ROLE OF SACRED GROVES IN TREE DIVERSITY CONSERVATION IN KATHMANDU VALLEY, NEPAL

A THESIS SUBMITTED TO THE

CENTRAL DEPARTMENT OF BOTANY

INSTITUTE OF SCIENCE AND TECHNOLOGY

TRIBHUVAN UNIVERSITY

NEPAL

FOR THE AWARD OF

DOCTOR OF PHILOSOPHY IN BOTANY

BY

LAXMI JOSHI SHRESTHA

APRIL 2016

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Recommendation

This is to recommend that **Ms Laxmi Joshi Shrestha** has carried out the research entitled ***"Role of Sacred Groves in Tree Diversity Conservation in Kathmandu Valley, Nepal"*** for the award of Doctor of Philosophy (Ph.D.) in Botany under my supervision. To my knowledge, this work has not been submitted for any other degree.

She has fulfilled all the requirements laid down by the Institute of Science and Technology (IOST), Tribhuvan University, Kirtipur for the submission of the thesis for the award of Ph.D. degree.

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Dr. Mohan Prasad Devkota
Professor
Department of Botany
Amrit Campus
Tribhuvan University
Thamel, Kathmandu,
Nepal

April 11, 2016

Certificate of Approval

[Date: 11/04/2016]

On the recommendation of Dr. Mohan Devkota, this Ph.D. thesis submitted by **Ms Laxmi Joshi Shrestha,** entitled ***"Role of Sacred Groves in Tree Diversity Conservation in Kathmandu Valley, Nepal"*** is forwarded by Central Department Research Committee (CDRC) to the Dean, IOST, T. U.

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Prof. Dr. Mohan Siwakoti
Head
Central Department of Botany
Tribhuvan University
Kirtipur, Kathmandu, Nepal

Declaration

This thesis entitled ***"Role of Sacred Groves in Tree Diversity Conservation in Kathmandu Valley, Nepal"*** is being submitted to the Central Department of Botany, Institute of Science and Technology (IOST), Tribhuvan University, Nepal for the award of the degree of Doctor of Philosophy (Ph.D.). The research work is carried out by me under the supervision of Prof. Dr. Mohan Prasad Devkota, Department of Botany, Amrit Campus, Tribhuvan University.

This research is original and has not been submitted earlier in part or full in this or any other form to any university or institute, here or elsewhere, for the award of any degree.

Laxmi Joshi Shrestha

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(Laxmi Joshi Shrestha)

April, 2016

Abstract

Study about the role of Sacred Groves in tree diversity, both native and planted species, conservation was conducted in Pashupati and Bajrabarahi Sacred Groves of Kathmandu valley, in the central middle hill physiographic region of Nepal. Study sites contain centuries old sacred groves preserved due to strong religious and socio-cultural practices and belief systems. The study was conducted to analyze the community structure and carbon stock in tree canopy and to assess regeneration status and threats to determine the conservation and values of sacred groves. Concentric Circular Plots with radius of 20 m prepared along eight and four parallel transects in Pashupati and Bajrabarahi Sacred Groves were used to get information on tree and soil characteristics and forest disturbances. Structured questionnaires were used to collect local perceptions about the role of Sacred Grove in biodiversity conservation.

From the phyto-sociological assessment three types of forest in Pashupati Sacred Grove and only one forest type was identified from Bajrabarahi Sacred Grove. In Pashupati Sacred Grove, 13 plant families with 17 mature tree species were recorded and 12 families with 18 mature tree species were identified from Bajrabarahi Sacred Grove. Both groves shared nine common families and ten common tree species with similarity indices 72% for families and 57% for tree species. Bajrabarahi Sacred Grove incorporated more developed forest community with mature trees and less number of stems (432 ha^{-1}) and higher crown cover percent (90.8%) than that of Pashupati Sacred Grove. Tree species of Pashupati Sacred Grove were more diverse (diversity index = 1.91) and more evenly distributed (evenness = 0.67) than Bajrabarahi Sacred Grove. Trees of both study sites contains 1014.23 tons of average Carbon stock and CO_2 3.7 mt. The highest amount of Carbon stock (622.09 t) and CO_2 (2.28 mt) was reported in the trees of *Quercus-Myrsine* forest and the lowest Carbon stock (113.98 t) and CO_2 (0.42 mt) in the trees of *Schima-Pyrus* forest of Pashupati Sacred Grove. The regeneration status of tree species in Pashupati was good and that found fair in Bajrabarahi Sacred Grove. Based on Disturbance Index the disturbance statuses of study area were identified as undisturbed, least disturbed, moderately disturbed and highly disturbed. The soil was found acidic in both groves; nitrogen content was low in Pashupati and medium in Bajrabarahi. The organic matter

content was in medium range and potassium and phosphorus content were found very high in the soil of both groves. Local people perceived the objective to establish sacred grove was for biodiversity conservation. The forest was found more protected in Bajrabarahi and less conserved in Pashupati. Local perception towards the conservation of sacred groves was optimistic and stakeholders realizing the positive role of local faiths and belief system toward conservation. As a pioneer concept of the participatory biodiversity conservation model, government needs to provide priority for the sacred grove conservation.

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Acronyms and Abbreviations

AGTB	Above Ground Tree Biomass
APG	Angiosperm Phylogeny Group
BPP	Biodiversity Profile Project
BCCI	Biodiversity Conservation Confidence Index
BSG	Bajrabarahi Sacred Grove
CBO	Community Based Organisation
CBS	Central Bureau of Statistics.
CCSP	Concentric Circular Sample Plot
cm	Centimeter
D	Density
DBH	Diameter at Breast Height
DFO	District Forest Office
DFRS	Department of Forest Research and Survey
DI	Disturbance Index
DNPWC	Department of National Parks and Wildlife Conservation
Do	Dominance
DoF	Department of Forest
DPR	Department of Plant Resources
DSCWM	Department of Soil Conservation and Watershed Management
F	Frequency
FIV	Family Importance Value
FNCCI	Federation of Nepal Chambers of Commerce and Industry
FRA	Forest Resource Assessment
FRS	Forest Resource Survey
FRISP	Forest Resourse Information System Project
GoN	Government of Nepal

GPS	Geographic Position System
ha	Hectare
HMGN	His Majesties, the Government of Nepal
IPCC	Intergovernmental Panel on Climate Change
IS	Index of Similarity
IUCN	International Union for Conservation of Nature
IVI	Importance Value Index
MAB	Man and the Biosphere
MI	Maturity Index
MoFSC	Ministry of Forest and Soil Conservation
mt	Metric ton
m	meter
NARC	Nepal Agricultural Research Council
NBS	Nepal Biodiversity Strategy
NBSIP	Nepal Biodiversity Strategy and Implementation Plan
NPC	National Planning Commission
OM	Organic matter
PADT	Pashupati Area Development Trust
PSG	Pashupati Sacred Grove
RD	Relative density
RDo	Relative dominance
REDD	Reducing Emissions from Deforestation and Forest Degradation
RF	Relative frequency
SDSTF	Seasonally Dry Sub Tropical Forest
t	ton
UNESCO	The United Nations Educational, Scientific and Cultural Organization
VDC	Village Development Committee

CHAPTER 1. INRODUCTION

1.1 Background

There is intimate connection between human society and natural resources from ancient time (Hanna and Jentoft, 1996 and Costanza and Folke, 1996) and people are associated physically, psychologically and spiritually with the biological resources (Ensminger, 1996). There are significant roles of biological resources to the people living close to nature (Wilson and Bryant, 1997). Different beliefs, religions and myths within the societies emphasize conservation and wise uses of natural resources because of the people who live within a fixed resource base (Majupuria, 1991, Jodha, 1996 and Primack, 2002). To conserve the natural resources from over exploitation, property rights to the resources use is in practice (Hanna and Jentoft, 1996, Costanza and Folke, 1996, Berkes, 1996 and Sharma, 2014), there are five basic rights found in societies namely- access, withdrawl, management, exclusion and alienation, which direct the utilization of the natural resources (Ensminger, 1996, McCay, 1996, Ostrom and Schlager, 1996 and Sharma, 2014). The indigenous people have been practicing of living in natural harmony with wise use of the available natural resources (Primack, 2002).

Biological diversity is the variability among living organisms in each ecological complex (Probst and Crow, 1991, Burton *et al*., 1992, Ehrlich and Ehrlich, 1992, Harper and Hawksworth, 1994, Elzinga *et al*., 2001, Melchias, 2001 and Aerts *et al*., 2006). Biodiversity encompasses all the species that currently exist on the Earth, the variations that exist within each of these species, and all the interactions that exist integrity of these interactions (Ehrlich and Ehrlich, 1992, Franklin, 1993, Harper and Hawksworth, 1994, Myers *et al*., 2000, Melchias, 2001, Cowling *et al*., 2003, Aerts *et al*. 2006, Miller *et al*., 2008 and Duffy, 2009). Biodiversity is important to maintain the health of ecosystems and even for the long-term survival of the human (Burton, *et al*., 1992, Farber, *et al*., 2002, Ferrier, 2002, Groot *et al*., 2002 and Boyd and Banzhaf, 2007). There are three interrelated and distinct levels of biodiversity namely species, genetic, and ecosystem (Elzinga, *et. al*., 2001, Melchias, 2001 and Aerts *et al*., 2006). Numerical value of biodiversity is generally expressed as a single index number, based on a combination of species richness, the number of individuals per sampling unit, and species evenness is species diversity (Melchias, 2001). The genetic variety, expressed in the variable in genetic characters, of a species from genes to individual beings to entire populations is genetic diversity. Measure of the structural variety of ecological systems, expressed in the number and types, is ecological diversity (Burton *et al*., 1992, Franklin, 1993, Gould, 2000 and Elzinga *et al*., 2001). Assessment of biodiversity is a means of quickly collecting information on the species present in each area.

Biodiversity can be categorized based on the space used by the different components as alpha, beta, and gamma diversity (Newman, 1993, Harper and Hawksworth, 1994, Harrison and Inouye, 2002, HMGN/MoFSC 2002, Aerts *et al*., 2006 and GoN/MoFSC 2014). Alpha (α) diversity is the biological diversity within a area, community or ecosystem and is generally known as the species richness of the area. Beta (β) diversity is a measurement of biodiversity which compares the species diversity of different areas in numerical terms. Gamma (γ) diversity is the richness of species in a range of habitats in a geographical area, whether it a region or landscape.

Diversity occurs when many species that are extremely close to fitness and when a very stable environment results in the very slow loss of species (Harper and Hawksworth, 1994). Thus, to slow down species loss, it is best to leave forests as undisturbed as possible (Melchias, 2001, Morwitz, 2002). Since most forested areas are disturbed by different factors, their biodiversity is determined by current and past disturbances (Melchias, 2001, Midgley *et al*., 2002, Malcolm *et al*., 2006, Miller *et al.*, 2008 and Keinan and Clark, 2012).

Forest have important role to conserve biodiversity, prevent soil erosion, provide water for irrigation and drinking, food and maintain wood supply (Ehrlich and Ehrlich, 1992, Boyd and Banzhaf, 2007) and climate regulation (Midgley *et al*., 2002). Forest management by professional forester was widely adopted during 1950s and the wildlife protection started during 1970s (Ehrlich and Ehrlich, 1992, Primack, 2002, Boyd and Banzhaf, 2007, Duffy, 2009).The concept about wise use of natural resources linked with fair distribution among present consumption and between present and future consumer arise after the World Commission on the Environment and Development (1987). This concept helped the wise use of natural resources without compromising the need of the future generation. The people responsible for habitat destruction are either unaware of other options or have no other choice for their own immediate survival, or are not aware about the importance of natural ecosystems in maintaining the quality of their own lives over the long term (Midgley *et al*., 2002, Malcolm *et al*., 2006 and Miller *et al*., 2008).

Forests play a key role in climate change, both sinks and sources of carbon dioxide (Midgley *et al*., 2002). The total standing above ground biomass of woody vegetation elements is one of the largest carbon pools. The above ground biomass comprises all woody stems, branches and leaves of living trees, creepers, climbers and epiphytes as well as herbaceous undergrowth. It has been estimated that deforestation and forest degradation contribute up to 20 percent of global emissions of carbon dioxide annually (Acharya *et. al*, 2009) and that standing forests sequester about 20 percent of global carbon dioxide emissions. Forests provide a more cost-effective means of reducing global carbon dioxide emissions than other sectors. If incentives could be provided to curb the deforestation and forest degradation plaguing many tropical countries, then forests could have a net positive impact on carbon sequestration and thereby contribute substantially to mitigating climate change (Midgley *et al*., 2002, Miller *et al*., 2008).

1.2 Sacred grove

Based on the existing property rights, different management systems are in practice around the world for conservation of natural resources (Berkes, 1996). There are native systems of resource management from many traditional communities based on their societal rules. These types of communities are distributed all over the world. Sacred grove is one of the traditional methods for resources management practiced from those communities using common property regime. Those communities or societies have long been responsible for the management of these sacred groves through traditional land tenure practices (Anthwal *et al*., 2006, Bhagwat and Rutte, 2006, Singh, 2012).

Sacred groves resemble to the protected areas, managed by local communities, who conserve these parts of forest from their religious faith called as "social fencing" (Singh, 2012) and are the centers of cultural and religious life of people and have long and diverse histories in human cultures and shown ancient links between peoples with their environments. Sacred groves are a universal human phenomenon not associated with any specific religion or worldview, but they have a strong religious perspective and are influenced by traditional local beliefs (Engel, 1985). Wherever sacred groves existed, indigenous traditional societies have spiritual relationships with the existing physical environment sustained them. A tract of virgin forest with rich biodiversity and managed by the local community based on the ground of indigenous cultural and religious beliefs, and taboos is considered as scared groves (Khumbongmayumi *et al*., 2006 and Singh, 2012). Those groves are the repositories of rare and endemic species as the remnant of the primary forest left untouched by the local inhabitants (Anthwal *et al.,* 2006).

The sacred groves which have significant contribution for the conservation of rare and endangered species are distributed throughout the world in different temporal and spatial scales (Malhotra *et al.,* 2001 and Mgumia and Oba, 2003). In the earlier centuries, conservation programs were based on religion and spiritual belief as reflected from the practice like: i) people used to raise trees species as an offering to god, ii) forests were used to preserve as religious sites, and iii) new species used to introduce from pilgrimage tour and preserved them in sacred grove. Some of the remnant of forests were also preserved as sacred groves due to its historical significance and spiritual value (Dash, 2005).

Sacred sites have major effect on environment conservation due to the special precautions and exclusion from social fencing associated with them (Singh, 2012). Limited human activity due to taboos and prohibitions, sacred groves frequently possess old growth vegetation, integrated nutrient cycling with high soil fertility, and many ecologically and socially valuable biotic species (Ramakrishnan, 1996, Godbole and Sarnaik, 2004). The sacred forest areas function as natural gene pool reserve and set an example of environment conservation by community participation (Gadgil and Vartak, 1975).

Sacred virgin forests date back to several thousands of years, when human society was in the primitive state and all forms of vegetation in the sacred groves were supposed to be under the protection of the reigning deity of that grove, and the removal of even a small twig is taboo. The role of sacred groves in the conservation of biodiversity has long been recognized (Gadgil and Vartak, 1976, Haridasan and Rao, 1985, Khan *et al*., 1997 and Hughes and Chandran, 1998) and have also been linked with the pre-agricultural, hunting and gathering societies (Gadgil and Vartak, 1975).

Sacred groves are often the last refuge for endemic and endangered plant and animal species. They are storehouses of medicinal plants valuable to local communities as well as modern pharmacopoeia, and they contain wild relatives of crop species that can help to improve cultivated varieties (Haridasan and Rao, 1985, Gadgil and Chandran, 1992, Khan *et al*., 1997, Chandrashekara and Sankar, 1998, Sukumaran and Jeeva, 2008, Pavendan and Rajasekaran, 2011). They are also very important in providing various types of ecosystem services. Many sacred groves contain water resources such as ponds and streams, and the vegetative mass that covers the floor of a grove can absorb water during rainy seasons and release it during times of drought. Trees also improve soil stability, prevent topsoil erosion and provide irrigation for agriculture in drier climates (Tiwari *et al.*, 1998a).

Long before the existence of officially protected areas, people were protecting their sacred lands through local rules and regulations like a fence (Singh, 2012). Sacred sites are one of the oldest methods of habitat protection on the planet and still form a large and mainly unrecognized network of sanctuaries around the world. The sacred grove is traditional resource management practices complement the more recent approaches of protected area management, based on western scientific knowledge (Ramakrishnan, 1996). It is increasingly clear that social context plays a major role in the success of conservation ventures; therefore, consideration of traditional stewardship and indigenous belief systems is crucial. It is because of the local people and their strong socio-religious beliefs and taboos the conservation and protection of the groves is possible (Ramkrishnan, 1996 and Singh, 2012).

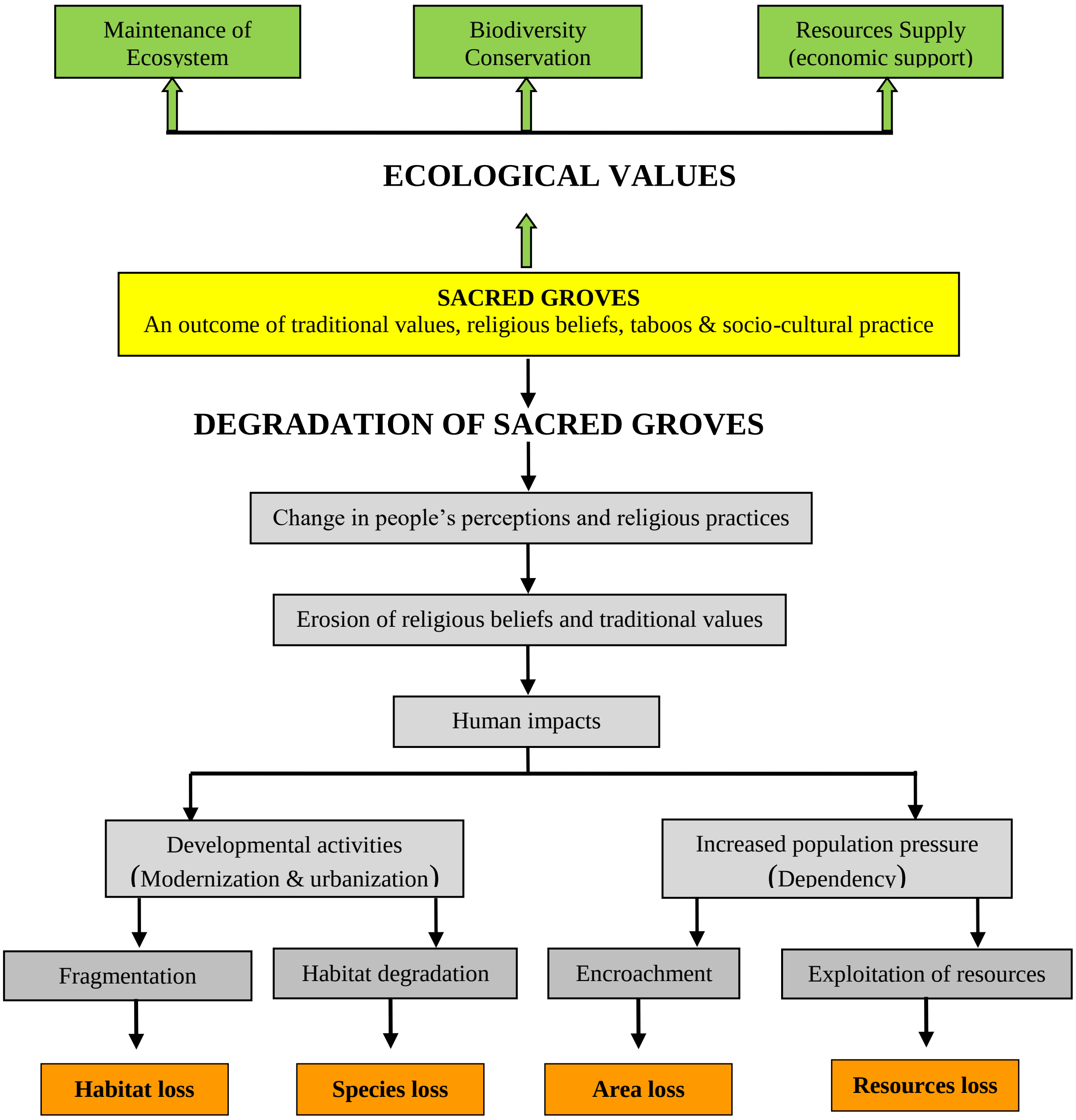


Figure 1. Diagrammatic presentation of sacred groves, their ecological value and relationship with changing traditional beliefs of people and human impacts, (Modified from Khumbongmayumi *et al.*, 2004).

Sacred sites have been established for many purposes, but most of them are protected due to belief that those sites are residence place of local deity (Vartak and Gadgil, 1981, Tiwari *et al.*, 1999 and Byers *et al.*, 2001 and Malhotra *et al.*, 2001). Anthropogenic activities like pollution, infrastructure development, disputes over land, and a general lack of respect for the intangible values of nature are leading to degradation of areas that have sometimes been held sacred by particular cultures for hundreds or even thousands of years. Although the sacred groves are environmentally, economically and religiously important, they are getting pressure from local communities through over harvesting for fuelwood, timber, fodder grazing their cattle. These anthropogenic pressures lead to decline the species diversity and change floristic composition of the area (Fig. 1).

1.3 Forest management in Nepal

Forests are also inseparably linked to the livelihoods of people in Nepal playing a vital role in reducing the incidence of poverty, bolstering local livelihoods, and supporting other co-benefits like biodiversity conservation and ecosystem services.

Resource degradation has exceeded after the nationalization of private forest in Nepal (1957) mostly due to the unstable government and lack of proper institution for conservation. Later the conservation activities were institutionalized in the form of Forest Law (1956) and Protected Area Law (HMGN 1973).

The lowland (subtropical) region of Nepal are known for valuable natural resources like Sal (*Shorea robusta*), provide valuable timber, one horned rhinoceros (*Rhinoceros unicornis*), Bengal tiger (*Panthera tigris*) and so on. Similarly, the riverine and subtropical forests in flood plain are very rich from biodiversity point of view. The density and population of flora and fauna has been decreasing outside the protected areas. The temperate mid-hill of this country has consisted different useful plants with variety of wildlife. The number of stem in Nepal forest is 429.93 ha^{-1} with 443 tree species. Similarly, the number of tree species reported in the midhill are 326 with 871.31 stems ha^{-1} (DFRS, 2015). These resources were also used unauthorized to fulfill the local demand (Bhatt, 1977). Therefore, arrangement between the institution and the involvement of local stakeholder was formalized for conservation of natural resource by participatory approach. This arrangement played a vital role for conservation, grazing pressure slow down and illegal collection of fuel wood and fodder and hunting was totally controlled.

Nepal is rich in its ethnic diversity so there are diverse human societies with different religious customs, myths and beliefs. These societies are intricately interconnected with their religion and customs and have been practicing generation old religious traditions by establishing various sized sacred groves devoted for their deities. Some of the sacred groves have been used as shrines and for spiritual worships (Tandan, 1996). Those are contributing for the conservation of local flora and fauna; one of the widest spread practices in the past, and helped to conserve cultural landscapes.

In Nepal, sacred groves have received considerable attention in conserving small patches of forest from a sociological, cultural and religious perspective. These groves have very old history of conserving forests patches around the religious sites and have been associated with deeply rooted religious and cultural beliefs, largely related with Hinduism and Buddhism.

Sacred groves in Nepal are maintained relatively in an undisturbed state as an expression of an important relationship of human beings with nature and dedicated to gods. The practices of maintaining and managing religious forest and its potential to incorporate the local communities in the resource management in one of the successful forest management practice in Nepal. Blending the local societal norms, tradition, customs, myths, and belief with the current holistic approach of management is the main features of Nepalese sacred groves or legally called as religious forest. In Nepal, forests are also protected and dedicated due to a particular god by establishing a shrine where various religious festivals and rituals are conducted by almost all casts and ethnic groups (Ingles, 1995). Uses of forests and their products for various religious purposes have been described for a long time ago in many cultural and religious documents of Nepal (Narhari and Satyal, 1956). Holy trees, shrub, and medicinal herbs related to a particular god in Hinduism and Buddhism are grown and protected for worshiping and this kind of practice helps in developing small scared groves which also help in conservation of plant diversity.

The management of the forest in Nepal is under the jurisdiction of Ministry of Forest and Soil Conservation (MoFSC). The five departments, namely Department of Forest (DoF), Department of National Parks and Wildlife Conservation (DNPWC), Department of Forest Research and Survey (DFRS), Department of Soil Conservation and Watershed Management (DSCWM), and Department of Plant Resources (DPR) are working under this ministry. Management of forest areas are within the jurisdiction of the Department of Forest and Department of National Parks and

Wildlife Conservation. Protected areas like national parks, wildlife reserves, hunting reserve, conservation areas and buffer zone are under the jurisdiction of the DNPWC. The rest of the forest areas, known as government forest, are under the jurisdiction of the DoF.

Current forest management regimes in Nepal include eleven different types. They are private forest, government managed forest, protected forest, buffer zone forest, buffer zone community forest, conservation area, community forest, religious forest, collaborative forest, leasehold forest, and public land forest (HMGN 1973, 1974, 1978, 1993, 1994, 1996, 2004). The management responsibilities of protected forest, buffer zone forest, and buffer zone community forest and conservation area are under DNPWC. Similarly, the management responsibility of private forest, government managed forest, community forest, religious forest (also known as sacred grove), collaborative forest, leasehold forest and public land forest is under the DoF (FRA/DFRS, 2014).

Nepal's Forest Act 1993 has defined a religious forest as "a forest area that has been legally handed over to a legally registered religious groups, 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 groves have received considerable attention in conserving small patches of forest from socio-cultural and religious perspective despite that in recent times they are facing severe threats and are in verge of destruction.

Assessment of the sacred groves are helpful to gather information about species preserved in the area, dynamics of plant communities, rational of preservation in the past, history and socio cultural values linked with particular species and societies (Bhagwat and Rutte, 2006). Since the immemorial time some of the sacred groves of Nepal are successfully conserved from the involvement of local people, which provide pioneer concept about community participation for resource conservation. These initial initiations of local people are stricter on resource uses and conservation modules are more concentrated for preservation. The rules formulated and followed from the local people for the preservation of the resources in the sacred groves is finally became the cultures that help for their conservation as social fencing. Thus, the sacred forest included very old growth of trees providing further habitats for arboreal species, like epiphytic and parasitic plants, insects and avian animal. Though there is a long history of religious forest or sacred groves in Nepal, their systematic documentation, assessment of floral and faunal diversity, role in environmental protection and soil preservation, perception of local people about sacred groves, and other importance are either lacking or overlooked.

Government of Nepal, as its commitments, has incorporated the principles, guidelines and practices of Millennium Ecosystem Assessment (MEA), Millennium Development Goals (MDG) and Sustainable Development Goals (SDG) in its national conservation strategy for the conservations of biodiversity of the country. Nepal's sacred groves have a great potential and provide appropriate opportunity to implement the principles, guidelines and practices MEA, MDG and SDG.

The study has tried to analyze the community structure and carbon stock in tree canopy, regeneration status of trees and potential threats with local perception for the conservation and values of oldest and largest sacred forests protected from the different management practices in Kathmandu valley of central midhill physiographic region of Nepal. Attempt has been made to evaluate the amount of carbon stock present in the selected sacred groves. The study has also aimed to analyze the assimilated carbon dioxide by the trees species, which provide good basis to the incentive provisioned for Reducing Emissions from Deforestation and Forest Degradation (REDD) mechanism and assist to fulfill one of the target of IPCC to mitigate climate change.

1.4 Rational of the study

Sacred groves are hailed as models of community based conservation and storehouse of valuable biodiversity. Their importance in forest conservation becomes even more significant given the current rate of deforestation in Nepal. Various sized sacred groves are distributed all over Nepal are rich in biodiversity demanding a greater understanding in the conservation of biodiversity. Kathmandu Valley contains centuries old sacred groves which have been the places of birth of strong religious and socio-cultural practices therefore, a greater focus and understanding of these groves in plant diversity conservation is undoubtedly needed.

Despite the role of sacred groves in the conservation of plant diversity that has long been recognized (Gadgil and Vartak, 1976, Haridasan and Rao, 1985, Khan *et. al*., 1997) they have remained overlooked in Nepal. Till now, there has not been a comprehensive survey of sacred groves carried out in Nepal and there is not official data regarding their exact number, area covered and their role in plant diversity conservation. A bio-cultural survey of sacred forest in Kathmandu Valley, Nepal was studied by Mansberger (1991) and several small size sacred groves were also reported from Nepal by Ingles (1995). Bhattarai and Baral (2008) have studied the role of scared grove in plant diversity conservation in Lumbini and Bhatta (2003) which compares community approaches of management in sacred and non- sacred landscapes in west Nepal. According to Department of Forest statistics (DoF, 2012), only 36 sacred groves covering an area of 2056 ha of forest is registered as sacred grove in various districts of Nepal and it has been believed that still a large number of groves yet to be registered. This amazing gap of knowledge indicates that sacred groves are not acknowledged in Nepal, their role in conserving biodiversity is less understood, and have remained overlooked by the Government of Nepal.

Despite strong religious beliefs and legal provisions of protection mentioned in Nepal's Forest Act 1993, sacred groves of Nepal are facing severe threats and are in the verge of destruction. Various anthropogenic activities are most likely threatening the biodiversity value of the sacred groves and are also invaded by alien weedy species replacing local species, as well (Fig 1.) Sacred groves are not only the sacred ecosystems functioning as a rich repository of nature's unique biodiversity, but also a product of the socio-ecological philosophy of our forefathers that have been cherishing since historic days. Sacred groves do not just help conserve valuable biodiversity, soil and water, but are also critical in regulating weather and climate cycles so vital for life to blossom and flourish on the planet. In recent years, people's need and greed have resulted in a weakening of religious beliefs thus sacred groves of the country are on the way to extinction due to various threats (Ingles, 1995). There is an urgent need for extensive research on biodiversity for their conservation and management by developing an appropriate strategy for their conservation.

In Nepal, biodiversity outside the protected area system is also rich because of a close relationship between religious, socio-cultural beliefs, taboos and conservation practices. These informal protected areas are important from the conservation point of view. These areas include sacred groves, which exhibit rich floral and faunal diversity with keystone species and indicate an ecosystem with various life forms (Ramakrishnan, 1996). In Nepal, there is increased vulnerability of sacred groves to various forms of degradation and it becomes necessary to protect them from land fragmentation and degradation, and changing belief systems.

Sacred groves are often considered as vestiges of original vegetation areas and wildlife habitats, which need to be investigated, by natural scientist, whether natural sacred groves could be used as reference sites for potential natural vegetation in an area suffering from environmental destruction. In areas where little, if any, original vegetation is left "untouched", natural sacred sites could eventually give an idea of the area's climax or sub-climax vegetation. Possibly, the sacred groves could serve as gene pools to restore stressed or degraded environments, using reforestation measures and may also provide basis for carbon stock measurement. Under the Program on Man and the Biosphere (MAB) and the World Heritage Convention as two global instruments, UNESCO protects many of the world's most important environmental sites. The UNESCO-MAB biosphere reserve concept clearly recognizes the importance of sacred groves and places them into the context of sustainable development. Therefore, this study will be an attempt to execute Nepal's obligation to UNESCO signed in the *Convention Concerning the Protection of the World Cultural and Natural Heritage* for the protection of cultural and natural heritage.

In view of this, the proposed study is designed to carry out an extensive assessment on the selected sacred groves of the Kathmandu Valley in central midhill to document and highlight the botanical significances of grove in conserving tree diversity, examine carbon stock and identify potential threats they are facing to suggest appropriate conservation measures (Fig.2).

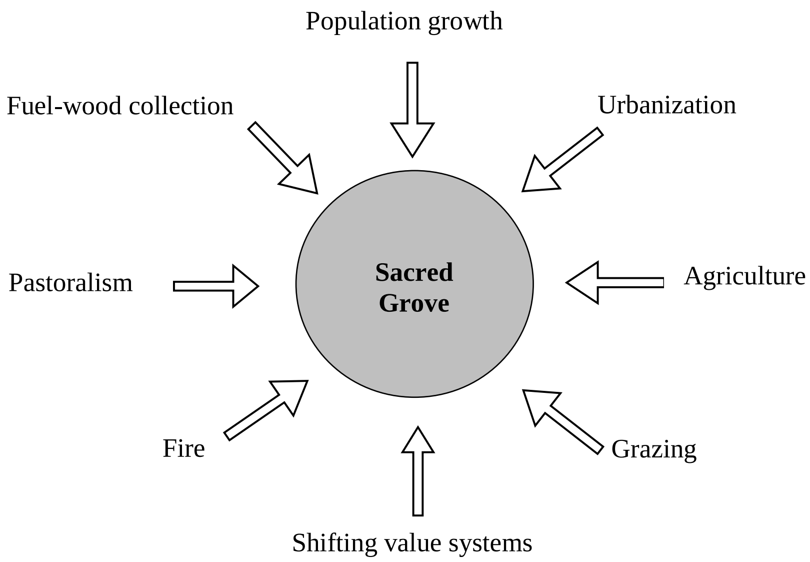


Figure 2. Sacred grove is subject to various pressures

1.5 Research questions

The study is designed to investigate the diversity of trees and determine whether the sacred groves selected for the study are degrading and loosing biodiversity due to drivers of deforestation. It will also try to assess if, in the current socio-cultural context, the notion of sacredness offers any protection to the sacred groves. The study will also question whether some ethnic groups value sacred groves more than other kinds of forest. The study specifically targets following questions to be answered at the end of the study:

- What is the current status of tree regeneration in each sacred grove under study?
- What are the potential causative factors for sacred grove degradation?
- How effective are the sacred groves in conserving tree diversity and storing carbon?
- Would it be possible to conserve groves through state intervention only or various stakeholders should be involved?
- Does the difference in people's attitudes and perceptions, if any, influence the use of sacred grove?

