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Do internal roadways influence tree diversity and density in a reserve forest? - A reality check at BRT Tiger Reserve, Karnataka, India

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Roadways are inevitable components in any human managed landscape across the world, with the sole objective to facilitate transportation. Reserve forests are not an exception to this situation. A roadway being a potential factor in influencing biodiversity, this study checks the possibility of relationship between the distance of tree communities from roads and the basic characteristics (diversity and density) of the communities in a protected forest. 30 distinct plots were studied across two ranges in BRT Tiger Reserve, Karnataka. For each plot, its average distance and minimum distance from a road and also from specific road types were calculated. In order to check the relationship of distance from road and community characteristics, correlation tests were carried out. It is inferred that the distance from internal roads and community characteristics does not possess any relationship in a reserve forest scenario. Though the possibility of influence by internal roads over tree communities is rendered nil in this study, cautious execution of road-based operations with-in the reserve forests in future is highly recommended.

Key words: Biodiversity conservation, correlation analysis, distance from roads, forest landscapes.

INTRODUCTION

Roads are ingenious creations of humans that make livelihood easier at a large scale. But, on an ecological basis, roads also play a crucial role over determining the state of biodiversity, in several ways. Predominantly, road edges display a variety of physical and chemical changes as a result of road operation and vehicle transports (Forman, 2000; Delgado et al., 2007; Parris and Schneider, 2008; Hoskin and Goosem, 2010) and are characterized by altered micro-climatic conditions, hydrology regimes, soil composition, increased levels of light and pollutants in the air, soil and water (Jaeger and Fahrig, 2004). Hence, the constraining factors along roadsides, such as alteration of normal hydrological flows, the introduction of chemicals or salts, vehicle exhaust emissions, wind gusts, excessive light, dust, etc., may play a vital role in promoting/demoting the spread of plants along roadsides, by causing variations in the habitat, environment or ecology (Rentch et al., 2005). Roads in general constitute a partial to complete barrier for movement of many organisms, depending on the

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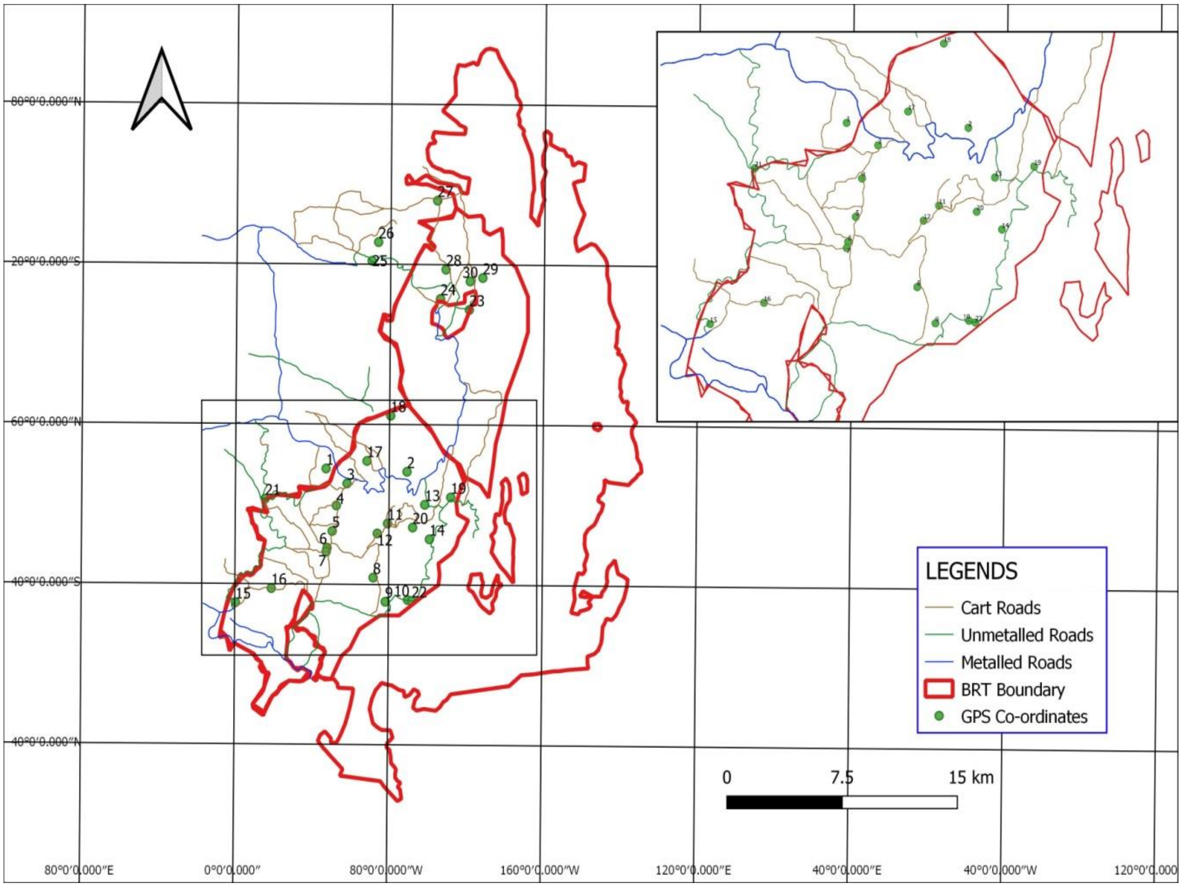

