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Tree Diversity Conservation Initiatives in Sacred Groves of Kathmandu Valley, Nepal

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Abstract

The study was conducted in two sacred groves of Kathmandu Valley, Pashupati Sacred Grove, and Bajrabarahi Sacred Grove, aiming to analyze the diversity of tree species and their role in conserving biodiversity. Parallel transects with concentric circular plot survey methods were applied for data collection. During the study, 23 tree species belonging to 22 genera and 15 families were recorded in Pashupati sacred grove, whereas only 19 tree species belonging to 16 genera and 13 families were recorded from Bajrabarahi Sacred Grove. The Shannon-Weiner diversity indices were higher (H=1.91) in Pashupati Sacred Grove compared to Bajrabarahi Sacred Grove, with 1.80 Shanon-Weiner Indices. Three types of forest were recorded from Pashupati Sacred Grove, namely the *Schima-Pyrus* forest, *Myrsine-Persea* forest, and *Quercus-Myrsine* forest, and only one *Neolitsia cuipala* forest from Bajrabarahi Sacred Grove. The sacred grove is one of the pioneers and community-based management regimes of the forest resource management system. It plays a decisive role in biodiversity conservation as it associated with many taboos and belief systems, thus providing a better opportunity for conservation compared to that of the government management system.

Keywords

Diversity index, importance value, management regimes, religious forest, similarity index

Introduction

Biological diversity is the variability among living organisms in a given ecological complex (Aerts *et al*., 2006) and is vital to maintain the health of ecosystems and the long-term survival of the human (Boyd and Banzhaf, 2007). There are three interrelated and distinct levels of biodiversity, namely species, genetic, and ecosystem (Melchias, 2001,Aerts *et al*., 2006). Biodiversity can be further categorized based on the space used by the different components as alpha, beta, and gamma diversity (Harrison and Inouye, 2002, HMGN/MoFSC 2002, and GoN/MoFSC2014). Forest are essential for the conservation of biodiversity and provide many types of ecosystem services. They prevent soil erosion, provide water for irrigation and drinking, food, and maintain wood supply (Boyd and Banzhaf 2007).

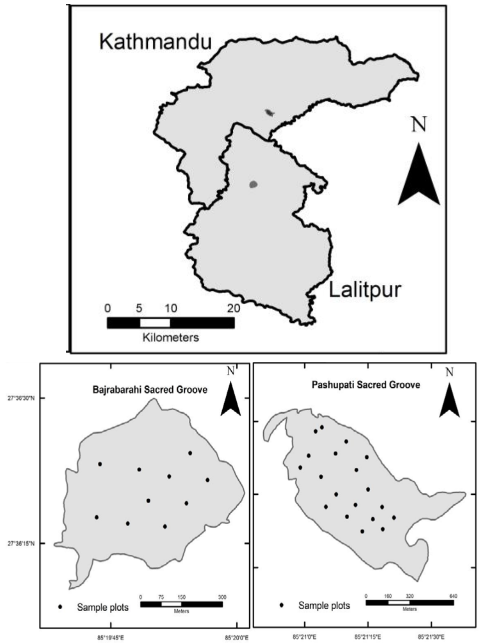
Sacred groves are forest patches having traditions and cultural values of local and indigenous people who conserve the groves with their strong socio-religious beliefs and taboos (Khumbongmayum *et al*., 2006). Sacred groves have received considerable attention as a pioneer of a community-managed forest management regime in Nepal. Based on the existing property rights, different management systems are in practice around the world for the conservation of natural resources (Berkes 1996). The sacred grove is one of the traditional methods for biodiversity conservation practiced from those communities by adopting a standard property regime. Those communities or societies have long been responsible for the management of the sacred forests through traditional land tenure systems.

Sacred groves have a significant effect on biodiversity conservation due to the special precautions and exclusion due to social fencing adopted from associated belief systems and taboos (Anthawal *et al*., 2006; Bhagwat and Rutte 2006; Singh 2012). Limited anthropogenic activities due to taboos and prohibitions allowed sacred groves to hold old growth vegetation and many ecologically and socially valuable biotic species (Ramakrishnan 1996; Godbole and Sarnaik 2004; Gadgil and Vartak 1975).

