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Research Article

Ecological exploration of Kuwana forest: A tropical moist deciduous forest of eastern Terai, India

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Abstract: The present study was conducted in the Kuwana forest of Gonda forest division in Uttar Pradesh to explore its ecological inventories. Random stratified sampling was adopted to collect the basic information like frequency, density and abundance for the calculation of importance value index (IVI). On the basis of principal component analysis (PCA) plot, three forest communities were identified and named as, *Syzygium* Lowland Forest (SLF), *Shorea* Miscellaneous Forest (SMF) and *Mallotus* Miscellaneous Forest (MMF). MMF community allowed the maximum 39 while SLF minimum 18 tree species growing in it. Conversely, SMF community showed higher heterogeneous tree diversity validated by lower Dominance index (0.088) and higher Simpson index (0.912). The values of these two indices were found very low in comparison with their range for tropical forests of India. On the otherhand the diversity indices (Shannon & Fisher alpha) was calculated as maximum (2.797 & 11.960 respectively) for MMF community, which indicates the existence of better tree diversity in this forest community. The higher values of Evenness & Equitability indices (0.646 & 0.859 respectively) for SMF community showed the more evenly distribution of tree species in this community.

Keywords: Tree, Phytosociology, Terai, Alpha diversity, Anthropogenic disturbances

Introduction

The phytodiversity of an area can be easily evaluated by two ways, floristic assessment and ecological exploration. In most of the cases, the floristic approach only deals with the qualitative assessment of the plant wealth of an area to know how many kinds of plants existing there. Conversely, the ecological exploration measure / quantify the phytodiversity *via* frequency, density, abundance, importance value index (IVI), different diversity indices etc. This quantitative information from a habitat is very useful for studying the temporal succession of plants in that particular location (Bajpai *et al.,* 2015a). To determine this, numbers of studies from the different parts of the world (Campbell *et al.,* 1986; Mooney and O'Connell, 1990; Campbell *et al.,* 1992; Perkins *et al.,* 1999; Marimon *et al.,* 2002; Lynch and Balmer, 2004; Timilsina *et al.,* 2007; Top *et al.,* 2009; Sambare *et al.,* 2011; Erenso *et al.,* 2014; Ravanbakhsh *et al.,* 2016; Nowak *et al.,* 2017) as well as from India (Singh and Singh, 1991; Parthasarathy, 1999; Sagar *et al.,* 2003; Panchal and Pandey, 2004; Kumar *et al.,* 2006; Chauhan *et al.,* 2008; Tripathi and Singh, 2009; Kibria and Saha, 2011; Bajpai *et al.,* 2012a; Gunaga *et al.,* 2013; Sarkar and Devi, 2014; Deori *et al.,* 2016; Sarkar *et al.,* 2017) have been conducted.

As far as India is concerned, most of the ecological studies come from the peninsular India. Only some scattered information (also not from all the forest areas) is available from rest of the area. When we focused only on the tropical moist deciduous forests of Northern India, only Terai landscape appear in the mind. It is a low-lying narrow stretch along the Himalayan foothills in the north of great plain of Ganga river system from Uttaranchal to Bihar (Bajpai *et al.,* 2015b). From biodiversity point of view, this eco-region is very rich and interesting as it is an ecotone between the Sub-Himalayan foothills and Gangetic plain (De, 2001; Bajpai *et al.,* 2015b). A long time before, this eco-region was entirely covered by natural Sal (*Shorea robusta* Gaertn. f.) forests; but now because of deforestation and non-sustainable management practices, the majority of its natural forests have been lost and now restricted to countable protected areas (Bajpai *et al.,* 2012b). These protected areas include national parks, wildlife sanctuaries as well as reserve forests. Consequently, the review literatures reveal that in the Terai region most of the ecological exploration studies have been conducted in wildlife sanctuary and national parks (Chaturvedi and Misra, 1985; Singh *et al.,* 1995; Pandey and Shukla, 1999; Tripathi *et al.,* 2004; Chauhan *et al.,* 2008; Shukla, 2009; Bajpai *et al.,* 2012a; Behera *et al.,* 2012). Thus, the present study was conducted to explore the ecological features of the Kuwana forest of Gonda forest division of Uttar Pradesh.

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Material and Methods

Study Site

The study was conducted in the Kuwana forest of Gonda forest division, Uttar Pradesh. The forest is situated between 26 47'30" and 27 32'30" N and 81 37'50" and 82 37'35" E; under Southern Gonda forest division. The forest is named on the name of Kuwana river a tributary of river Rapti. The forest is of tropical moist deciduous type (Champion and Seth 1968) with an area of about 4860.64 hectares (Suman and Upadhyay, 2009).

