Impact of roads on biodiversity: a case study from Karekhola rural road in Surkhet district of Nepal

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Loss and degradation of biodiversity is continuing despite the past conservation efforts in Nepal. Out of many potential causes, this study strives to investigate the effects of a road project on biodiversity in the Middle Hills of Nepal. Information about floristic composition was collected from the adjoining community forests using group of 30 circular sample plots, each located at 50 m and 20 m far from the edge of the road. Results provide evidence that rural road projects are contributing to reduction of biodiversity which may be due to the removal of low-yielding timber species near the road-edge. The study also suggests that proximity to road-edge reduces under-storey vegetation which will lead less capable forest to sustain its original biodiversity. However, silvicultural operations have potential to minimize the indirect loss of biodiversity caused by road projects.

Key words: Community forests, Middle Hills, rural road, woody plant species' diversity

Diversity of species plays an important role in ecosystem functions and services. Nepal possesses a disproportionately high diversity of flora and fauna at genetic, species and ecosystem levels due to its unique geographic position and altitudinal variations. The Government of Nepal (GoN) is committed to the protection and management of biological resources and their diversity on a sustainable basis (MFSC, 2014). As a signatory country of the Convention on Biological Diversity (CBD), the GoN has revised the country's National Biodiversity Strategy and Action Plan (NBSAP) in 2014. In addition, the GoN has put a lot of efforts in the past regarding implementation of International agreements as well as formulation of strategies to include the local communities in biodiversity conservation. However, the efforts made so far mainly relate to reducing poaching, trade and illegal activities within the protected areas. Other threats like unplanned road projects, the key causes of habitat loss and fragmentation, are usually underestimated. The problem is not restricted to motorways. However, narrow country roads occupy less area per kilometer, and are more frequent than motorways, so their combine effect upon the landscape can be considerably larger (Seiler, 2001).

Road provides a basis for long-term development in the rural areas, but the environmental consequences cannot be neglected only foreseeing economy. Unplanned and wrongly designed economic development can cause destabilization of the natural environment, which is evidenced by many past efforts in Nepal and elsewhere. Earlier studies (WWF, 2013; MFSC, 2014) have found that unplanned rural roads constructed by the local governments are one of the major threats to environment and biodiversity. The Department of Roads estimates that around 25,000 kilometers rural road tracks had been opened in Nepal by 2010, most of which have been constructed without any environmental safeguard (DOR, 2010).

Forest roads are termed as "ecosystems" as they occupy ecological space (Hall *et al.*, 1992) and provide habitat for associated plants and animals (Lugo and Gucinski, 2000). Road infrastructure causes direct and indirect loss in forest ecosystem. Direct loss refers to the reduction of forest area and indirect loss of roads refers to fragmentation and degradation of the ecosystem (Geneletti, 2003). One of the major effects of roads relates to its edge effects, which can be defined as the alternation to habitat quality due to proximity to edge. It can cause indirect loss of habitat by changing species composition, temperature, moisture, light availability and wind speed and, therefore, alteration in original biodiversity (Gysel, 1951). The effect of edge on plant

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diversity can occur up to 30 m far from the road or even beyond (Seiler, 2001).

The study was, moreover, a descriptive research limited to investigating the impacts of road projects on diversity of woody plant species. In order to assess the impacts of roads on diversity of woody plant species, the effects mainly upon the species diversity and the structural diversity were investigated. These indirect effects of road projects were assessed by comparing and analyzing woody plant species distribution in between two effect-zones (20 m and 50 m far from road-edge).

Materials and methods

Study area

The study area is located between 28°36’14” N and 28°36’20” N latitude and between 81°38’19” E and 81°38’58” E longitude in the adjoining forests of the Karekhola Rural Road. The road connects Jarbuta Village Development Committee (VDC) and Birendranagar Municipality of Surkhet District situated in the Middle Hills (Fig. 1). The earthen road is 5 m wide and 1.46 km long. The study was conducted in 2012.