The management of the forest in Nepal is under the jurisdiction of the Ministry of Forests and Environment (MoEF). Current forest management regimes in Nepal included eleven different types, and the sacred grove is one of that. They are private forest, the government managed forest, protected forest, buffer zone forest, buffer zone community forest, conservation area, community forest, a sacred forest, collaborative forest, leasehold forest, and public land forest (FRA/DFRS, 2014). Nepal's Forest Act 1992 has defined a sacred forest as "a forest area that has been legally handed over to a legally registered religious group, communities, or organizations to carry out and continue traditional religious activities by sustainably utilizing its resources as described in its management plan." In Nepal, sacred forests have received considerable attention in conserving biological diversity from socio-cultural and religious perspectives. Recently they are facing severe threats and are on the verge of destruction (Shrestha 2009). The study was designed to assess the selected two sacred groves of Kathmandu valley to document and highlight the significances of the grove in conserving the diversity of tree species and types of forest ecosystems.

Study area

The study was conducted in two sacred groves of Kathmandu valley in the mid-hill physiographic zone of the Central Development Region of Nepal (Map.1). The first was the oldest and famous religious site of Hindu called as Pashupati Sacred Grove (PSG) that belongs to Lord Pashupatinath Temple in Kathmandu district, the capital city of Nepal. The PSG islocated in between 27°42'25" to 27°42'36" N, and 85°20'12" to 85°21'29" E at an elevation of 1,300 m covering 83.55 ha area. The PSG is inscribed as a world heritage site by UNESCO in 1979 and is more than 1400 years old (Mansberger 1991; Tandan 1996). Pashupati Area Development Trust (PADT), a government organization, has undertaken management responsibility of this grove. The second was Bajrabarahi Sacred Grove (BSG) located at the south-east corner of Kathmandu valley, in Chapagaun of Godawari Municipality, Lalitpur district. It is situated at an elevation of 1440 m between 27°36'15.88" to 27°36'24.62" N latitude, and 85°19'40.58" to 85°19'50.59" E longitude, covering 18.29 ha area. This forest represents 900 years old relict vegetation consisting of evergreen and deciduous trees (Mansberger 1991).Jyotidaya Sangh, a community-based organization, has undertaken management responsibility of this sacred forest since 1994.



Map1. Location of study area and distribution of surveyed plots.

Methodology

Data for tree-level characteristics were collected from concentric circular plots (CCPs) established in parallel transects of 150 m apart from each other, traversing north-south direction, with the help of the Google Earth image. The central point of CCP was identified by using the Geographic Position System (GPS) incorporated already identified coordinates from Google Earth images (FRA/

DFRS, 2010, 2014). Plots were constructed at 100 m intervals within each transect and established 25 m inside the forest margin to reduce the edge effect. Tree level characteristics like height, diameter at breast height (DBH) of each tree inside the concentric circular plot were recorded. Percentage canopy cover of the plots was measured with the help of a Spherical Densitometer, 20 m away from the center at four cardinal directions, and one at the plot center. The height and DBH of trees (a woody plant with single bole, >5 cm DBH, and >1.3 m height) were measured with the help of Vertex IV with Transponder T3 and diameter tape, respectively.

Collected data were analyzed to find community structure of trees by calculating frequency, relative frequency, density, relative density, dominance, relative dominance, importance value index, and basal area for each tree species following Mueller-Dombois and Ellenberg (1974). Importance values index (IVI) of individual trees species available in the particular vegetation was calculated by adding the relative values of frequency, density, and dominance(Curtis 1959; Sharma *et al*., 2012; Shrestha *et al*., 2014). The name of each forest type was determined by ordering the Importance values of each tree species.

The most dominant family of forest trees was determined by ordering Family Importance Value (FIV) of each tree species belongs to the specific families. The importance value of families was calculated by summing the relative density, relative diversity, and relative dominance (Scott *et al*., 1983).