1.6 Hypotheses

The study focused on testing the following hypotheses:

1. Sacred groves help in conserving tree species diversity.
2. Different belief systems are considered to be important in contributing the biodiversity conservation of sacred grove.

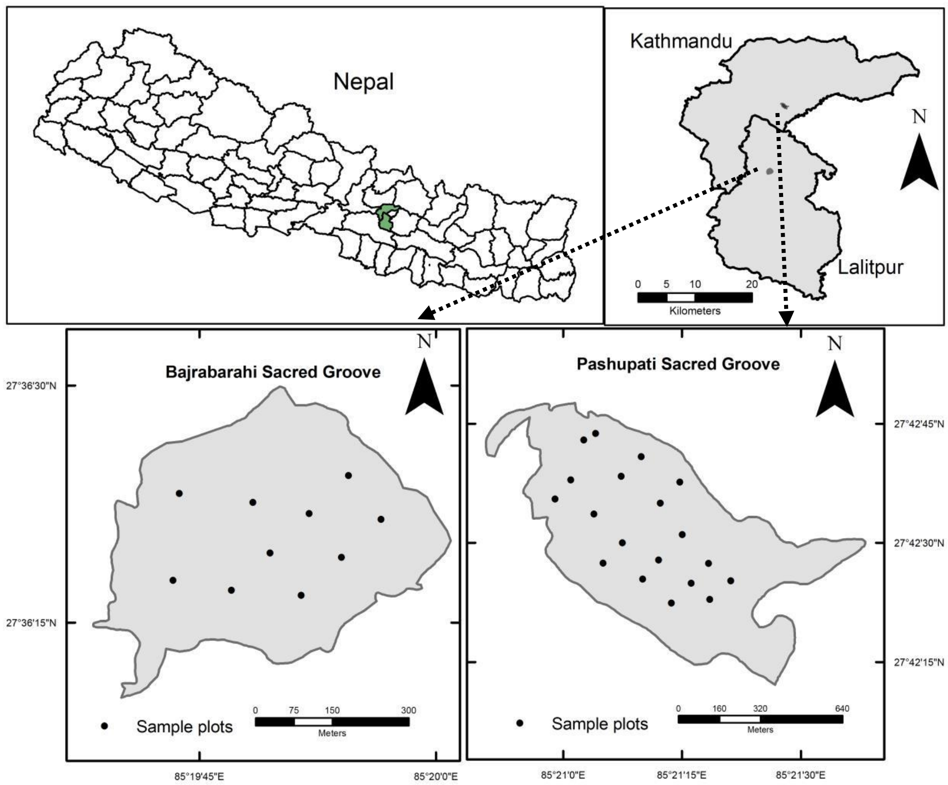
1.7 Objectives

The general objective of the proposed research is to assess the status of selected sacred groves in Kathmandu valley by measuring the diversity of trees. The specific objectives of this study are:

- To assess the phyto-sociology of tree species.
- To estimate the carbon stock of trees species.
- To evaluate regeneration of trees and identify potential causes of threats to the groves.
- To assess the perceptions of local communities on the need of conservation of sacred groves.

1.8 The study area

Two sacred groves of Kathmandu Valley were chosen for the study from the Midhill region of Central Nepal. One of them was an oldest and famous religious site of Hindu culture called as Pashupati Sacred Grove (PSG) that belongs to Lord Pashupatinath Temple in Kathmandu district, the capital city of Nepal. The second one was Bajrabarahi Sacred Grove (BSG) located around Bajrabarahi Temple, another famous religious site in Lalitpur District of Kathmandu valley (Map 1).



Map 1. Location of study area and distribution of surveyed plots.

1.8.1 Pashupati Sacred Grove

1.8.1.1 Historical review

The population of Nepal is mainly derived from Indo-Aryan and Mongol stock (Majupuria, 1991). According to 2012 census, about 81.3% Nepal's population is found to be dominated by Hindu religion and next higher group is about 9% Buddhist, followed by Islam 4.3%, and other minor groups such as Kirat, Christians, Jain, and Sikh (CBS 2012). Pashupatinath, considered as the symbol of lord *Shiva*, is being worshipped by different religious communities (Hindu, Buddhist, Sikh, and Jain) of the world and regarded as deity who provides salvation to all living beings. This grove has been specified as the most sacred pilgrimage and is famous place of faith in Hindu religion. By recognizing the cultural and religious importance of Pashupati area, UNESCO has recognized the Pashupati Sacred Grove as cultural heritage site in 1978 (Shrestha, 2001). Since ancient time, the Pashupati Sacred Grove has been a place of salvation from earthly bondage and a place of meditation of many Shaints. Religious epics like Himawatkhanda (Narhari and Satyal, 1956), Nepal Mahatmaya (Khanal, 1971) and Pashupati Puran (Risal, 1972) have described the value and importance of Pashupat area. The antiquity of Pashupati area can be traced back to ancient Gopalas' monarchies when they took initial steps to consider this area devoted to lord *Shiva*. The different monarchies like Kirat, Lichavvi and Malla followed the cultures of Gopala's and developed the area devoting to Lord Shiva. The development of Pashupatinath complex and surrounding areas took speed only after second century AD (NPC, 1993).

Though there are no limitations of devotees to visit Pashupati area every day to pay homage to Lord Shiva, but the number is much more in the different religious occasions like Shivaratri (no moon day in March), Balachaturdashi and Teej (women festival). During Malla's dynasty Pashupati area was used as fort and called as *Barabu Gad* (Tandan, 1996) and wad considered important in balancing the nature and provide safe resort for people during invasion by enemies.

Several efforts have been enforced in the past, for the conservation of Pashupati Sacred Grove (*Sleshmantak* forest) such as ban on tree felling, prohibition of firewood or a leaf collection or set forest fire, and killing of wild animals (Tandan, 1996). Traditionally, the dead and dried trees of Pashupati Sacred Grove are considered as saints and are permitted for the preparation of divine feast (*Bhog)* and sacrificial fire (*Dhuni*) in Pashupatinth, Guheswari and Gorakhnath. There is tradition of cutting branch of *Pyrus pashia* from PSG to erect pole at Basantapur Darbar Square to indicate the starting of colorful festival of Holi or Fagu in full moon day of March (Tandan, 1996).

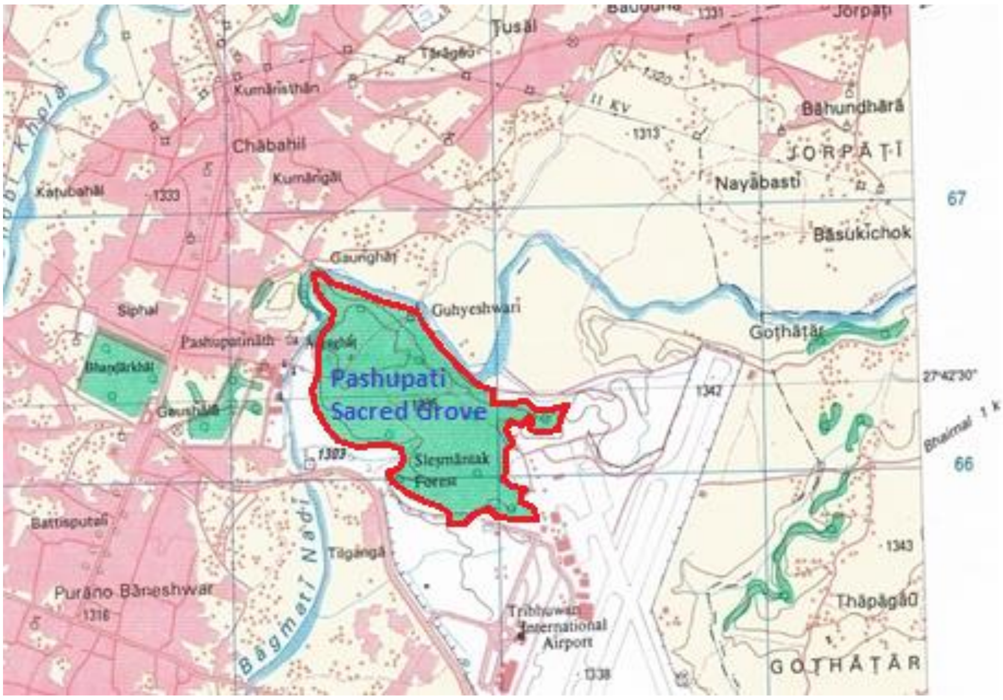
The Pashupati sacred grove is also known from its traditional name '*Slesmantak*' forest. The Sanskrit name of forest Sleshmantak refer to Nepalese Hog Plum tree (*Choerospondias axillaris*) that has once dominated the forest in the past (Narhari and Satyal, 1956).

1.8.1.2 Administrative and legal status

Based on the approved master plan, Pashupati Area Development Trust (PADT) is managing the area including the temples and the forest. Ministry of Culture, Tourism and Civil Aviation is the line ministry of PADT. Conservation activities conducted by PADT in PSG are: plantation and protection of *Choerospondias axillaris* and other ornamental flowers, fruits, religious trees in degraded forest areas, establishment of deer park, net and barbed wire fencing, appointment of forest guards, as well as construction of compound wall in PSG.

1.8.1.3 Topography, drainage and hydrology

Pashupati Sacred Grove is in the suburbs of Kathmandu City between 27°42'25.68"N to 27°42'34.79" N, and 85°21'20.65"E to 85°20'58.94" E. Pashupati area covers approximately 264 ha of land and the altitude range from 1300 m to 1337 m. The total forest area covers 83.55 ha with a buffer zone of 11.55 ha (Map 2). The forest is surrounded by Bagmati River in north and west, Tribhuvan International Airport in east and Tilganga River in south (Shrestha, 2001).



Map 2. Location of the Pashupati Sacred Grove (Scale 1:25,000)

1.8.1.4 Geology and Soil

The Pashupati area belongs to plain terrace system of Kathmandu Valley with thick sand and thin clay in alternate bands without large boulders, which has been formed due to Bagmati River. The soil type is mainly sandy loam. The top soil is followed by lacustrine sediments. The natural drainage system is controlled by the gullies pattern (Shrestha, 2001).

1.8.1.5 Flora

The area is in central midhill of Nepal, which is characterized with the presence of sub-tropical type of vegetation (Stainton, 1972). Previous vegetation study of this area concluded that it is a remnant forests that has dominated the valley floor long back (Shrestha, 2001). The vegetation consists of mixed evergreen broad-leaved trees like *Acer oblongum, Ilex excela, Michelia champaca, Myrsine capitellata, Myrica esculenta, Schima wallichii, Stranvaesia nussia, Quercus glauca, Quercus lanata*. The wet gullies are occupied by *Alnus nepalensis.* Common shrub species are *Clerodendrum fragrans, Hymenopogon parasiticus, Justicia adhatoda, Lantana camara, Randia tetrasperma, Rubus ellipticus, Rhus parviflora* and *Sambucus adnata* (Shrestha, 2001). The alien trees such as *Araucaria bidwillii, Callistemon citrinus, Caryota urens, Cinnamomum camphora, Eucalyptus citriodora, Gravillea robusta, Jacaranda mimosifolia, Magnolia grandiflora, Nerium indicum, Populus deltoides, Salix babyloncia* and *Thuja occidentalis* are found as avenues trees. Trees like *Aegle marmelos, Choerospondias axillaris, Elaeocarpus sphaericus, Juglans regia, Sapium mukorossi* are few and sparsely distributed (Shrestha, 2001).

1.8.1.6 Fauna

The study area also provides habitat to a variety of wildlife such as Rhesus monkey (*Macaca mulatta),* Indian grey mongoose (*Herpestes edwardsii*), Golden jackal (*Canis aureus),* Jungle cat (*Felis chaus),* Yellow-bellied weasel (*Mustela kathiah*) and small Indian civet (*Viverricula indica*). The common bird species found are Common Pariah Kite (*Milvus migrans*), Common Myna (*Acridotheres tristis),* Blue Rock Pigeon (*Columba livia),* Jungle Crow (*Corvus splendens),* Spotted Dove (*Streptopelia chinensis),* Indian Grifforn (*Gyps indicus),* Spotted Owlet (*Athene brama),* Black-headed Shrike (*Lanius schach) etc.* Available herpetofauna in this area are Common Asian Toad (*Bufo melanostictus),* Bull frog (*Rana tigrina),* Common Garden Lizard (*Calotes versicolor*), Blind Snake (*Ramphotyphlops braminus*), Common Wolf Snake (*Lycodon aulicus),* Banded Kurki Snake (*Oligodon arnensis*) and Checkered Keel Back Water Snake (*Xenochrophis piscator).*

1.8.2 Bajrabarahi Sacred Grove

1.8.2.1 Historical review

The forest is named after the name of goddess *Barahi*, which is one of the four Barahi Temples found in the valley. This temple was established during Malla's dynasty in March 727 AD. It is believed that the current temple and idol were established in a pond situated at the middle of the forest. There is the belief that goddess Bajrabarahi incarnated from existing pond and a temple was established in the area (Pradhan, 2006).

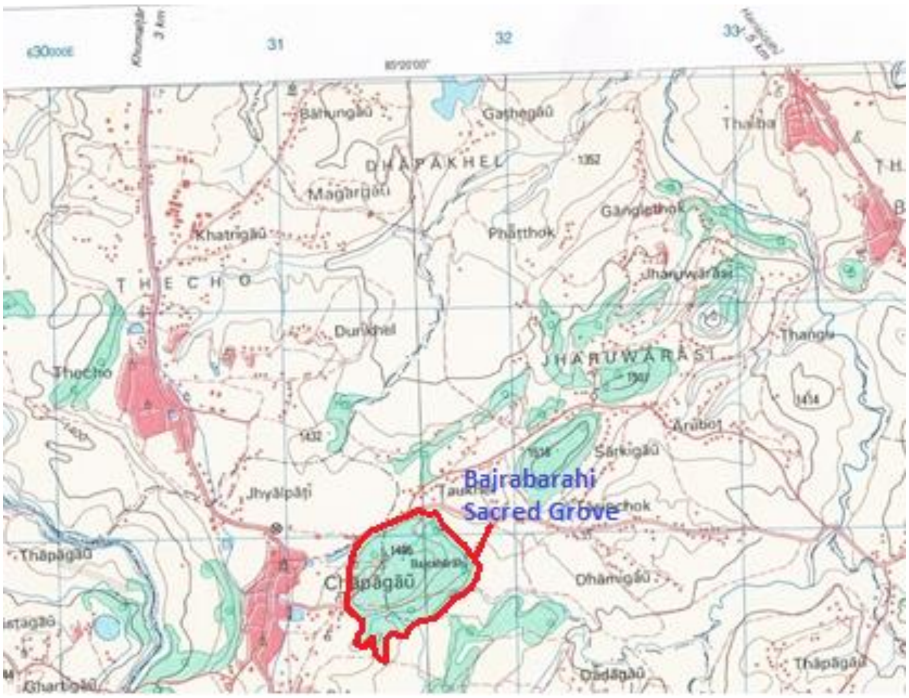
The temple has become famous for pilgrimage and in-country tourism due to religious belief, location, having dense forest, sceneries with fresh and open environment. Numerous followers have been visiting the area each year during different festivals and occasions. There is tradition with the local people not to carry a single leaf or piece of wood outside the forest. If they do so, then misfortune might fall upon them. There is another strong belief system that once leaves were swept outside the forest, it will return before the night falls (Pradhan, 2006). This belief system worked as social fencing and helped a lot for the protection of this forest. But during these days some of the local people, mostly outsider, started the collection of fallen leaves and stems for household purposes. The wooden logs from the forest is only used to burn dead bodies. One of the endemic Nepalese bird species, Spiny Babler (*Turdoides nipalensis)*, locally called Kade Vyakur, is first time recorded from this grove (Pradhan, 2006).

1.8.2.2 Administrative and legal status

A local community based organization named Jyotidaya Sangh is managing BSG since 1993, after the grove was handed over to this organization by District Forest Office (DFO), Lalitpur under the Forest Act of Nepal. Since then, several conservation activities have been carried out like barbed wire fencing arround the grove, appointing security guard, enforcement of rules and regulations for conservation, prohibition of hunting, collection of fire wood and pruning.

1.8.2.3 Topography, drainage and hydrology

Bajrabarahi temple is located at southern corner of Kathmandu Valley, in Chapagaun VDC of Lalitpur district at elevation of 1440 m and is surrounded by sacred forest, having an area of 18.29 ha. Bajrabarahi sacred grove is located between 27°36'15.88"N to 27°36'24.62" N, and 85°19'40.56"E to 85°19'50.49" E. In eastern border of this grove there is Jharuwarashi VDC, in western border there is Saraswoti ground and road and in south health post, cultivated land and in north there is road (Map 3).



Map 3. Location of Bajrabarahi Sacred Grove (Scale 1:25,000)

1.8.2.4 Flora

The study area is included in central midhills of Nepal having subtropical vegetation. It is one of the last remaining natural climax forest found in the valley floor but still the grove shows good floral diversity with 160 recorded plant species (IUCN, 1996). Major tree species found in BSG are *Actinodaphne agustifolia*, *Albizia lebbeck, Alnus nepalensis*, *Ardisia macrocrapa*, *Castanopsis indica*, *Castanopsis tribuloides*, *Choerospondias axillaris*, *Ficus bengalensis*, *Myrica esculenta*, *Myrsine semiserrata*, *Neolitsea cuipala*, *Pyrus pashia*, *Quercus glauca*, *Rhododendron arboreum* and *Zizyphus incurva*. Similarly, the common shrub species are *Berberis aristata*¸ *Clerodendrum philippinum*, *Cassia occidentalis*, *Justicia adhatoda*, *Rubus ellipticus*, *Urtica dioica* and *Vitex negundo*.

1.8.2.5 Fauna

The study area comprises 48 bird species (IUCN, 1996) including the endemic bird Spiney babler (*Turdoides nipalensis*). Some common fauna recorded from this forest are Rhesus monkey (*Macaca mulatta),* Golden jackal (*Canis aureus),* Common leopard (*Panthera pardus*) and Jungle cat *(Felis chaus*).

1.8.2.6 Climate

The meteorological data of the study area is based on the record of Meteorological Station at Tribhuvan International Airport, which lies adjacent to the study area (GoN, 2013). The monthly variation in relative humidity, temperature and rainfall are shown in graph (Fig. 3). The average annual temperature becomes maximum (31.9º C) during June and minimum during the months of December (2.0º C). The average relative humidity ranged 70-86%. The average annual rainfall exceeds more than 1480.4 mm and about 80% of rainfall occurs during the monsoon season (June to September). The study area is characterized with 4 distinct seasons, spring (March-May), summer (June-August), autumn (September-November) and winter (December-February).

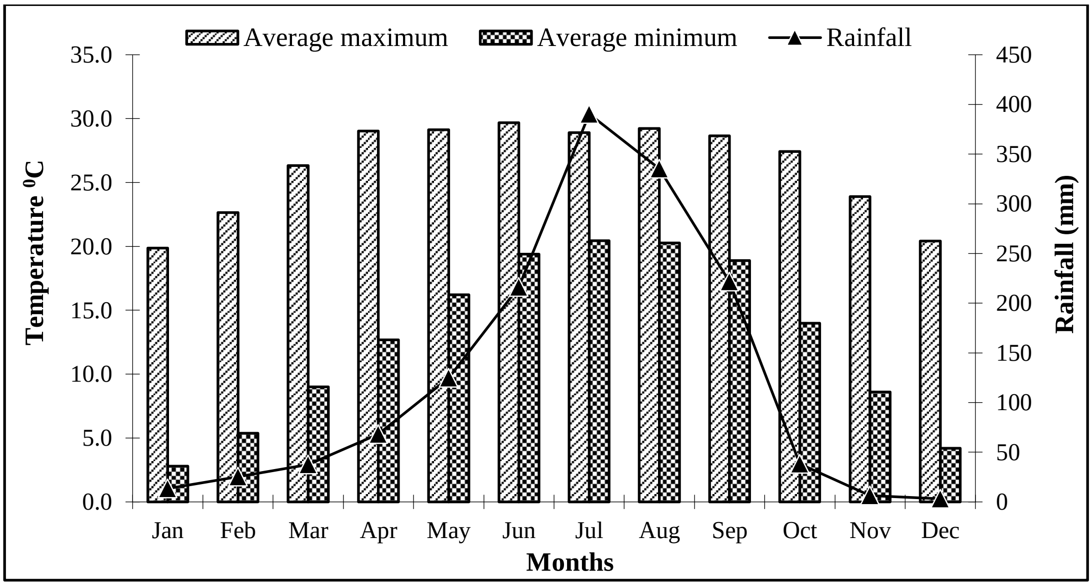


Figure 3. Mean annual maximum and minimum temperatures and rain fall during 2000-2012 at Tribhuvan International Airport

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

Forest, which is one of the important natural resources, provides the economic opportunities for livelihood improvement to the people and regulates important ecological functions like control of erosion, watershed protection and biodiversity conservation (Ehrlich and Ehrlich, 1992, Byod and Banzhaf, 2007). The growing population and less enforcement of existing rules and regulations resulted different anthropogenic pressures in the existing forest of Nepal. Resource degradation has exceeded during the nationalization of private forest in 1957 in Nepal (Sharma, 2013). This happened due to unstable government and lack of proper institutions for conservation. Later conservation activities were institutionalized in the form of Forest Law (1956) and Protected Area Law (1973).

Based on the existing five types of rights available in the natural resources namely access, withdrawal, management, exclusion, and alienation properties are classified in four categories. Those properties are private properties, state managed properties, community properties, and open access or no property. In the private properties, the owners have authority to employ all kind rights, but those activities need to be accepted from the society. In the common properties, the owners have four types of rights namely access, withdrawal, management and exclusion for its management (Wilson and Bryant 1997, Sharma 2014).

The management regimes of natural resources are also based on the existing property rights. As being one type of natural resource, forests of Nepal have different management systems or management regimes based on the property rights and are guided from existing rules and regulations. Sacred grove is pioneer and one of the ancient method of resource management existed in Nepal. The management of sacred groves was traditionally based on religious faith and deities practiced in the communities. Those practices were recently legalized from the rules and regulations. Among existing eleven forest management regimes in Nepal, religious forest (Sacred Grove) is one managed by local community after handing over its management from

Government (HMGN 1973, 1974, 1978, 1993, 1994, 1996, 2004, FRA/DFRS, 2010, 2014).

Various sized sacred groves have been managed by local communities from their belief system, all over the world. Local people have considered the sacred grove as the dwellings of their deities and are the sites for religious and cultural rituals serving as valuable storehouses of biological resources. Sacred groves are forests that have been protected since the ages by traditional societies (Saikia, 2006). The management implications of sacred groves are based on religious faith and believe systems which also contributed for the conservation of different resources, including biodiversity (Singh, 2012). In the past sacred groves were distributed in all the regions of the world, and their entities were placed sacred by communities employing religions as well as economic and social organizations. It is believed that these sacred virgin forests date back to thousands of years when human society was in the primitive state. Gadgil and Vartak, (1975) traced the historical link of the sacred groves to the pre-agricultural, hunting and gathering stage of societies and are believed to be pre-Vedic in origin. Sacred groves are forest patches rich in biodiversity, having traditions and cultural values of local and indigenous people who protect the groves with their strong socio-religious beliefs and taboos (Khumbongmayum *et al*., 2006).

All forms of vegetation available in the groves are believed to be under the protection of reigning deity of the local society of that grove, and the removal of even a small twig is considered a taboo. Collection and removal of any material from the sacred groves is prohibited due to religious belief and social norms in many societies of the world (Gadgil and Vartak, 1975, Khan *et al.* 1987, Khiewtam and Ramakrishnan, 1989, Pradhan, 2006). Sacred groves having climax form of vegetation succession and protected due to social fencing, can also be used as indicators for potential natural vegetation (Schaaf, 1998, Singh, 2012) and played vital role for the wellbeing of the society.

In many regions of the world, sacred sites have demonstrated a major effect on species conservation, regulation of ecological phenomenon and environmental protection due to the special precautions and restrictions associated within their management concepts. Sacred groves and their management implications could be useful tools for the management of sustainable landscapes. Cultural beliefs in association with ecological economics residing in the management of sacred grove could prove to be a useful concept for landscape management and may provide helpful tools for protecting the biodiversity including wildlife (Karanth, 1998).

Sacred places have long and diverse histories in human cultures and demonstrate ancient links between peoples and their environments. Sacred places are universal human phenomenon not associated with any specific religion or world view, but they have a strong religious context and influenced by traditional local beliefs (Engel, 1985). The result of limitation in anthropogenic activities due to taboos and prohibitions, sacred places frequently possess old growth vegetation, integrated nutrient cycling with high soil fertility and many ecologically and socially valuable plant species (Anthwal *et al.*, 2006, Singh, 2012). Societies have long been responsible for the conservation of nature in sacred places through traditional and stewardship practices. These kinds of practices have made groves the repositories of rare and endemic species as the remnant of the primary forest left untouched by the local inhabitants (Ramakrishnan, 1996, Chandrashekara and Sankar, 1998, Anthwal *et al*., 2006, Bhakat *et al*., 2008).

Sacred forests have been protected around the world for a variety of reasons. Most of them are protected due to religious practices or ceremonies, as burial grounds and for their watershed value (Hughes and Chandran, 1998, Deil *et al*., 2005, Malhotra *et al.*, 1997). Besides these, sacred groves also provide several ecosystem services like reduction in erosion, conservation of soil, maintenance of hydrological cycle, availability of water and natural dispersal of seeds of useful species (Tiwari *et al.*, 1998a).

The sacred groves help in maintaining the desirable health of ecosystem, reduce habitat destruction, conserve the viable population of pollinators and predators, serve as the potential source of propagules that are required for colonization of wastelands and fallows, conserve the indigenous flora and fauna and preserve the cultural and ethical practices developed through indigenous knowledge of generations (Ramakrishnan and Ram, 1988, Godbole *et al*., 1998, Tiwari *et al*., 1998, 1998a, Godbole and Sarnaik, 2004). Thus, traditional nature of worship practices as followed in different parts of world do contribute to the promotion of the local or regional and national goals of conservation of biodiversity (Chandrashekara and Sankar, 1998, Kadamba *et al*., 2000, Ramanujam and Kadamba, 2001, Ramanujam and Cyrill, 2003, Basu, 2000, Tripathi *et al.*, 2002, Jamir, 2002, Jamir and Pandey, 2002, Law, 2002, Upadhaya, 2002, Khumbongmayum *et al*.,2004, Khiewtam, 1986, Khan *et al*., 1987, Barik, 1992, Rao, 1992, Khiewtam and Ramakrishnan, 1993, Barik *et al*., 1996a and 1996b, Rao *et al*., 1997, Tiwari *et al*., 1999, Tripathi *et al*., 2002, Pandey *et al*., 2003, Upadahya *et al*., 2003, Mishra *et al*., 2004).

2.2 Sacred Groves of the World

In many parts of world, care and respect for nature has been influenced by religious beliefs and indigenous practices. The existence of sacred groves has been reported in many parts of world including Asia, Africa, Europe, Australia and America (Hughes and Chandra, 1998). Sacred groves are also reported from different countries like Ghana, Senegal, Sumatra, Nigeria, Syria, Turkey and Japan (Gadgil and Vartak, 1976, MAB, 1995).

Sacred groves have also been very successful in preserving various biological resources including the vegetation. Sacred sites with their importance for nature conservation and increase cultural belief have been studied in Bangladesh (Hussain 1998, Islam *et al*., 1998), India (Boraiah *et al*., 2003, Bhagwat *et al*., 2005, Khumbongmayum *et al*., 2006, Bhakat *et al*. 2008), in Tanzania (Mgumia and Oba, 2003), representing different habitats and vegetation types available in those areas.

Sacred grove representing different ethnic groups have been reported in Sundarbans mangrove forest of Bangladesh with rich vegetation types and a unique place of worship for low caste Hindus, who visit it once in a year for prayer (Islam *et al*., 1998). Mohamed (1998) has also reported the importance of sacred grove in promoting the historical and geographical tradition of the rural people in Afghanistan. Similar is the case in Ghana (Michaloud and Dury, 1998) where sacred groves have played positive role in the socio-economic and cultural lives of many rural people.). However, in Mongolia sacred groves are not protected by the state rules and regulations but few sacred places which have been declared officially as sacred sites from the Government (Gongorin, 1998).

In India, sacred groves have been studied extensively and at least 13,720 sacred groves have been enumerated from various regions of the country (Malhotra *et al*., 2001). The numbers of sacred groves in India as estimated by the experts were 100,000 to 150,000 (Pushpagandan *et al.*, 1998, Ramakrishnan, 1998, 2001). Majority of the sacred groves studied in India are distributed mainly in the Western Ghats, North Eastern India and Central India (Gadgil and Vartak, 1976, Burman, 1992, Rodgers, 1994, Balasubramanyam and Induchoodan, 1996, Tripathi 2001, Khumbongmayum *et al*., 2005). Sacred groves of India have also been reported in Meghalaya (Boojh and Ramakrishnan, 1983, Mitra and Pal, 1994, Ramakrishnan, 1996, Tiwari *et al*., 1998a, Jamir, 2002, Law, 2002, Upadhaya, 2002, Mishra *et al*., 2004), Manipur (Khumbongmayum *et al*., 2004, 2005), Western Ghats (Gadgil and Vartak, 1976), and Bihar as well as Rajasthan (Mitra and Pal, 1994). However, sacred groves have been described by Burman (1992) and Rodgers (1994) all over the Himalayas, from northwest to northeast India.

2.3 Sacred groves in Nepal

Sacred groves have received considerable attention, as a pioneer of traditionally community managed natural resource management practices in Nepal. Government of Nepal has formulated and applies rules, regulation and strategies for the management of sacred groves (HMGN 1973, 1974, 1978, 1993, 1994, 1996, 2002, 2004) for modernizing these old practices and encouraging and involving more communities.

Forest Act (1993) of Nepal has provided legal authority to District Forest Officers to handover the management sacred groves to the local communities. Similarly, in buffer zone area Chief Warden of the concerned protected area could also hand over management of sacred grove to concerned communities as buffer zone religious forest (HMGN, 1996).

There are eleven types of forest management regimes under practice in Nepal (FRA/DFRS, 2014). Those regimes include forest management from private to community and to state. The sacred groves, legally known as religious forest, are one of the community managed regime (HMGN, 1993). There are legal provisions for the management of sacred groves and they are managed under the Forest Act 1993 of Nepal. A proper and comprehensive documentation of available groves inside the country is lacking. According to Department of Forest statistics, 36 sacred groves with the area of 2056 ha, are registered as sacred grove inthe country (DoF, 2012).

Sacred groves in Nepal have been studied from different researchers in various time periods including Mansberger (1991), Ingles (1995), Shrestha (2001), Bhatta (2003), Bhattarai and Baral (2008), and Tandan (1996) as some of the major studies. These studies have included bio-cultural survey of sacred forest in Kathmandu Valley (Mansberger, 1991), small size sacred groves (Ingles, 1995), ecological study of Sleshmantak forest (Shrestha, 2001), community approaches to natural resources management comparison between sacred and non-sacred landscapes (Bhatta, 2003), the role of scared grove in plant diversity conservation (Bhattarai and Baral, 2008) and cultural database of PSG (Tandan, 1996).

2.4 Legislations related to Biodiversity Conservation in Nepal

As a commitment to conserve its biological diversity by sustainably utilizing its renewable resources, Nepal endorsed the theme of World conservation Union by preparing national Conservation Strategy in 1988. Recognizing the need for a comprehensive long-term plan to meet the basic needs of the people by sustainably managing the forest resources in Nepal, Master Plan for Forestry Sector in Nepal (MPFSN) was prepared in 1988. The Master Plan, endorsed by HMG in 1989, presents a comprehensive strategy for 21 years of management of forestry in Nepal (HMG/ADB/FINNIDA 1988). After realizing the significance of biological diversity and its potential role in socio-cultural and economic development, Nepal signed the UN Convention on Biological Diversity (CBD) in 1992 and became the party since February 1994. Since then Nepal has given due respect for the implementation of CBD. The country has been engaged in giving continuity to decades long conservation efforts and taking new initiatives to meet international obligation in conserving its valuable biological diversity. Regarding this, Nepal Biodiversity Strategy (NBS) had been prepared and implemented in 2002. Following to this, Government of Nepal identified and prioritized various programs and prepared Nepal Biodiversity Strategy and Implementation Plan (NBSIP) 2006 – 2010 to implement NBS 2002 (HMGN/MoFSC 2006). Recently, country has also prepared and implemented Nepal Biodiversity Strategy and Action Plan (1014-2020).