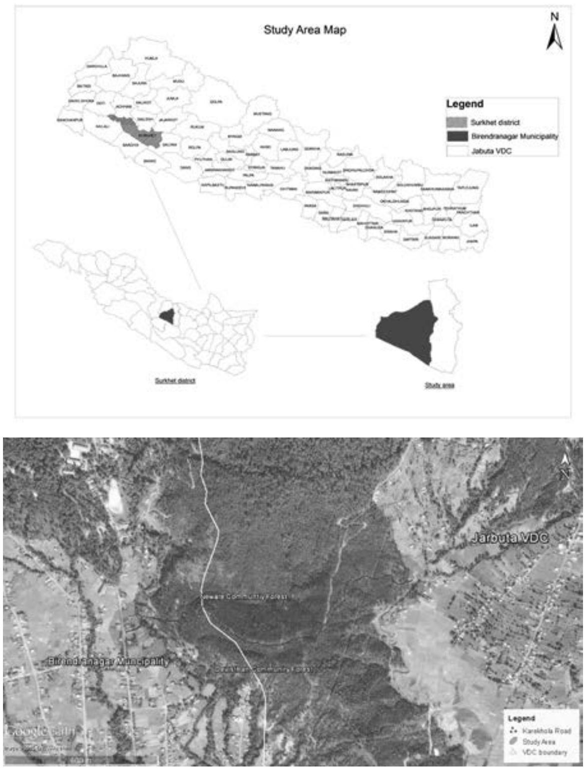

Fig. 1: Map showing the location of the study area in Western Nepal

The road is the main pillar in the development of Jarbuta VDC area. All kinds of traffic are being used to transport essential goods to meet livelihood requirements of the people of Jarbuta VDC. The road passes through Neware Community Forest (CF) in the northern part and Devis than CF in the southern part. The adjoining CFs are managed by the local Community Forest User Groups (CFUGs) according to the respective operational plans. The FUGs have deployed the locally-hired forest guards for protection of the forests.

Methodology

Systematic sampling was used for the collection of primary data on diversity of woody species in the CFs. First of all, reconnaissance survey was carried out and the Karekhola Road was surveyed with the help of GPS (Global Positioning System) Device. Preliminary data analysis was done using GIS (Geographical information System) Software. The forest area lost due to road construction was determined by multiplying the length of the road with its width. Similarly, the spacing between the two successive plots (45 m) was determined on the basis of different factors, such as length of the road (1.46 km), maximum coverage of the road in the study area and the possibility of intersection of the area of the sample plots on the road bends.

Then from the starting point (on the road), 45 m distance was marked on the road-length with the help of a Measuring Tape. Making perpendicular to the road length, concentric circular sample plots (CCSPs) with 1 m, 3 m and 10 m radii were laid out at 20 m and 50 m distances from both the edges of the road (Fig. 1 and 2) with the help of the Measuring Tape. The sampling protocol developed and used by the International Forestry Resources and Institutions Research Network (IFRIRN) was used for assessing the forest conditions (IFRI, 2013). This research protocol has been widely used by the researchers in the past (Gautam, 2002; Gautam, 2006). In the innermost circle of the plot (1 m radius), all the woody seedlings were identified and counted. In the next circle (3 m radius), all the shrubs, saplings, and climbers were identified and counted, and also the diameters and the heights of the woody stems having diameter at breast height (DBH) in 2.5–10 cm class were recorded. In the largest circle (10 m radius), all the stems with 10 cm or greater DBH were counted, and their diameters and heights measured. The same process was repeated from the opposite edge of the road. Again, at the distance of 45 m from the previous location, the same process was repeated. In this way, altogether 30 circular sample plots were laid at 20 m and 50 m distances from the road-edge throughout the study area.

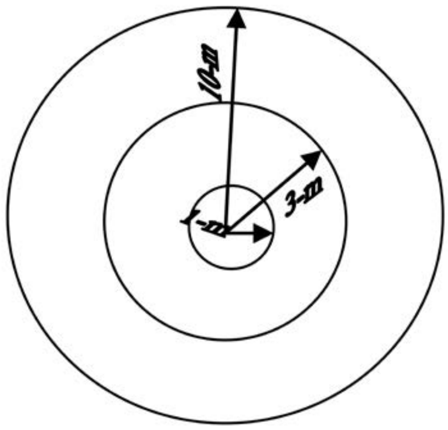

Fig. 2: A concentric circular sample plot

The woody plant species' diversity was assessed and compared using the Simpson's Diversity Index (D) and the Sorenson's Similarity Index (SSI).

<u>Simpson's Diversity Index (D):</u> It gives the probabilities that the two randomly chosen individuals drawn from a population belong to the same species. Higher the probabilities that both the individuals belong to the same species, lower the diversity. For finite communities (where all members have been counted),

Simpson's Diversity Index (D) = $\sum pi^2$
(Baral and Katzensteiner, 2009),

Where, pi is the proportional abundance of the ith species i.e. the proportion of individuals of a given species relative to the total no. of individual in an effect-zone (i.e. forest stand).

<u>Sorenson's Similarity Index (SSI):</u> It is a very simple measurement of beta diversity. The SSI value ranges from 0 where there is no species overlap between the effect-zones to 1 when exactly the same species are found in both the effect-zones.