Figure 1. GIS map showing BRT boundary, internal roadways and plots (refer to Table 1).

mobility and behavior of taxa and on road characteristics, influencing changes in plant-animal interactions (Jaeger and Fahrig, 2004). Also, under the influence of possible elevated CO_2 in the roadside vicinities, plants may grow faster and spread efficiently by enhanced photosynthetic activity (Miquel et al., 2004) or through enhanced root formation/activity (Madhu and Hatfield, 2013), leading to variations in leaf or root biomass, respectively. Alternatively, elevated CO_2 might also cause retarded growth of plants, by its negative effect on stomatal conductance/respiration, affecting the transpiration driven mass flow of Nitrogen in the soil (Daniel and Wang, 2008; Uddling, 2015).

Understanding the role of protected areas in conserving biodiversity is a prime objective in conservation biology. Anthropogenic activities within these protected areas, in particular, roads, can alter the spatiotemporal dynamics of biological diversity there. However, our understanding of how the presence and position of roads affects tree communities and paves way for biodiversity conservation is limited. One major positive role played by roads is the facilitation of forest monitoring and biodiversity conservation (M'Woueni et al., 2019). And, low-traffic roads can also lead to increase in habitat heterogeneity in any structurally poor forest (Salek et al., 2010). Though the overall capacity of roadways is known, its influential potential in a reserve forest scenario is quite unexplored. Hence, this study aims to bring about clarity in the subject, by considering BRT Tiger Reserve. It is a well-protected reserve forest of over 540 km^2 in India, at the confluence of the Western Ghats and the Eastern Ghats mountain ranges.

MATERIALS AND METHODS

Using stratified random sampling protocol in a GIS platform (ArcGIS 10.6.1), 30 distinct spots were marked across two ranges, viz., K. Gudi and Yelandur, in BRT Tiger Reserve, Karnataka. Following standard protocols (Reddy et al., 2018), 0.1 ha plots were established at the derived spots, irrespective of their distance from the roads, and tree inventory data were collected for each plot, during December 2018 to January 2019 (Figure 1).

Later, using GIS (QGIS 3.8), with the help of georeferenced toposheet maps (SOI maps- Karnataka, Tamil Nadu 57H4, 58E1, 58E2, 58E5) and shape file of BRT, distinct lines were obtained for metalled roads, unmetalled roads and cart roads, separately, across the two covered ranges. The GPS points for the plots were laid over as a layer, and their perpendicular distances from the roads were calculated efficiently. For each plot, its total average distance and minimum distance from a road was calculated. In

Table 1. GPS coordinates (in degree decimals) for the plots.