There are over two dozen of Acts and Regulations linked to the implementation of NBS 2002. They range from the green sectors to brown sectors of Nepal. Following are some of the major legislations pertinent to NBS implementation:

- National parks and wildlife Conservation Act 1973
- Plant protection Act 1973
- Forest Act 1993
- Environment Protection Act 1996
- National Parks and Wildlife Conservation Regulations 1974
- Himalayan National Parks Regulations 1979
- Environment Protection Rules 1997
- Environment Protection Regulations 1997
- Buffer Zone Regulations 1996
- Community Forestry Guidelines 1996
- Buffer Zone Management Guidelines 1999
- Forest Sector Policy 2000
- Collaborative Forest Management Guidelines 2004
- National Biodiversity Strategy and Action Plan 2014-2020
- Forest Policy 2015

Forest Act 1993 and Forest Regulation 1995 provide detail provisions of establishment of religious forests, resource utilization and management practices, and even the provisions of actions that can be taken against the community, if fails to follow the management plan. Similarly, recently developed Forest Policy 2015 has the provision of forests management under community, leasehold, buffer zone community, protected and religious systems that will be made capable and upgrade to share equitable benefit based on ecosystem, economic and society level.

Out of nine strategies identified by NBS 2002, one strategy is for the management of religious forests of the country but NBSIP 2006-2010 could not propose any plans of implementation for the management of religious forests under forest Biodiversity Conservation Through Community Participation (outside protected areas). Similarly, the Fourth National Report to the Convention on Biological Diversity 2009, GoN, has identified Priority Implementation Projects for the conservation of biological diversity but there is weak to fair status of Supportive environment have been identified for Forest Biodiversity Conservation through Community Participation (outside protected areas).

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. Similarly, Goal No. 7 "Ensure environmental sustainability" of Millennium Development Goal, target number 9 is to "Integrate the principles of sustainable development into country policies and programs and reverse the loss of environmental resources". The Aichi Biodiversity Target number 2 stated "biodiversity values have been integrated into national and local development and poverty reduction strategies and planning processes and are being incorporated into national accounting, as appropriate, and reporting systems". These targets and goals have been accepted by NBSAP (2014-2020) and different conservation strategies have been addressed but the sacred groves have not been included in the action plan.

According to Sustainable Development Goal Nepal (2015), forest sector has achieved significant increase in forest area from 37% (1990) to 39. 6% (2014), and forest managed by communities has increased by 0.013 million ha (1990) to 1.65 million ha (2014). Despite the increment in the forest area and community managed forest area, Sustainable Development Goals Nepal (2015), does not have any provision for the conservation and management of scared groves of the country (NPC 2015). Current study resulted that the forest area of Nepal has been increased up to 44.74% (DFRS 2015).

2.5 Sacred groves and biodiversity conservation

The role of sacred groves in the biodiversity conservation has been well accepted since a long time ago. Several studies in the past that had been involved sacred groves had stated the importance of religious belief in biodiversity conservation. The studies had focused in different aspects of sacred groves and their importance for biodiversity conservation. These studies had reported high woody species richness and taxonomic diversity (Jamir and Pandey, 2002, Mgumia and Oba, 2003, Boraiah *et al*., 2003, Upadhaya *et. al*., 2003, Khumbongmayum *et al*., 2006, Bhakat *et al*., 2008, Ramshankar, 2010., Rawat *et al*., 2011) inside the sacred groves.

Studies have shown that sacred groves have been supporting in the conservation of rare, endemic and endangered species (Gadgil and Chandran, 1992, Khan *et al*., 1997, Chandrashekara and Sankar, 1998, Sukumaran and Jeeva, 2008, Malhotra *et al.*, 2001 and Pavendan and Rajasekaran, 2011) in different part of the world. Sacred groves or sacred trees are also serving as homes for different animals with epiphytic and parasitic plant (Devkota, 2011) and hence, they indirectly help in the conservation of biological diversity (Islam *et al*., 1998). Several trees having non-timber values, useful macro fungi, and plants with medicinal properties were found abundant in sacred groves of Western Ghats (Bhagwat *et al*., 2005). They also reported that threatened trees were more abundant in sacred groves than in reserve forest. Mohanta *et al*., 2010 studied thirteen sacred groves in Garo Hills of Meghalaya, and conducted detailed survey for the assessment of floral and faunal diversity, with ethno-cultural values and management status.

Sacred groves are also served as storehouses of biological diversity, and remained undisturbed from anthropogenic activities. In three sacred groves of Jaintia Hills in Meghalaya, a total of 395 plant species of 108 families were distributed in 28 ha area (Jamir and Pandey, 2002). Haridasan and Rao (1985) reported that at least 50 rare and endangered species were thriving in sacred groves of Meghalaya. Similarly, high tree density and high degree of species richness were recognized inside scared groves (Upadhaya *et al.*, 2003).

2.6 Socio-cultural practices

Sacred natural sites have become important areas for nature conservation in different culture associated with different societies, around the world. Traditional respect for nature and access restrictions to sacred grove is one of the important reason for having high biological diversity within the sacred grove otherwise the area might have changed in to degraded environment (Schaaf, 2003) as majority of people are influenced by some kind of spiritual faith. Description about the religious and cultural practices, people's attitudes and role of beliefs, faith, folklores and taboos associated with sacred groves have been provided by different workers. The cultural and religious belief with taboos provided the positive roles for the species conservation in sacred groves (Gadgil and Vartak, 1975, 1976, Messerschmidt, 1987, Khiewtam and Ramakrishnan, 1989, Ramakrishnan, 1996, Singh *et al*., 1996, Nair *et al*., 1997, Tiwari *et al*., 1999, Vartak and Gadgil, 1981, Oliver *et al*., 1997, Sinha and Maikhuri, 1998, Swamy *et al*., 1998, Basu, 2000, Kushalappa *et al*., 2001, Ramanujam and Kadamba, 2001, Anderson *et al*., 2005, Higgins-Zogib *et al*., 2005, Dudley *et al*., 2009 and Singh, 2012).

Traditional and cultural practices associated with different societies all over the world are important aspects promoting the conservation of sacred groves (Sethi, 1993, Visalakshi, 1995, Swamy *et al*., 1998, Ramanujam and Kadamba, 2001, and Kumar and Swamy, 2003). Similarly, the religious and cultural importance of a single species also plays important role for the conservation of sacred groves and the species available in the area (Ramanujam and Kadamba, 2001, and Kumar and Swamy, 2003).

2.7 Drivers of deforestation and threats

Religious beliefs and taboos have been considered as main factors for the protection and conservation of sacred groves (Vartak and Gadgil, 1981, Tiwari *et al*., 1999 and Byers *et al*., 2001). Different anthropogenic disturbances and environmental degradations due to developmental activities, urbanization, and exploitation of resources have been threatening the conservation of sacred groves all over the world (Jha *et al*., 1998, Saxena *et al*., 1998, Kushalappa *et al*., 2001, Aerts *et al*., 2006 and

Sukumaran and Jeeva, 2008) and even some of them have disappeared (Saikia, 2006). Though sacred groves play important role in conservation of forest, they may not be solely responsible for its protection. The impacts due to different anthropogenic activities may also be responsible for the proper protection of sacred areas in association with other factors (Sing, 2006).

The anthropogenic disturbances result impacts on the forest community structure, forest canopy and wood density. Different magnitudes of anthropogenic activities have resulted sharp decline in tree density and their basal area in the sacred groves of India (Uniyal *et al*., 2010). The quantity of biomass as well as carbon stock of the scared grove also depends on the condition of forest. Biomass and carbon stock of the forest shows increament in the forest areas without any kind of disturbances (Hu, 2005, Yang *et. al.*, 2005, Duan *et al.*, 2007, Liu and Li, 2007, Zhou *et al.*, 2007, Fan *et al.*, 2008, Ravindranath *et al.*, 2008, Zhang *et al.*, 2009 and Yamashita *et al.*, 2012).

There is degradation of forest all over the world **(**Miller *et al*., 1989, Hawksworth and Mould, 1991 and Raven, 1994). Nepal is no exception to this and it has been predicted that it will lose ten species of highly valuable timber, six species of fiber, six species of edible fruit trees, four species of traditional medicinal herbs and some 50 species of little known trees and shrubs; and this would severely alter the habitats for 200 species of birds, 40 species of mammals and 20 species of reptiles and amphibians (HMG/IUCN 1988), if the same trend remains the same. Different threats and challenges are identified for the biodiversity conservation in Nepal (Chaudhary, 2000, HMGN/MoFSC, 2002, GoN/MoFSC 2014).

In Nepal, due to lack of public awareness and participation, habitat loss, forest destruction and degradation are taking place by clearing of the forest. Very large area about 400000 ha of forest has been converted in to agricultural land and scrub-land for livestock grazing (FRISP 1994) within a period of 15 years (1964–1979). Between 1978 and 1991, about 99,000 ha of tropical Sal forest in the Terai was cleared with an average rate of deforestation of 1.3% per year (FRISP 1994). The slash and burn system of traditional farming with its associated shifting cultivation has been causing forest destruction and degradation particularly in the mid-hills. Settlement programs for landless people in the forest areas of the Terai districts have converted the forest to agricultural land.

According to CBS (2012), the total population of Nepal is about 26.49 million with an annual growth rate of 1.35%. Similarly, population distribution in the Terai is 50. 27%, 43% in the hills and 6.73.8% in the highlands. More than 65% of people are still depend on firewood as a source of energy causing significantly negative effects on forest are all over the country since 23.8% of the population in Nepal is still living below the poverty line (CBS 2012). Increasing poverty in the rural areas of Nepal has direct impact on environmental deterioration and biodiversity loss. Improvement of poverty in rural areas is not only for economic reasons, but also for preserving the environment and biodiversity (Hagen, 1996).

Lack of proper management of natural resources, deforestation and improper farming practices in watersheds has accelerated soil erosion. The loss of soil has affected yields on agricultural land, reservoirs and irrigation system which lead towards loss of biodiversity. People in Nepal use forest resources for fuel, fodder, timber, medicines and food. Over-exploitation of these valuable plants in the collection or harvesting procedure has been leading plants towards extinction from the natural habitat. Thus, several valuable species are under threat.

Illegal hunting is practiced throughout Nepal (BPP 1995) due to inadequate institutional, administrative, planning and management capacity. The trade in wildlife species in terms of furs and skins, musk pods, tiger bones, snake and reptile skins is the primary cause in reducing the populations of animal species (Shrestha and Gupta, 1993). Penalties set for killing or trading wild animals in terms of high cash payment and imprisonment by 1993 amendments of the National Parks and Wildlife Conservation (NPWC) Act 1973 have not been effective to control poaching wildlife other than flagship mammals, and the killing of animals continues. Therefore, the major problems of environmental management in Nepal lie not in the biology of the species concerned but rather in the social, economic, and political areas within which people operate (Machlis, 1992, McNeely 1992).

2.8 Carbon stock

Carbon is one of the essential life component and green plants have unique ability to assimilate carbon dioxide with water as the raw materials (Jain, 1983). Carbon sequestration is the capture and storage of atmospheric carbon dioxide by green plants during photosynthesis. Carbon stock is the amount of carbon stored in living biomass, soil, litter, dead wood and fallen stumps. Carbon stock represents the net exchange of carbon fluxes in ecosystem (Keith *et al*., 2009). In the carbon cycle, largest exchange occurs between the atmosphere and terrestrial biota, and between the atmosphere and ocean surface water however ocean contain about 50 times as much carbon as the atmosphere and terrestrial vegetation and soil contain about three and half times as much carbon as the atmosphere (Kolshus, 2001).

Biomass is an important property of an ecosystem because it influences hydrology, erosion, nutrient cycling, carbon storage and biological diversity. It is used to monitor the dynamics of terrestrial carbon (Achard *et al*., 2002, DeFries *et al*., 2002, Houghton, 2003, 2005). However, the estimates of carbon storage in tropical forests range widely (Houghton *et al*., 2001, Dilling *et al*., 2003, Eva *et al*., 2003; Fearnside and Laurance, 2003), which increase uncertainty in models of carbon emission.

Uncertainty about the biomass in the tropical forests may influence estimates of carbon emission as much as deforestation rates (Houghton, 2005). One problem that arises is the absence of a clear understanding of the underlying structure of studied forests, especially with respect to the horizontal and vertical distribution of biomass, and species diversity and the relationship between them (Asner *et al*., 2002, Vieira *et al*., 2004 and Broadbent *et al*., 2008). Structure of forests is strongly related to anthropogenic factors (Clark *et al*., 1995, Sabatier *et al*., 1997 and Pelissier *et al*., 2002), which makes the system more complex and widely differ the biomass contents due to forest degradation.

Biomass itself is not an ecosystem service (Daily, 1997), but it has been used as an indicator of ecosystem services (Portela and Rademacher, 2001), because biomass contains high percentage of carbon (approximately 50%), and carbon stock is an ecosystem service. In Amazon, payment for ecosystem services in the form of international carbon trading (Gullison *et al*., 2007, Wunder, 2007, Laurance, 2008 and Ferraro, 2008) is one proposed method to reduce deforestation rates (Butler and Laurance, 2008).

In the forest, high concentration of carbon is stored in the tree and soil (Acharya *et al*., 2009). The trees capture carbon dioxide from the atmosphere and store in the form of fixed biomass during the growth process. Thus, trees can contribute in reducing the concentration of carbon dioxide from atmosphere by accumulating in the form of biomass (Chavan and Rasal, 2010). Tropical riverine and *Alnus nepalensis* forest types sequester highest carbon in Nepal (Baral *et al*., 2009).

The rate of carbon sequestration depends on the growth characteristics of tree species, the conditions for growth, and the number of individuals of the trees. The rate is high in young age of trees between 20 to 50 years (Myers and Goreau, 1991). The growth of trees and the preservation of old forests are important in regulating the size of the overall terrestrial carbon sink. The temperate and boreal forests ecosystem stored largest biomass and soil organic matter (Hyovonen *et al*., 2007). *Eucalyptus regnans* forest of moist temperate region in Central Highlands of Victoria, Australia has World's highest biomass carbon density (1,053 t ha^{-1} in living and 1,867 t ha^{-1} in living plus dead biomass) (Keith *et al*., 2009). The total standing above-ground biomass of woody vegetation is also one of the largest carbon pools. Above ground biomass can determine an ecosystem's potential for carbon storage, which plays an important role in the regulation of atmospheric carbon dioxide and global climate change (Bunker *et al*., 2005).

Forest have important role as the carbon sink. So, it plays important role in REDD (Reduce Emission by Deforestation and Forest Degradation) mechanism of Nepal (Acharya *et al*., 2009). The community managed forests of Nepal are helping as the accessible alternatives for carbon sequestration (Mandal and Van, 2005, Mandal *et al*., 2013 and Sharma *et al*., 2014). Recent study carried out by DFRS (2015) have shown that 108.88 t ha^{-1} of carbon has been stored by the tree species in Nepal's forest. In the midhill physiographic region the tree carbon stock has been calculated as 79.42 t ha^{-1} (DFRS 2015a).

2.9 Regeneration status

The woody species are the important component for the formation of forest community. Types of forest communities largely depend on physical characteristics of sites, species diversity and regeneration status of species (Khumbongmayum *et al*., 2006). The regeneration performance of forests largely depends on population structure characterized by the production and germination of seed, establishment of seedlings and saplings in the forest (Rao, 1988). Saxena and Singh (1984) and Shankar (2001) have shown that the regeneration status of a forest is greatly affected by the number of seedlings and saplings. They have shown that complete absence of seedlings and saplings of tree species in a forest denotes poor regeneration, while presence of sufficient number of young individuals in each population indicates successful regeneration. The presence of sufficient number of seedlings, saplings and young trees is greatly influenced by interaction of biotic and abiotic components of forest environment (Boring *et al.*, 1981 and Aksamit and Irving, 1984).

Several authors have predicted regeneration status of tree species based on the age and diameter class (Marks, 1974, Bormann and Likens, 1979, Veblen *et al*., 1979, Bhuyan *et al.*, 2003 and Duchok *et al*., 2005). Researches about population structure and regeneration status have been carried out by different workers in varied forest ecosystems of the world (Pritts and Hancock, 1983, Saxena *et al*., 1984, Khan *et al*., 1987, Ashton and Hall, 1992, Cao *et al*., 1996, Gunatilleke *et al*., 2001, Shankar, 2001, Pandey and Shukla, 2001, Murthy *et al*., 2002, Khumbongmayum *et al*., 2005, 2006, Pokhriyal *et al*., 2010). Population structure of tree and its implication to identify their regeneration status have been studied in different forest types of India (Baduni and Sharma, 2001, Bhandari, 2003, Sood and Bhatia, 1991, Pande *et al*., 2002, Parthasarathy, 2001, Yadava *et al*., 1991, Maram and Khan, 1998 and Bhuyan *et al*., 2002, 2003, Davidar *et al*., 2007).

Density, population structure and regeneration status of tree species have been studied in the different sacred groves of the world. The number of seedlings and saplings were found more in sacred groves than other reserves or natural forests (Boraiah *et al*., 2003, Khumbongmayum *et al*., 2006). The species richness and regeneration status were found greater in sacred groves than state managed reserve forests (Boraiah *et al*., 2003). Recent study on the forest status resulted that the number of stem per hectare in Nepalese forest was 429.93 individuals with that of midhill was 871.31 individuals (DFRS 2015).

The effect of different intensity of disturbances on regeneration of tree species has been studied in different forest ecosystems. Good regenerating forests were found either in undisturbed or least disturbed stands and poor regeneration was observed in highly disturbed stands (Rikhari *et al*., 2000, Pandey and Shukla, 2001, Bhuyan *et al*., 2002, Mishra *et al*., 2003, Duchok *et al*., 2005 and Uniyal *et al*., 2010).

CHAPTER 3. MATERIALS AND METHODS

3.1 Study site selection

Based on the Forest Act (HMGN 1993) and Forest Regulations (HMGN 1994, 2004) of Government of Nepal (GoN), each District Forest Offices (DFOs) is the main authority to handover government forest to the communities or organizations, called as users' group, for its management as religious forest or sacred grove. After taking management responsibility from the government authority, the users' group needs to work according to the approved management plan. In the current study, only those sacred groves which have legal status according to current forest act, rules and regulations of GoN were selected.

During the initial period, the users' groups which have taken the responsibility of sacred grove's management have less understanding about the proper implementation of management plan. The implementation of management plan will be more realistic when the users' groups become much experience or mature. Realizing this fact, sacred groves implementing at least two management plans or having at least ten years of experiences were selected for this study.

Sacred groves consist of old growth or virgin forest with matured trees conserved due to local taboos and belief systems. As the study, has focused to find the tree diversity in selected sacred groves, small sized forest may not be appropriate to fulfill the objective of this study. There will be difficulties for replication of sampling plots within in sacred groves having smaller area. So, to get sufficient number of sample plots large sized sacred groves (≥ 10 ha) were selected for this study.

Considering the confluence of eastern and western Himalayan flora in the Central Nepal (Stainton, 1972, Hara *et al*., 1978, 1982, Hara and Williams, 1979, Sharma, 2014), which may have contribution for higher plant diversity, the study sites were selected from the Central development region. Similarly, the areas having widely accepted from socio-cultural belief were also considered for the site selection.

In early May 2010, rigorous information regarding the sacred groves in the Central Development Region of Nepal was collected from different sources. The sources of information were Ministry of Forest and Soil Conservation, Department of Forest, Department of National Parks and Wildlife Conservation, National Trust for Nature Conservation, World Wildlife Fund–Nepal Program and District Forest Offices. Published reports, management plans, books, bulletins and newspapers were also consulted as sources of information.

After collecting the initial information from different sources, preliminary visits were made in potential sites to get the general information about sacred groves. Visits were made to Changu Narayan of Bhaktapur District, Bajrabarahi of Lalitpur District, and Swaymbhu and Pashupatinath Sacred Groves of Kathmandu Valley in 2010. Two sites, namely Pashupati and Bajrabarahi sacred groves were selected based on the above mention criteria. Selected two sacred groves have great historical importance, socio-cultural belief and representing the forest ecosystem of central mid land in Nepal. Field inventory was carried out during March 2012 to December 2013.

3.2 Inventory design

Prior to the field work information on descriptive features of respective groves such as geographical profile, phyto-geography, ecological profile and cultural aspects were reviewed, observed and documented. The study adopted both quantitative and qualitative methods, which are described as follows:

Quantitative data were collected for the phyto-sociological analysis of sacred grove, which included collection of tree level charecteristics by establishing concentric circular sampling plots. Field sampling design was based on the methodology adopted by Forest Resources Assessment Nepal (FRA/DFRS, 2010, 2014) for the forest inventory of Nepal.

Prior to start actual field work researcher had participated on a in depth orientation training conducted by FRA, Nepal about the data collection procedures. After this training a preliminary field visits were made to test the field data sheet and familiarize with the different instruments used for the measurement of tree level characteristics.

Those instruments used were Vertex IV and Transponder T3 – to measure tree distance and height, and densitometer for the measurement of crown cover.

With the help of Google Earth Image north-south parallel transects (n=8 in PSG and n=4 in BSG) 150 m apart from each other were established across the study sites. Coordinates to establish concentric circular sample plots (CCSPs) were collected along each transect at an interval of 100 m. Those coordinates (latitude and longitude) were considered as plot center to establish CCSPs. The central point of each CCSP was identified with the help of Geographic Position System (Garmin 52S) which included already entered coordinates identified by using Google Earth Images. Details of the sampling plot used for data collection are given in figure 4.

3.3 Data collection

Concentric circular sample plots (CCSPs) were used to collect data of tree level characteristic and soil sample. The circles of a CCSP with different radii and diameter thresholds, respectively, were centered at the same point (FRA/DFRS, 2010, 2014). The outermost plot was used for tallying larger trees, whereas inner plots were used for measuring trees belonging into smaller size classes, respectively (FRA/DFRS, 2010, 2014).

The CCSP consisted four circular plots plot with the radius of 20 m (1257.1 m^2) all big size trees with diameter at breast height (DBH) ≥30 cm was measured, plot with the radius 15 m (707.1 m^2) trees with DBH 20.0 cm to 30.0 cm were measured, the third largest plot with the radius 8 m (201.1 m^2) trees with DBH from 10.0 cm to 20.0 cm were measured, fourth plot with the radius 4 m (50.2 m^2) trees with DBH 5.0 cm to 10.0 cm were measured. The innermost circle (with 4 m radius) was also used to measure sapling for regeneration analysis. In the CCSP, the tree positions from plot center were obtained through Bussol Compass and Vertex IV and Transponder T3.

The tree level characteristics like local and scientific names, height, and DBH were collected from each CCSP. The height and DBH of trees (woody plant with single bole >5 cm DBH and >1.3 m height) were measured with help of Vertex IV and Transponder T3 as well as diameter tape respectively. Vertex was calibrated using standard procedure with the help of linear tape before utilizing for measurement. The collected data were recorded in the field data sheet (Annex 1). Percentage canopy cover of the plots were measured with the help of a Spherical Densiometer, 20 m away from the center at four cardinal directions and one at the plot center. The seedling and sapling were measured from four subplots with the radius of 2 m (12.6 m^2) located 10 meters from the plot center of the CCSP in four cardinal directions (Fig.4). Individual seedlings and saplings of different tree species were counted and data were recorded in the already designed field form (Annex 2) and later entered in Microsoft Excel.

Specimens of unidentified plants were collected for herbarium preparation following standard procedure (Bridsons and Forman, 1998). Those plant species were later identified either by using available literatures (Stainton, 1972, Hara *et. al*., 1978, 1982, Hara and Williams, 1979, Polunin and Stainton, 1984, Malla *et al.*, 1986, Stainton, 1988, Press *et al.*, 2000, HMG 1994, Shrestha, 2001a, Sharma, 2014) and comparing with deposited specimens at National Herbarium and Plant Laboratories (KATH). The plant list has been adopted to update recent scientific names (DPR 2010, 2011, 2012). The habit and habitat of these tree were noted along with photographs

3.4 Soil collection

Soil samples were collected from each plot. Litters and debris were removed from the soil surface and samples were collected from five soil pits (15 cm x 15 cm x 5 cm). The pits for soil sample collection were prepared one in each four cardinal directions (north, east, west and south) 20 m far from plot center and one in the plot center of the CCPS (Fig. 4). Those soil samples, 200 gm from each pit were mixed together and packed in a polythene bag. The samples were properly labeled, air-dried to prevent harmful changes (Zobel *et al.*, 1987).

3.5 Vegetation data analysis

Collected data were analyzed to find distribution pattern of trees by calculating frequency, relative frequency, density, relative density, dominance, relative dominance, importance value index, volume and basal area for each tree species following Mueller-Dombois and Ellenberg (1974). The specific results were determined by applying following formulae (Zobel, *et al.*, 1987).

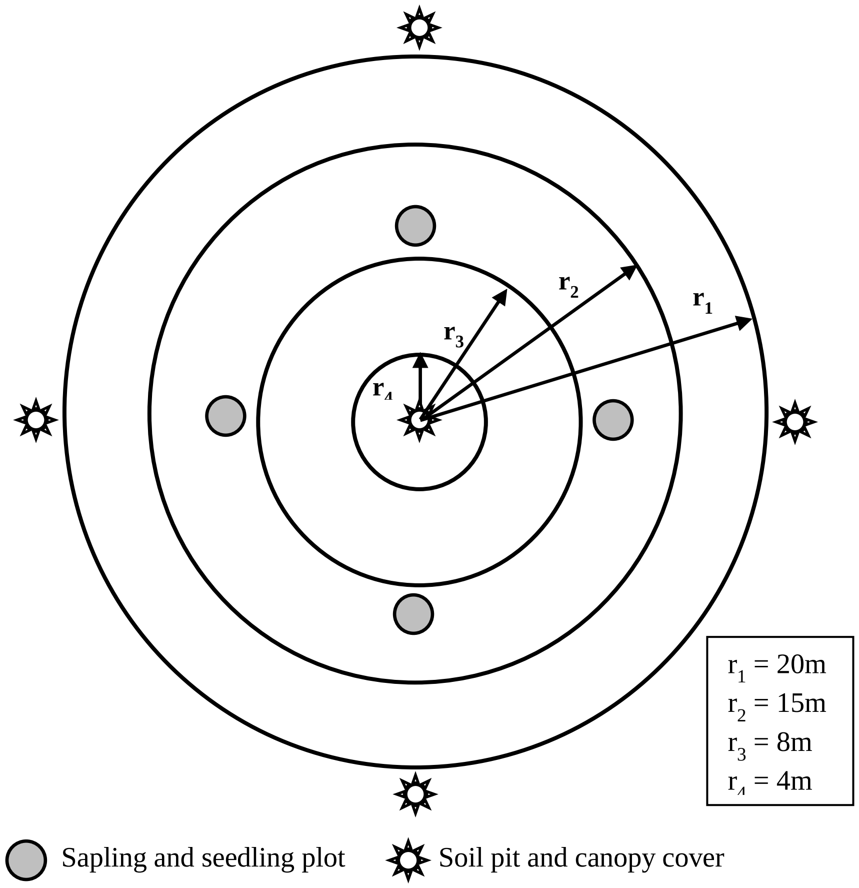


Figure 4. Layout of Concentric Circular Sample Plot

a). <u>Frequency (f)</u>

Frequency is the proportion of sampling units containing the species.

$$f_i = \frac{n_i}{N} * 100$$

Where,

f_i = Frequency of species i

n_i = Number of quadrats in which species i occurred

N = Total number of quadrats studied

b). Relative frequency (Rf)

$$Rf_i = \frac{f_i}{\overline{F}} * 100$$

Where,

Rf_i = Relative frequency

f_i = Frequency of species i

$\overline{F}$ = Sum of frequencies for all species

c). Density (d)

Density is the number of individuals per unit area.

$$d_i = \frac{n_i}{N * A} * 10000$$

Where,

d_i = Density (ha^{-1}) of species i

n_i = Total number of individuals of species i

N = Total number of quadrats studied

A = Area of a quadrat

d). Relative density (Rd)

$$Rd_i = \frac{d_i}{\overline{D}} * 100$$

Where,

Rd_i = Relative density of species i

d_i = Density of species i

$\overline{D}$ = Total density of all species

e). Dominance (do)

Dominance is amount of ground covered by the tree trunk.

$$do_i = \frac{Ba_i}{N * A} * 10000$$

Where,

do_i = Dominance (ha^{-1}) of species i

Ba_i = Total basal/coverage area of species i

N = Total number of quadrats studied

A = Area of a quadrat

f). <u>Relative dominance (Rdo)</u>

$$\text{Rdo}_\text{i} = \frac{do_i}{\overline{Do}} * 100$$

Where,

Rdo_i = Relative dominance of species i

do_i = Dominance/coverage of species i

$\overline{Do}$ = Total dominance/coverage of all species

g). <u>Importance Value Index (IVI)</u>

Name of each forests and shrub land type was determined by ordering the Importance Values of each tree species. Importance Value was obtained by summation of the relative frequency, relative density, and relative dominance.

$$IVI_x = RF_x + RD_x + Rdo_x$$

Where,

IVI_x = Importance Value Index of species x

RF_x = Relative Frequency of species x

RD_x = Relative Density of species x

Rdo_x = Relative Dominance of species x

h). <u>Family Importance Value (FIV)</u>

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

FIV = Relative density + Relative diversity + Relative dominance

Where,

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

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

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

i). Shannon index of diversity was utilized to calculate tree diversity:

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

Where,

H = Shannon index of species diversity

Pi = Proportion of total number of individual of species i

S = Number of species

Evenness was calculated by dividing Shannon-Weiner diversity index with the log value of total number of species found in the area.

j). Sørensen's index of similarity (Sørensen, 1948) was employed to compare similarity between different vegetation types:

$$IS = \frac{2C}{A + B} x100$$

Where,

IS = Index of similarity

A = Total number of species in habitat A

B = Total number of species in habitat B

C = Number of common species in both habitats

k). Maturity index (Pechi-Sermolli, 1948) is an important indicator of more developed plant community of specific area, which was calculated as follows:

$$MI = \frac{\sum f}{n}$$

Where,

MI = Maturity index of the habitat

f = Frequency of individual species in the habitat

n = Number of species in the habitat

3.6 Analysis of carbon sequestration

Amount of carbon stock in tree species was calculated from the above ground biomass of trees. Tree volume was calculated from DBH and height and the above ground biomass was calculated by using allometric equations incorporating DBH, height and wood specific gravity was used from the biomass tables produced by the Government of Nepal and other published papers were used for wood specific gravity for individual tree species (Chave *et al*., 2005, Mandal *et al*., 2013, Sharma *et al*., 2014). Biomass stock density was converted to carbon stock density by multiplying with 0.47 (IPCC, 2006). The steps utilized for the calculation of carbon dioxide sequestered in the tree were as follows.

1. Determine the dry weight of the tree,
2. Determine the weight of carbon in the tree, and
3. Determine the weight of carbon dioxide sequestered in the tree.

To determine the total weight of the tree, primary data were collected for vegetation analysis from were collected from concentric circular sample plots (CCSPs) were used. Detailed about data collection methodology is described under vegetation data collection subheading.

The dry weights of the trees (above ground tree biomass) were analysed by using allometric model. Above ground biomass of trees with DBH ≥5cm was estimated by using allometric equation which include information on trunk diameter at breast height (DBH) in cm, total tree height (H) in m and wood-specific gravity (ρ) in g cm^{-3} (Petersson *et al.*, 2012). Since the climate of the study groves is moist, with 1480 mm average annual rainfall and sub-tropical evergreen forests, the following allometric equation developed by Chave *et al*., (2005) was appropriate to use for the above ground tree biomass analysis (AGTB).

$$AGTB = 0.0509\ \rho\ D^2\ H$$

Where,

AGTB = aboveground tree biomass (kg)

ρ= wood specific gravity (g cm^{-3})

D = tree diameter at breast height (cm)

H = tree height (m)

The wood specific gravity was extracted from equation developed by Sharma and Pukkala (1990) and other published literatures. The biomass stock density (in kg m^{-2}) was calculated by summing up of individual weights (in kg) of a sampling area and dividing it by total sampled area. The value was converted to t ha^{-1} by multiplying it by 10 (Subedi *et al*., 2010).

The biomass stock densities were converted to carbon stock densities (weight of carbon in the tree) by using the IPCC (2006) carbon fraction of 0.47. Root-to-shoot ratio value of 1:5 (20% of AGTB) was used to find below ground biomass (MacDicken, 1997). Total carbon stock density of tree vegetation was calculated by summing up above ground and below ground tree carbon stock density.

Carbon dioxide (CO_2) is composed of one molecule of Carbon and 2 molecules of Oxygen. The atomic weight of Carbon is 12.0 and that of Oxygen is 15.99. The weight of CO_2 is (C + 2 x O) 43.99. The ratio of CO_2 to C is 43.99/12.0=3.67. Therefore, to determine the weight of carbon dioxide sequestered in the tree, the weight of carbon in the tree was multiplied by 3.67.

3.7 Soil analysis

The collected soil samples were analyzed in the lab of Soil Science Division, Nepal Agricultural Research Council (NARC), Khumaltar, Lalitpur. Standard methods were used to measure soil pH (soil: water ratio is 1:2), organic matter content was done by volumetric method, total Nitrogen analysis by Kjeldahl method (1883), available phosphorus by Bray and Kurt (1945) (Year), available potassium by flame photometer method and soil texture by hydrometer method (Bouyoucos, 1962). The analyzed soil samples were categorized in to five categories based on the nutrient values: very low, low, medium, high and very high according to GoN 2010 (Annex 3).