FIV = Relative density + Relative diversity + Relative dominance

Where,

$$\text{Relative density} = \frac{\text{Number of trees in family i}}{\text{Total number of trees}} * 100$$

$$\text{Relative diversity} = \frac{\text{Number of species in family i}}{\text{Total number of species}} * 100$$

$$\text{Relative dominance} = \frac{\text{Basal area of family i}}{\text{Total basal area}} * 100$$

The similarity index was calculated to compare the similarity between two sacred groves by using Sorensen's index of similarity (Sorensen 1948). The similarity index is the ratio of total common species and the total number of species in both sacred groves. More developed forest communities were identified by using a maturity index given by Pichi-Sermolli (1948). The maturity index is the ratio of the sum of frequencies of individual species in the habitat and the total number of species in the habitat.

The Shannon-Weiner species diversity index (Shannon and Weiner 1963) was calculated by using the following formula:

$$H = -\sum_{i=1}^{s} (pi)(\log pi)$$

H = Shannon index of species diversity

Pi = Proportion of the total number of individual of species i

S = Number of species

Evenness (E) was calculated by dividing the Shannon-Weiner diversity index with the log value of the total number of species found in the area. A simple statistic like correlation was applied whether the comparison was needed.

To assess the disturbances in the forest, physical conditions of individual tallied trees within CCPs were noted. Based on biomass removal, tree cutting, domestic and wildlife grazing, and other anthropogenic activities, disturbance levels were classified into four categories as undisturbed, least disturbed, moderately disturbed, and profoundly disturbed. The degree of disturbance was measured through a disturbance index (DI) based on the percent number of cut, dead, or damaged of individual trees in the plant communities. A DI value of 60 was taken as the lower limit of high disturbance and a value of 30 as the upper limit of low disturbances (Pandey and Shukla 2001).

Results

From three forest types of PSG 23 tree species, including seedling, they belonged to 22 genera, and 15 families were recorded. Based on the phytosociological analysis, identified forest types in PSG were *Schima-Pyrus*, *Myrsine-Persea*, and *Quercus-Myrsine*.

Schima-Pyrus forest occupied a 20.9 ha area, which also incorporated deer park (4.8 ha). In this forest, 14 tree species belonging to eleven families were recorded with a density of 319 individual trees per ha. *Schima wallichii* was found the most critical tree (IVI = 81.4) species in this forest (Fig. 1). The tree canopy cover of this forest was 55%. Among the recorded families, variations were recorded in the number of species, number of stems, tree diameter, tree height, and basal area. Single species represented eight families, and three families had two species. Based on the family importance value (FIV), Theaceae (FIV=77.4) was the most critical family, followed by Rosaceae (FIV=54.0) (Fig. 5).

In *the Mysrine-Persea* forest, 11 species belong to eight families with a density of 603 individual trees per hector were recorded. The geographical area covered by this forest was 22.5 ha. From the phytosociological analysis, *Myrsine capitellata* (IVI = 142.0) was found more essential tree species (Fig. 2). Tree canopy cover of this forest was 80.96%. Among the recorded families, five families were represented by single species and three families by two species. Based on FIV, the most crucial family was Myrsinaceae (FIV=159.35), followed by Lauraceae (FIV=31.31) (Fig. 6).

5 tree species were belonging to five families with 677 individual trees per ha in *the Quercus-Myrsine* forest. The geographical area occupied by the forest was 40.1 ha, with 85.8% canopy coverage of trees. Based on the analyzed IVI, the more critical tree of this forest was *Quercus glauca* (IVI = 138.5) (Fig. 3). Single species represented all families of this forest. The most crucial family was Fagaceae (FIV=133.4), followed by Myrsinaceae (FIV=51.1) (Fig.7).

Only one forest type (*Neolitsea cuipala*) was recognized in BSG with 19 tree species, including seedling, belonging to 16 genera, and 13 families. This sacred grove was dominated by *Neolitsea cuipala* having the highest IVI (111.3) (Fig. 4). The canopy cover of this grove was 90.8%. In BSG, 432 individual trees per hector belonging to 13 families were recorded, out of which eight families were represented by only one species and five families represented by two species. Based on FIV, Lauraceae (FIV = 106.3) and Fagaceae (FIV = 40.2) were the most prominent families in this forest (Fig.8).