Sorenson's Similarity Index (SSI) = $2c / (S_1 + S_2)$
(Magurran, 1988),

Where,
S_1 = Total no. of species found in the CCSP located at 20m distance from the road edge,

S_2 = Total no. of species found in the CCSP located at 50 m distance from the road edge, and

C = No. of species common to both the effect-zones.

Structural diversity

In order to compare the structural diversity of the two effect-zones, the DBH and height distribution classes were prepared. The diameters (at breast height) were categorized into the classes of 0–5 cm, 5–10 cm, 10–15 cm, and above 15 cm. Then, the DBH class distributions between the two zones were compared, and analyzed. Similarly, the heights were categorized into the classes of 1–5 m, 5–10 m, and above 10 m, and the heights between the two zones were also compared and analyzed.

Results and discussion

Plant species found in the two types of effect-zones

Altogether, 23 plant species including 18 tree species, 3 shrub species and 2 woody climber species were found in the study area. A total of 19 plant species were found in the effect-zone at 20 m distance while a total of 16 plant species were found in the effect-zone at 50 m distance. Seven tree species, three shrub species and two woody climbers were common in both the effect-zones (Table 1). The difference in species richness between the two zones could be due to the edge effects, which often results higher species richness and greater numbers of exotic species at the edges (Ranney *et al.*, 1981), and potential ecosystem processes and productivity function alters (Laurance *et al.*, 1997).

The calculated Sorenson's Similarity Index (SSI) value of the two effect-zones was found to be 0.69 (near to value 1) which indicated that the species found in both the effect-zones were more or less similar. *Shorea robusta* was found to be the dominant tree species in both the effect-zones. Other common tree species noticed were *Dalbergia sissoo, Terminalia alata* and *Buchanania latifolia*. Similarly, *Argemore maxicana* was found to be the principal shrub species in both the effect-zones.

Table 1: List of the plant species found in the two effect-zones

S.N.	Local Name	Botanical Name	20 m distance	50 m distance
1.	Sal (T)	*Shorea robusta*	√	√
2.	Sissoo (T)	*Dalbergia sissoo*	√	√
3.	Jamun (T)	*Syzigium cumini*	√	√
4.	Khirro (T)	*Wrightia arborea*	√	
5.	Tate (T)	*Sapindus mukorossi*	√	
6.	Ranisalla (T)	*Pinus roxbughii*		√
7.	Khannyu (T)	*Ficus semicordata*		√
8.	Pyar (T)	*Buchanania latifolia*	√	√
9.	Tilka (T)	*Wendlendia appendiculata*	√	√
10.	Bhorla (W)	*Bauhinia vahlli*	√	√
11.	Bhalayo (T)	*Rhus wallichii*	√	
12.	Bot dhanyero (T)	*Largerstromia parviflora*	√	
13.	Gaitihare (T)	*Inula cappa*		√
14.	Saj (T)	*Terminalia alata*	√	√
15.	Imili (T)	*Tamarindus indica*	√	√
16.	Kyamuno (T)	*Syzigium cerasoides*	√	
17.	Mauwa (T)	*Madhuca indica*	√	
18.	Amba (T)	*Psidium guajava*	√	
19.	Latimauwa (S)	*Engelhardia spicata*	√	√
20.	Kutmero (T)	*Litsea monopetala*		√
21.	Mainfalkada (S)	*Catuna regamspinosa*	√	√
22.	Badulpate (W)	*Cissampelos pareira*	√	√
23.	Thakkal (S)	*Argemore maxicana*	√	√

Note: T = Tree, S = Shrub and W = Woody climber

Species diversity of trees

Altogether, 11 plant species were found to be at tree stage in the effect-zone at 20 m distance while a total of 10 plant species were found to be at that stage in the effect-zone at 50 m distance (Table 1). For the higher plant species diversity, the number of plant species present in an effect-zone is not so important, but the even distribution of each individual plant species within the zone is important. In the effect-zone at 50 m distance, the plant species were found to be evenly distributed as compared to the one in the effect-zone at 20 m distance. The Simpson's Diversity Index (D) was found to be 0.6057 in the effect-zone at 50 m distance while it was 0.7113 at 20 m distance (Table 2). Thus, the value of D was found to be slightly less within the effect-zone at 50 m distance as compared to the one within the effect-zone at 20 m distance, which showed that the effect-zone at 50 m distance was rich in plant diversity as compared to the effect-zone at 20 m distance due to the road-edge effects.