3.8 Analysis of regeneration

On the basis, standard forestry practices, recorded trees from vegetation data collection were divided in three growth classes namely adult, sapling and seedling. In this study the sampled tree species were classified in to five growth forms based on DBH and height (FRS, 1967 and 1973, FRA/DFRS, 2010, 2014):

1. Seedling: Individual having 30 – 100 cm height or <5 cm DBH
2. Sapling: Individual with ≥ 5 – 12.6 cm DBH
3. Pole: Individuals having >12.7 – 27.6 cm DBH
4. Small saw timber: Individual with 27.7 – 53 cm DBH, and
5. Large saw timber: Individual having more than 53 cm DBH

The densities of seedling and saplings were considered as the indicator of regeneration status of respective groves. Regeneration status of tree species was analyzed based on population size of seedlings and sapling (Shankar, 2001, Khumbongmayum *et al*., 2006):

a) Good regeneration: Regeneration status was considered good if the forest (or individual) have more density of seedling than sapling and sapling is more than adult (seedling > sapling > adult).

b) Fair regeneration: For the fairly regenerating forest (or individual) there should be more, equal or less density of seedling than sapling and equal or less number of sapling than adult. Similarly, if density of seedling was greater than the adult, this was also considered as fairly regenerating forest. If the density of seedling was less than or equal to sapling and density of sapling was greater than or equal to adult, this stage was also considered as fair regeneration. In the fairly regenerating forest the density status of individuals in different growth class should be:

- Seedling > or ≤ sapling ≤ adult,
- Seedling > adult, and
- Seedling ≤ sapling ≥ adult

c) Poor regeneration: If forest (or individual) had no seedlings, survived only in the sapling stage and population of saplings may be less, more or equal to adults, this category was considered as poorly regenerating forest.

d) New regeneration: If the forest (or individual) had only saplings and/or seedlings without having adults, this forest (or individual) was considered as newly regenerating forest (or individual).

e) No regeneration: If sapling and seedling stages were absent and only adults were present, this type of forest (or individual) was considered as not regenerating forest (or individual).

3.9 Forest disturbances

Physical conditions of every tallied tree individual within CCSPs were noted in the field form for disturbance categories (Annex 4). The disturbance categories for live trees include healthy, partly broken at the top or were partly dry. The disturbance categories for dead trees included standing dead, completely dry, and fallen (green or dry) by wind-breaks, or other reasons. Disturbances on tree vegetation in each CCSP was assessed by counting the individual tree which was lopped, logged, cut, burnt etc. Besides the disturbance on vegetation, other disturbances like erosion, access track, drain, rubbish dumping, picnic spot, permanent structure, grazing (livestock and wildlife), litter collection, fencing, access road within each CCSP were also assessed.

Disturbance levels were categorized as undisturbed, least disturbed, moderately disturbed and highly disturbed in terms of biomass removal, tree cutting, livestock and wildlife grazing as well as other anthropogenic activities. The degree of disturbance was measured through a disturbance index (DI) based on the percent number of cut, dead or damaged individual trees of associated plant communities (Pandey and Shukla, 2001). 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. For physical disturbances, the level of disturbance was determined as follows (Annex 5) (FRA/DFRS, 2010, 2014):

a) Erosion: The removal of thin layer of top soil was considered as least, formation of finger size gullies was considered as moderate and formation of large gully was considered as high disturbance level.

b) Access track, drain, access road, slashing, grazing and litter collection:
   i. Least disturbed: The affected area due to those disturbances covered <5% area within the CCSP.
   ii. Moderately disturbed: The disturbances affected 5-10% area within CCSP.
   iii. Highly disturbed: The disturbances affected more than 10% area of CCSP.

c) Fence lines and power lines:
   i. Least disturbed: Lines crossing from margin of CCSP.
   ii. Moderately disturbed: Lines crossing within 10% area of CCSP, and
   iii. Highly disturbed: A line crossing from the middle of plot.

d) Rubbish dumping, picnic spot, earth work and water point:
   i. Least disturbed: If those activities were more than 1 m far from CCSP edge
   ii. Moderately disturbed: If the effected portion due to those activities effected inner 1 m portion of CCSP margin, and
   iii. Highly disturbed: If the effected portions due to those disturbances penetrated inner 3 m distance from CCSP edge.

3.10 Analysis of disturbance indices

Indices of each disturbance were calculated by assigning points to disturbance level. For high intensity of disturbances 3 points were assigned, 2 points were assigned for moderate intensity of disturbances, and 1 point was assigned for least intensity of disturbances. Sum of these points of each disturbance categories were considered as diffusion index. The diffusion index was calculated for each CCSP. The total values of each available index in specific CCSP were classified into three groups as: below average, average and above average values. The average disturbance value was considered as the benchmark (Raihan and Haque, 2007). Based on the total score of disturbance indices, each plot was divided into three different categories. The total disturbance scores of each plot, with its probable minimum, maximum and average score was analyzed and interpreted as follows.

1. Least disturb: The plot with disturbance index less than average value,
2. Moderately disturb: Plots with disturbance index equal to the average value, and
3. Highly disturb: The disturbance index of plot with more than average value.

3.11 Statistical analysis

The collected information was analyzed by using Microsoft excel (2007) and Minitab version 16. Secondary data from other research works were also used for analysis. Wherever possible the collected data were analyzed by different statistical tests like standard deviation, means, medians, correlation and significant tests (Johnson and Bhattacharya, 1996). Analysis of Variance was conducted to determine the mean difference between species richness, diversity index, evenness and maturity index (Johnson and Bhattacharya, 1996). Paired *t*-tests were used to compare carbon with species richness, diversity index, evenness, maturity index and crown cover: soil parameters with tree regeneration; drivers of deforestation with tree regeneration (Johnson and Bhattacharya, 1996).

3.12 Local perception

Structured questionnaire survey, direct observation, and review of related document were applied for the assessment of local perception regarding sacred groves.

Structured questionnaires were prepared to collect local perceptions about the role of sacred groves on biodiversity conservation. Before conducting survey the questionnaire was pretested and refined based on the finding of pretest. Survey was conducted with the peoples having different disciplines, ethnicity, age group, and occupations. They included visitors of different age groups, priests, government officials, forest users', and members of forest management committee. Two sets of questionnaires, one set was for local people and visitors and other for management authority, were used to collect local perception (Annex 6).

To interpret general information of the respondents, surveyed questionnaires were categorized into six different groups. They were background/demography, experience/behavior, opinion/belief, knowledge, sentimental, and sensory questions. The following were major topical areas classified in the questionnaire to get the overall impression of informant about sacred grove:

- History of the sacred grove,
- Traditional approaches for the management of sacred grove,
- Difference in management practices for sacred and non-sacred sites,
- Need/importance of sacred groves,
- Influence of ethnicity and user's rights on the management practices,
- Transformation of traditional knowledge of management from one generation to the other,
- Enforcement of regulations, and
- Role and responsibility of government and local communities in the management of the sites.

3.13 Analysis of perception

Based on conceptual understanding about the importance of sacred groves on biodiversity conservation the questionnaires applied for the perception survey were classified into four different sub-groups. The arranged sub-groups of the questionnaires were knowledge about the sacred grove conservation, benefits obtained from sacred grove, management of sacred grove, and suggestions for resolving conservation related problems.

Biodiversity Conservation Confidence Index (BCCI) was applied to assess the local perception on sacred groves. This index was calculated by converting the qualitative answers provided during the questionnaire survey to quantitative data by assigning weighted values to each response. For each positive response, the highest weighted value 2 was assigned for the optimistic response (very good), 1 weighted value was assigned for less optimistic response (good/positive/yes), 0 weighted value was assigned for neutral (don't know) response. In some special cases, weighted value 3 was assigned for most optimistic response. Similarly, for the negative response, -1 weighted value was assigned for negative (no) response, and -2 weighted values were assigned for least optimistic (worst) response. The sum of these assigned weighted values was called as the diffusion index. The diffusion index was calculated for each question (Raihan and Haque, 2007, FNCCI, 2012).

Based on the total score values obtained for the indices, they were classified into three groups. These were – below average, average and above average. The average value was considered as the benchmark (Raihan and Haque, 2007, FNCCI, 2012). It thus follows that if:

BCCI < average, the confidence index is worse,
BCCI = average, the confidence index is unchanged, and
BCCI > average, the confidence index is better.

The results were analyzed and interpreted on these bases. The frequency and percentage of responses of individual questions were calculated. The details steps used for the sampling and weighting strategies were as follows.

1. Frequencies of respondents and options for individual questions were calculated,
2. Percentage of responded answers was calculated,
3. Weighted value was provided for each options and perception score was calculated for each question,
4. Provided weighted value was based on the objective of the research,
5. Biodiversity related options was provided positive values,
6. Total score of each question, with their probable minimum, maximum and average score was calculated, and
7. Interpretations were made by comparing these scores.

CHAPTER 4. RESULTS AND DISCUSSIONS

4.1 Inventory plots

In total, 145 circular plots were inventoried in both sacred groves. The numbers of inventoried plots in PSG were 95 and that of BSG were 50. The area covered by these plots in PSG was 2.48 ha, which was 2.96% of total area of PSG (83.55 ha) and the area covered in BSG by these plots was 1.30 ha, which was 7.1% of total area covered by BSG (18.29 ha) (Tab. 1).

Table 1. Number of plots surveyed in the study areas

Vegetation types	Number of studied circular plots		
	Trees	Seedlings/saplings	Total
Neolitsea cuipala forest (BSG)	10	40	50
Schima-Pyrus forest (PSG)	9	36	45
Myrsine-Persea forest (PSG)	5	20	25
Quercus-Myrsine forest (PSG)	5	20	25
Total	**29**	**116**	**145**

The maximum area covered by the inventoried circular plot was in *Neolitsea cuipala* forest (7.16%) of Bajrabarahi Sacred Grove and minimum was in *Quercus-Myrsine* forest (1.59%) of Pashupati Sacred Grove (Tab. 2).

Table 2. Area covered by plots in different vegetation types

Vegetation types	Total area (ha)	Area covered by plots (ha)	Area covered by plots (%)
Neolitsea cuipala forest (BSG)	18.3	1.3	7.1
Schima-Pyrus forest (PSG)	20.9	1.2	5.6
Myrsine-Persea forest (PSG)	22.5	0.6	2.8
Quercus-Myrsine forest (PSG)	40.1	0.6	1.6
Total	**101.9**	**3.7**	**17.1**

4.2 Phyto-sociology

Phyto-sociology of the tree species in both the sacred groves was analyzed separately by using standard procedures and described accordingly as follows:

4.2.1 Pashupati Sacred Grove

From the phyto-sociologial analysis of tree species, three types of forest were identified from Pashupati Sacred Grove. They were *Schima-Pyrus* forest, *Myrsine-Persea* forest and *Quercus-Myrsine* forest.

A. *Schima-Pyrus* forest

This forest occupied 20.9 ha area and included deer park (4.8 ha) at Mirgasthali. The average tree height of this forest was 15.2 ± 7.8 m with 40.9 ± 18.1cm of average diameter at breast height (DBH). In this forest 14 tree species were recorded with the population of 319 individual trees per ha. The height of tree in this forest was reached up to 35 m (*Araucaria bidwillii)*. *Schima wallichii* was found most important tree (IVI = 81.4) followed by *Pyrus pashia* (IVI = 51.5), *Alnus nepalensis* (IVI = 46.9), and *Persea odoratissima* (IVI = 26.9), respectively in this forest (Tab. 3). The tree canopy cover of this forest was 55%.

Table 3. Tree compositions with their IVI in *Schima-Pyrus* forest

SN	Species	Relative frequency	Relative density	Relative dominance	Importance Value
1	*Schima wallichii*	18.9	38.4	24.1	81.4
2	*Pyrus pashia*	13.5	19.5	18.5	51.5
3	*Alnus nepalensis*	2.7	17.0	27.2	46.9
4	*Persea odoratissima*	13.5	5.3	8.1	26.9
5	*Myrsine capitellata*	13.5	4.2	4.3	21.9
6	*Hymenodictyon excelsum*	2.7	6.9	6.7	16.3
7	*Araucaria bidwillii*	2.7	2.5	4.1	9.3
8	*Zizyphus incurva*	5.4	2.2	1.2	8.8
9	*Quercus glauca*	5.4	1.1	1.7	8.2
10	*Syzygium cumini*	5.4	1.1	1.4	8.0
11	*Stranvaesia nussia*	5.4	0.6	1.3	7.2
12	*Celtis australis*	5.4	0.6	0.9	6.8
13	*Castanopsis tribuloides*	2.7	0.6	0.2	3.5

SN	Species	Relative frequency	Relative density	Relative dominance	Importance Value
14	*Eurya acuminata*	2.7	0.3	0.4	3.4
Total		**100.0**	**100.0**	**100.0**	**300.0**

In this forest, 319 individual trees per hectare were recorded which were belonging to eleven families however, there were variations in the number of species, number of stems, tree diameter, tree height and basal area among the recorded families. Eight families were represented by one species and three families had two species. Based on family importance value (FIV), Theaceae (FIV = 77.4) was the most important family followed by Rosaceae (FIV = 54.0). The dominance of these families in this forest was due to having more population of tree (38.6% in Theaceae and 20.0% in Rosaceae) and basal area (44.2% of total) (Tab. 4).

Table 4. Recorded families with their importance value in *Schima-Pyrus* forest

Family	FIV	No. of species in family	Number of individual ha^{-1}	Basal area m^2/ha
Theaceae	77.4	2	123	10.2
Rosaceae	54.0	2	64	8.2
Betulaceae	51.3	1	54	11.3
Rubiaceae	20.8	1	22	2.8
Lauraceae	20.5	1	17	3.4
Fagaceae	17.9	2	5	0.8
Myrsinaceae	15.6	1	13	1.8
Araucariaceae	13.7	1	8	1.7
Rhamnaceae	10.6	1	7	0.5
Myrtaceae	9.7	1	4	0.6
Ulmaceae	8.6	1	2	0.4
Total	**300.0**	**14**	**319**	**41.5**

B. *Mysrine-Persea* forest

A total of 11 species with the population of 603 individual trees per hectare were recorded from this forest. The geographical area covered by this forest was 22.5 ha. The average tree height recorded from this forest was 11.7 ± 5.0 m with 30.7± 17.3 cm of average DBH. The maximum height of tree recorded from this forest was 25.9 m (*Castanopsis tribuloides*). From the phyto-sociological analysis of this forest, *Myrsine capitellata* (IVI = 142.0) was found more important tree followed by *Persea odoratissima* (IVI = 38.9) (Tab. 5). Tree canopy cover of this forest was 80.96%.

Table 5. Tree compositions with their IVI in *Myrsine-Persea* forest

SN	Species	Relative frequency	Relative density	Relative dominance	Importance Value
1	*Myrsine capitellata*	16.7	62.2	63.1	142.0
2	*Persea odoratissima*	16.7	9.8	12.4	38.9
3	*Schima wallichii*	16.7	5.3	4.0	26.0
4	*Myrsine semiserrata*	4.2	7.7	8.2	20.1
5	*Syzygium cumini*	12.5	3.4	3.4	19.3
6	*Castanopsis tribuloides*	8.3	5.4	3.7	17.4
7	*Quercus glauca*	8.3	0.9	0.8	10.0
8	*Choerospondias axillaris*	4.2	2.9	1.8	8.9
9	*Stranvaesia nussia*	4.2	1.4	1.6	7.2
10	*Pyrus pashia*	4.2	0.6	0.8	5.6
11	*Myrica esculenta*	4.2	0.3	0.3	4.8
Total		**100.0**	**100.0**	**100.0**	**300.0**

In *Mysrine-Persea* forest of PSG a total of 603 individual trees per hectare were recorded at species level belonging to eight families. There were variations in the number of species, number individuals, tree diameter, tree height and basal area among recorded families. Five families were represented by single species and three families by two species. Based on FIV the most important family in this forest was Myrsinaceae (FIV=159.35) followed by Lauraceae (FIV=31.31). They were also dominant in terms of individuals (71.2 % in Myrsinaceae and 12.4 % in Lauraceae) and basal area (79.7% of total) (Tab. 6).

Table 6. Recorded families with their importance value in *Mysrine-Persea* forest

Family	FIV	Number of species	Number of individual ha^{-1}	Basal area m^{-2}
Myrsinaceae	159.4	2	429	50.6
Lauraceae	31.3	1	75	7.1
Fagaceae	28.9	2	27	4.5
Rosaceae	22.6	2	14	1.5
Theaceae	18.4	1	24	3.8
Myrtaceae	15.9	1	21	2.4

Family	FIV	Number of species	Number of individual ha^{-1}	Basal area m^{-2}
Anacardiaceae	13.9	1	11	2.1
Myricaceae	9.7	1	2	0.2
Total	**300.0**	**11**	**603**	**72.3**

C. *Quercus-Myrsine* forest

The study revealed the presence of 5 tree species with the population of 677 individual trees in each hectare of this forest. The geographical area occupied by the forest was 40.1 ha. The average height of tree was 12.6 ± 5.1 m with 28.5± 13.7cm of average DBH. The maximum height of tree in this forest was 28 m (*Schima wallichii*). Based on the analyzed IVI, the more important tree of this forest was *Quercus glauca* (IVI = 138.5) followed by *Myrsine capitellata* (IVI = 56.2) (Tab. 7). Canopy coverage of the trees in this forest was 85.8%.

Table 7. Tree compositions with their IVI in *Quercus-Myrsine* forest

SN	Species	Relative frequency	Relative density	Relative dominance	Importance Value
1	*Quercus glauca*	25.0	56.6	56.9	138.5
2	*Myrsine capitellata*	25.0	14.6	16.6	56.2
3	*Schima wallichii*	25.0	15.5	14.4	54.9
4	*Syzygium cumini*	20.0	12.7	11.6	44.3
5	*Persea odoratissima*	5.0	0.7	0.6	6.3
Total		**100.0**	**100.0**	**100.0**	**300.0**

In this forest, 677 individual trees species per hectare belonging to five families were identified. All families were represented by single species. The most important family was Fagaceae (FIV=133.4) followed by Myrsinaceae (FIV=51.1). These families were also dominant in terms of individual (71.1%) and basal area (73.4%) (Tab. 8).

Table 8. Recorded families with their importance value in *Quercus-Myrsine* forest

Family	FIV	Number of species	Number of individual ha^{-1}	Basal area m^{-2}
Fagaceae	133.4	1	383	48.3
Myrsinaceae	51.1	1	99	14.1
Theaceae	49.9	1	105	12.2
Myrtaceae	44.3	1	86	9.9

Family	FIV	Number of species	Number of individual ha^{-1}	Basal area m^{-2}
Lauraceae	21.3	1	5	0.5
Total	**300.0**	**5**	**677**	**85.0**

4.2.2 Bajrabarahi Sacred Grove

A. *Neolitsea cuipala* forest

From the phyto-sociological analysis, only one forest type *Neolitsea cuipala* was recognized in the BSG. The forest was dominated by *Neolitsea cuipala* having highest IVI (111.3) followed by *Castanopsis indica (*IVI=36.9) (Tab. 9). In this forest 18 tree species with 432 individual trees per hectare were recorded. The geographical area covered by this forest was 18.29 ha. Among the recorded tree species *Schima wallichii* reached maximum height (35 m) and the maximum DBH (111 cm). The average tree height in this forest was 18.6±12.7 m and the average DBH of tree was 36.6 ±19.44 cm. The canopy cover of this grove was 90.8%.

Table 9. Tree compositions with their IVI in *Neolitsea cuipala* forest

SN	Tree species	Relative frequency	Relative density	Relative dominance	Importance Value
1	*Neolitsea cuipala*	16.4	51.5	43.4	111.3
2	*Castanopsis indica*	14.8	9.6	12.5	36.9
3	*Choerospondias axillaris*	11.5	10.7	13.1	35.3
4	*Schima wallichii*	11.5	3.9	8.3	23.7
5	*Myrsine capitellata*	6.6	6.3	5.6	18.5
6	*Castanopsis tribuloides*	8.2	3.7	3.3	15.1
7	*Cassia fistula*	3.3	4.1	4.3	11.6
8	*Areca catechu*	5	2.0	1.8	8.8
9	*Albizia julibrissin*	5	1.3	0.7	7.0
10	*Syzygium cumini*	4.9	0.9	1.0	6.8
11	*Hymenodictyon excelsum*	1.6	2.4	2.4	6.4
12	*Myrsine semiserrata*	1.6	1.3	1.4	4.3
13	*Rhus succedanea*	1.6	1.3	1.2	4.1
14	*Myrica esculenta*	1.6	0.4	0.5	2.4
15	*Sapium insigne*	1.6	0.2	0.2	2.0
16	*Celtis australis*	1.6	0.2	0.2	2.0
17	*Persea odoratissima*	1.6	0.2	0.2	1.9
18	*Albizia lebbeck*	1.6	0.2	0.1	1.9
Total		**100.0**	**100.0**	**100.0**	**300.0**

In BSG, 432 ha^{-1} trees were recorded within 12 families. There were variations in the number of species, individual trees, tree DBH, tree height and basal area among families. The forest comprised seven families 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 important families in this forest. These families were also dominant in terms of number of individual trees (51.7% in Lauraceae and 13.3% in Fagaceae) and basal area (43.7% and 16% respectively) (Tab. 10).

Table 10. Recorded families with their importance value in *Neolitsea cuipala* forest

Family	FIV	Number of species	Number of individual ha^{-1}	Basal area m^2
Lauraceae	106.3	2	222	26.2
Fagaceae	40.2	2	57	9.5
Anacardiaceae	37.4	2	52	8.6
Leguminosae	27.3	3	24	3.1
Myrsinaceae	25.7	2	33	4.2
Theaceae	17.8	1	17	5.0
Rubiaceae	10.3	1	10	1.4
Palmae	9.3	1	9	1.1
Myrtaceae	7.5	1	4	0.6
Myricaceae	6.4	1	2	0.3
Eurphorbiaceae	6.0	1	1	0.1
Ulmaceae	5.8	1	1	0.1
Total	**300.0**	**18**	**432**	**60.1**

4.3 Forest status

In BSG, 18 species of trees with the density of 432 $ha^{-1\ stem}$ were recorded. In PSG 17 tree species with density of 533 ha^{-1} stems were recorded. Complete list of seedling, sapling and adult tree species of PSG and BSG is given in annex 9. Only one type of forest *Neolitsea cuipala* was identified in BSG, whereas in PSG three types forest were namely *Schima-Pyrus*, *Myrsine-Persea* and *Quercus-Myrsine* were recorded based on IVI value. In BSG trees belonging to 12 families were recorded and there were13 families in PSG. Both groves shared nine common families and ten common tree species. The common families were Anacardiaceae, Rubiaceae, Theaceae, Myrtaceae, Myricaceae, Myrsinaceae, Fagaceae, Lauraceae and Ulmaceae. Similarly, the common tree species were *Schima wallichii*, *Syzygium cumini*, *Myrica esculenta*, *Myrsine semiserrata, Choerospondias axillaris, Castanopsis tribuloides, Myrsine capitellata, Persea odoratissima, Celtis australis* and *Hymenodictyon excelsum*. From the index of similarity (IS), more than 72% of families and 57% of tree species were found to be similar in both groves. The maturity indices (MI) indicated that BSG incorporated more developed forest community (MI = 33.9) than that of PSG (MI = 26.0). The BSG incorporated less number of stems per hectare (n=432) with higher crown cover (90.8%) than that of PSG (Tab. 11, Fig.5).

Table 11. Tree characteristics of the study areas

Characteristics/ Parameters	Bajrabarahi SG	Pashupati SG
Average tree height (m)	18.6±12.7	13.3±6.3
Average DBH (cm)	36.6±19.4	33.6±17.4
Tree density (number/ha)	432	533
Number of forest type	1	3
Shannon-Weiner Diversity Index	1.80	1.91
Evenness	0.62	0.67

The Shannon-Weiner species diversity indexes were 1.80 and 1.91 for BSG and PSG, respectively. This indicated that PSG was most diverse than BSG**.** Similarly, Evenness value indicated that tree species of PSG (0.67) were more evenly distributed than that of BSG (0.62).

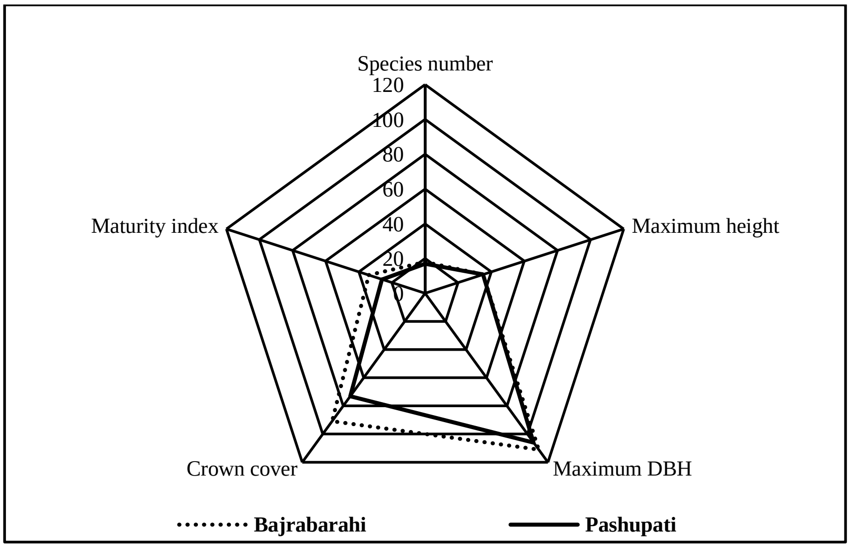


Figure 5. Tree characteristics of the study areas

4.4 Assessment of Carbon

Total numbers of studied plots for the primary productivity assessment of trees were 19 in PSG and 10 in BSG. Details about the circular plots are given in table 6. The area covered by these circular plots in PSG was 2.39 ha, which was 2.9% of total area covered by PSG (83.55 ha). The area covered by these CCSPs in BSG was 1.26 ha, which was 6.9% of its total area (18.29 ha). In PSG three types of forest namely *Schima-Pyrus, Mysrine-Persea* and *Quercus-Myrsine* were recorded, whereas only one type of forest *Neolitsea cuipala* was identified in BSG. Area covered by those CCSPs was highest in *Neolitsea cuipala* forest followed by *Schima-Pyrus, Mysrine-Persea* and *Quercus-Myrsine* forests respectively (Tab. 12).

Table 12. Number of CCSPs studied and area covered by the plots in different forest types

Forest types	**Sacred grove**	**Number of plots studied**	**Area covered by plot (ha)**	**Area covered (%)**
Schima-Pyrus forest	PSG	9	1.1	5.5
Myrsine-Persea forest	PSG	5	0.6	2.8
Quercus-Myrsine forest	PSG	5	0.6	1.5
Neolitsea cuipala forest	BSG	10	1.3	6.9
Total		**29**	**3.6**	**15.7**

Among different carbon pools of forest, the study analyzed the carbon stock of standing trees only. The leakage of the carbon was not incorporated in the result due to the absence of proper data and records of dead wood and cut stumps. The details of the amount of carbon stock present in trees of different forest types of PSG and BSG is calculated and presented as follows:

4.4.1 Schima-Pyrus forest

In this forest *Schima wallichii* was found most important tree (IVI=81.4) followed by *Pyrus pashia* (IVI = 51.5) (Tab. 3). There were 14 species of trees with the population of 319 individuals per hectare (Tab. 4). Average tree height of this forest was 15.2 ±7.8 m with an average DBH of 40.9 ±18.1cm. Average carbon stock of each species of tree in this forest was 5.45 t ha^{-1}. Total carbon stock of this forest was 1595.75 t of carbon and highest carbon stock was recorded in *Schima wallichi* (51.68 t ha^{-1}) tree followed by *Persea odoratissima* (10.41 t ha^{-1}) and *Araucaria bidwillii* (3.59 t ha^{-1}). The total carbon dioxide assimilated by this forest was 5.86 mt (Tab. 13).

Table 13. Carbon stock in tree species of *Schima-Pyrus* forest

Species	Total carbon (t ha^{-1})	Total carbon (t)	Total CO_2 (mt)
Schima wallichii	51.68	1080.08	3.96
Persea odoratissima	10.41	217.48	0.8
Araucaria bidwilli	3.59	74.95	0.28
Quercus glauca	2.28	47.58	0.17
Pyrus pashia	2.24	46.79	0.17
Celtis australis	2.02	42.18	0.15
Syzygium cumini	1.94	40.53	0.15
Myrsine capitellata	0.96	20.17	0.07
Stranvaesia nussia	0.36	7.44	0.03
Alnus nepalensis	0.34	7.1	0.03
Zizyphus incurva	0.22	4.55	0.02
Hymenodictyon excelsum	0.12	2.61	0.01
Eurya acuminata	0.11	2.39	0.01
Castanopsis tribuloides	0.09	1.9	0.01
Total	**76.35**	**1595.75**	**5.86**

4.4.2 Myrsine-Persea forest

The more dominant tree of this forest was *Myrsine capitellata* (IVI =142.0) followed by *Persea odoratissima* (IVI =38.9) (Tab. 5). Eleven tree species were found in this forest with their average height and DBH as 11.7 ± 5.0 m with 30.7 ± 17.3 cm, respectively. This forest includes 603 individual trees per hectare (Tab. 6). Total carbon stock of the trees species in this forest was 1457.33 t. The average carbon stock of each tree species in this forest was 5.89 t ha^{-1}. In this forest, highest carbon stock was recorded in *Schima wallichi* (18.27 t ha^{-1}) species followed by *Myrsine capitellata* (10.81 t ha^{-1}). Total carbon dioxide assimilated in this forest was 5.35 mt (Tab. 14).

Table 14. Carbon stock in tree species of *Myrsine-Persea* forest

Species	Total carbon (t ha^{-1})	Total carbon (t)	Total CO_2 (mt)
Schima wallichii (DC.)	18.27	411.21	1.50
Myrsine capitellata	10.81	243.42	0.89
Persea odoratissima	10.09	227.21	0.83
Syzygium cumini	8.92	200.85	0.73
Castanopsis tribuloides	7.11	160.03	0.58
Choreospondias axilaris	3.28	74.01	0.27
Quercus glauca	1.96	44.22	0.16
Stranvaesia nussia	1.53	34.44	0.12
Myrica esculenta	1.20	27.07	0.09
Pyrus pashia	1.11	25.15	0.09
Myrsine semiserrata	0.42	9.66	0.03
Total	**64.77**	**1457.33**	**5.35**

4.4.3 Quercus-Myrsine forest

The more dominant tree species of this forest was *Quercus glauca* (IVI =138.5) followed by *Myrsine capitellata* (IVI =56.2) (Tab. 7). In this forest five tree species were recorded with their average height and DBH as 12.6±5.1 m and 28.5±13.7 cm, respectively. The number of stems reported from this forest was 677 individuals per hectare (Tab. 8). The average carbon stock in the tree was found 15.51 t ha^{-1}. Total carbon stock of the tree species in this forest was 3110.46 t. The highest carbon stock was recorded in the tree species of *Schima wallichi* (41.82 t ha^{-1}) followed by *Quercus glauca* (16.37 t ha^{-1}). Total carbon dioxide assimilated by the tree species of this forest was 11.42 mt (Tab. 15).

Table 15. Carbon stock in tree species of *Quercus-Myrsine* forest

Species	Total carbon (t ha^{-1})	Total carbon (t)	Total CO_2 (mt)
Schima wallichii	41.82	1676.80	6.15
Quercus glauca	16.37	656.26	2.41
Persea odoratissima	11.22	449.83	1.65
Myrsine capitellata	7.12	285.48	1.05
Syzium cumini	1.05	42.10	0.15
Total	**77.57**	**3110.46**	**11.42**

4.4.4 Neolitsea cuipala forest

Eighteen tree species were recorded from this forest and among them *Neolitsea cuipala* was a dominant tree (IVI=111.3) followed by *Castanopsis indica* (IVI=36.9) (Tab. 9). The average height and DBH of the reported trees in this forest was 18.6±12.7 m and 36.6±19.44 cm respectively. This forest had 432 individual trees per hectare (Tab. 10). Total carbon stock of tree species recorded in this forest was 143.37 t ha^{-1} with the average carbon stock of each tree species was 7.96 t ha^{-1}. The highest carbon stock was recorded in the tree species of *Neolitsea cuipala* (49.71 t ha^{-1}) followed by *Castanopsis indica* (31.29 t ha^{-1}). Total carbon dioxide assimilated in this forest was 9.62 mt (Tab. 16).

Table 16. Carbon stock in tree species of *Neolitsea cuipala* forest

Species	Total carbon (t ha^{-1})	Total (t)	Total CO_2 (mt)
Neolitsea cuipala	49.71	909.12	3.34
Castanopsis indica	31.29	572.22	2.10
Schima wallichii	27.02	494.25	1.81
Choerospondias axillaris	13.74	251.38	0.92
Castanopsis tribuloides	5.37	98.13	0.36
Cassia fistula	3.45	63.13	0.23
Syzygium cumini	2.96	54.15	0.20
Myrsine capitellata	2.03	37.17	0.14
Myrica esculenta	1.75	31.93	0.12
Areca catechu	1.24	22.76	0.08
Albizia julibrissin	0.90	16.54	0.06
Myrsine semiserrata	0.73	13.37	0.05
Rhus succedanea	0.64	11.72	0.04
Sapium insigne	0.57	10.50	0.04
Celtis australis	0.54	9.86	0.04
Persea odoratissima	0.52	9.45	0.03
Hymenodictyon excelsum	0.48	8.81	0.03
Albizia lebbeck	0.43	7.78	0.03
Total	**143.37**	**2622.28**	**9.62**

4.5 Carbon stock

The total carbon stock in *Neolitsea cuipala*, *Quercus-Myrsine*, *Schima-Pyrus and Myrsine-Persea*, was 143.37 t, 77.57 t, 76.35 t and 64.77 t ha^{-1}respectively. There was variation in total carbon stock in different forest types of BSG and PSG. The highest quantity of carbon stock was recorded in *Neolitsea cuipala* forest (143.37 t ha^{-1}) and the lowest carbon stock was in *Myrsine-Persea* forest (64.77 t ha^{-1}).