Plot	N	E	Plot.	N	E
1	11.90791	77.07389	16	11.84043	77.04111
2	11.90606	77.12222	17	11.91218	77.09833
3	11.89948	77.08639	18	11.93768	77.1125
4	11.88704	77.08	19	11.89156	77.14833
5	11.87264	77.0775	20	11.87458	77.12556
6	11.86323	77.07444	21	11.89091	77.0375
7	11.86099	77.07389	22	11.83303	77.125
8	11.84631	77.10194	23	11.99738	77.15944
9	11.83271	77.10917	24	12.00359	77.14222
10	11.83367	77.1225	25	12.02511	77.10139
11	11.87687	77.11056	26	12.03567	77.10528
12	11.87123	77.10444	27	12.05905	77.14056
13	11.88742	77.13278	28	12.02012	77.14556
14	11.86792	77.13556	29	12.01539	77.1675
15	11.83248	77.01972	30	12.01344	77.16

addition, average distance and minimum distance from specific road types were also calculated, expressed in meters.

Each of the plant characteristics variables, namely, density and richness, were calculated by counting the number of trees per 0.1 ha plot area and the number of different species within the sampling plot, respectively.

In order to check the relationship between two variables; that is, distance from road and community characteristics, correlation tests (Pearson, 1896; Spearman, 1904) were used.

RESULTS

The respective variables for tree density, richness and distances from roads (in meters) for the 30 plots analyzed in this study are presented in Table 2. Tree density ranged from 7 to 62, and richness varied from 3 to 14 tree species per sampling plot area. Average distance from a main road and minimum distance from a main road occurred only for three Plots (Sl. Nos. 1 – 3). The average distance from a main road ranged from 315 to 1012 m, and the minimum distance from a main road ranged from 315 to 669 m. The average distance from an unmetalled road ranged from 24 to 1196 m; and for the minimum distance from the unmetalled road the range also was the same, 24 to 1196 m. On the whole, as may be expected, there were more sample sites that had cart roads in this locale. The average distance from a cart road, and the minimum distance from a cart road, both ranged from 0.006 to 2504 m. Correlation coefficients for the variables of plant characteristics (density and richness) related to geographic variables (road distances) are presented in Table 3. A correlation coefficient (r or r_s) can range in value from -1 to +1. The larger the absolute value of the coefficient, the stronger the relationship between the variables. As shown in Table 3, none of the correlation values are sufficiently large in value to be considered significant. Therefore, evidently, there is no detectable relationship between the distance from road and plant community characteristics for the data collected in this study.

DISCUSSION

In human settlement landscapes, non-forest woody vegetation represents an important component of green infrastructure in the agricultural areas, where natural and semi-natural forest cover has only a low land use proportion (Tóth et al., 2016). Urban afforestation produces a great enhancement in the flora of cities; but if improperly planted, they generate disturbances (de Oliveira et al., 2018). Street trees are a significant component of urban zones, which can remove a significant amount of CO_2 from the surroundings annually, equivalent to the removal of several thousand cars from the road (McPherson et al., 2016). Most urbanized municipalities have a surplus of non-native species and also trees belonging to native species, as street trees (Thomsen et al., 2016). Narrow roads, usually in congested residential neighborhoods, have fewer trees, smaller-sized tree species and a lower species diversity compared to wide roads (Nagendra and Gopal, 2010). Whereas, in disturbance-prone, human accessible forest landscapes, logging roads can trigger forest degradation by reducing the integrity of the ecosystem and providing access for encroachment, as most logging roads are abandoned after timber harvesting (Kleinschroth et al., 2016). Inter- correlated suite of changes can occur along the margins of the logging roads, like increases in understory foliage density, decreases in sapling density and decreases in tree species richness (Malcolm and Ray, 2000). The

Table 2. Respective tree density, richness and distances from roads (in meters) for the considered plots.