Data Collection and Analysis

Random stratified sampling (Greig-Smith 1983; Krebs, 1989) was adopted to collect the ecological data. Quadrates of 20 × 20 m were plotted to collect the basic information required for the calculation of frequency, density and abundance (Curtis and McIntosh, 1950). Data were collected only for the tree species (CBH ≥20 cm) (Bajpai *et al.,* 2015a). Relative values of frequency, density and abundance were used to calculate the Importance Value Index (IVI) for tree species in every quadrate. This IVI data was further used to re-congregate the quadrates to know the possible forest communities of the forests with the help of principal component analysis (PCA) using multivar option in PAST version 2.12 (Jongman *et al.,* 1995; Bajpai *et al.,* 2012a). Different alpha diversity indices (Simpson, 1949; Cottam and Curtis, 1956; ter Braak and Prentice, 1988) were also computed for the better understanding of forests of the study area.

Results and Discussion

The scattered graph of principal component analysis (PCA) clearly indicated that the forest of the study area can be congregated into three forests communities (Figure 1). On the basis of their representing tree species as well as habitat, these communities were named as, *Syzygium* Lowland Forest (SLF), *Shorea* Miscellaneous Forest (SMF) and *Mallotus* Miscellaneous Forest (MMF). In SLF the dominating tree is the *Syzygium cumini* (L.) Skeels with IVI of 155.35, followed by *Barringtonia acutangula* (L.) Gaertn. (31.46), *Mallotus philippensis* (Lam.) Müll.Arg. (28.47) and *Streblus asper* Lour. (25.40), thus named as same (Table 1). *Shorea robusta* Gaertn. (67.72), *Syzygium cumini* (L.) Skeels (39.82) and *Mallotus philippensis* (Lam.) Müll.Arg. (38.04) are the dominating trees of SMF; while the MMF community is dominated by *Mallotus philippensis* (Lam.) Müll.Arg. (38.04), *Syzygium cumini* (L.) Skeels (39.82), *Terminalia elliptica* Willd. (37.12) and *Bridelia retusa* (L.) A.Juss. (31.26).

The result of PCA claimed the existence of three forest communities in the study site *i.e. Syzygium* Lowland Forest (SLF), *Shorea* Miscellaneous Forest (SMF) and *Mallotus* Miscellaneous Forest (MMF). Similar kind of forests communities were also reported by other workers from the Terai eco-region (Tripathi and Singh, 2009; Bajpai *et al.,* 2012a; Bajpai *et al.,* 2015a). The first three dominant species (*Syzygium cumini* (L.) Skeels, *Barringtonia acutangula* (L.) Gaertn. and *Mallotus philippensis* (Lam.) Müll.Arg.) of SLF community were moisture loving and the characteristic species of lowlands. The quadrates coming in this forest community were usually located near the Kuwana river, which also supports its above said nature of habitat. The SMF community was the residue of old natural *Shorea* (Sal) forest of the Terai eco-region. Although, the composition of this forest community has been changed with the time because of anthropogenic activities (Bajpai *et al.,* 2012b); but *Shorea robusta* Gaertn. is still a dominating tree in this community of the study site as well as in the several other forest patches of the Terai eco-region (Bajpai *et al.,* 2012a). One thing is very interesting to report from SMF, is the presence of *Syzygium cumini* (L.) Skeels as the second most dominating tree species in this community. It is remarkable, because the presence of this expansionist species may become a thread for the seedlings of *Shorea robusta* Gaertn. The MMF community is the patch of forest where the loss of natural *Shorea robusta* Gaertn. (Sal) was maximum due to deforestation of these trees for their valuable timber wood and now this opportunity (presence of more open space) is grasped by *Mallotus philippensis* (Lam.) Müll.Arg. and *Syzygium cumini* (L.) Skeels by increasing their population in this area.

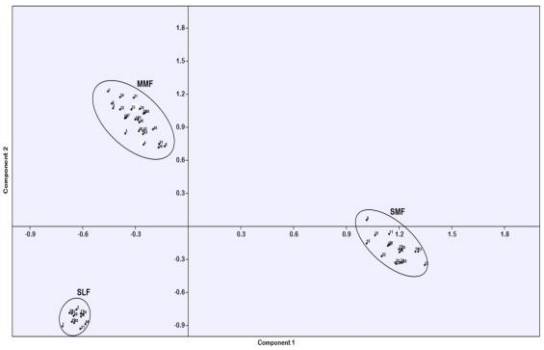

Figure 1. Principal component analysis plot showing the different forest communities: *Syzygium* Lowland Forest (SLF), *Shorea* Miscellaneous Forest (SMF) and *Mallotus* Miscellaneous Forest (MMF).