It has been found that the total average carbon stock in tree species of PSG and BSG together was 1014.23 t. The highest amount of average carbon stock (622.09 t) was found in *Quercus-Myrsine* forest followed by *Neolitsea cuipala* (145.68 t) forest. The lowest Carbon stock was recorded from *Schima-Pyrus* forest, 113.98 t (Tab. 17).

Table 17. Carbon stock in the tree species of different forests

Forest type	**Carbon stock (t)**
Quercus-Myrsine forest (PSG)	622.09
Neolitsea cuipala forest (BSG)	145.68
Myrsine-Persea forest (PSG)	132.48
Schima-Pyrus forest (PSG)	113.98
Total	**1014.23**

It was found that the trees species of PSG and BSG were assimilating 3.7 mt of average carbon dioxide. The highest amount of carbon dioxide was found in *Quercus-Myrsine* forest (2.28 mt). The lowest carbon dioxide was found in *Schima-Pyrus* forest (0.42 mt) (Fig. 6).

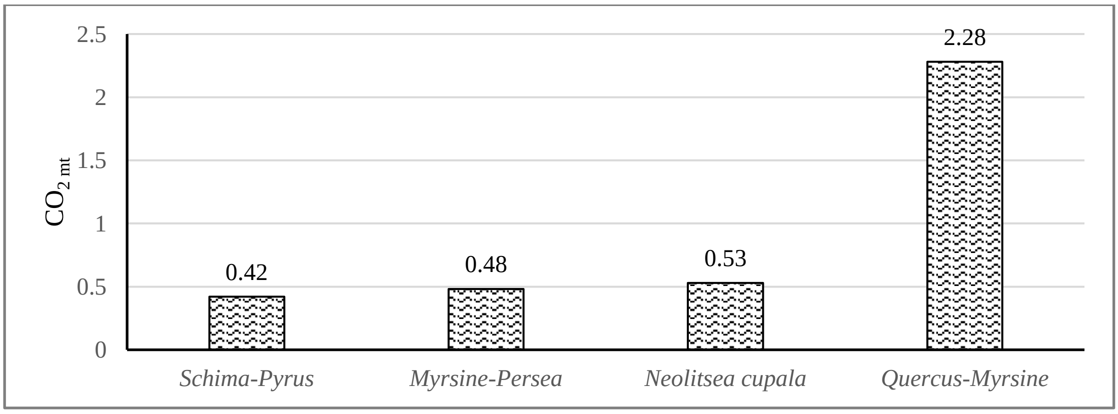


Figure 6. Total amount of carbon dioxide accommodated by trees in different forests

4.6 Species richness and carbon stock

In *Neolitsea cuipala* forest of BSG, the number of tree species was highest (n=18) and amount of carbon stock (143.37 t ha^{-1}) was also highest in comparison to other forest types of PSG. In *Quercus-Myrsine* forest of PSG the carbon stock was 77.57 t ha^{-1} and the number of tree species was found lowest (n=5). The lowest carbon stock was recorded from *Myrsine-Persea* forest (64.77 t ha^{-1}) whereas the tree species richness was high (n=11). In *Schima-Pyrus* forest the number of tree species was 14 and the carbon stock recorded was 76.35 t ha^{-1} (Tab. 18). There is strong positive correlation (r = 0.69) between number of species and carbon stock. The available number of tree species significantly affect the carbon stock of the forest of study area (t=4.88, p<0.05, df=6).

Table 18. Species richness and carbon stock in different forest types of the study area

Forest types	No. of species	Carbon stock (t ha^{-1})
Neolitsea cuipala forest (BSG)	18	143.37
Quercus-Myrsine forest (PSG)	5	77.57
Schima-Pyrus forest (PSG)	14	76.35
Myrsine-Persea forest (PSG)	11	64.77

4.7 Diversity, evenness and carbon stock

In both the studied sites *Schima-Pyrus* forest was found more diverse than other forest types. In this forest Shannon-Winner diversity index was found highest (1.84) but carbon stock was low (76.35 t ha^{-1}) in comparison to other forest types. In *Quercus-Myrsine* forest carbon stock was 77.57 t ha^{-1} and the diversity index was found lowest (1.19). In *Neolitsea cuipala* forest the carbon stock was highest (143 t ha^{-1}) and diversity index was 1.80. Similarly, in *Myrsine-Persea* forest carbon stock was lowest (64.77 t ha^{-1}) and diversity index was 1.35 (Tab. 19). There was significant effect of diversity index in carbon stock of the forest in the study area (t=5.01, p<0.05, df=6).

Evenness value indicates that the available tree species in *Quercus-Myrsine* forest were more evenly distributed (0.74) than other forest types. The carbon stock found was 77.57 t ha^{-1} in this forest. On the other hand, tree species in *Myrsine-Persea* forest were least evenly distributed (0.56) and carbon stock was found low (64.77 t ha^{-1}). In *Schima-Pyrus* forest the carbon stock found was 76.35 t ha-^{1} with high evenness value (0.70). In *Neolitsea cuipala* forest the carbon stock was found highest (143.37 t ha^{-1}) and evenness was 0.62 (Tab. 19). The evenness of tree species significantly affect the available carbon stock of the forest in the study area (t = 5.03, $p<0.05$, df=6).

Table 19. Diversity, evenness and carbon stock in different forest types of the study area

Foresttype	Shannon-diversity	Evenness	Carbon stock (t ha-^{1})
Neolitsea cuipala	1.80	0.62	143.37
Quercus-Myrsine	1.19	0.74	77.57
Schima-Pyrus	1.84	0.70	76.35
Myrsine-Persea	1.35	0.56	64.77

4.8 Maturity, canopy cover and carbon stock

The carbon stock (143.37 t ha^{-1}) and canopy coverage (90.8%) was found highest in *Neolitsea cuipala* forest compared to the other forests of the study area. Maturity index of *Quercus-Myrsine* forest was found highest (80.0) with carbon stock 77.56 t ha^{-1}. Similarly, the maturity index of *Schima-Pyrus* forest was found lowest (29.4) with 76.35 t ha^{-1} carbon stock. The maturity indices in *Myrsine-Persea* and *Neolitsea cuipala* forests were 43.6 and 33.9 with their carbon stocks 64.77 t ha^{-1} and 143.37 t ha^{-1} respectively (Tab. 20). There was negative correlation (r = - 0.32) between maturity index and carbon stock, but there was positive correlation (r = 0.48) between carbon stock and canopy cover. There were no significant effects of maturity index (t = 1.82, p<0.05, df = 6) and canopy cover (t=0.79, $p<0.05$, df=6) in tree carbon stock of the study sites.

Table 20. Carbon stock, maturity index and canopy cover in different forest types of the study area

Forest types	Canopy cover (%)	Maturity index	Carbon stock (t ha^{-1})
Neolitsea cuipala forest	90.80	33.9	143.37
Quercus-Myrsine forest	85.80	80.0	77.57
Schima-Pyrus forest	55.00	29.4	76.35
Myrsine-Persea forest	80.96	43.6	64.77

4.9 Forest regeneration, soil parameters and threats

The regeneration study in the study area recognized both good (PSG) and fair (BSG) regeneration status. The disturbances which have adversely affected on the regeneration of tree species in both sacred groves were freshly cut trees, dead or rotten trees, coppice re-growth, erosion, access tracks, rubbish dumping, picnic spot, cemetery, sport activities, livestock grazing, wildlife grazing, water collection point, earth work, fence lines, and construction of permanent structures like buildings as well as toilets. Based on disturbance indices, the disturbance status of sacred groves was recognized as undisturbed, least disturbed, moderately disturbed and highly disturbed. The physical and chemical natures of soil which may help on the regeneration of tree species were also analyzed. The general condition of soil was acidic in both groves; the nitrogen content was low in PSG and medium in BSG. The organic matter was in medium range and potassium and phosphorus were very high in both groves. The details of the findings were described below.

4.9.1 Pashupati Sacred Grove

4.9.1.1 Disturbances

The identified disturbances in PSG were freshly cut trees, dead or rotten trees, coppice re-growth, erosion, access track, rubbish dumping, picnic spot, cemetery, sport activities (badminton court), livestock and wildlife grazing, water point, earth work, fence lines, construction of permanent structures like buildings as well as army camp (Fig. 7). Among the total 19 studied plots, 42% were found least disturbed, 37% were highly disturbed and 21% were found moderately disturbed (Fig.8).

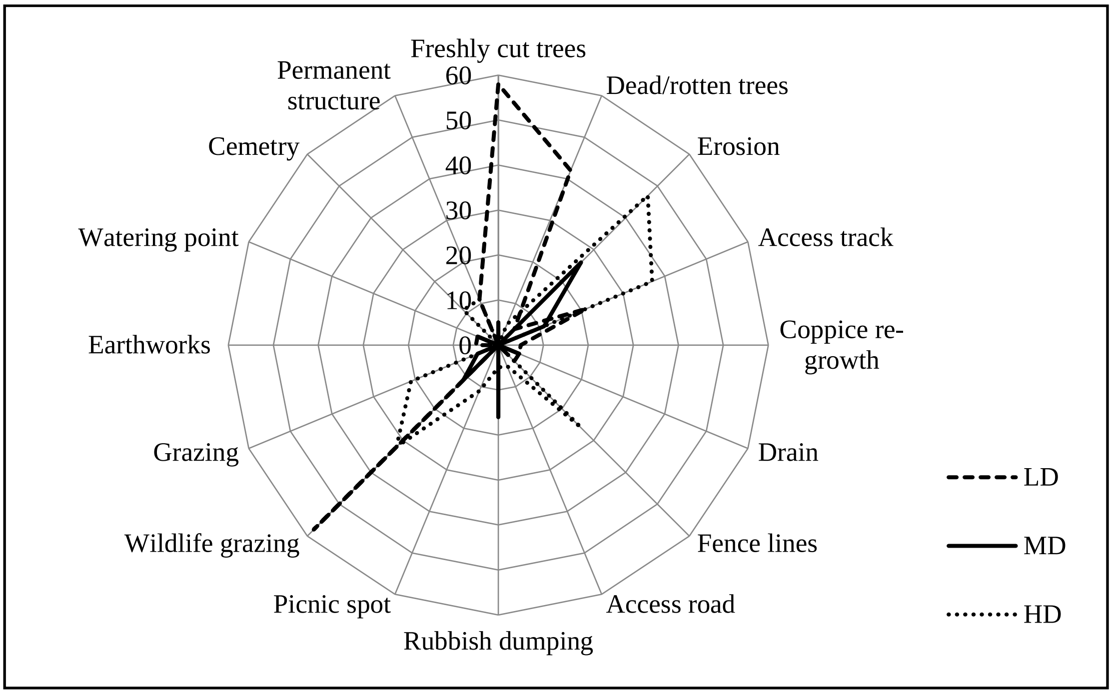


Figure 7. Disturbances studied in PSG (LD – least disturbed, MD – moderately disturbed, HD – highly disturbed).

In the least disturbed plots of PSG, numbers of seedlings were 2,089 ha^{-1}, saplings were 298 ha^{-1} and adult trees were 240 ha^{-1}, which showed good regeneration status. In moderately disturbed plots the numbers of seedlings were 398 ha^{-1}, saplings were 311 ha^{-1} and adults were 237 ha^{-1}, which showed good regeneration. In highly disturbed plots the numbers of seedlings were 28 ha^{-1}, saplings were 169 ha^{-1} and adults were 212 ha^{-1}, with poor regeneration status (Tab. 21). In the study area, there was significant effect of disturbances in tree regeneration (t = 1.82, $p<0.05$, df = 18).

Table 21. Regeneration status of forest in PSG

Disturbance Status	Seedling ha^{-1}	Sapling ha^{-1}	Tree ha^{-1}	Regeneration status
Least disturbed	2089	298	240	Good
Moderately disturbed	398	311	237	Good
Highly disturbed	28	169	212	Poor

There were three types of forest based on the dominance of tree species in PSG, namely *Schima-Pyrus, Myrsine-Persea* and *Quercus-Myrsine*. In *Schima-Pyrus* forest 11% plots were found moderately disturbed, 44% plots were found highly disturbed, and 45% plots were found least disturbed. Similarly, in *Myrsine-Persea* forest 40% plots were identified as moderately disturbed and 60% plots were identified as highly disturbed. In *Quercus-Myrsine* forest 20% plots were found moderately disturbed and 80% plots were found least disturbed.

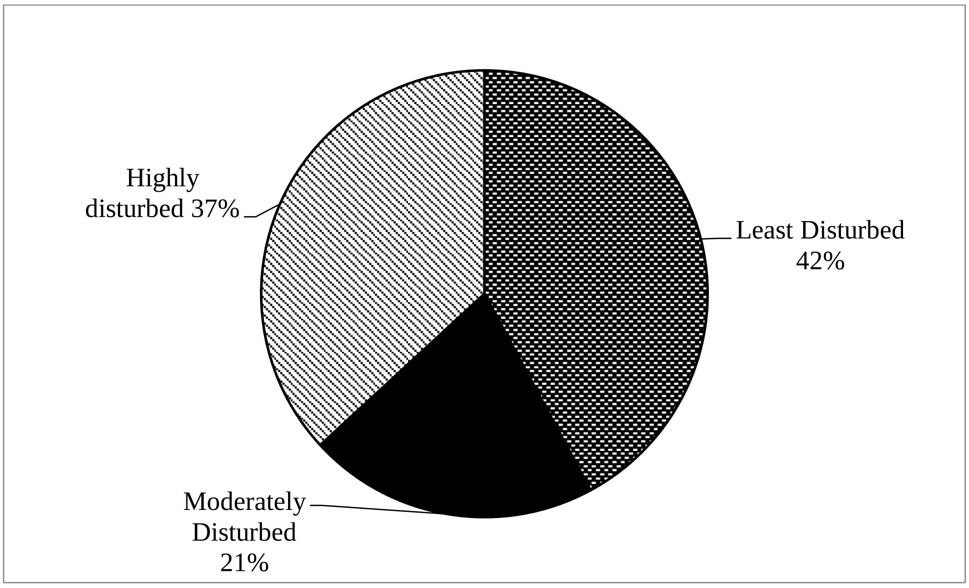


Figure 8. Disturbance status of PSG

4.9.1.2 Forest regeneration

In PSG, the number of seedling per hectare was greater than that of the sapling and tree and there were equal number of saplings and trees individuals per hectare. So, the status of tree regeneration in Pashupati sacred grove was good (Fig.9).

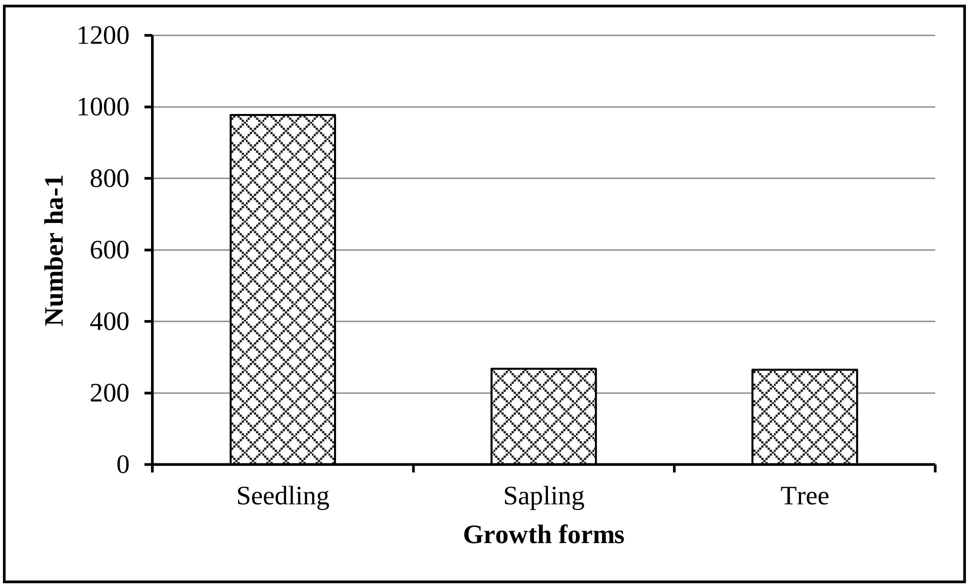


Figure 9. Regeneration status of tree species in PSG

The regeneration status of tree species in the Pashupati sacred grove were found good in 10%, fair in 21%, poor in 37% and not regenerating in 32% of the area (Fig. 10).

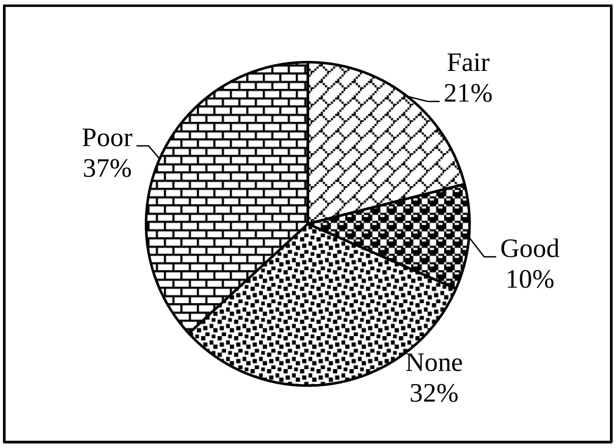


Figure 10. Regeneration status of trees in Pashupati Sacred Grove

Out of recorded 23 tree species in PSG, two species showed good, seven species showed fair, three species showed poor regeneration, and three species were not regenerating at all. Similarly, eight species of the recorded tree species were found as new (Fig. 11).

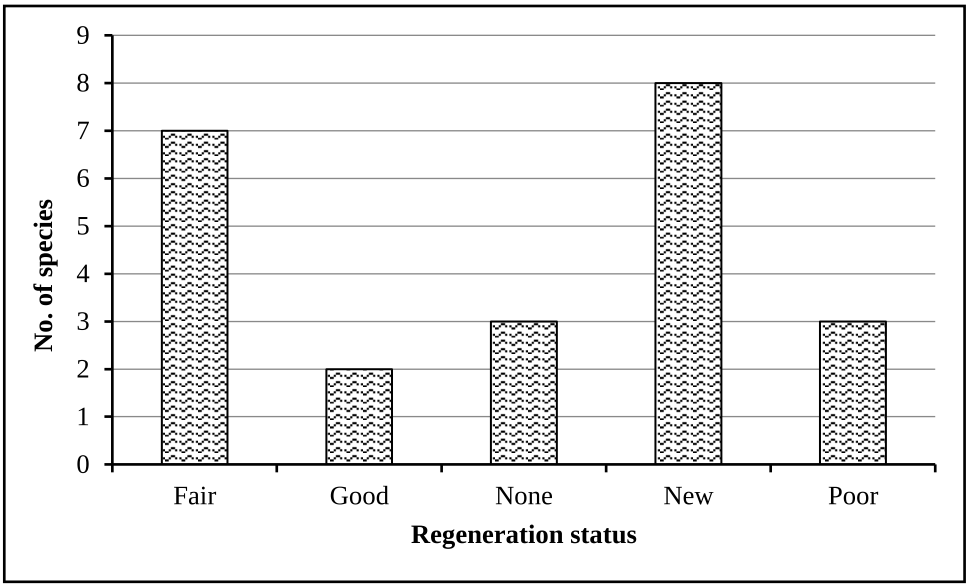


Figure 11. Regeneration statuses of tree species in PSG

Regeneration of two species of trees, namely *Myrsine capitellata* and *Pyrus pashia* was found good, seven species of trees were fairly regenerating, three species of trees were poorly regenerating, three species of trees were not regenerating and eight species trees were newly arising at seedling and sapling stages (Tab. 22). The regeneration status of the tree was good in *Schima-Pyrus* forest. There was fair regeneration of tree species in *Myrsine-Persea* and *Quercus-Myrsine* forests of PSG.

Table 22. Regeneration statuses of tree species in PSG

SN	Name of tree species	Seedling ha^{-1}	Sapling ha^{-1}	Tree ha^{-1}	Status
1	*Choerospondias axillaris*	0	3	1	Poor
2	*Araucaria bidwillii*	0	0	3	None
3	*Alnus nepalensis*	0	41	0	New
4	*Betula alnoides*	13	0	0	New
5	*Castanopsis tribuloides*	0	0	8	None
6	*Quercus glauca*	13	0	31	fair
7	*Juglans regia*	66	0	0	New
8	*Litsea lanceifolia*	199	0	0	New
9	*Persea odoratissima*	87	20	46	Fair
10	*Morus serrata*	15	0	0	New
11	*Myrica esculenta*	0	0	1	None
12	*Myrsine capitellata*	273	163	96	Good
13	*Myrsine semiserrata*	0	13	3	Poor
14	*Syzygium cumini*	13	0	10	Fair
15	*Fraxinus floribunda*	27	0	0	New
16	*Zizyphus incurva*	0	2	1	Poor
17	*Prunus cerasoides*	13	0	0	New
18	*Pyrus pashia*	75	16	5	Good
19	*Stranvaesia nussia*	15	0	3	Fair
20	*Hymenodictyon excelsum*	0	7	0	New
21	*Eurya acuminata*	40	0	1	Fair
22	*Schima wallichii*	99	3	55	Fair
23	*Celtis australis*	29	0	1	Fair
Total		**977**	**268**	**265**	**Good**

Among the studied plots of PSG, seedling of tree species was found highest in plot number 5 (11,346 individual ha^{-1}) in *Schima-Pyrus* forest with good regeneration status followed by plot number 29 (2,386 individual ha^{-1}) in *Quercus-Myrsine* forest with fair state of regeneration. The highest number of saplings was recorded from plot number 5 (1,543 individual ha^{-1}) followed by plot number 24 (947 individuals' ha^{-1}) which was fair stage in regeneration (Annex 7). Similarly, the highest number of adult trees were recorded in plot number 29 (660 ha^{-1}) with fair regeneration followed by plot number 20 (557 ha^{-1}) with poor regeneration status.

A. *Schima-Pyrus* forest

In *Schima-Pyrus* forest of PSG total of 16 species of trees were recorded. This forest was in good status of regeneration. Among 16 recorded tree species, one species showed good, five species fair, one species poor and five species lacked regeneration (Fig. 12). Four new tree species were regenerating, two species of these were recorded in seedling layer (*Morus serrate* and *Litsea lanceifolia*) and two species were recorded in sapling layer (*Hymenodictyon excelsum* and *Alnus nepalensis.* Only six tree species showed good to fair regeneration. The dominant tree species of this forest, *Schima wallichii* showed fair regeneration, but this species was absent in the sapling layer. In this forest *Pyrus pashia* showed good regeneration status. *Zizyphus incurva* was poorly regenerated species and other five tree species *Eurya acuminata, Syzygium cumini*, *Araucaria bidwillii*, *Castanopsis tribuloides* and *Quercus glauca* were not regenerating. The absence of saplings growing stage of *Schima wallichii* and other species in this forest was mainly due to the disturbances like the deer park (DI=3), heavy wild life grazing (DI=3), and access tracks (DI=3) and erosion (DI=3).

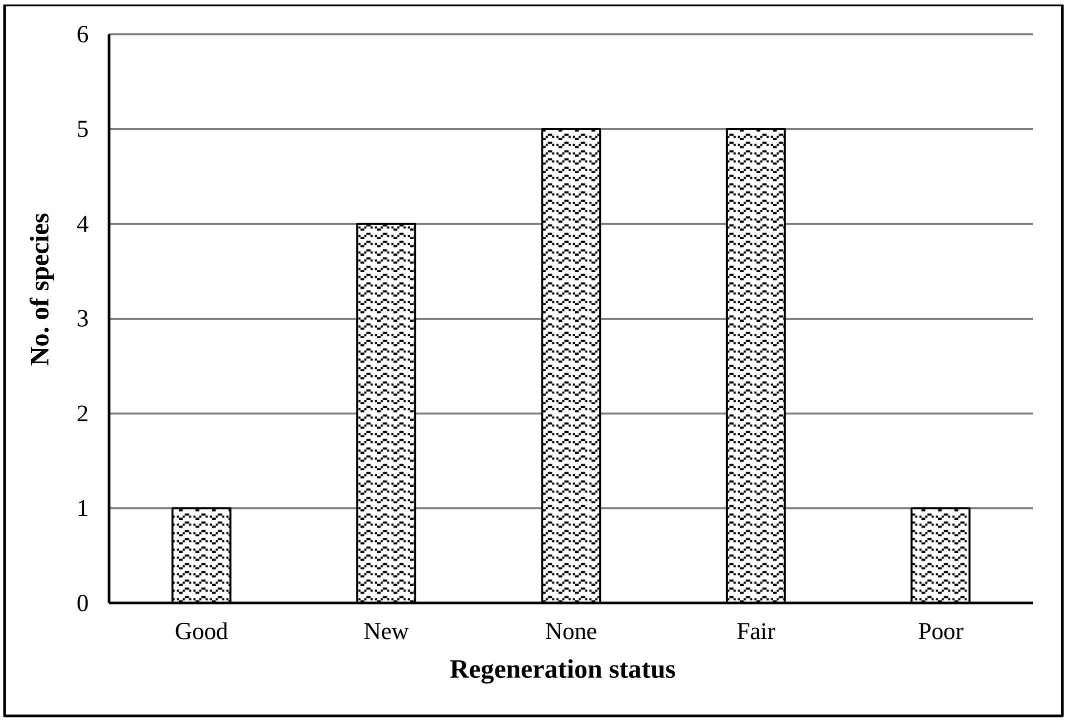


Figure 12. Regeneration statuses of tree species in *Schima-Pyrus* forest.

B. *Myrsine- Persea* forest

In *Myrsine-Persea* forest 12 species of trees were recorded. The regeneration status of this forest was found fair. Out of 12 tree species, three species showed fair regeneration, three species had poor, and five species were not regenerating and one species new species. A new species (*Juglanus regia*) was regenerating in seedling layer. The most dominant tree species *Myrsine capitellata* was found poor stage of regeneration. Similarly, another important tree species of PSG *Choerospondias axillaris* which was one of the historically important and symbolic trees of Sleshmantak forest was in poor stage of regeneration. *Persea odaratissima* was fairly regenerating while other two species *Pyrus pashia* and *Syzygium cumini* had fair stage of regeneration. Sapling stage of these three-tree species were absent (Fig.13). In this forest, five tree species have failed to regenerate. Absence of seedlings or saplings stage of some tree species was due to disturbances like access track (DI=3), fragmentation of forest due to construction of road during Maoist insurgency period (DI=3), cemetery (DI=3) and erosions (DI=3).

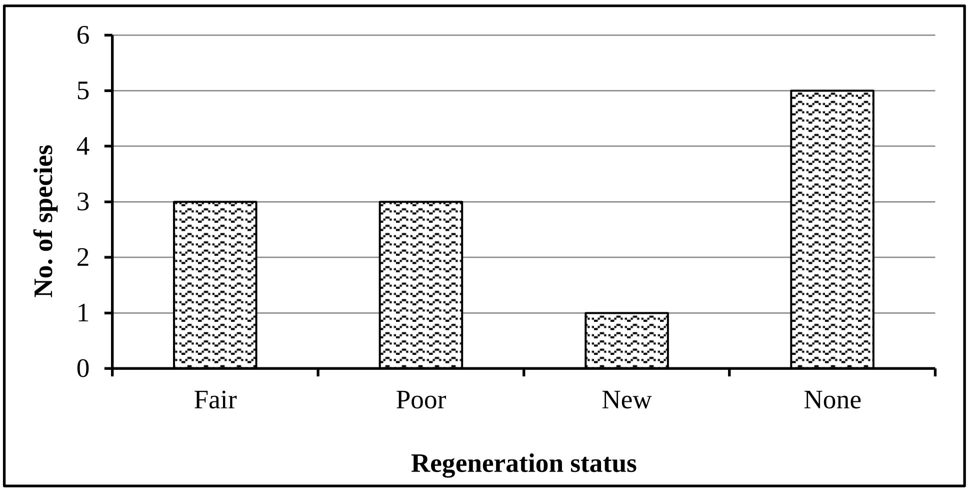


Figure 13. Regeneration statuses of tree species in *Myrsine-Persea* forest

C. *Quercus-Myrsine* forest

In *Quercus-Myrsine* forest 10 species of trees were recorded. The regeneration status of this forest was fair. Among ten species, one species showed good, three species showed fair, one species showed no regeneration and five new species growing at seedling stage. The recorded five new species *Eurya acuminata, Fraxinus floribunda, Pyrus pashia, Prunus cerasoides* and *Betula alnoides* were found regenerating at seedling stage. One of the dominant tree species *Myrsine capitellata* was in good status of regeneration. Other two species *Schima wallichii* and *Persea odoratissima* showed fair regeneration. Other tree species *Quercus glauca*was also found at fair stage of regeneration but the sapling stage of this species was absent. Another species *Syzygium cumini* was not regenerating (Fig. 14). This forest was least disturbed.

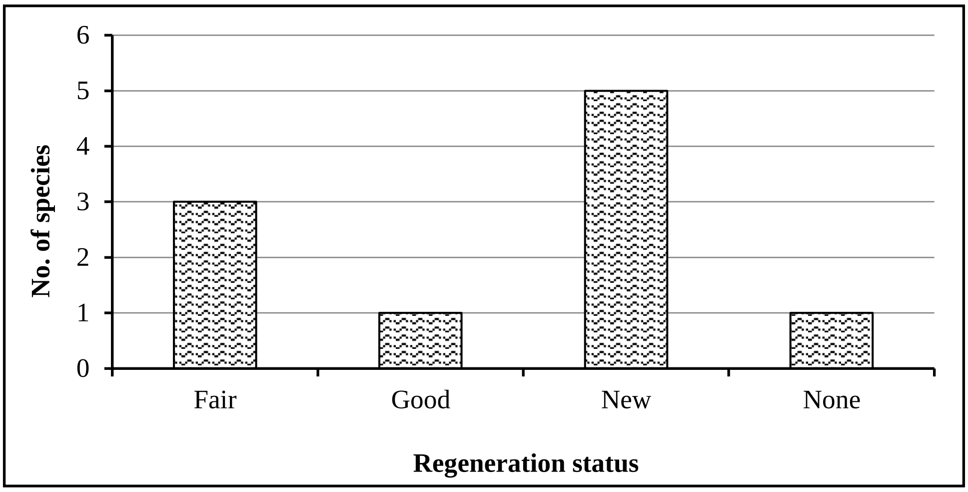


Figure 14. Regeneration statuses of tree species in *Quercus-Myrsine* forest

4.9.1.3 Soil characteristics

Both physical and chemical natures of soil of PSG were analyzed. The analyzed soil characteristics of PSG were soil texture, organic matter, soil pH, and soil nutrient like nitrogen, phosphorus and potassium.

a. Physical characteristics

i) Sand

The average sand level available in the soil of PSG was 63%. The ranges of available sand found in the soil of Pashupati sacred grove 42.4% to 79%.

ii) Silt

The silt found in the soil of PSG was ranged from 12.5% to 46.2% with the average of 27%.

iii) Clay

The clay found in the soil of PSG was ranged from 7.1% to 15.1% with an average clay content was 10%.

iv) Soil type

Two types of soil were recorded from the PSG. Loamy soil was found in 16% and sandy loam was recorded in 84% of the study area.

b. Chemical characteristics

i) Nitrogen

The average nitrogen content in the soil of PSG was 0.1%. The lowest range was 0.06% and highest of nitrogen content in the soil was 0.35%. The findings indicated that the nitrogen content of the soil was in low range (Annex 3).

ii) Phosphorus

The average phosphorus content found in the soil of PSG was 348 kg ha^{-1}. The lowest phosphorus content was 42.15 kg ha^{-1} and that of highest was 1200.56 kg ha^{-1}. The findings indicated that the phosphorus content of the soil was in very high range (Annex 3).

iii) Potassium

The average potassium content found in the soil of PSG was 902 kg ha^{-1}. The lowest potassium content was 268.8 kg ha^{-1} and that of highest was 1344 kg ha^{-1}. The findings indicated that the potassium content of the soil was in very high range (Annex 3).

iv) Organic matters

The average range of organic matter found in the soil of PSG was 3.7%. The lowest range of organic matter was 0.59% and that of highest was 5.76%. The findings indicated that the organic matter content of the soil was in medium range (Annex 3).

v) Soil pH

The average pH found in the soil of PSG was 4.7. The lowest pH of soil recorded was 4.1 and that of highest was 5.6. The finding indicated that the soil pH of PSG was acidic.

4.9.2 Bajrabarahi Sacred Grove

4.11.2.1 Disturbances

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 spot, fence lines, and construction of permanent structures like buildings and toilets (Fig.15).

