koeler	Poaceae	H	Native
26	*Echinochloa colona* (L.) Link	Poaceae	H	Native
27	*Elephantopus scaber* L.	Asteraceae	H	Native
28	*Emilia sonchifolia* (L.) DC. ex DC.	Asteraceae	H	Native
29	*Enicostema axillare* (Poir. ex Lam.) A.Raynal	Gentianaceae	H	Native
30	*Eragrostis* sp.	Poaceae	H	Native
31	*Eulalia trispicata* (Schult.) Henrard	Poaceae	H	Native
32	*Euphorbia heterophylla* L.	Euphorbiaceae	H	Native
33	*Euphorbia hirta* L.	Euphorbiaceae	H	Native
34	*Euphorbia* sp.	Euphorbiaceae	H	Native
35	*Evolvulus alsinoides* (L.) L.	Convolvulaceae	H	Native
36	*Exacum pumilum* Griseb.	Gentianaceae	H	Native
37	*Habenaria longicorniculata* J.Graham	Orchidaceae	H	Native, Endemic
38	*Heteropogon contortus* (L.) P.Beauv. ex Roem. & Schult.	Poaceae	H	Native
39	*Heteropogon triticeus* (R.Br.) Stapf ex Craib	Poaceae	H	Native
40	*Impatiens oppositifolia* L.	Balsaminaceae	H	Native
41	*Indigofera cordifolia* Roth	Leguminosae	H	Native
42	*Indigofera linifolia* (L.f.) Retz.	Leguminosae	H	Native
43	*Ipomoea eriocarpa* R. Br.	Convolvulaceae	C	Native
44	*Ischaemum afrum* (J.F.Gmel.) Dandy	Poaceae	H	Native, Endemic
45	*Ischaemum travancorense* Stapf ex C.E.C.Fisch.	Poaceae	H	Native, Endemic
46	*Lavandula bipinnata* (Roth) Kuntze	Lamiaceae	H	Native
47	*Lepidagathis cristata* Willd.	Acanthaceae	H	Native
48	*Leucas longifolia* Benth.	Lamiaceae	H	Native

Continued

No.	Species	Family	Habit	Native/Non-Native/Endemic
49	*Leucas stelligera* Wall. ex Benth.	Lamiaceae	H	Native
50	*Lophopogon tridentatus* (Roxb.) Hack.	Poaceae	H	Native, Endemic
51	*Melanocenchris jacquemontii* Jaub. & Spach	Poaceae	H	Native
52	*Melochia corchorifolia* L.	Malvaceae	H	Native
53	*Oldenlandia* sp.	Rubiaceae	H	Native
54	*Oplismenus compositus* (L.) P.Beauv.	Poaceae	H	Native
55	*Pentanema indicum* (L.) Ling	Asteraceae	H	Native
56	*Polygala chinensis* L.	Polygalaceae	H	Native
57	*Pulicaria wightiana* (DC.) C.B.Clarke	Asteraceae	H	Native
58	*Rhynchospora wightiana* (Nees) Steud.	Cyperaceae	H	Native
59	*Rostellularia* sp.	Acanthaceae	H	Native
60	*Sesamum laciniatum* Klein ex Willd.	Pedaliaceae	H	Native
61	*Sehima nervosum* (Rottler) Stapf	Poaceae	H	Native
62	*Sehima sulcatum* (Hack.) A.Camus	Poaceae	H	Native, Endemic
63	*Senecio bombayensis* N.P.Balakr.	Asteraceae	H	Native
64	*Senna tora* (L.) Roxb.	Leguminosae	H	Native
65	*Sida cordata* (Burm.f.) Borss.Waalk.	Malvaceae	H	Native
66	*Sida rhombifolia* L.	Malvaceae	H	Native
67	*Smithia bigemina* Dalzell	Leguminosae	H	Native
68	*Sopubia delphinifolia* G.Don	Orobanchaceae	RP	Native
69	*Spermacoce hispida* L.	Rubiaceae	H	Native
70	*Stylosanthes hamata* (L.) Taub.	Leguminosae	H	Non-Native
71	*Tephrosia purpurea* (L.) Pers.	Leguminosae	H	Native
72	*Tetrapogon tenellus* (Roxb.) Chiov.	Poaceae	H	Native
73	*Thelepogon elegans* Roth	Poaceae	H	Native
74	*Themeda quadrivalvis* (L.) Kuntze	Poaceae	H	Native
75	*Themeda triandra* Forssk.	Poaceae	H	Native
76	*Tribulus terrestris* L.	Zygophyllaceae	H	Native
77	*Trichodesma indicum* (L.) Lehm.	Boraginaceae	H	Native
78	*Tridax procumbens* (L.) L.	Asteraceae	H	Native
79	*Urena lobata* L.	Malvaceae	H	Native
80	*Vernonia cinerea* (L.) Less.	Asteraceae	H	Non-Native
81	*Vigna* sp.	Leguminosae	C	Native
82	*Xanthium strumarium* L.	Asteraceae	H	Non-Native
83	*Zornia gibbosa* Span.	Leguminosae	H	Native

(Received for publication 5 January 2015; accepted 7 December 2015)