When we see the overall inventory of the encountered forest communities, it results that the MMF community bears maximum 39 tree species, while the SLF community only 18 species (Table 2). The maximum number of site specific species was maintained by MMF (18) followed by SMF (2) and SLF (1). Twelve tree species were found common in all the three communities; 14 species were shared by SMF & SLF, 16 by SLF & MMF and maximum 20 by MMF & SMF (Figure 2). When we talk about different indices (Table 2), Dominance index was computed maximum for SLF (0.301), whereas minimum for SMF (0.088); Simpson index was maximum for SMF (0.912), while minimum for SLF

(0.699); Shannon & Fisher alpha indices maximum for MMF (2.797 & 11.960 respectively), however minimum for SLF (1.779 & 4.204 respectively); Evenness & Equitability indices were calculated maximum for SMF (0.646 & 0.859 respectively), but minimum for SLF (0.329 & 0.616 respectively).

Although, the maximum number of trees (39) and site-specific species (18) in MMF but the SMF community shows the higher heterogeneous tree diversity because of lower Dominance index (0.088) and higher Simpson index (0.912). The values of these two indices are very low in comparison with the range for tropical forest of India (0.21–0.97 for Dominance and 0.83–4.15 for Simpson index) (Singh *et al.,* 1984; Parthasarathy *et al.,* 1992; Visalakshi, 1995; Supriya and Yadava, 2006; Tripathi and Singh, 2009; Bajpai *et al.,* 2012a; Sarkar and Devi, 2014; Bajpai *et al.,* 2015a). These lesser values of Dominance and Simpson indices are very worrisome for the sustainability of the forest as it indicates the poor heterogeneous tree flora of the site. The presence of maximum Shannon & Fisher alpha indices for MMF (2.797 & 11.960 respectively) indicates the presence of better species diversity in comparison with the other two forest communities of the study site. The value of Shannon diversity index is within the range (0.83–4.10) reported for Indian tropics (Singh *et al.,* 1984; Parthasarathy *et al.,* 1992; Visalakshi, 1995; Bajpai *et al.,* 2012a; Bajpai *et al.,* 2015a). The maximum values of Evenness & Equitability indices (0.646 & 0.859 respectively) for SMF reveal that the species are more evenly distributed in this community.

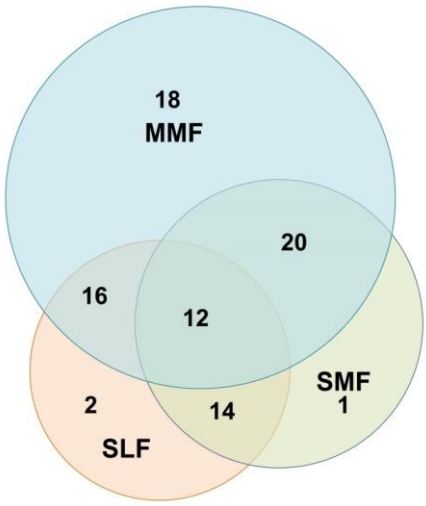

Figure 2. Species distribution in different forest communities in Kuwana forest (SLF- *Syzygium* Lowland Forest, SMF- *Shorea* Miscellaneous Forest and MMF- *Mallotus* Miscellaneous Forest).

Table 1. Importance value index (IVI) of tree species in three forest communities in Kuwana forest (SLF- *Syzygium* Lowland Forest, SMF- *Shorea* Miscellaneous Forest and MMF- *Mallotus* Miscellaneous Forest).