Based on the Similarity index (IS), more than 72% of families and 57% of tree species were similar between BSG and PSG. Similarly, the analysis of maturity indices (MI) indicated that BSG was a more developed forest community (MI = 33.9) than that of PSG (MI = 26.0). The BSG included

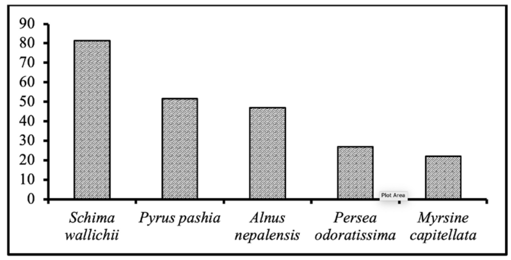


Fig. 1. Importance value index of five dominant plant species in Schima-Pyrus forest of PSG

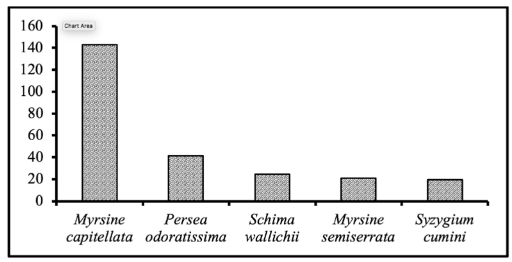


Fig. 2. Importance value index of five dominant plant species in Myrsine-Persea forest of PSG

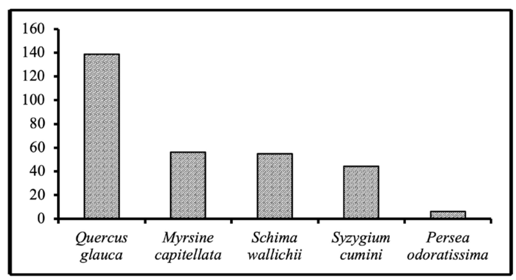


Fig. 3. Importance value index of five dominant plant species in Quercus-Myrsine forest of PSG

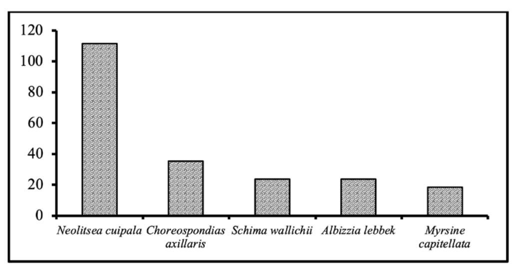


Fig. 4. Importance value index of five dominant plant species in Neolitseacuipala forest of BSG

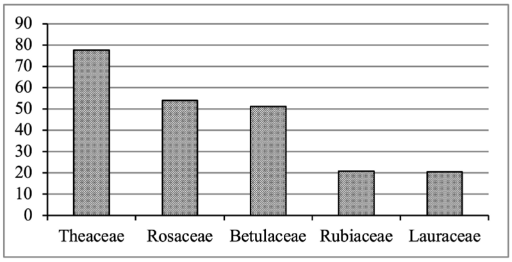


Fig.5. Family importance value of Schima-Pyrus forest of PSG

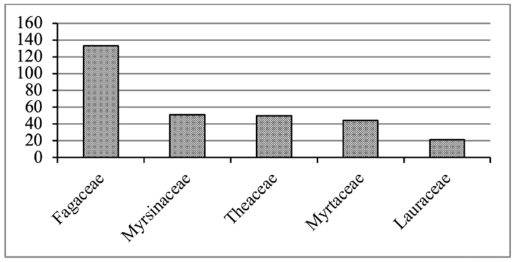


Fig.7. Family importance value of Quercus-Myrsine forest of PSG

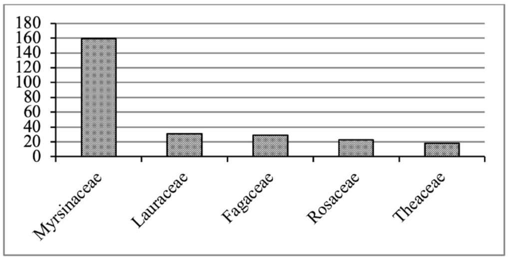


Fig.6. Family importance value of five major families of Myrsine-Persea forest of PSG