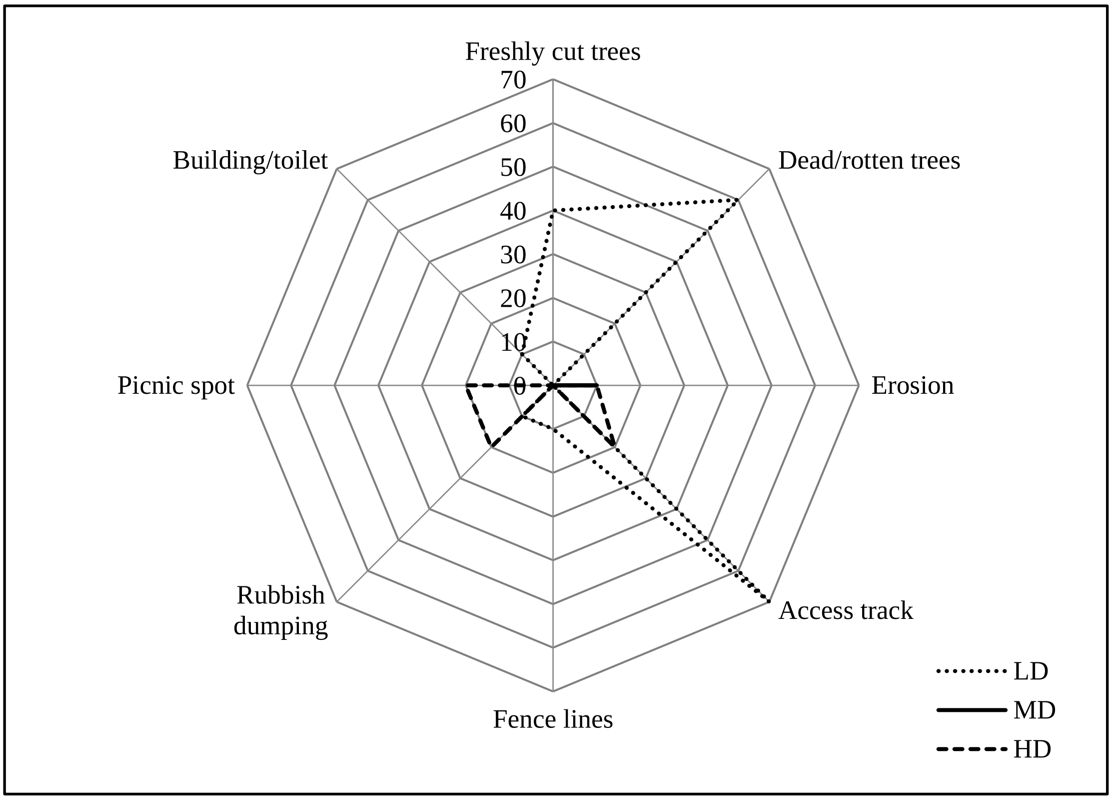


Figure 15. Types of disturbances and their intensity in BSG (LD–least disturbed, MD–moderately disturbed, HD–highly disturbed)

The study revealed that 10% of the study area was undisturbed, 10% were moderately disturbed, 20% were highly disturbed, and 60% were least disturbed (Fig. 16).

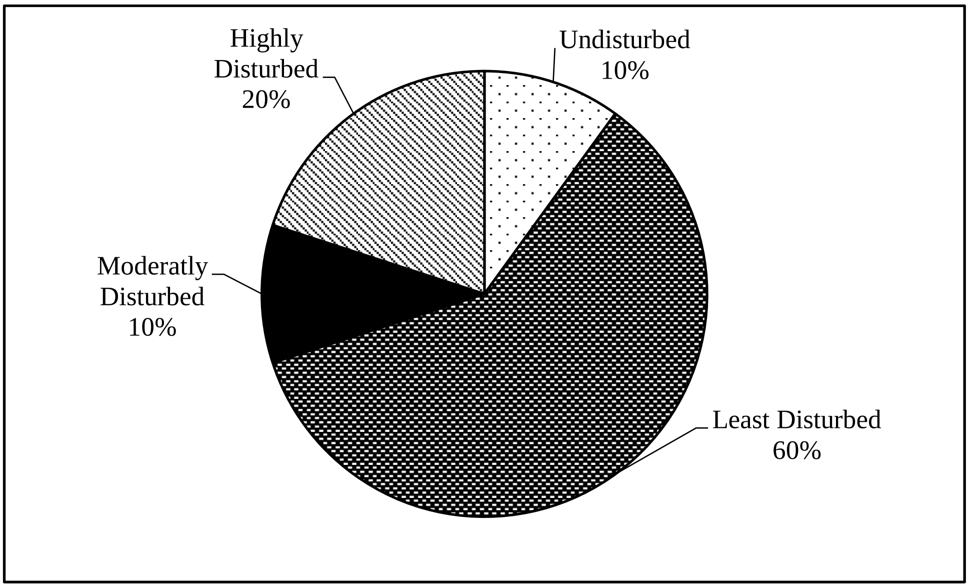


Figure 16. Disturbance status of BSG

The highest number of seedlings (3,981 ha^{-1}) and adult trees (430 ha^{-1}) were recorded from the undisturbed forest areas (Tab. 23). The sapling stage of tree were absent in these areas and indicated the fair regeneration status. In least, disturbed areas, the recorded numbers of seedlings were 1558 ha^{-1}, saplings were 17 ha^{-1} and trees were 409 ha^{-1} with fair regeneration status. In the moderately disturbed forest seedlings were absent, numbers of saplings were 199 ha^{-1} and the numbers of adult trees were found 263 ha^{-1} with poor status of regeneration. In highly disturbed forest areas the seedlings and sapling stage of tree were absent and the numbers of adults were 462 ha^{-1} which showed no regeneration status. There was significant effect of disturbances in tree regeneration (t=2.80, p<0.05, df=9).

Table 23. Regeneration status of forest in BSG

Disturbance Status	Seedling ha^{-1}	Sapling ha^{-1}	Tree ha^{-1}	Regeneration status
Undisturbed	3981	0	430	Fair
Least disturbed	1558	17	409	Fair
Moderately disturbed	0	199	263	Poor
Highly disturbed	0	0	462	None

4.9.2.2 Forest regeneration

The regeneration status of available tree species in Bajrabarahi sacred grove was fair. Out of 19 recorded tree species from BSG 26.3% tree species showed fair regeneration, 68.4% trees were not regenerating and a new species, *Boehmeria rugulosa*, was regenerating in seedling stage (Fig. 17).

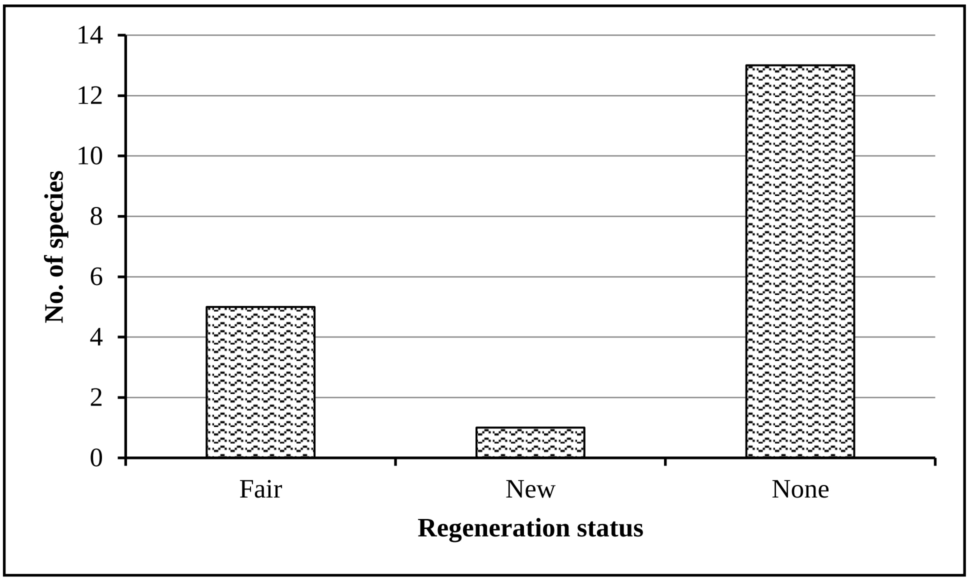


Figure 17. Regeneration statuses of tree species in Bajrabarahi sacred grove

The regeneration status of available tree species in BSG was poor in 10%, fair in 60% and no regeneration in 30% of the area (Fig.18).

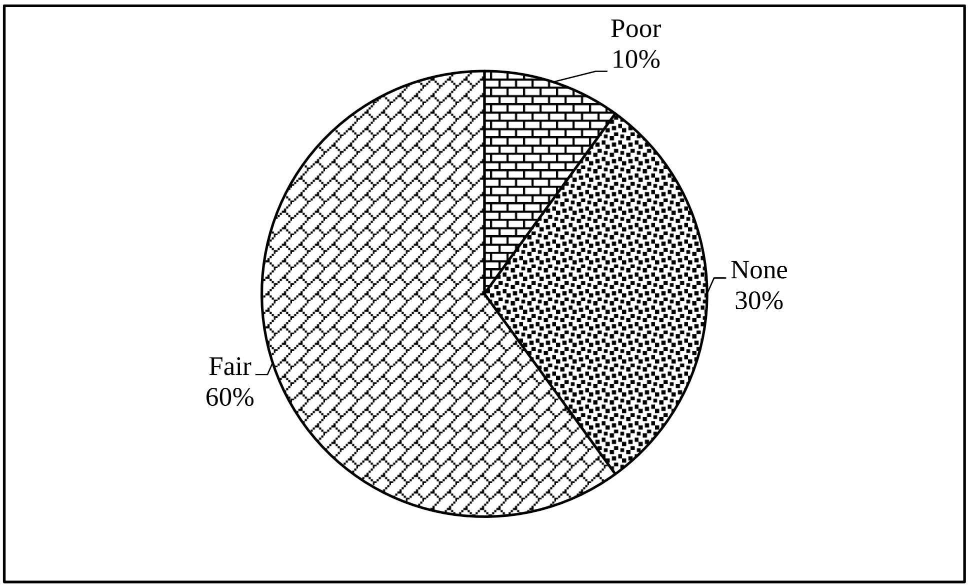


Figure 18. Regeneration statusesof tree species in Bajrabarahi sacred grove

In this forest the most dominant tree species *Neolitsea cuipala, Castanopsis tribuloides,* and *Castanopsis indica* including other two tree species, *Abizia lebbeck* and *Celtis australis*, showed fair regeneration. The sapling stage of these tree species was absent. In BSG *Castanopsis tribuloides* had good population of seedlings, but these were not maturing enough as saplings and adult stages. Thirteen tree species were not regenerating in BSG (Tab.24).

Table 24. Regeneration status of tree species in BSG

SN	Name of tree species	Family	Seedling	Sapling	Adult	Status
1	*Albizia julibrissin*	Leguminosae	0	0	1	None
2	*Albizia lebbeck*	Leguminosae	279	0	6	Fair
3	*Areca catechu*	Palmae	0	0	8	None
4	*Boehmeria rugulosa*	Urticaceae	179	0	0	New
5	*Cassia fistula*	Leguminosae	0	0	16	None
6	*Castanopsis indica*	Fagaceae	199	0	41	Fair
7	*Castanopsis tribuloides*	Fagaceae	916	5	10	Fair
8	*Celtis australis*	Ulmaceae	20	0	1	Fair
9	*Choerospondias axillaris*	Anacardiaceae	0	0	45	None
10	*Hymenodictyon excelsum*	Rubiaceae	0	0	10	None
11	*Myrica esculenta*	Myricaceae	0	0	2	None
12	*Myrsine capitellata*	Myrsinaceae	0	0	26	None
13	*Myrsine semiserrata*	Myrsinaceae	0	0	6	None
14	*Neolitsea cuipala*	Lauraceae	537	25	196	Fair
15	*Persea odoratissima*	Lauraceae	0	0	1	None
16	*Rhus succedanea*	Anacardiaceae	0	0	6	None
17	*Sapium insigne*	Eurphorbiaceae	0	0	1	None
18	*Schima wallichii*	Theaceae	0	0	17	None
19	*Syzygium cumini*	Myrtaceae	0	0	4	None

The highest number of seedlings (3,981 ha^{-1}) was recorded from plot number 7 followed by plot number 8 (3,583 ha^{-1}) with fair regeneration. The sapling stages of tree were recorded from two plots only. The highest number of sapling (199 ha^{-1}) was recorded from plot number 13 with poor regeneration status and was followed by plot number 9 with number of sapling 103 ha^{-1} had fair status of regeneration. The highest numbers of adult trees (700 ha^{-1}) were recorded from plot number 5 with fair regeneration status and was followed by plot number 11 (525 ha^{-1}) with no regeneration status (Annex 8).

4.9.2.3 Soil characteristics

The soil characteristics studied in BSG were soil texture, organic matter, soil pH, and soil nutrients like nitrogen, phosphorus, and potassium.

a. Physical characteristics

i) Sand

The average level of sand available in the soil of PSG was 39.96%. Level of sand availability in the soil was ranged from 7.2% to 56.0%.

ii) Silt

The level of silt availability in BSG was between 15.4% and 50.25%. The soil of BSG included 39.76% silt in average.

iii) Clay

The range of clay level recorded in the soil of BSG was from 9.8% to 77.4%. The average level of clay content in the soil of BSG was 20.3%.

iv) Soil type

Based on the available proportion of sand, silt and clay three types of soils were recorded from BSG. The available soil type in BSG were loamy 70%, silt loam 10%, sandy loam 10%, and clay 10% (Fig. 19).

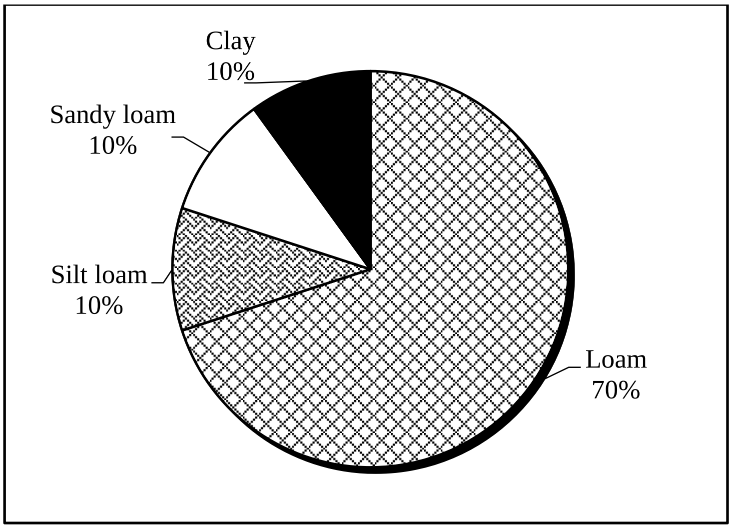


Figure 19. Soil types in Bajrabarahi sacred grove

b. Chemical characteristics

i) Nitrogen

The average level of nitrogen content found in the BSG was 0.11%. The lowest level of nitrogen was 0.06% and that of highest was 0.27%. The findings indicate that the nitrogen content of the soil was in medium range (Annex 3).

ii) Phosphorus

The average level of phosphorus content recorded in the soil of BSG was 168.87 kg ha^{-1}. The lowest level of phosphorus was 53.59 kg ha^{-1} and that of highest was 388.99 kg ha^{-1}. The findings indicate that the phosphorus content of the soil was in very high range (Annex 3).

iii) Potassium

The average level of potassium content recorded in the soil of BSG was 617.07%. The lowest level of potassium was 328 kg ha^{-1} and highest is 1003.33 kg ha^{-1}. The findings indicated that the potassium content of the soil was in very high range (Annex 3).

iv) Organic matters

The average level of organic matters content found in the soil of BSG was 2.54%. The lowest level of organic matters was 0.41% and the highest was 7.91%. The findings indicated that the organic matters content of the soil was in medium range (Annex 3).

V) Soil pH

The average pH found in the soil of BSG was 4.2. The lowest pH of soil recorded was 3.8 and that of heighest was 4.6. The finding indicated that the soil pH of BSG was acidic.

4.10 Local perceptions

In total 65 persons were interviewed in each sacred grove by using structured questionnaires (Annex 6). Before interviewing, the interviewers were briefed the goal and objectives of the research and interview were taken when they were confident enough in answering the questions. Total time spent for questionnaire survey in each sacred grove was 1500 minutes. The average time used for each questionnaire survey was 23.1 minutes.

The questionnaire survey was conducted to get local perceptions about sacred groves. The perceptions were categorized in to four issues, namely sacred grove conservation, benefit from sacred grove, management of sacred grove and suggestions for sacred grove conservation.

Regarding the sacred grove conservation, local people of both sacred groves perceived that the objective of sacred grove establishment was for biodiversity conservation in both sacred groves. They realized that the forest was protected and preserved than the past in BSG but less conserved in PSG due to increasing anthropogenic activities. The findings illustrated that the perception towards the sacred grove conservation was positive, in both grovess.

In both sacred groves, local people appreciated for providing benefit to biodiversity conservation and helping to increase religious belief in local people. The natural resources of sacred groves were not used with few exceptions only for cultural and religious purposes. They also realized the income generated from the sacred grove was supporting for the management of sacred grove.

Local people blamed both management group and government authorities were responsible for the degradation of sacred grove in PSG. But, in BSG they admitted the management group played vital role for forest conservation. Local people recognized the available rules for proper utilization of natural resources, involvement of users in conservation activities, and acquired help from local community for the management of forest areas.

Local people suggested to conduct effective awareness programs for forest conservation and involved stakeholders for planning and solving the conservation related problems in both groves. The details about the local perceptions are described as follows:

4.10.1 Pashupati Sacred Grove

4.10.1.1 Sacred grove conservation

i) Objective of establishment

Regarding the objectives of establishment of sacred grove 38% responded for religious reason; 6% responded for religious motivation; 31% responded both for religious purpose and biodiversity conservation; 2% responded for religious purpose, religious motivation and biodiversity conservation; 13% responded for religious purpose and religious motivation; 4% responded for religious purpose and increase income; and 6% responded for religious motivation and biodiversity conservation (Fig. 20). Analyzed BCCI was towards positive direction, indicating the objective to establish sacred grove was for biodiversity conservation

ii) Knowledge on biodiversity

Concerning the knowledge on biodiversity 73% knew about the concept and 27% of people did not know about its concept. Analyzed BCCI was positive which revealed that most them were aware about biodiversity.

iii) Importance of sacred grove in biodiversity conservation

Regarding the knowledge on the importance of sacred grove for the conservation of biological diversity 63% responded the importance of sacred grove for biodiversity conservation, 8% responded that sacred groves played significance role in biodiversity conservation, 27% people were not aware about it, and 2% people did not recognize its role on biodiversity conservation (Fig. 21). Analyzed BCCI showed the positive value, which illustrated that sacred grove played important role in biodiversity conservation.

iv) Changes in the forest status

About the existing status of forest 38% people responded the current forest condition was good, 12% responded the forest condition was same as before, 42% indicated the condition was degrading, and 8% responded about the condition was utterly degraded (Fig. 22). Analyzed result of BCCI was negative which illustrated the forest condition was degraded than the past.

v) Local perception towards the conservation

The perception of local people about conservation of sacred grove indicated that 96% people responded it positively and 4% people ignored it. Analyzed BCCI indicated the positive result. So, local perception towards the conservation of sacred grove was positive.

4.10.1.2 Benefit from sacred grove

i) Acquired benefits

Concerning the direct or indirect benefit from sacred grove 2% people responded its benefit for biodiversity conservation, 33% people reacted for religious activity, 2% responded for income source and biodiversity conservation, 56% responded for all option and 7% responded for religious activity and biodiversity conservation (Fig. 23). Analyzed result indicated positive value of BCCI. Local people perceived that the sacred grove was beneficial to them.

ii) Increase in religious belief

Regarding the role of sacred grove to increase religious belief 34% people responded the sacred grove played vital role to increase religious belief, 52% people reacted its limited role to increase religious belief, 10% people indicated not having such role, and 4% people responded they were not aware about it (Fig. 24). Analyzed result indicated the positive value of BCCI. Local people perceived the sacred grove helped to increase religious belief.

iii) Resources use

From the sacred grove 60% people responded for the use of fire wood and 40% responded that the resources were not used. Analyzed result indicated the negative value of BCCI. Local people perceived that natural resources were used from the sacred forest.

iv) Effects of forest use

Concerning the effects of resource use on the forest, 38% people responded they were not using the resources so there was no effect on the forest, 14% people reacted the loss of forest resources, 2% people responded for biodiversity loss, 6% people replied for erosion, 6% responded for the loss of forest and biodiversity as well as erosion, 15% responded for the loss of forest and loss of biodiversity, and 19% people responded for the loss of forest and help to increase erosion (Fig. 25). Analyzed result indicated the negative BCCI value. Local people supposed that the impact of excessive use of the forest leads to its degradation.

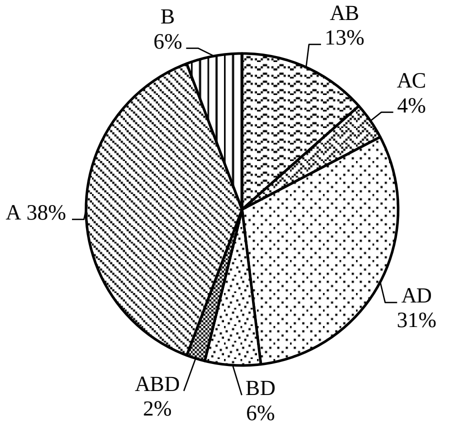


Figure 20. Peoples' opinion about the objective of sacred grove establishment in PSG (A-religious purpose, B-religious motivation, C-income gineneration, D-biodiversity conservation)

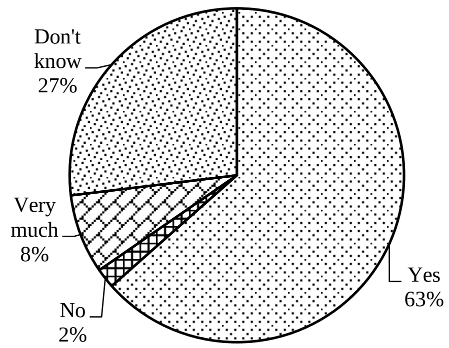


Figure 21. Peoples' opinion about the importance of sacred grove in biodiversity conservation in PSG

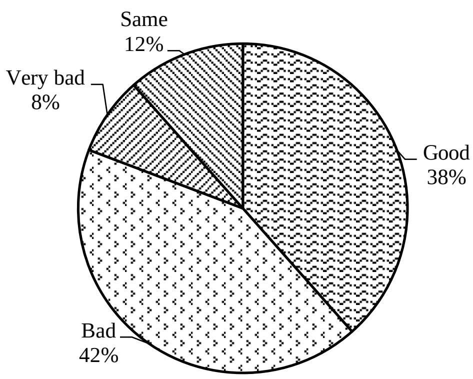


Figure 22. Peoples' opinion about the forest status in PSG

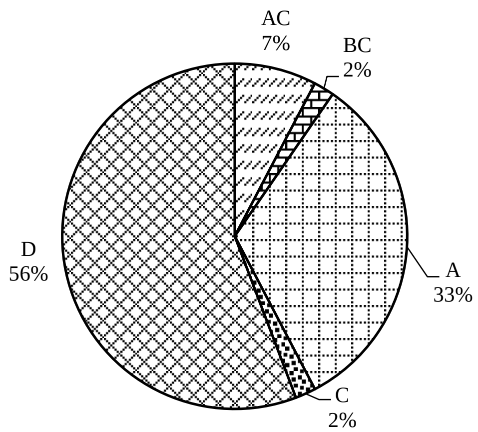


Figure 23. Peoples' opinion about the benefit from sacred grove in PSG (A-religious activity, B- income source, C-biodiversity conservation, and D-all options)

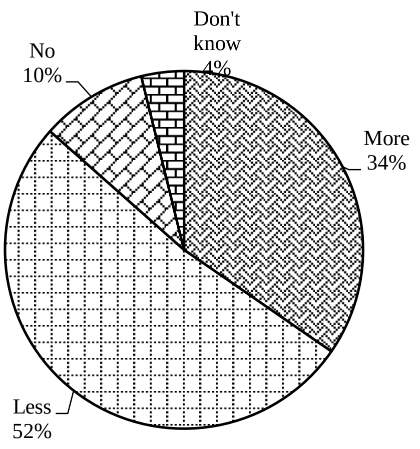


Figure 24. Peoples' opinion about the role of sacred grove to increase religious belief in PSG

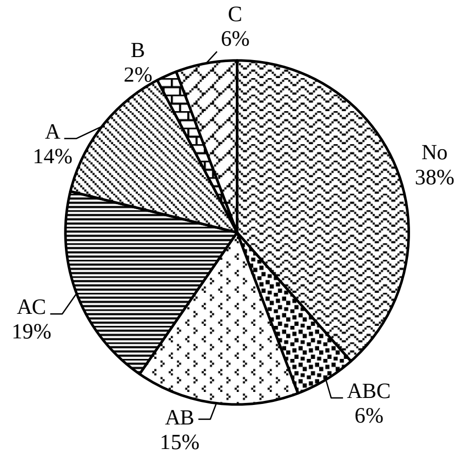


Figure 25. Peoples' perception regarding the effects of forest resource use in PSG (A-forest loss, B-biodiversity loss, C-erosion and D-not using)

v) Income generation

In response to the income generation from sacred grove 90% people responded that sacred grove has been a source for income generation, 4% people were not aware about its role and 6% people responded it has no role of income generation (Fig. 26). Analyzed result indicated the positive value of BCCI. Local people supported that there was no enough income generation from sacred grove to support PADT for the management activities of the forest.

4.10.1.3 Management of sacred grove

i) Responsibility for good or bad conditions of sacred grove

Concerning the current conditions of sacred grove 11% people responded that government was responsible, 2% people indicated the role of local CBOs (institution), 4% reacted that local people were responsible, 9% responded that PADT was responsible, 13% indicated that government and local people were responsible, 2% responded for local people and PADT, 3% replied for local CBOs and PADT, 2% indicated for government and local CBOs as well as local people, 3% responded for local CBOs and local people, 40% responded for government and PADT, and 11% responded for all options (Fig. 27). Analyzed result indicated the positive BCCI value. Local people perceived that PADT and the government were more responsible for the degraded conditions of sacred grove.

ii) Rules and regulation

About the rules for using the natural resources 84% people reacted that there were rules, 11% responded they were not aware, 2% replied the available rules were not enough, and 3% responded there were no rules (Fig. 28). Analyzed result indicated the positive value of BCCI which emphasized that the local people know that there were rules and regulations to use natural resources.

iii) Local participation

Concerning the involvement of local people in conservation activities 33% people responded their involvement, 9% reacted that they were not aware about it, 36% replied for less involvement, and 22% responded for no involvement (Fig. 29). Analyzed result indicated the positive value of BCCI and there was the involvement of local people in conservation activities.

iv) Support from local community

On the topic of the support received from local community for sacred grove management 46% people responded for their involvement in cleaning, 2% replied for their involvement on security, 2% responded for community participation, 4% replied for donation, 7% responded for security and cleaning, 26% reacted for donation and cleaning, 9% responded for community participation and cleaning, 2% replied for community participation and security, and 2% responded for all provided options (Fig. 30). Analyzed result indicated positive BCCI value. Local people perceived that the management authority was receiving support from local community for the management of sacred grove.

4.10.1.4 Suggestions for sacred grove conservation

Concerning the suggestions for solving conservation problems in the sacred grove 10% people responded for involvement of stakeholders during planning process, 9% replied for awareness, 4% responded for law enforcement, 6% reacted that law was not sufficient, 4% responded for law enforcement and awareness, 2% replied that the law was not sufficient and law enforcement as well as involvement of stakeholders during planning process, 6% responded for law enforcement and involvement of stakeholders during planning process, 40% replied for awareness program and involvement of stakeholders during planning process, 2% reacted for law enforcement and awareness as well as involvement of stakeholders during planning process, 9% replied that law was not sufficient and involvement of stakeholders during planning process, 4% responded that the law was not sufficient and awareness, and 4% provided their responses for all options (Fig. 31). Local people suggested that there should be awareness raising programs and involvement of stakeholders during planning process for solving the conservation related problems.

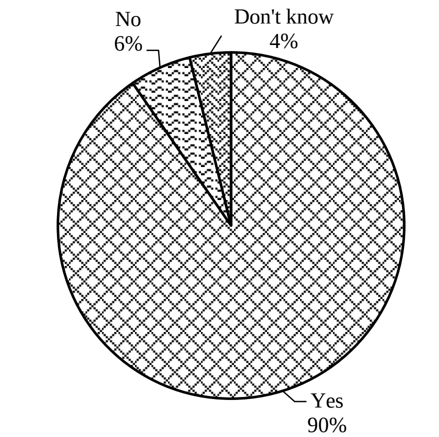


Figure 26. Peoples' opinion about the role of sacred groves for income generation in PSG

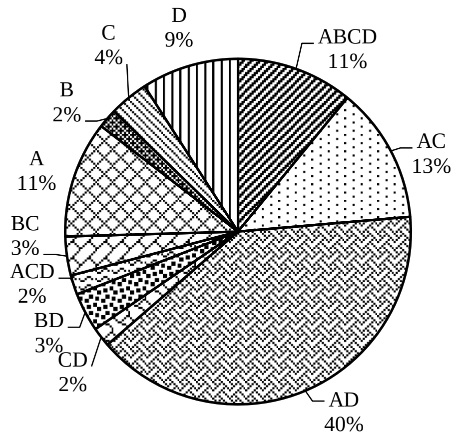


Figure 27. Peoples' opinion about the responsible authorities for sacred grove management in PSG (A-government, B-local body, C-local people and D-management group)

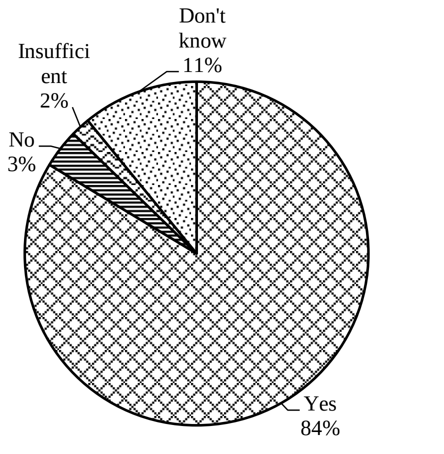


Figure 28. Peoples' opinion about the available rules and regulation for sacred grove management in PSG

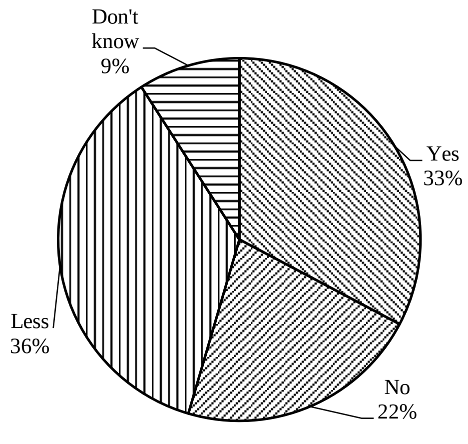


Figure 29. Peoples' opinion about the local participation in sacred grove conservation in PSG

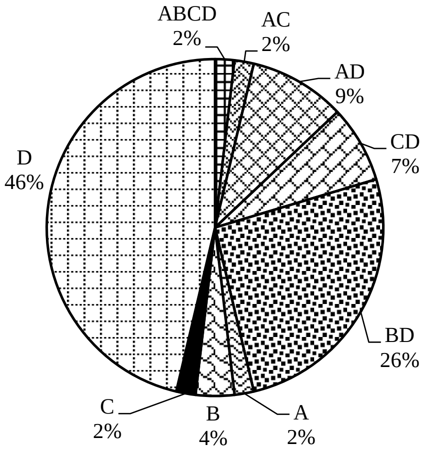


Figure 30. Peoples' opinion about the types of support from local people for the management of sacred grove in PSG (A-community participation, B-donation, C-security, and D-cleaning)

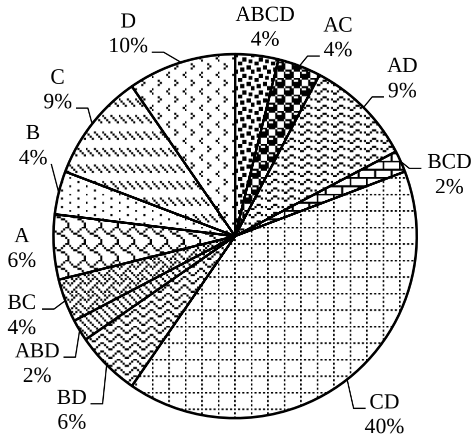


Figure 31. Peoples' suggestions for sacred grove conservation in (A-need to have sufficient law, B-law enforcement, PSG C-awareness and D-involvement of stakeholder on planning process)

14.10.2 Bajrabarahi Sacred Grove

4.12.2.1 Sacred grove conservation

i) Objective of establishment

Concerning the objective of establishment of sacred grove 51% people responded for religious purposes, 9% replied for religious motivation, 13% reacted for biodiversity conservation, 5% responded for all provided options, 2% indicated for religious purposes and religious motivation as well as biodiversity conservation, 4% responded for religious purposes and religious motivation, 6% reacted for religious purposes and increase income, 6% responded for religious purposes and biodiversity conservation, and 4% replied for increase income and biodiversity conservation. According to the analysis, the objective of the establishment of sacred grove was religious purpose (Fig. 32). Analyzed result of biodiversity conservation confidence index (BCCI) showed the positive response. Thus, perception of local people for objective of establishment of sacred grove was biodiversity conservation.

ii) Knowledge about biodiversity

About the knowledge about biodiversity 43% people know about it and more than half portion (57%) people were not aware about it. Analyzed result of BCCI showed the negative response which indicated that the local people were less informed about biodiversity.

iii) Contribution of sacred grove in biodiversity conservation

Concerning the knowledge about the importance of sacred grove in biodiversity conservation 45% people responded that there was important role of sacred grove in biodiversity conservation, 25% replied for significant role in biodiversity conservation, 30% people were not aware about it (Fig. 33). Analyzed result of BCCI showed the positive response. Local people perceived that there was importance of sacred grove in biodiversity conservation.

iv) Changes in the forest status

Regarding the status of forest 92% people responded that the condition of forest was good, 4% replied that the forest condition was same as before, 4% reacted that the condition was degraded than before (Fig. 34). Analyzed result of BCCI was positive and local people perceived that the forest condition was in good condition in comparison to the past.

v) Local perception towards the conservation

On the topic of the perception of local people toward the conservation 96% people responded positively, 2% replied negatively and 2% responded for hindrance (Fig. 35). Analyzed result of BCCI showed the better response, so the perception of local people for biodiversity conservation was positive.