Table 2: Simpson's Diversity Index values in the two effect-zones

S.N.	Forest stand (effect-zone)	Stage of the plants	Simpson's Index (D)
1.	At 20 m distance	Tree	0.7113
		Sapling	0.7187
		Seedling	0.4449
2.	At 50 m distance	Tree	0.6057
		Sapling	0.6850
		Seedling	0.3881

Species diversity of saplings

Altogether, 7 plant species at sapling stage were found in the effect-zone at 20 m distance while a total of 9 plant species at that stage were found in the effect-zone at 50 m distance. A total number of 167 and 225 saplings of *S. robusta* were recorded in the effect-zones at 20 m distance and 50 m distance, respectively. *S. robusta* was found to be unevenly distributed in the effect-zone at 20 m distance than in the effect-zone at 50 m distance; other plant species were found to be in very few numbers. On the contrary, other species were found to be evenly distributed in the effect-zone at 50 m distance in spite of the dominancy of *S. robusta*. The Simpson's Diversity Index was found to be 0.7187 in the effect-zone at 20 m distance and 0.6850 in the effect-zone at 50 m distance, indicating a little bit higher plant diversity in the effect-zone at 50 m distance than in the effect-zone at 20 m distance. The result also showed that the forest stand (effect-zone) at 50 m distance was richer in species diversity at sapling stage as compared to the one at 20 m distance.

Species diversity of seedlings

Altogether, 10 plant species were found at seedling stage in the effect-zone at 50 m distance while 11 plant species were noticed at that stage in the effect-zone at 20 m distance. A total of 242 seedlings of *S. robusta* were found to be distributed in the effect-zone at 20 m distance while a total of 205 seedlings of this species were found in the effect-zone at 50 m distance. The Simpson's Diversity Indices were found to be 0.4449 and 0.3881 in the effect-zones at 20 m and 50 m distances, respectively (Table 2). The result showed that the effect-zone at 50 m distance possessed more plant diversity at seedling stage as at tree and sapling stages than the effect-zone at 20 m distance due to the proximity to the road-edge.

In the community-managed forests, removal of bigger and older trees is carried out during silvicultural operations so as to provide space for preferred species of younger trees (Baral and Katzensteiner, 2009). Due to the removal of older trees, appropriate environment is created to regenerate new crop and also establishment of the younger ones which leads the forest towards more diverse in undergrowth. Suding (2001) carried out one of the several studies which also documented proportionate relationship between species richness and light availability on the forest floor.

Structural diversity

Moreover, dominant trees with 10–15 cm DBH class and 5–10 m height class were found to be distributed in the study area. Trees with higher DBH classes (10–15 cm and above 15 cm) and higher height classes (5–10 m and above 10 m) were found to be distributed more in the effect-zone at 20 m distance than in the effect-zone at 50 m distance (Fig. 3 and 4). On the contrary, plants with lower DBH classes (0–5 cm and 5–10 cm) and lower height class (0–5 m) were found to be distributed more in the effect-zone at 50 m distance than in the effect-zone at 20 m distance. The study indicated that the under-storey vegetation in the effect-zone at 20 m distance was comparatively lesser than that in the effect-zone at 50 m distance. This reveals that the roads affect not only upon plant species' diversity but also have potential impact on structural diversity. This also reveals that proximity to road edge reduces under-storey vegetation and results less sustainable forest.

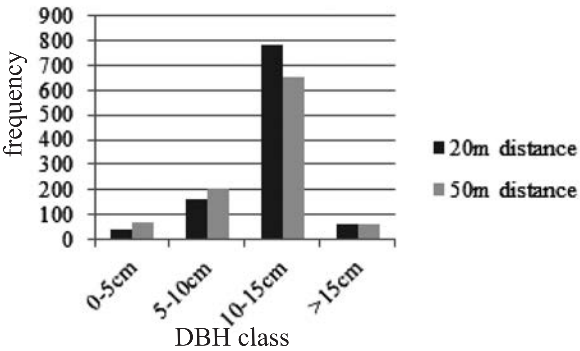

Fig. 3: Plant distribution in terms of DBH classes in the two effect-zones

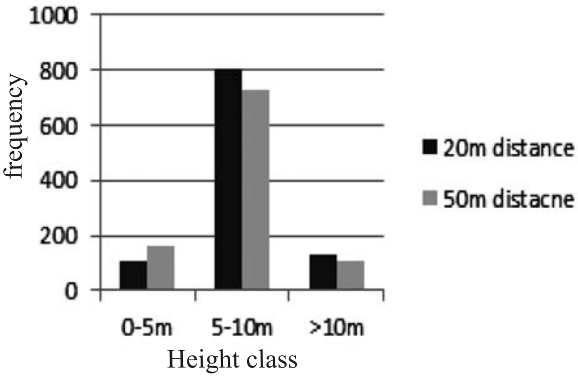

Fig. 4: Plant distribution in terms of height classes in the two effect-zones

Several studies show that silvicultural practices can have a positive or neutral effect on under-storey plant species richness (Jenkins and Parkers, 1999). So, proper silviculture practices can, to some extent, reduce the effects of road-edge on the forests. Nevertheless, the number of plant species is not only one component of biological diversity that should be considered; under-storey species composition, spatial scale, number of endemic species and taxonomic singularity of the elements must also be taken into consideration (Ojeda *et al.*, 1995; Zavala and Oria, 1995).