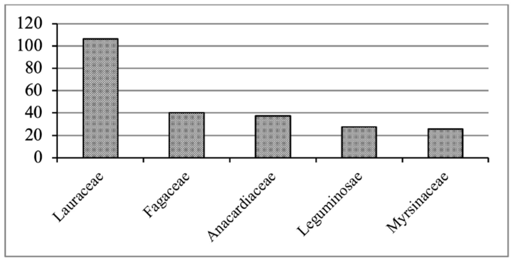


Fig. 8. Family importance value of Neolitsea cuipala forest of BSG

less number of the stem (432 per ha) with higher crown cover (90.8%) than that of PSG. However, in terms of the Shannon-Weiner species diversity index of the tree, PSG was more diverse (H = 1.91) than BSG (H = 1.80). Similarly, the tree species of PSG were more evenly distributed (E = 0.67) than the BSG (E = 0.62).

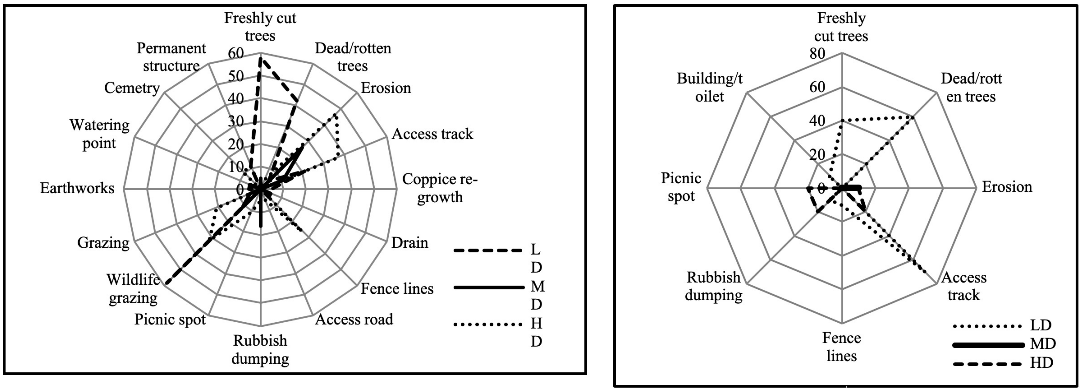
The identified disturbances in PSG were freshly cut trees, dead or rotten trees, coppice regrowth, erosion, access track, rubbish dumping, picnic spots, cemetery, sports activities, domestic and wildlife grazing, water point, earthwork, fence lines, construction of permanent structures like buildings as well as an army camp. In PSG, 42% area was least disturbed, 37% was profoundly disturbed, and 21% was moderately disturbed (Fig. 9a).

Different types of disturbances were recorded from the forest areas of BSG. They were freshly cut trees, dead or rotten trees, soil erosion, access track, rubbish dumping, picnic spots, fence lines, and construction of permanent structures like buildings and toilets. In BSG, 10% of the study area was undisturbed, 10% was moderately disturbed, 20% was profoundly disturbed, and 60% was least disturbed (Fig, 9b).

Discussions

The species compositions in different physiographic regions of Nepal are varied based on the available climatic condition and physiography (Stainton, 1972, FRA/DFRS, 2014; Sharma 2014). The PSG included different micro-topography, which thereby created different microclimates. The elevation of this grove is ranged between 1310 to 1335 m, and slope ranges between 0°-90°. Small tributaries of Bagmati River have permanent sources of water (Shrestha 2001) of PSG. The combination of all these physical factors made the PSG as a unique area for mosaics of forest types. So, in this study, three types of forests, namely *Schima-Pyrus*, *Myrsine-Persea*, and *Quercus-Myrsine*, were identified than the previously identified only one *Myrsine–Schima* forest (Shrestha 2001).