4.10.2.2 Benefit from sacred grove

i) Acquired benefits

Regarding the benefits acquired from sacred grove directly or indirectly 7% people responded for its importance in biodiversity conservation, 32% reacted for religious activity, 4% explained for income source, 51% responded for all option, 4% replied for religious activityandbiodiversity conservation, and 2% responded both for the income source and biodiversity conservation (Fig. 36). The analyzed BCCI result indicated the positive response. Thus, local people perceived that sacred grove played role for biodiversity conservation.

ii) Increase religious belief

Concerning the religious belief 81% people responded that sacred grove helped to increase more religious belief, 15% replied for its less role to increase religious belief and 4% people did not aware about it (Fig. 37). Analyzed result of BCCI was positive which indicated that sacred grove played important role to increase religious belief.

iii) Resources use

Regarding the types of resources used from the sacred grove 23% people replied for use of the resources as firewood and 77% people responded that resources were not used. Analyzed result indicated the positive BCCI value. So, forest resources of sacred grove were not in use at local level.

iv) Effects of forest use

About the effect of forest use 89% people responded they were not using the resources so there was no effect on forest, and 11% of people replied for forest degradation. Analyzed result indicates the positive value of BCCI. Local people perceived that since the forest resources were not in use there was no degradation of forest from anthropogenic activities.

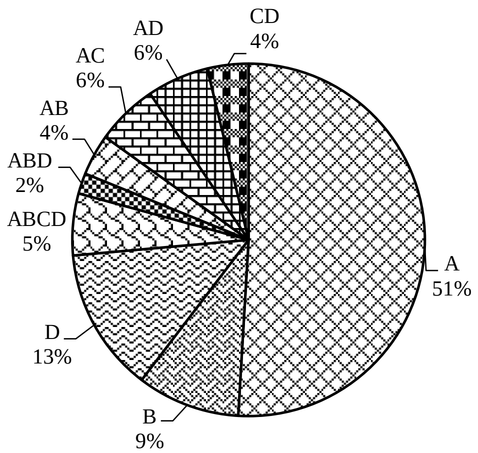


Figure 32. Peoples' opinion about the objective of sacred grove establishment in BSG (A-religious purpose, B-religious motivation, C-income generation and D-biodiversity conservation)

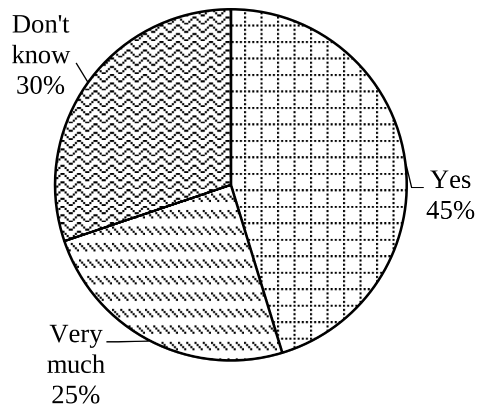


Figure 33. Peoples' opinion about the contribution of sacred grove in biodiversity conservation in BSG

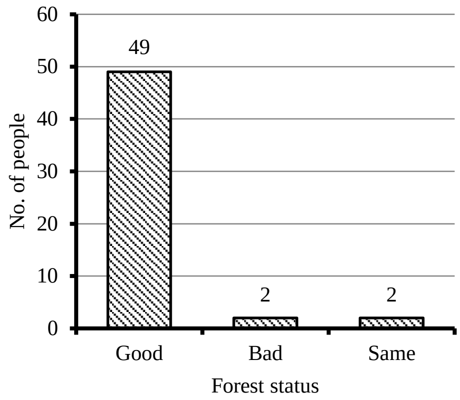


Figure 34. Peoples' opinion about the forest status in BSG

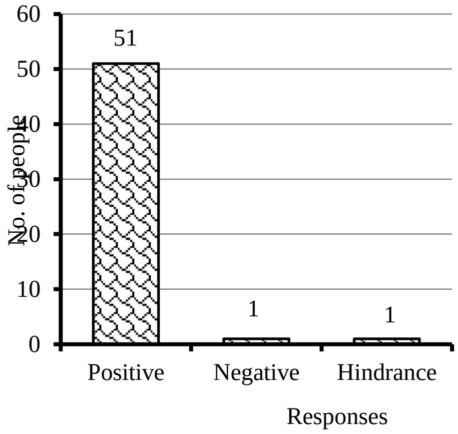


Figure 35. Peoples' response regarding the conservation of sacred grove in BSG

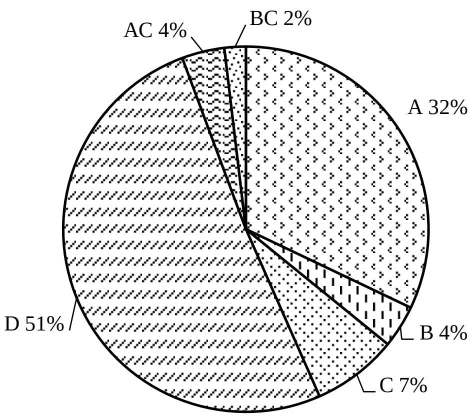


Figure 36. Peoples' opinion regarding the benefit obtained from sacred grovein BSG (A-religious activity, B-income source, C-biodiversity conservation, and D-all options)

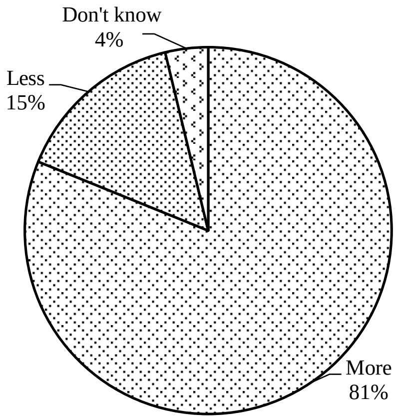


Figure 37. Peoples' opinion about the role of sacred grove to increase religious belief in BSG

v) Income generation

Concerning the income generation from sacred grove 96% people replied that sacred grove provided income generation opportunities and 4% reacted that they were not aware about it. Analyzed result indicated the positive BCCI value. Local people perceived that sacred grove provided oppertunities for the income generation which was supporting for its better management.

4.10.2.3 Management of sacred grove

i) Responsibility for good or bad conditions of sacred grove

Regarding the condition of sacred grove 9% people responded that government was responsible, 12% replied local CBOs (institution) was more responsible, 12% reacted about the local people were responsible, 46% responded to management group was responsible, 5% replied both for government and local people were responsible, 10% responded for government and local CBOs as well as management group were responsible, 2% reacted for local people and management group, 2% responded for government and local CBOs, and 2% replied for government and local CBOs as well as local people (Fig. 38). Analyzed result indicated the positive value of BCCI. Local people perceived that the management group (Jyotidaya Sangh) was more responsible for the better management forest.

ii) Rules and regulation

About the rules and regulation to use natural resources 76% people responded that the rules and regulations were existed, 12% replied they were not aware about it, 2% reacted that existed rules and regulation were not sufficient, and 10% responded that there were no rules and regulations (Fig. 39). Analyzed result indicated positive BCCI value, which reflected that rules and regulations to use natural resources were available.

iii) Local participation

About the involvement of users in conservation activities 60% people responded that they were involved, 5% replied they were not aware about it, 21% reacted for less involvement, and 14% responded for no involvement (Fig. 40). Analyzed result of BCCI was positive which indicated that there was the participation of local people in conservation activities.

iv) Support from local community

Concerning the support received from local community for management 29% people responded for their involvement in cleaning, 5% replied for local contribution and cleaning, 12% reacted for local contribution, 10% responded for local contribution and donation as well as cleaning, 5% reacted about donation, 4% replied for donation and security as well as cleaning, 5% responded for security, 7% reacted for local contribution and donation, 2% replied for local contribution and donation as well as security, and 21% responded for all options (Fig. 41). Analyzed result indicated the positive value of BCCI. So, there were supports from local community for the management of sacred grove.

4.10.2.4 Suggestions for sacred grove conservation

About the suggestions for solving conservation problems 2% people responded that the law was not sufficient and need to involve stakeholders during planning process, 4% replied that the law was not sufficient, 2% reacted for law enforcement, 51% responded for conducting awareness programs, 37% replied for involvement of stakeholders during planning process, 4% reacted that the law was not sufficient and need to conduct awareness programs (Fig. 42). Local people suggested that there should be awareness raising campaign for resolving conservation related problems in BSG.

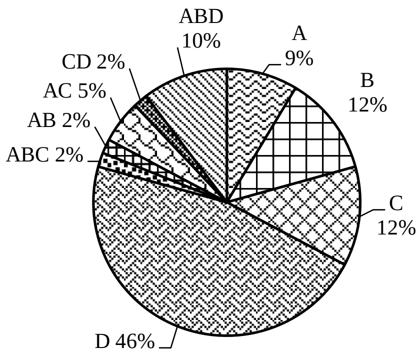


Figure 38. Peoples' opinion about the responsible authorities for sacred grove management in BSG (A-government, B-local body, C-local people and D-management group)

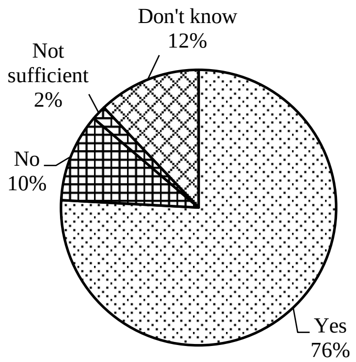
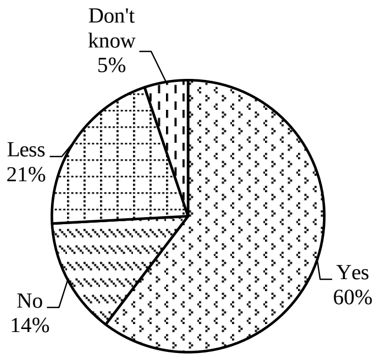


Figure 39. Peoples' opinion about the available rules and regulation for sacred grove management in BSG



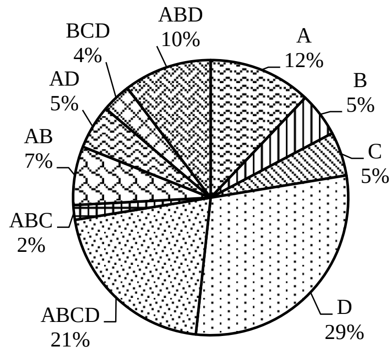


Figure 40. Peoples' opinion about the local participation in sacred grove conservation in BSG

Figure 41. Peoples' opinion about the types of support received from local community for the management of sacred grove in BSG (A-community participation, B-donation, C-security, and D-cleaning)

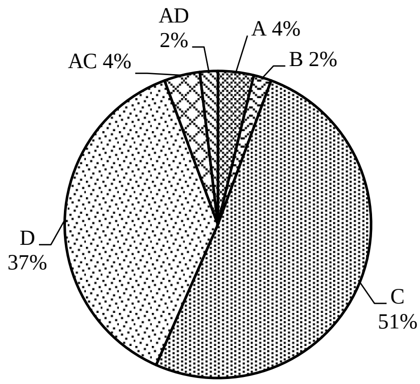


Figure 42. Peoples' suggestions for sacred grove conservation in BSG (A-need to have sufficient law, B-law enforcement, C-awareness, D-involvement of stakeholder on planning process)

4.11 Discussions

From the phyto-sociological assessment three types of forest in Pashupati Sacred Grove (PSG) and only one forest type has been identified from Bajrabarahi Sacred Grove (BSG). In PSG 13 families of plant species were recorded and 12 families were identified from BSG. Both groves shared nine common families and ten common tree species with similarity indices 72% for families and 57% for tree species. BSG incorporated more developed forest community with less number of stems (432 ha^{-1})

and higher crown cover percent (90.8%) than that of PSG. Tree species of PSG were more diverse (H = 1.91) and more evenly distributed (evenness=0.67) than BSG (H=1.81 and evenness = 0.62). Trees of both study sites assimilated 1014.23 t of average Carbon stock and 3.7 mt of CO_2. The highest amount of Carbon (662.09 t) and CO_2 (2.28 mt) was sequestered by *Quercus-Myrsine* forest and the lowest Carbon (113.98 t) and CO_2 (0.41 mt) was recorded from *Schima-Pyrus* forest of Pashupati. The regeneration status of tree species in PSG was good and fair in BSG. Based on disturbance index three categories of disturbances undisturbed, least disturbed, moderately disturbed and highly disturbed were recognized. The soil was found acidic in both groves; nitrogen content was low in PSG and medium in BSG. The organic matter content was in medium range and potassium and phosphorus content were found very high in the soil of both groves.

Conservation of biodiversity is the main objective of establishing sacred groves as perceived by the local people. BSG is better conserved compared to PSG. Local perception towards the conservation of sacred groves was optimistic and stakeholders have realized the positive role of local faiths and belief systems contribute in biodiversity conservation.

4.11.1 Phyto-sociology

Considering the location of forest in the middle of urban area, most of the previous studies carried out in PSG had mainly focused on its religious values, enumeration of plant and wildlife, and its role on environment and forest conservation (Marriot, 1978, Bajracharya *et al*., 1988 and Tandan, 1996). Forests are valuable sources of different useful plants and animal resources. Forests provide different bio-resources, including food and medicine, which play important role for local livelihood (Sharma, 2014). The Pashupati Sacred Grove is also source of commercially valuable medicinal plants (Joshi *et al*., 1998).

In Nepal, there is common practice of providing name to any sites based on its unique characteristics. So, Pashupati Sacred Grove was previously popular as Sleshmantak forest and used to be dominant forest of *Choerospoandias axillaris* (Nepalese Hog Plum) (Narhari and Satyal, 1956). This forest was also considered as a good habitat for wild mammals, like deer and monkeys (Tandan, 1996). Four basic components of habitat such as food, cover, water, and space should be available for survival of a wildlife species in given habitat (Gopal, 1992). The available large trees of Nepalese Hog Plum provided the seasonal foods as well as coverage for available wild animals. The Nepalese Hog Plum was found no more dominating tree in Pashupati sacred grove. The available wildlife either relied on the food provided from the visitors (Rhesus monkey) or from staffs of deer park (*Antelope* species).

The available microclimate determines the types of plant species available in the area. The physiographical conditions are also equally important for the distribution of plant species. The species compositions in different physiographic regions of Nepal are varied based on the available climatic condition and topography (Stainton, 1972, FRA/DFRS, 2014). The Pashupati Sacred Grove has different micro-topography, which has created different microclimate suitable for different vegetation composition. The elevation of this grove varies between 1300 and 1337 m and slope ranges between 0° - 90°. The combination of all these climatic and topographic factors have made the Pashupati Sacred Grove as a unique area where three forest types, namely *Schima-Pyrus*, *Myrsine-Persea*, and *Quercus-Myrsine* have been identified by the study than the previously identified only one *Myrsine–Schima* forest (Shrestha, 2001).

This study has focused to find the forest composition based on the plot sampling rather than to enumerate available tree species (Joshi *et al*., 1998 and Shrestha, 2001) in the sacred groves. The numbers of species available in the study areas were based on the measured trees inside the sampling plot. The studied plots are the sampled area and represent lesser area than the total area. Therefore, the number of tree species in this study was found less than (n = 23) the already enumerated species by Joshi *et al*., 1998 and Shrestha, 2001 (n = 85). Similarly, tree density in Pashupati Sacred Grove was also found less than the previously recorded (601 ha^{-1}), having maximum tree height of *Schima wallichii* (18.6 m). The previous enumeration of plant species (Shrestha, 2001) was conducted only in a portion of the PSG, resulting higher number of tree density ha^{-1}.

The first hypothesis of this study was to find out the role of sacred groves in tree diversity conservation. A total of 23 tree species in PSG and 19 tree species were recorded in BSG that has resulted into three forest types in PSG and only one in BSG based on IVI value of dominant tree species. Similarly, the maturity index in PSG was 26.0 and 33.9 in BSG with 73.92% canopy cover in PSG and 90.8% in BSG. The Shannon-Winner Diversity index was 1.91 and 1.81 in PSG and BSG, respectively. These findings are in favor of first hypothesis that the sacred groves have important role in conserving tree diversity resulting into various forest types, in the studied grove.

In PSG, two barking deer (*Muntiacus muntjak*) and ten spotted deer (*Axis axis*) and twenty blackbucks (*Antelope cervicarpa*) were reintroduced in 2004 by The Department of National Parks and Wildlife Conservation in 4.8 ha area of Mrigsthali Forest (Shrestha, 2009). A total of 33 dead trees per ha, representing 7% of total tree have been recorded from this grove. The recorded dead trees in this grove were higher than the other studied sites. Considering the heavy pressure of reintroduced deer species, Mrigasthali Forest had been considered as a dying forest patch (Shrestha, 2009). Finding of current study also supported the previous finding (Shrestha, 2009) with higher density of reintroduced deer (42 ha^{-1}) and having large number of standing dead trees (33 ha^{-1}) with least (59.4%) cover of tree canopy.

Current study has reflected that tree density has differed according to the forest types. There is a reciprocal relation between tree canopy cover and density of tree that has affected the regeneration of tree species. So, the canopy coverage is one of the indicators of the forest degradation. Current study has provided the similar result having 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 with less tree density, where as in PSG the canopy coverage is low with high tree density. This result also matches with the general ecological principle. There was less canopy cover and less density of tree in degraded forest of Mrigasthali as reported from previous study (Shrestha, 2009).

In BSG only one forest type of *Neolitsea cuipala* was identified based on importance value index (Tab. 9) with 432 stem ha^{-1}. The tallest tree of the forest was *Schima wallichii* (35 m) which also have maximum DBH (111 cm). This result was also supported by previous study carried out by IUCN (1996), initiated by local community based organization Jyotidaya Sangh, which reported only one forest type dominated by *Neolitsea cuipala* having 30 tree species with the density of 348 ha^{-1}. Same study also reported *Neolitsea ciupala* incorporated highest number of stem ha^{-1}, *Schima wallichii* having maximum height (38 m) and *Ficus religiosa* having maximum DBH (190 cm).

Current study was conducted in the midhill physiographic region of Nepal. The climatic conditions of the current study sites have been divided in to four distinct seasons, namely spring (March-May), summer (June-August), autumn (September-November) and winter (December-February). In the current study the Pashupati Sacred Ggrove with three forest types, namely *Schima-Pyrus*, *Myrsine-Persea*, and *Quercus-Myrcine* included 11, 8, and 5 families of plants, respectively. Similarly, during this study 12 plant families were identified in BSG. The highest number of tree species in the families with higher FIV was 2. Similar kind of study conducted in the Eastern Brazil identified 10 dominant plant families based on Family Importance Value (Scott *et al*., 1983). The result was based on the data analysis of 600 individual trees. They found Myrtaceae as a most important family. 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 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 current study was lower than that of Brazil.

Present study was conducted in subtropical climatic condition of midhill physiographic region of Nepal with 1480.4 mm rainfall and 70-86% relative humidity. These are the determinant limiting physical factors for the vegetative growth of plant and number of plant species. The average species per families 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 *Neolitsea cuipala* forest. The average numbers of species per families were nearly similar with the study conducted by Shankar, (2001) in Mahananda Sanctuary of India. The number of species and families recorded in present study was lower than that of the Mahananda Sanctuary of India (87 species, 42 families) that was due to climatic variations and the physiography. Though, the number of available plant species is higher in Mahananda Sanctuary, however the average species richness per family was 2 (Shankar, 2001). That may be due to the presence of more mono-specific families in the study area of India.

In this study 13 and 12 families of plant species were recorded from PSG and BSG, respectively. These study sites have been conserving 23 tree species in PSG and 19 tree species in BSG. The studied sacred groves, have shared nine common families and ten common tree species with similarity indices of 72% and 57% for families and species, respectively. Analysis of species diversity has indicated that PSG has more diverse species (H = 1.91) and more even distribution (evenness=0.67) than BSG (H=1.81 and evenness = 0.62). This has indicated that the sacred groves have important role in biodiversity conservation. Like the findings of present study, a research conducted in miniature sacred groves in Western Ghats of India covering an area of 13.1 ha recorded 329 plant species belonging to 251 genera and 100 families. The area belongs to tropical region with different physiographic condition ranging from seashore to hills up to 1829 m (Sukumaran *et al*., 2008). The number of plant species and families recorded in those studies are greater than the current study was due to the difference in physiographic as well as climatic conditions and it also belongs to the biodiversity hot spot area in the world (McNeely *et al.*, 1990, WCMC, 1994). The findings of current study also showed similarities with other studies conducted in the sacred groves of Jammu (Sharma and Devi, 2014), Kabi sacred grove of Sikkim (Dash, 2005), Jaintia Hills (Jamir and Pandey, 2003, Upadhaya *et al.*, 2003), Western Ghats (Kanade *et al*., 2008, Ganesh *et al*., 1996 and Sukumaran and Jeeva, 2008), and sacred grove of West Bengal (Bhakat *et al.*, 2008), India which have also concluded that sacred groves have important role in the biodiversity conservation.

The results of present study have shown that PSG has higher tree density and species richness compared to that of BSG revealing that BSG has more developed forest community due to community managed system supported by strong religious belief, taboos resembling the results of Khumbongmayum *et al*., (2005), Manipur India. The study was conducted in four sacred groves revealed that density–diameter distribution of woody species showed highest stand density and species richness in the lowest girth class and decreased in the succeeding girth classes (Khumbongmayum *et al*., 2005) Similarly, Bhattarai and Baral, (2008) also reported that, sacred groves significantly contribute in the conservation of local biodiversity while studying the Lumbini Sacred Grove of Nepal. Likewise, 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).

The present study conducted in two sacred groves covering 101.84 ha area identified 4 types of vegetation based on IVI of tree species like Ramanujam and Cyril (2003), whereas the number of species in this study was found less due to different physiographic region. A study conducted by Ramanujam and Cyril (2003) have found that sacred groves conserve rare plant species in 15.6 ha of four sacred groves in two anthropogenic stands and two natural forest patches of Pondicherry region of South India. They recorded 111 plant species belonging to 103 genera and 53 families with four vegetation types based on IVI.

In the present study Shannon-Wiener index was found high in PSG than community managed BSG. As PSG was highly disturbed forest than BSG, in disturbed part there is open canopy and chance of growing new species resulting in increase of diversity which resemble the general ecological principle. Similar study was conducted to evaluate the role of the sacred grove of the Yi nationality in Chuxiong of Yunnan, China (Liu *et al*., 2000). Three forest communities under different system of management were studied and found highest species richness, endemic species and Shannon-Wiener index (67, 17 and 2.39) than natural forest and common forest (Liu *et al*., 2000) concluding that the sacred groves play an important role in local biodiversity conservation and management.

While studying the 78 sacred groves associated with church in the central and northern highlands of Ethiopia by Aerts *et al.* (2016), found that the native forest and forest biodiversity is mainly confined to these forests. Though those sacred groves are very small (2 ha) more than 50 % of tree species present in tropical northeast Africa were represented. Present study resembled with Aerts *et al*., (2016) in having the similar paterrn of tree species composition. Like present study, Ethiopean church forests have same conservation value like BSG and PSG which represent the old remnants forests of Kathmandu valley. In the same way both sacred groves in Nepal and Ethiopia have the same nature of threats to local biodiversity which are further worsen by climate change. In a similar kind of study, Winchester *et al*., (2011) has also concluded that Ethiopian church forests have significant role in conserving local biodiversity despite their very small size (11.5 ha).

The present study conducted in two sacred groves of Nepal, managed by different management systems, one managed by government and the other by local Newar dominated community of Bajrabarahi area, with strong taboos and religious practices, is more efficient in conservation practices than government managed PSG. Jyotidaya Sangh has carried out management initiative in BSG where various local stakeholders are involved for decision making for the conservation practices. Whereas, in case of PSG that has been managed by the government initiative has no stakeholder involvement in decision making for the conservation practices. These two types of management practices have greatly influenced the conservation of sacred groves like the result of study carried out in India. While assessing the strength and weakness of different management system in conserving sacred groves, Chandrashakara and Sankar (1998) and Sukumaran *et al*. (2008). found that the plant diversity is well conserved in the area managed by local community Similar result was also found in another study conducted in Tanzania where the tree species richness and taxonomic diversity in groves was found higher in sacred groves than other national forests (Mgumia and Oba, 2003). Several factors have been identified that are negatively affecting the forest in PSG, during the study, such as overgrazing, firewood collection, uncontrolled human access, burial ground, newly opened access road, access tracks, and lack of conservation awareness among the locals. Present study has found that the high density of deer in the Mrigsthali deer park (42 ha^{-1}) is the main cause of forest loss in PSG.

4.11.2 Carbon stock

Forest trees are one of main carbon sink of terrestrial ecosystem. The carbon assimilation capacity is different with different tree species. The amount of carbon sink was higher in some trees species with largest girth size tallest like *Schima wallichi* and *Choerospondias axillaris* and with the tree having high biomass like *Quercus glauca*. Current findings correspond with the previous findings (Myneni *et. al*, 2001, Sharma *et al*., 2014, Nepali *et al*., 2015) that forest is one of the major terrestrial carbon sink and the amount of the carbon sink is different according to the species.

The carbon stock in the study area varied according to the types of forest and number of trees per hectare. If the areas of the forests were different the amount of total carbon assimilated in a forest type will automatically be different. The species composition of the forest also differs the average amount of assimilated carbon in the forest type. The more developed forest community of the study area was the *Quercus-Myrsine* forest. The largest girth sized and tallest *Schima wallicii* (41.82 t ha^{-1}) trees were the main carbon sink in this forest. The amount (t ha^{-1}) of assimilated carbon in the forest types of study area varied according to the girth size, height and wood specific gravity of tree species. The more developed plant community has high maturity index (Pichi-Sermolli, 1948). The maturity index is an important indicator for the maturity of plant communities in a specific area and season (Khan *et al*., 2012). In present study, the result was based on one time data collection, thus there was no comparison of maturity index in different season. Though, the maturity index of forest community has not significantly affected ($t = 1.82$, $p<0.05$, $df = 6$) on the carbon stock in the forest of study area, the carbon stock was found high (77.57 t ha^{-1}) in the forest with higher maturity index in *Quercus-Myrsine* forest (MI=80) than the *Schima-Pyrus* forest (MI=29.4) of PSG. It showed that mature forest community incorporate higher carbon as indicated by the other study conducted in lowland area of Nepal (Sharma *et al.*, 2014). However, other study shows that the old growth, mature forest with larger girth size and taller trees are large carbon pool (Luyssaert *et al*., 2008).

This study was conducted in midhills physiographic region of central Nepal with sampling intensity 2.9% in PSG and 6.9% in BSG. Trees of PSG and BSG incorporated 1014.23 t of average carbon stock and 3.7 mt of carbon dioxide. The highest amount of carbon stock (622.09 t) and CO_2 (2.28 mt) was accumulated in *Quercus-Myrsine* forest. The highest carbon stock was recorded in *Schima wallicii* (41.82 t ha^{-1}). A study conducted in the forest of Far Western Terai physiographic region of Nepal with the sampling intensity of 0.02% recorded average tree biomass of 186.6 t ha^{-1} and *Shorea robusta* exhibited the highest biomass of 89.8 t ha^{-1}, followed by *Terminalia tomentosa* 41.0 t ha^{-1}, with one forest type *Shorea robusta* (Gautam *et al.,* 2010). Similar kind of study that was conducted in community managed forest of Chitwan National Park's buffer zone with sampling intensity 2.4% recorded five forest types. Trees of that buffer zone community forest were sequestering 3333.7 t of carbon and 12.1 mt carbon dioxide. The highest amount of Carbon (1206.9 t) and Co_2 (4.4 mt) was accumulated by *Dalbergia sissoo* forest. The highest carbon sequestrating tree was *Dalbergia sissoo* (262.5 t ha^{-1}) (Sharma *et al*., 2014). The difference found in the forest category and carbon stocks in these studies were due to difference in physiographic region and wood density of tree species. The difference found in the forest category and carbon stocks in between these studies were due to difference in physiographic region, species composition and wood density of tree species. In the present study, there was significant difference (F = 13.42, α = 0.05, df = 3, 12) of the mean among species richness, diversity index, evenness and maturity index of the studied forest.

The sampling intensity in this study, which played a major role for the analysis of carbon stock, was 6.9% in BSG. The analyzed carbon stock density in BSG was 143.37 t ha^{-1}. The reported tree species from this forest is 18. Other study in BSG with the sampling intensity 0.6%, recorded 1011 t ha^{-1} carbon and six major tree species were identified (Nepali *et al*., 2015).

The current study identified main disturbances like wildlife grazing, erosion, cut/dead trees, picnic spots, access track, road and cemetery. In *Schima-Pyrus* forest the disturbance index was very high. It was considered as dying patch of forest due having large number of standing dead trees (33 ha^{-1}) resulted from overgrazing pressure of densely populated (42 ha^{-1}) reintroduced antelope and deer species. This forest patch was found highly degraded and the carbon stock recorded was 76.35 t ha^{-1} with stem density of 318 ha^{-1} and less canopy coverage (55%). The *Neolitsea cuipala* forest of BSG was least disturbed with stem density of 432 ha^{-1} and highest canopy coverage (90.80%) and carbon stock (143.37 t ha^{-1}). The current study also showed significant effect of diversity index in carbon stock of the forest (t=5.01, $p<0.05$, df=6). Study conducted in collaborative forests, Mahotari district of Tarai, Central Nepal identified five main disturbance factors like grazing, fire, logging, growth of invasive species and encroachment. The finding showed that the level of carbon stock differs in different forest depending on how the diverse of deforestation and forest degradation influence over them (Mandal *et al.*, 2012). This finding corresponds with the findings of other study that the carbon stock was always high in the less disturbed forest (Hu, 2005, Yang *et al.*, 2005, Liu and Li 2007, Zhou *et al.*, 2007, Duan *et al.*, 2007, Fan *et al.*, 2008, Ravindranath *et al.*, 2008, Zhang *et al.*, 2009, Yamashita *et al.*, 2012, Sharma *et al.*, 2014). There is positive relationship between biodiversity and carbon stock (Midgley *et al.*, 2002, Mandal *et al.*, 2013).

The annual rainfall of the study area was highest during the monsoon period. So, the area remains dry in one season. The forest of the study area was seasonally dry sub-tropical forest (SDSTF), as named by previous studies (Becknell *et al.*, 2012). The less disturbed forest areas of PSG incorporated the highest carbon assimilation capacity than the other areas. The findings about the biomass estimation (double of the carbon stock density) of the current study resembled with the similar studies conducted in the different areas of the world. In those studies, the average aboveground biomass in mature SDSTF ranged from 39 to 334 t ha^{-1} and single climatic variable, mean annual precipitation, explained over 50% of the variation in aboveground biomass. The previous studies conducted in the different areas of SDSTF considered the similar findings regarding the biomass and their carbon assimilation capacity (Becknell *et al*., 2012). Carbon stock measurement of any areas was a key factor to understand the relationship between changes in land use and carbon dioxide emissions. The dry wooded land with less precipitation results the savanna woodland in the Africa. A study conducted in the different savannas system of Miombo woodland in Mozambique resulted the 21.2 t ha^{-1} carbon in tree (Ryan *et al*., 2010). Conversion of forestland to the agriculture land is common practice in Seasonally Dry Sub Tropical Forest (SDTF) (Becknell *et al.*, 2012). If such agriculture land is conserved initial result will be savanna type of grassland. The rate of annual precipitation has direct effect for the carbon stock in the forest ecosystem (Becknell *et. al*, 2012). The annual precipitation is much higher in the current study area which finalized the higher density of carbon stock than the savanna woodlot of Africa.

4.11.3 Forest management and regeneration

There are eleven categories of forest management regimes in Nepal (HMGN 1973, 1974, 1978, 1993, 1994, 1996, 2004). They are mainly government-managed forest and community managed forest whose management are under the Department of Forest. The religious forest is handed over to any religious body, group or community for its management, conservation and utilization. The study conducted in the religious forest, also called sacred groves, of Nepal representing the midhill physiographic region, the local perceptions in the sacred groves showed that the community managed sacred grove helps in biodiversity conservation. They were involved in conservation activities and helping managing institution for better conservation. They strongly believe in taboos and their religious belief is strong which helped like "social fencing" in conservation. Similar study 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 (Bhatta, 2003).

The regeneration status of tree species in the study area were identified as good (PSG) and fair (BSG). This study has identified that the density of seedling, sapling and adult was found higher in least disturbed stand than moderately disturbed stand while no regeneration in highly disturbed stand. It has also identified that higher numbers of adult trees were available in undisturbed and least disturbed stand. The study has also found that stem density was higher in the open canopy forest with less anthropogenic activities and there was higher density of seedling than the adult trees. The current study also favor the general ecological principles that open canopy provide space to regenerate new species which ultimately effect on species richness of the area. There are some essential plant nutrients which have positive role in plant regeneration (Jain, 1983). Among the assessed macronutrients Nitrogen, Potassium and Phosphorus have their effect in the tree regeneration of the study area. There was significant effect of available Nitrogen content in the soil of PSG (t=1.83, $p<0.05$, df=18) and BSG (t=2.80, $p<0.05$, df=9) in tree regeneration. There was no significant effect of soil Phosphorus in tree regeneration of PSG (t=1.30, $p<0.05$, df=18). Whereas, there was significant effect of Phosphorus in tree regeneration in BSG (t=2.45, $p<0.05$, df=9). In PSG though phosphorus content in the soil is in high range and not show significant effect in regeneration due to having comparatively high disturbances (Annex 7). There was no significant effect of soil Potassium in tree regeneration of PSG (t=0.48, $p<0.05$, df=18) and BSG (t=1.52, $p<0.05$, df=9). There was significant effect of organic matter in tree regeneration of PSG (t=1.82, $p<0.05$, df=18) and BSG (t=2.79, $p<0.05$, df=9).