S.N.	Tree species	SLF	SMF	MMF
1	*Acacia nilotica* (L.) Delile	0.82	0.00	0.00
2	*Aegle marmelos* (L.) Corrêa	8.65	11.37	15.96
3	*Artocarpus lacucha* Buch.-Ham.	0.00	0.00	0.69
4	*Azadirachta indica* A.Juss.	0.00	0.83	2.37
5	*Barringtonia acutangula* (L.) Gaertn.	31.46	10.34	6.60
6	*Bauhinia variegata* L.	0.00	0.00	0.67
7	*Bridelia retusa* (L.) A.Juss.	0.00	31.26	5.40
8	*Cordia dichotoma* G.Forst.	0.00	0.00	1.53
9	*Eucalyptus regnans* F.Muell.	0.00	4.75	1.56
10	*Ficus benghalensis* L.	6.31	10.67	14.79
11	*Ficus hispida* L.f.	0.00	0.00	0.60
12	*Ficus palmata* subsp. *virgata* Browicz	0.88	0.00	1.44
13	*Ficus racemosa* L.	2.67	1.87	5.80
14	*Ficus religiosa* L.	4.01	15.46	0.00
15	*Flacourtia indica* (Burm.f.) Merr.	0.00	0.00	2.46
16	*Haldina cordifolia* (Roxb.) Ridsdale	0.00	0.00	1.17
17	*Holarrhena pubescens* Wall. ex G.Don	0.00	0.00	0.72
18	*Hymenodictyon orixense* (Roxb.) Mabb.	0.00	0.00	1.71
19	*Lagerstroemia speciosa* (L.) Pers.	0.00	2.19	2.60
20	*Lannea coromandelica* (Houtt.) Merr.	1.93	9.10	4.45
21	*Litsea monopetala* (Roxb.) Pers.	16.79	6.13	11.36
22	*Madhuca indica* J.F.Gmel.	0.00	3.02	12.75
23	*Mallotus nudilorus* (L.) Kulju & Welzen	5.24	4.29	3.17
24	*Mallotus philippensis* (Lam.) Müll.Arg.	28.47	45.52	38.04
25	*Mangifera indica* L.	0.00	1.32	0.65
26	*Melia azedarach* L.	0.00	0.00	1.33
27	*Miliusa tomentosa* (Roxb.) J.Sinclair	0.00	0.00	2.78
28	*Mitragyna parvifolia* (Roxb.) Korth.	1.75	0.00	0.00
29	*Phyllanthus emblica* L.	0.00	0.00	2.73
30	*Pongamia pinnata* (L.) Pierre	0.95	0.00	2.79
31	*Pterocarpus marsupium* Roxb.	0.00	0.00	2.95
32	*Randia dumetorum* (Retz.) Lam.	0.00	0.00	0.80
33	*Saraca asoca* (Roxb.) Willd.	0.00	0.00	0.75
34	*Semecarpus anacardium* L.f.	0.00	0.00	0.80
35	*Shorea robusta* Gaertn.	3.62	24.16	67.72
36	*Streblus asper* Lour.	25.40	21.78	13.49

37	*Syzygium cumini* (L.) Skeels	155.35	38.16	39.82
38	*Tectona grandis* L.f.	1.60	14.06	17.85
39	*Terminalia arjuna* (Roxb. ex DC.) Wight & Arn.	0.00	0.00	2.99
40	*Terminalia bellirica* (Gaertn.) Roxb.	0.00	4.84	0.00
41	*Terminalia chebula* Retz.	0.00	0.00	1.45
42	*Terminalia elliptica* Willd.	0.00	37.12	2.25
43	*Ziziphus mauritiana* Lamk.	4.11	1.76	2.98
	Total	**300.00**	**300.00**	**300.00**

Table 2. Inventory details of forest communities of Kuwana forest (SLF- *Syzygium* Lowland Forest, SMF- *Shorea* Miscellaneous Forest and MMF- *Mallotus* Miscellaneous Forest).

	SLF	SMF	MMF
Number of species	18	22	39
Site Specific species	2	1	18
Dominance_D	0.301	0.088	0.101
Simpson_1-D	0.699	0.912	0.899
Shannon_H	1.779	2.654	2.797
Fisher_alpha	4.204	5.469	11.960
Evenness_e^H/S	0.329	0.646	0.420
Equitability_J	0.616	0.859	0.763

Conclusion

The study quantitatively explores the ecology of Kuwana forest situated Gonda forest division of Uttar Pradesh and concluded the occurrence of three forest communities (*i.e. Syzygium* Lowland Forest, *Shorea* Miscellaneous Forest and *Mallotus* Miscellaneous Forest) in it. The IVI data of these forest communities clearly indicate that the *Syzygium cumini* (L.) Skeels is acting as expansionist species and expanding its area of occupancy; whereas, *Shorea robusta* Gaertn. is struggling to safeguard its current population size. The Dominance and Simpson indices are very low in comparison with the available range for the tropical forest of India. It is a serious issue regarding the health as well as sustainability of the forest, accordingly here we are suggesting immediate short-term conservation programmes followed by long term programmes for the betterment of the forest dynamics.

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