In PSG, two barking deer (*Muntiacus muntjak*) and ten spotted deer (*Axis axis*) and twenty blackbucks (*Antelope cervicarpa*) were reintroduced in 2004 (Shrestha 2009). The reintroduced site is located in *the Schima-Pyrus* forest at Mrigasthali and named as deer park with 4.8 ha area and 7 individual deer per ha. This area included 33 dead trees per ha, which represented



(a) (b)

Fig. 9. Types of disturbances and their intensity in PSG (a) and BSG (b). (LD–least disturbed, MD–moderately disturbed, HD–highly disturbed)

7% of the total tree recorded from this area. The recorded dead trees in this area were higher than the other study sites. Due to the heavy pressure of reintroduced deer species, the Mrigasthali forest was announced a dying forest patch (Shrestha 2009). The finding of the current study also supported the previous result (Shrestha 2009) with a high density of reintroduced deer (36 individuals per ha) and having a large number of standing dead trees (33 ha^{-1}) with least (59.4%) cover of the tree canopy.

The current study reflected that tree density differed according to the forest types. The density of the tree also related to the tree canopy coverage of the forest. So, the canopy coverage is one of the indicators of forest degradation. There were less canopy cover and less density of tree in the degraded forest of Mrigasthali (Shrestha 2009). The current study provided a similar result having a strong correlation between tree canopy cover and tree density (r = 0.997). The general ecological principle in the open canopy forest, stem per unit area was highest due to having more light in the ground. In this study, forest canopy coverage in BSG was high, but the density was less, whereas in PSG the, canopy coverage is low, and density was high. This result also matches with the general ecological principle.

In BSG, a similar type of study carried out by IUCN (1996) reported only one forest type dominated by *Neolitsea cuipala* having 30 tree species with a density of 348 per ha. The same study also reported *Neolitsea cuipala* incorporated highest number of stem per ha. The current study also resembled the previous findings of IUCN (1996).

A study conducted in Eastern Brazil identified 10 dominant plant families based on FIV (Scott, *et al*., 1983). It was based on the data analysis of 600 individual trees. They found Myrtaceae as the most famous family. The current study was conducted in the mid-hill physiographic region of Nepal. The climatic condition of the present study sites has been divided into four distinct seasons, namely spring (March-May), summer (June-August), autumn (September-November), and winter (December-February). In the current study, the Pashupati Sacred Grove, which included three forest types, namely *Schima-Pyrus*, *Myrsine-Persea*, and *Quercus-Myrcine*, included 11, 8, and 5 families of plants species respectively.

Similarly, during this study, 12 families of plants were identified from BSG. The highest number of species in the families with higher FIV was 2. The Brazilian study was conducted in the Tropical lowland wet forest, which is one of the biodiversity hot spot areas (McNeely *et al*., 1990; WCMC 1994). Similarly, the climatic condition of the Brazilian forest is a uniform type. These factors may vary the availability of species and families of the tree species. So, the number of families and species of plants in this study was lower than that of Brazil.

A similar type of study was conducted in dry Sal (*Shorea robusta*) dominated forest in the Eastern Himalayan lowlands of India in Mahananda Sanctuary, Darjeeling. That area belongs to tropical to the subtropical region with altitudinal variations from 100 to 1700 m. The average annual rainfall and relative humidity were high all year round. The study identified Euphorbiaceae as the most dominant and prominent family of the plant with eight species followed by Lauraceae, Meliaceae, and Leguminosae based on the number of individual trees, basal areas and importance value (Shanker 2001). There was a higher number of plant species and families (87 species, 42 families) than the current study. The present study was conducted in the subtropical climatic condition of the mid-hill physiographic region of Nepal with comparatively low rainfall and relative humidity than the Mahananda Sanctuary of India. Those are the determinant limiting physical factors for the vegetative growth of plants and the number of plant species. Thus, the number of species and families recorded in the present study was lower than that of India. Though the number of available plant species is higher in India, however, the average species richness per family was 2 (Shanker 2001). The average species per family in the current study were 1.3 in *Schima-Pyrus* forest, 1.0 *in Quercus-Myrsine* forest, 1.4 in *Myrsine-Persea* forest, and 1.5 in the *Neolitsea cuipala* forest. The average numbers of species per family were nearly similar to the current study. That may be due to the presence of more mono-specific families in the study area of India.