Distribution of major plant species

S. robusta, T. alata, Syzigium cumini, D. sissoo, A. maxicana and *Engelhardia spicata* were categorized as major species and the rest were categorized as others for the purpose of the study. At tree stage, *S. robusta* was found to be unevenly distributed in the effect-zone at 20 m distance than in the effect-zone at 50 m distance (Fig. 5a), and other major species were either almost equally distributed (e.g. *T. alata*) in both effect-zones or more distributed (*S. cumini* and *D. sissoo*) in the effect-zone at 50 m distance (Table 5b).

At sapling stage, all the major plant species were found to be distributed higher in the effect-zone at 50 m distance than in the effect-zone at 20 m distance. The distribution of other species at sapling stage was higher in the effect-zone at 20 m distance. At sapling stage, only *Catunaregam spinosa* was found to be distributed in the effect-zone at 50 m distance, but fodders like *Ficus semicordata* and *Listea monopetala* were not detected at sapling stage in the effect-zone at 20 m distance. At seedling stage, *S. robusta, T. alata, S. cumini* and *C. spinosa* were found to be in higher distribution in the effect zone at 20 m distance than in the effect-zone at 50 m distance.

On the other hand, all the three shrub species *viz. E. spicata, C. spinosa* and *A. maxicana* were found to be equally distributed at their seedling stage in both the effect-zones. On the other hand, the two species of woody climber *viz. Cissampelo spareira* and *Bauhinia vahlli* were also found to be less distributed in the effect-zone at 20 m distance.

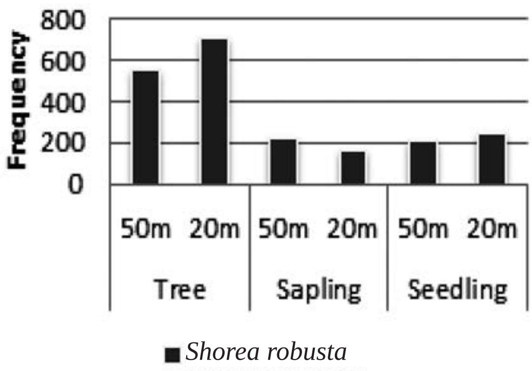

Fig. 5a: Distribution of *S. robusta* at different stages in the two zones

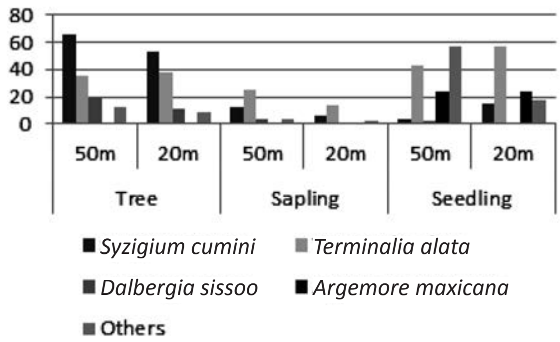

Fig. 5b: Distribution of major plant species except *S. robusta* at different stages in two zones

Communities are highly promoting and protecting timber yielding trees like *S. robusta* even in mixed *S. robusta* forest (Ojha and Bhattarai, 2001; Acharya, 2003) at the expenses of low quality timber-yielding species and shrubs (Kandel, 2007 cited by Shrestha *et al.*, 2010; Acharya *et al.*, 2007; Shrestha, 2005), which may be one of the causes behind the less woody plant species' diversity in the effect-zone at 20 m distance. Proximity to road-edge makes easy to remove other valuable species from the forest.

Conclusion

The study indicates that roads bring about adverse impacts upon the woody plant species diversity in the adjoining forests. Proximity to road-edge reduces species diversity due to removal of low-yielding timber species. The findings of the study also reveal that the effects of road-edge cause reduction in under-storey vegetation. However, the removal of over mature, dead, dying, diseased and deformed trees can have positive effects upon the species diversity in the forest. Therefore, silvicultural operations should be carried out in the forests nearby roads so as to mitigate the adverse impacts caused by the roads.

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