Plot	Density	Richness	Total avg. dist. from road	Total min. dist. from road	Avg. Dist. from M.R.	Min. dist. from M.R.	Avg. dist. from U.R.	Min. dist. from U.R.	Avg. dist. from C.R.	Min. dist. from C.R.
1	7	3	920	669	1012	669	-	-	828	677
2	12	6	982	480	982	480	-	-	-	-
3	25	10	229	142	315	315	-	-	142	142
4	24	6	133	27	-	-	-	-	133	27
5	21	6	270	107	-	-	-	-	270	107
6	60	12	166	141	-	-	-	-	166	141
7	33	7	3.2	3.2	-	-	-	-	3.2	3.2
8	62	5	152	152	-	-	-	-	152	152
9	33	9	357	268	-	-	268	268	446	446
10	53	10	24	24	-	-	24	24	-	-
11	24	8	7.5	7.5	-	-	-	-	7.5	7.5
12	42	9	14	14	-	-	-	-	14	14
13	36	9	512	269	-	-	269	269	755	755
14	45	8	207	207	-	-	207	207	-	-
15	14	3	146	50	-	-	50	50	242	242
16	14	7	0.006	0.006	-	-	-	-	0.006	0.006
17	41	13	521	260	-	-	-	-	521	260
18	51	8	1850	1196	-	-	1196	1196	2504	2504
19	30	14	417	153	-	-	153	153	681	681
20	17	7	472	451	-	-	-	-	472	451
21	11	4	57	47	-	-	57	47	-	-
22	39	9	18	18	-	-	18	18	-	-
23	38	12	120	120	-	-	120	120	-	-
24	37	6	623	364	-	-	823	823	423	364
25	18	8	55	55	-	-	55	55	-	-
26	9	7	661	448	-	-	873	873	448	448
27	28	10	149	122	-	-	-	-	149	122
28	23	10	174	174	-	-	-	-	174	174
29	35	12	501	501	-	-	-	-	501	501
30	33	11	541	307	-	-	-	-	541	307

Avg.- Average; Min.- Minimum; Dist.- Distance; -, not applicable; M.R.- Metalled Road; U.R.- Unmetalled road; C.R.- Cart Road.

distance to logging roads and to unlogged forest can influence post-logging recovery, emphasizing the importance of edge effects in previously logged forests (Katovai et al., 2016). Most importantly, along roads, shade-tolerant aliens are to be monitored and removed as they can

Table 3. Correlation results for the considered variables.

X	Y	Pearson correlation coefficient (r)	Spearman correlation coefficient (r_s)
Density	Total Avg. dist.	-0.012	-0.081
Density	Total Min. dist.	0.019	-0.035
Richness	Total Min. dist.	-0.069	0.048
Richness	Total Avg. dist.	-0.072	0.008
Density	Avg. Dist. from metalled road	0	0
Density	Avg. Dist. from unmetalled road	0.140	-0.049
Density	Avg. Dist. from cart road	0.203	0.088
Richness	Avg. Dist. from metalled road	0	0
Richness	Avg. Dist. from unmetalled road	-0.141	-0.155
Richness	Avg. Dist. from cart road	0.042	0.185
Density	Min. Dist. from metalled road	0	0
Density	Min. Dist. from unmetalled road	0.143	-0.033
Density	Min. Dist. from cart road	0.211	0.088
Richness	Min. Dist. from metalled road	0	0
Richness	Min. Dist. from unmetalled road	-0.138	-0.139
Richness	Min. Dist. from cart road	0.031	0.152

Avg.- Average; Min.- Minimum; Dist.- Distance.

potentially invade natural forests (Heinrichs et al., 2018).

In a protected area, not much study of the impact of roads on tree communities has been carried out, except for the compulsive report on dynamics of trees at traditional agroforestry parks in a West African biosphere reserve (M'Woueni et al., 2019). A significant decline of tree density was reported, affected by their proximity to monitoring roads and human populations, as local people continually extracted timber. Also, tree density was found comparatively higher in farms close to the monitoring roads used by park rangers to patrol the park, indicating the importance of conservation surveillance. In the present study, an assessment of road impacts on trees, within a well-protected reserve forest, is presented for 30 randomly selected plots. Cardinally, the data show that internal roads are not influential on the density and richness of the tree communities in the well-protected forest landscape examined in this study. However, a strong emphasis is made to retain the pristinity of forests by managing internal road-based operations to be as minimal and non-destructive as possible.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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