A study conducted in four sacred groves of Manipur, India, revealed that density–diameter distribution of woody species showed highest stand density and species richness in the lowest girth class and decreased in the following girth classes (Khumbongmayum *et al*., 2006). In the current study, PSG incorporated higher tree density and richness than BSG. The present study revealed that BSG has more mature trees due to community-managed systems supported by strong religious belief, taboos resembling the results of Manipur study. A similar survey conducted in Far Western Development Region of Nepal on community approaches to natural resource management resembled with current findings that collaborative approach of forest management (community forest) and religious forest or sacred grove was more effective in conservation of biodiversity due to religious belief, social taboos and cultural aspect (Bhatt 2003). The study conducted by Bhattarai and Baral (2008) also concludes that sacred groves play a significant role in biodiversity conservation while studying the Lumbini sacred grove of Nepal. Similarly, the study of the mistletoe diversity in five sacred groves of Kathmandu Valley has concluded that the rich plant diversity of sacred groves has supported 45% mistletoe diversity reported from Nepal (Devkota 2013).

During the study tree cutting, lopping, fire, erosion, access track, and roads, fence lines, high tension lines, rubbish dumping, picnic spots, wildlife and livestock grazing; litter collection, earthworks, and water storage tanks were directly observed as significant drivers of deforestation and forest degradation. In some sites of the studied groves, forest areas were either replaced or fragmented with road and trail construction, as well as the creation of picnic spots to attract tourists. Both sacred groves have a massive influx of people, from all over the country and neighboring India, during religious festivals such as Maha Shivaratri, Teej, Bala Chaturdashi and Janai Purnima in PSG and similarly during various festivals (*Jatras*) occurring throughout the year in BSG. Both groves offered ethical, aesthetic values, which attract a large number of local people during holidays. Being a UNESCO World Heritage Site, PSG has become an attraction to a large number of international tourists to observe Hindu rituals. Local traditions and customs have been challenged by westernized urban cultures learned from a large number of tourists visiting the area.

The Pashupati sacred grove is fragmented by road construction, which leads to loss of species and interruption in ecological function. The forest areas of PSG were also found encroached from government line agencies for the extension of International Airport. These drivers of deforestation recorded in current study areas resembled with the study conducted in the sacred groves of Karnataka, India. In Karnataka, the documented threats for the conservation of sacred forests were development projects, commercial forestry, and shift in the belief system, Sanskritisation, pilgrimage and tourism, removal of biomass, encroachment, modernization and market forces, and fragmentation and perforation (Gokhale 2005). The study conducted in sacred groves of Jammu, India, also identified similar types of threats, namely construction activities, livestock grazing, and modernization for the long term conservation of sacred forests (Sharma and Devi 2014).

Conclusion

Although Pashupati Sacred Grove has a higher diversity of tree species contributing to three forest types compared to Bajrabarahi Sacred Grove, which has only one forest type but has a more developed forest community, Pashupati Sacred Grove has many anthropogenic disturbances threatening the tree diversity of the grove. Since Pashupati Sacred Grove is an essential site for domestic and international pilgrims, has been facing more anthropogenic severe disturbances threatening the tree diversity. Whereas, local communities, of Lalitpur district are practicing the forest management of Bajrabarahi Sacred Grove by the active involvement and participation and have proven to be more efficient in tree diversity conservation. There are no specific plans and programs proposed in the National Biodiversity Strategy and Action Plan (NBSAP) 2014-2020, Nepal for the conservation and management of biodiversity located in the scattered sacred groves all over the country, so it has been strongly recommended to develop and implement a separate policy for the conservation of sacred groves.

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