Study about the forest regeneration conducted in the wet evergreen *Dipteracarpus* forests of Assam Valley, tropical evergreen forest of Arunachal Pradesh, India (Bhuyan *et al*., 2002), Uttara Khanda and Western Ghats of India (Murthy *et al*., 2002) also identified higher number of adult trees in less disturbed forest. The study conducted in Garhwal Himalaya of India also identified higher numbers of adult trees density in undisturbed and least disturbed stand (Uniyal *et al*., 2010). Another study conducted in Manipur of India, identified highest stand density and species richness in the lowest girth class (30-60 cm) and decreased in the succeeding girth classes (Khumbongmayum *et al*., 2005). A study conducted in tropical forest in Garo Hills of Northeast India identified that primary forests were more tree-rich and diverse than secondary forests or Sal plantations (Kumar *et al.*, 2006).

A study conducted to assess the anthropogenic impact on the vegetation structure and regeneration of dominant tree species, in mixed broadleaved forest of the buffer zone community forest of the Sagarmatha (Everest) National Park, identified disturbed and semi-disturbed areas. The seedling and sapling density was found much lower in disturbed area than the semi-disturbed (Giri and Katzensteiner, 2013). In the present study, density of seedling and sapling of tree species was also reported low in disturbed and high in least- and un-disturbed areas.

4.11.4 Threat and local perceptions

During the study tree cutting, lopping, fire, erosion, access track and roads, fence lines, high-tension lines, rubbish dumping, picnic spot, wildlife and livestock grazing; litter collection, earthworks, and water storage tanks were directly observed as major drivers of deforestation and degradation of forest in the groves. In some study sites of the groves, forest areas were either replaced with permanent structures or fragmented with road and trail construction, as well as construction of picnic spots to attract tourists. Both sacred groves have a large 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 good aesthetic values which attract many local people during holidays. Being a UNESCO World Heritage Site, PSG has become an attraction to many international tourists to observe Hindu rituals. Local traditions and customs have been challenged by westernized urban cultures learned from large number of tourist visiting the area. Modern education system has also failed to respect the local traditions and customs. Thus, sacred groves have been losing its cultural importance for the younger generation of local people.

Modernization and market forces initiated the management authority to increase income employed for the better management of sacred groves. The increase in visitors will be helpful for the income generation of management authority, but it become threats from the biodiversity conservation point of view. The lure of short-term commercial gains has initiated destruction of traditional resource base, including the sacred groves.

The Pashupati sacred grove is fragmented by a road construction during Maoist insurgency which has led species loss and interruption in ecological function. The forest area of PSG has also been as found encroached from government line agencies for the extension of International Airport and extension of Nepal Army barracks which provide security to the 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 recorded threats for the conservation of sacred groves were development projects, commercial forestry, and shift in 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 groves (Sharma and Devi, 2014).

In PSG, the main goal of the area was to promote the religious belief and conserve archeological objects rather than biodiversity conservation. This may be only cause of forest degradation in PSG than that of BSG. Different activities have been conducted by PADT to conserve and facilitate the ongoing taboos. Those activities and taboos may or may not have contributed successfully in biodiversity conservation of PSG. Biodiversity conservation related activities like legalization of religious forest, plantation of *Choerospondias axillaris* and other ornamental flowers, fruits, religious trees in degraded part of forest, establishment of deer park, netted and barbed wire fencing, appointment of forest guards, as well as construction of compound wall were implemented by PADT. Despite these attempts to conserve biodiversity, PSG has gone under lots of changes in the past. Activities like allocation of forest land for cemetery, construction of 7 m wide and 800 m long road runs through Sleshmantak forest fragmenting PSG in two parts, access track, temples, old age home, *Ashram* and *Dharmasala*, were not in favor of biodiversity conservation. These taboo related and developmental activities were found as the major factor for deforestation and forest degradation which has ultimately provided negative impacts on biodiversity conservation. Similar kinds of problems have been reported in the religious forest as aesthetic value in the sacred groves of Morocco (Deil *et al*., 2005). A study conducted on human impact on sacred grove of India, identified that sacred groves played significant role for forest conservation. Some other factors and the goal of managing organization may not help in biodiversity conservation inside sacred groves (Sing, 2006).

In BSG the forest management responsibilities were handed over to community based institution the “Jyotidaya Sangh”. The community has practiced several conservation friendly activities like fencing around the grove, regulations of illegal activities inside the grove, enforcement of rules for conservation and appointments of forest guards are some of them. Beside those BSG has developed facilities in certain pocket areas of forest for eco-tourism promotion which include construction of stone paved walking trails, picnic shades, water storage tanks and toilets. These community initiations have found to be not performing satisfactorily in biodiversity conservation in BSG, though the forest is comparatively more conserved than PADT managed PSG.

The main purpose of visit to a religious site is religious belief and taboos related to the area. In the changing socio-cultural context, the purpose of visit was not only limited to religion but also for recreational events. The limitation of entertaining sites in the urban area is also a reason to accelerate the visitors to the sacred groves. To attract the visitors other than the religious reason, the managing institution of BSG constructed walking trails, picnic spots and other related facilities inside the forest area. These construction works have contributed adversely in biodiversity conservation in the area. This has indicated that the biodiversity conservation also links with the socio-cultural trends of the society. Those may be harmful for the conservation of biological resource of the sacred groves. Similar kind of study was conducted in Morocco concluded that the land use changes in the sacred groves due to the change in socio-cultural changes increased the recreational tourism than the pilgrimage, which ultimately resulted the loss of biodiversity in changing landscapes (Berriane, 1990, 1992).

Sacred groves are distributed mainly in government owned forest lands, all over the country, belonging to different departments under Ministry of Forest and Soil Conservation. The ministry is also responsible for their management according to the acts, rules and regulation formulated by the Government of Nepal. But, there are no nationwide records regarding the distribution, numbers, users' and area covered by sacred groves. The government has been unsuccessful in keeping the records of sacred groves which are found in various sizes all over the country. This has indicated that local practices of forest conservation had been never paid attention as a tool for better management option of forest in response to local demand and biodiversity conservation. Similar types of result were observed in Karnataka, India, where uniqueness of sacred groves, their role for conserving vulnerable species, and tradition of management by the local peoples had been never paid attention from government side (Gokhale, 2005).

Being a signatory country of the different international conventions like the World Heritage Convention (1972), Convention on International Trade in Endangered Species of Wild Fauna and Flora (1975), Ramsar Convention (1975), and Convention on Biological Diversity (1992) Nepal has moral obligation to prepare conservation related legislations not contradicting with them (HMGN/MoFSC 2002). One of the aim of those conventions are to prepare homogeneous and uniform environment for the management of resources with number of specialized institutions for respective corresponding functions and is considered as globalization (Pandey and Rao, 2002). But, in small scale societies single cultural institutions, like sacred groves, need to perform multiple functions. Employing the bureaucratic administrative system by the country, on the global pattern of rational management, caused a change in scenario and created confusion over the resource ownership and relevancy about the sacred grove institution (Pandey and Rao, 2002). Globalization has created an impact on the local cultural domain and this interaction is an ongoing process. The impact of globalization in the groves has resulted in cracks in local norms and cultural system. As a spiritual threat, conversion of religion has caused shift in belief system ultimately responsible for the degradation of sacred grove.

Other hypothesis of this study is whether belief system plays important role for the conservation of sacred grove. Based on the canopy cover and the intensity of disturbances occurring in the study areas, the forest of BSG is more conserved compared to the forest of PSG. The study has found that the strong belief system of the local communities of Bajrabarahi area related to taboos and religious practices have contributed in the conservation of the forest of BSG. The results of the study are also in favor of the second hypothesis that belief system has played important role for the conservation of sacred groves.

CHAPTER 5. SUMMARY AND CONCLUSIONS

5.1 Summary

Biological diversity is the variability among living organisms in each ecological complex. Based on the existing property right regimes, different management systems are in practice around the world for conservation of natural resources. Sacred grove, is a practice of managing common property, is an ancient method of resources management. In Nepal, different societies are so intricately interconnected with their religion and customs and have been practicing generations old religious traditions by establishing various sized sacred groves devoted for their deities. These are contributing for the conservation of local flora and fauna; one of the widest spread practices in the past, and helped to conserve cultural landscapes. The study has attempted to analyze the community structure and carbon stock in tree canopy, their regeneration status and threats with local perception for the conservation and values of Pashupati and Bajrabarahi sacred groves of Kathmandu valley in central midhill physiographic region of Nepal. The overall objective of the proposed research was to assess the status of sacred groves in the study area by assessing the diversity of trees. The specific objectives of this study were to: assess the phyto-sociology in tree canopy, estimate sequestrated carbon by tree species, assess regeneration of trees and identify the potential causes of threats to the sacred groves, and assess local perceptions about conservation of sacred groves.

The study adopted both quantitative and qualitative methods. Quantitative methods for data collection were used for the phyto-sociological analysis of sacred grove, which included data collection by establishing concentric circular sample plots (CCSPs). Concentric circular sample plots (CCSPs) were used to collect data about tree level characteristic and soil sample. The circles of a CCSP with different radii and diameter thresholds, respectively, were centered at the same point. The outermost plot was used for tallying larger trees, whereas inner plots were used for measuring trees belonging into smaller size classes, respectively. The tree level characteristics like local and scientific names, height, and DBH were collected from each CCSP. Crown cover of the forest was measured by using densiometer. Soil samples were collected from five soil pits, four located in each cardinal directions in each sample plot, from and one in plot center of the CCPS.

Soil samples were analyzed in the laboratory of Soil Science Division, Nepal Agricultural Research Council, Khumaltar, Lalitpur. Standard methods were used to measure soil pH (soil: water ratio is 1:2), organic matter content was analyzed by volumetric method, total Nitrogen analysis by Kjeldahl method, available phosphorus by Bray and Kurt, available potassium by flame photometer method and soil texture by hydrometer method. The analyzed soil nutrients were classified into five categories like very low, low, medium, high, and very high.

The density of saplings and seedlings were considered as the indicator of regeneration status of each dominant tree species. Regeneration status of tree species was analyzed based on population size of seedlings and sapling and the status were classified in five categories as good regeneration, fair regeneration, poor regeneration, new regeneration, and no regeneration. Physical conditions of every tallied tree individual within CCSPs were noted to analyze the disturbance categories. Disturbance level of the forest was categorized as undisturbed, least disturbed, moderately disturbed, and highly disturbed in terms of biomass removal, tree cutting, development activities as well as livestock and wildlife grazing. Indices of each disturbance were calculated by assigning points to disturbance level and summing them to find diffusion index.

Questionnaire survey, direct observation, and review of related document were used for the assessment of local perception about sacred groves. Based on conceptual understanding about the importance of sacred groves on biodiversity conservation the questionnaires used for survey were classified into four different sub-groups. Biodiversity conservation confidence index (BCCI) was applied to assess the local perception on sacred groves.

In total 145 circular plots (PSG = 95, BSG = 50) were surveyed in the study areas. From the phyto-sociologial analysis of tree species, three types of forest were identified from Pashupati Sacred Grove. They were *Schima-Pyrus* forest, *Myrsine-Persea* forest and *Quercus-Myrsine* forest.

Schima-Pyrus forest occupied 20.9 ha area and incorporated deer park (4.8 ha) at Mirgasthali. In this forest 14 tree species were recorded with the density of 319 individual trees per ha. In this forest *Schima wallichii* was found most important tree (IVI = 81.4) species. The tree canopy cover of this forest was 55%. The recorded trees in this forest were belonging to eleven families. In *Mysrine-Persea* forest 11 species with the density of 603 ha^{-1} were recorded. The geographical area covered by this forest was 22.5 ha. From the phyto-sociological analysis of this forest, *Myrsine capitellata* (IVI = 142.0) was found more important tree species. Tree canopy cover of this forest was 80.96%. The recorded trees of this forest were belonging to eight families. There were 5 tree species with 677 stems ha^{-1} in *Quercus-Myrsine* Forest. The geographical area occupied by the forest was 40.1 ha. Based on the analyzed IVI, the more important tree of this forest was *Quercus glauca* (IVI = 138.5). Canopy coverage of the trees in this forest was 85.8%. The recorded trees of this forest were belonged to five families.

Only one forest type (*Neolitsea cuipala* forest) was recognized in the Bajrabarahi sacred grove. In this forest 18 tree species with 432 stems ha^{-1} per hectare were recorded. The geographical area covered by this forest was 18.29 ha. This sacred grove was dominated by *Neolitsea cuipala* having highest IVI (111.3). The canopy cover of this grove was 90.8%. The recorded trees of this forest were from 12 families. In BSG 432 stems ha^{-1} belonging to 12 families were recorded.

From the index of similarity (IS), more than 72% of families and 57% of tree species were found to be similar between BSG and PSG. Similarly, the analysis of maturity indices (MI) indicated that BSG forest incorporated more developed forest community (MI = 33.9) than that of PSG (MI = 26.0). The BSG incorporated less number of stem (432 ha^{-1}) with higher crown cover than that of PSG. The calculated values of Shannon-Weiner species diversity index were 1.80 and 1.91 for BSG and PSG, respectively. This indicated that PSG is most diverse than BSG in term of tree diversity. Similarly, Evenness value indicated that tree species of Pashupati Sacred Groves (0.67) were more evenly distributed than that of Bajrabarahi Sacred Groves (0.62).

In *Schima-Pyrus* forest of PSG average carbon stock density of each species of tree was 5.45 t ha^{-1}. The total carbon dioxide assimilated by this forest was 5.86 mt. Total carbon stock density of the trees species in *Myrsine-Persea* forest of PSG was 64.77 t ha^{-1}. Total carbon dioxide sequestrated in this forest was 5.35 mt. The average carbon stock density in the tree of *Quercus-Myrsine* forest of PSG was 15.51 t ha^{-1}. Total carbon dioxide sequestrated by the tree species of this forest was 11.42 mt. In *Neolitsea cuipala* forest of BSG total carbon stock density of tree species was 143.37 t ha^{-1}. Total carbon dioxide sequestrated in this forest was 9.62 metric ton. The trees of PSG and BSG together incorporated 1014.23 t of average Carbon. The highest amount of Carbon (622.09 t) was reported in *Quercus-Myrsine* forest followed by *Neolitsea cuipala* (145.68 t) forest. Trees of PSG and BSG were assimilating 3.7 mt of average carbon dioxide.

The regeneration status of PSG was good and fair in BSG. The identified disturbances in the study were freshly cut trees, dead or rotten trees, coppice re-growth, erosion, access track, rubbish dumping, picnic spot, cemetery, badminton court, grazing, water point, earth work, fence lines, and construction of permanent structures like buildings as well as toilets. The disturbance statuses of sacred groves were identified as undisturbed, least disturbed, moderately disturbed and highly disturbed based on disturbance index. The general condition of soil was acidic in both groves; the nitrogen content was low in PSG and medium in BSG. The organic matter was in medium range and potassium and phosphorus were very high in both groves. The average sand level available in the soil of PSG was 63% (42.4-79 %), silt 27% (12.5-46.2%), clay 10% (7.1- 15.1%). Two types of soil were recorded from the Pashupati Sacred Grove.

In PSG, the number of seedling per hectare was greater than the sapling and tree and there were equal number of saplings and trees per hectare. So, the status of tree regeneration in Pashupati sacred grove was good. The highest number of seedling (2089 ha^{-1}), saplings (298 ha^{-1}) and adult (240 ha^{-1}) were recorded in least disturbed areas of PSG. Out of recorded 23 tree species in PSG, 9% showed good, 30% showed fair, 13% showed poor regeneration, and 13% were not regenerating. Similarly, 35% of the recorded tree species were found as new. The regeneration status of the tree was good in *Schima-Pyrus* forest type. There was fair regeneration of tree species in *Myrsine-Persea* and *Quercus-Myrsine* forests.

The highest number of seedlings (3,981 ha^{-1}) and adult trees (430 ha^{-1}) were recorded from the undisturbed forest areas of BSG. The regeneration status of tree species in Bajrabarahi sacred grove was fair. Out of 19 recorded tree species from BSG 26.3% tree species showed fair regeneration, 68.4% trees were not regenerating and a new species, *Boehmeria rugulosa*, was regenerating in seedling stage. The average sand available in the soil of BSG was 39.96% (7.2 - 56.0%), the average silt was 39.76% (15.4 - 50.25%) and the average clay recorded was 20.3% (9.8 - 77.4%). Three types of soils were recorded from BSG; they were loamy, silt loam and sandy loam.

Regarding the sacred grove conservation, local people of PSG and BSG perceived that the objective of sacred grove establishment is for biodiversity conservation. The people of local communities have realized that the forest is better protected and preserved than in the past in BSG but less conserved in PSG due to more anthropogenic activities. The findings have shown that the perception towards the sacred grove conservation was positive.

In PSG and BSG local people have appreciated sacred groves for providing benefit for biodiversity conservation and helping to increase religious belief in the comunity. The natural resources of sacred groves were not used with few exceptions for cultural and religious purposes. They have also realized that the income generated from the sacred grove is a good initiation in supporting the management of sacred grove.

Local people of surrounding communities of PSG have made both management group and government responsible for the degradation of sacred grove. But, in BSG they admitted that the management group has played a pivotal role for the conservation of forest. Local people recognized that the existing rules for utilizing natural resources, involvement of users in conservation activities, and acquired help from local community for the management of forest areas. Local people suggested to conduct effective awareness programs for forest conservation and involved stakeholders for planning and solving the conservation related problems in both sacred groves.

Local communities have consideredthe sacred groves as biodiversity conservation sites and religious belief promotion sites, as well. Despite the rules and regulation from the government side for the management of sacred groves, the latest plans and strategies have ignored the importance of sacred groves, neither there is proper documentation of existing groves within the country is available. Realizing its importance for the conservation of local culture and belief system as well as pioneer concept of the involvement of local community for biodiversity conservation government should also need to prioritize the management of sacred groves in the national conservation programs.

5.2 Conclusion

Sacred groves represent the meeting ground of cultural and biological diversities, and protection of these sacred sites could contribute in strengthening the movement to save the planet's precious biological and cultural landscape. Centuries old tradition of sacred groves, for resource conservation have been practiced since time immemorial by utilizing the local belief systems and traditions, acts like a norm for "social fence", had been identified and integrated in recent legal framework as one of the forest management regimes in Nepal. On one hand the groves play important role for safeguarding local belief systems and taboos, while on the other hand they play significant role for the conservation of biological diversity. It is one of the oldest common pool resource management model practiced for the conservation of forest resources. Sacred groves offer safeguarding of habitats, ecosystems as well as species and this conservation approach has awfully accepted from local people. Despite being threatened by many threats; PSG has supported higher biodiversity and is important in conserving tree diversity compared to BSG. Local microclimates have created different forest types in sacred groves with dominating tree species. The diversity of forest in terms of area and species composition with the size of tree is found to be the determinant factors for the carbon sequestration.

Eighteen different types of threats related to natural and anthropogenic disturbances, also known as drivers of deforestation and forest degradation have been identified in sacred groves. Local inhabitants, in association with community based organizations, are important in distinguishing and executing the role of faiths and customs in conservation activities. Local communities have considered the sacred groves as sites for the promotion of biodiversity conservation and religious belief despite numerous challenges that need to be addressed in future. Although, the sacred groves or religious forests have been identified as an important regime for natural resource management by the GoN, but the latest government plans and strategies have not adequately addressed the importance of these groves and excluded from the recent National Biodiversity Strategy and Implementation Plan 2014-2020. Realizing its importance for the conservation of local culture and belief system as well as pioneer concept of the involvement of local community for biodiversity conservation government should also need to provide priority for the management of sacred groves. Greater sensitivity towards the promotion of well-established and effective conservation traditions adopted by the local communities need to be recognized by the government side.

The principal conclusion is that sacred groves are an important but largely unrecognized, and highly threatened, pioneer network of conservation sites with the ability to make a significant contribution toward conserving and restoring biological and cultural diversities. The following 10 conclusions drawn from this research given below suggest steps toward supporting sacred groves as an important means of conserving nature and culture and provide the conceptual foundation for the recommendations:

1. From the phyto-sociological analysis of tree species three forest types namely *Schima-Pyrus* forest (20.9 ha), *Myrsine-Persea* forest (22.5 ha) and *Quercus-Myrsine* forest (40.1 ha) in PSG and only one forest type, *Neolitsea cuipala* forest (18.29 ha), was recognized in BSG.

2. A total of 23 tree species in PSG and 19 tree species were recorded in BSG, similarly the maturity index in PSG was 26.0 and 33.9 in BSG. The canopy cover in PSG was 73.92% and 90.8% in BSG. The Shannon-Winner Diversity index was 1.91 and 1.81 in PSG and BSG, respectively.

3. It has been recorded that the total average carbon stock in tree species of PSG and BSG together was 1014.23 t. The higher amount of Carbon stock (622.09 t) was recorded in *Quercus-Myrsine* forest followed by *Neolitsea cuipala* (145.68 t) forest. Trees of PSG and BSG were found to have assimilated 3.7 mt of average carbon dioxide.

4. In *Schima-Pyrus* forest of PSG average carbon stock of each species of tree was 5.45 t ha^{-1}. The total carbon dioxide sequestration by this forest was 5.86 mt and the total carbon stock of the trees species in *Myrsine-Persea* forest of PSG was 64.77 t ha^{-1}. Total carbon dioxide assimilated in this forest was 5.35 mt and thetotal carbon stock in the tree of *Quercus-Myrsine* forest of PSG was 77.57 t ha^{-1}. Total carbon dioxide assimilated by the tree species of this forest was 11.42 mt. In *Neolitsea cuipala* forest of BSG total carbon stock density of tree species was 143.37 t ha^{-1}. Total carbon dioxide incorporated in this forest was 9.62 mt.

5. The general condition of soil was acidic in both groves; the nitrogen content was low in PSG and medium in BSG. The organic matter was in medium range and potassium and phosphorus were very high in both groves. The average sand level available in the soil of PSG was 63% (42.4-79 %), silt 27% (12.5- 46.2%), clay 10% (7.1- 15.1%). Two types of soil were recorded from the Pashupati Sacred Grove, they were loamy soil and sandy loam. The average sand available in the soil of BSG was 39.96% (7.2- 56.0%), the average silt was 39.76% (15.4- 50.25%) and the average clay recorded was 20.3% (9.8 - 77.4%). Three types of soils were recorded from BSG; they were loamy, silt loam and sandy loam.

6. The regeneration status of PSG was good and fair in BSG. The regeneration status of the tree was good in *Schima-Pyrus* forest type. There was fair regeneration of tree species in *Myrsine-Persea* and *Quercus-Myrsine* forests.

7. Out of recorded 23 tree species in PSG, 9% showed good, 30% showed fair, 13% showed poor regeneration, and 13% were not regenerating. Similarly, 35% of the recorded tree species were found as new. Out of 19 recorded tree species from

BSG, 26.3% species showed fair regeneration, 68.4% were not regenerating and a new species was regenerating in seedling stage.

8. The identified disturbances in the study were freshly cut trees, dead or rotten trees, coppice re-growth, erosion, access track, rubbish dumping, picnic spot, cemetery, sport activities, grazing, wildlife grazing, water point, earth work, fence lines, and construction of permanent structures like buildings as well as toilets. Based on disturbance indices, the disturbance statuses of sacred groves were identified as undisturbed, least disturbed, moderately disturbed and highly disturbed.

9. Local people of PSG and BSG perceived that the main objective of sacred grove establishment was for biodiversity conservation. Local communities of BSG have recognized that the grove is in better protected and preserved condition than in the past compared to PSG due to more anthropogenic activities. Local people have understood the importance of sacred groves in biodiversity conservation and its role in increasing religious belief.

10. Local people visiting PSG have blamed both management group and government were responsible for the degradation of sacred grove. But, in BSG they admitted that the management group have played vital role in the conservation of forest. Local people have been familiar with the available rules for utilizing natural resources, involvement of users in conservation activities, and acquired help from local community for the management of forest areas.

Local communities have considered the sacred groves as the sites of both biodiversity conservation and religious belief promotion. Despite of government's commitments for the management and conservation of nation's biodiversity, the latest plans and strategies have inadequately addressed the conservation and management of sacred groves. Realizing the importance of sacred groves for the conservation of local culture and belief system as well as pioneer concept of community involvement for biodiversity conservation, government should also need to prioritize and develop programs for the management of sacred groves. The specific recommendations drawn from the study for the conservation of sacred grove in Nepal are as follows:

5.3 Recommendations

1. Document and categorize sacred groves, scattered all over the country, and integrate them in a conservation network.

2. Conduct biodiversity inventory in all sacred groves of the nation and prioritize them for conservation based on their existing conditions.

3. Support the autonomous protection and management of sacred groves by promoting stakeholder consent, participation, inclusion and collaboration by encouraging improved knowledge and understanding of sacred groves, while preparing management plan and action plan for their conservation.

4. Increase understanding and awareness, particularly at national level, of the importance and role of sacred groves, and promote the formation of appropriate national policies and laws for their legal protection. Also, respect the rights of stakeholder within an appropriate framework of national policy.

5. Sacred groves should be recognized as one of the pioneer steps and indigenous method of community managed resource site. Management of sacred grove should be encouraged to hand over to the local communities within appropriate government conservation policy and law.

6. Sacred groves should have a policy for the conservation of local biodiversity and religious values rather than a source of income from recreational sites.

7. Need to halt the encroachment of sacred grove in the name of development activities by the government or management groups.

8. Prior to introduction of new species either plant or animal, detailed plans and action plans for the management of those species need to prepare. Those plans must be properly executed for the management of a species, e.g. introduction of deer in PSG.

9. The study strongly recommends to restore the degraded forest patch of PSG by transferring the deer from the Deer Park.

10. Sacred grove should be managed as important religious sites rather than conservation unfriendly activities based in the belief systems concerning to an ethnic group (e. g. cemetery).

11. Documentation and preservation of information concerning traditional beliefs and attitude related to sacred groves should be maintained. Such type of prospective should be incorporated in conservation education and awareness programs that might have the extra utility or facilitating effective environmental communications across generations. Support cultural revitalization and the strengthening of communities and their connections with their sacred groves.

12. Sacred groves should also be recognized as repositories of different rare species as well as reserves of carbon and gene pools. The steps must be taken to increase awareness among the visitors, villagers and communities living nearby regarding the importance and relevance of conservation of sacred groves.

13. Access and generate funding for sacred natural sites identifying a diversity of resources (financial and otherwise) to support sacred groves.

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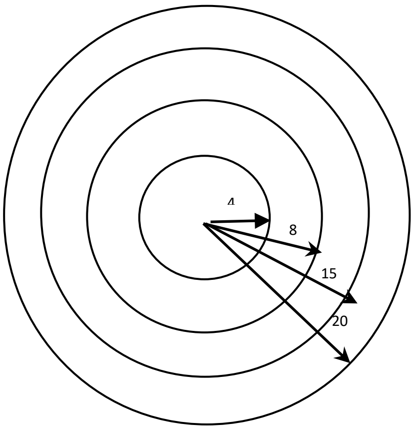
Annex 1 - Field data sheet

Data Sheet - Role of sacred groves in Biodiversity conservation in Nepal							
Site:				Transect No.:	Plot No.:		Sheet No.:
Altitude:				Slope:	Lat. N:		Long. E:
Canopy Cover (%)			1=	2=	3=	4=	5=
Field personnel:							Date:
Tree No.	**Bearing**	**Distance**	**Species code**	**Tree Scientific Name**	**DBH (cm)**	**Height (m)**	**Remarks**
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
11							



DBH Threshold
4m = 5 to <10 cm DBH
8m = 10 to <20 cm DBH
15m = 20 to <30 cm DBH
20m = 30 or >30 cm DBH

Annex 2 - Field form for seedling and saplings

Sub- plot (2m radius) N E S W	No.	Species name	Seedlings (30cm-100cm height and <5cm dbh.)		Sapling (≥ 5cm-12.6cm dbh.)	
			Frequency	Mean ht.	Frequency	Mean ht.

Annex 3 - Rating chart for soil test data.

Nutrients	Very Low	Low	Medium	High	Very High
1. Organic matter %	Less than 1	1-2.50	2.50-5.0	5.0-10.0	More than 10
2. Nitrogen %	Less than 0.05	0.05-0.10	0.1-0.2	0.2-0.4	More than 0.4
3. Phosphorus kg/ha	Less than 10	10-30	30-35	55-110	More than 110
4. Potassium Kg/ha	Less than 56	56-112	112-280	280-504	More than 504

Annex 4 - Field data sheet for disturbance study

Role of sacred groves in Biodiversity conservation in Nepal								
Field data sheet for disturbance study								
Site:		Transect No.:		Plot No.:				
Field personnel:						Date:		
Freshly cut trees				Dead/rotten trees				
No.	Species name	DBH		No.	Species name		DBH	
1				1				
2				2				
3				3				
4				4				
5				5				
6				6				
7				7				
Lopped				Other Disturbances				
No.	Species name	Number	Remarks	No.	Type	Type	Y /	Intensity
1				1	**ER**	Erosion		
2				2	**AT**	Access track		
3				3	**CR**	Coppice re-		
4				4	**DR**	Drain		
5				5	**FL**	Fence Lines		
6				6	**AR**	Access road		
7				7	**PL**	Power lines		
8				8	**RD**	Rubbish		
Burnt				9	**SL**	Slashing		
No.	Tree species	Number	Remarks	10	**PS**	Picnic spot		
1				11	**GR**	Grazing		
2				12	**LC**	Litter		
3				13	**EA**	Earthworks		
4				14	**WP**	Water point		
5						Other		

Annex 5 - Disturbance intensity categories and parameters.

Disturbances	**Less (1)**	**Medium (2)**	**High (3)**
Access road	<5% area of plot	5-10% area of plot	>10% are of plot
Access track	<5% area of plot	5-10% area of plot	>10% are of plot
Burnt	1 tree burnt	2 tree burnt	>2 tree burnt
Coppice re-growth	In 1 coppice	In 2 coppice	In >2 coppice
Dead/rotten trees	Dead/rotten trees percent= <30%	Dead/rotten trees percent= >30%-<60%	Dead/rotten trees percent= >60%
Drain	<5% area of plot	5-10% area of plot	>10% are of plot
Earthworks	Upto 1m far from plot	1m inside from plot margin	Inside 3 m from plot
Erosion	Removal thin layer from top soil	Finger size gullies formation	Large gully formition
Fence lines	Cross from margin of plot	Cross from 10% area of plot	Cross from the
Freshly cut trees	Tree cut percent= <30%	Tree cut percent= >30%-<60%	Tree cut percent= >60%
Grazing	Grazed in <5% plot area	Grazed in 5-10% plot area	Grazed in >10% plot
Litter collection	Collected from <5% area	Collected from 5-10% area	Collected from >10%
Lopped	1 tree lopped	2 tree lopped	>2 tree lopped
Picnic spot	Up to 1m far from plot	1m inside from plot margin	Inside 3 m from plot
Power lines	Cross from margin of plot	Cross from 10% area of plot	Cross from the
Rubbish	Up to 1m far from plot	1m inside from plot margin	Inside 3 m from plot
Slashing	<5% area of plot slashed	5-10% area of plot slashed	>10% area of plot
Water point	Up to 1m far from plot	1m inside from plot margin	Inside 3 m from plot

Annex 6 - Questionnaire for social survey of sacred grove

Name of scared grove…………………………………District……………………………….

Municipality/ VDC……………………………Ward No………Location…………………….

Name of interviewee……………………………………. Sex………. Age…………………

District……………………. Municipality/ VDC………………………Ward No……………

Location…………………………Qualification………………………………………………

Name of interviewer………………………………………. Date…………………………

Questions for general people

1. Since how long you have been living in this place?
2. Since how long you have been visiting this grove?

   A) 0 – 5 yrs. B) 6 – 10 yrs. C) 11 – 15 yrs. D) >15 yrs.

3. What is the purpose of you visit to this grove?

   A) Worshiping B) Nature walk C) Morning walk D) Others

Local people's knowledge regarding sacred grove

4. What could be the objective of establishment of sacred grove, in your opinion?

   A) Religious purpose, B) Religious motivation

   C) Generate income for temple D) Biodiversity conservation

5. Do you know what biodiversity is?

   A) Yes B) No

6. Is this sacred grove contribute in conservation of biodiversity?

   A. Yes B. No C. Very high D. Don't know

7. Have you observed any changes in the status of forest in comparison to the past?

   A. Good B. Bad C. Very bad D. Same

8. Who do you think is responsible for such condition of sacred grove?

   A. Government B. Local bodies C. Local people D. Management group

9. What are direct or indirect benefits from sacred grove?

   A. Religious activity B. Source of income

C. Biodiversity conservation D. All

10. Does this sacred grove helps to increase religious belief in people?

A. More B.Less C. No D. Don’t know

11. What types of users come to visit this sacred grove?

A. Religious B. Nature lover C. Entertainment D. Others

12. What types of resources are used from the grove?

A. Fodder/grass/food B. Fire wood C. Timber D. Not used

13. If resources are used, what are the effects on the forest?

A. Loss of forest B. Loss of biodiversity C. Erosion D. No effect

14. Are the users from local communities or outsiders?

A. Local B. Outsiders C. Priest D. Don’t know

15. Is there any rules to use natural resources?

A. Yes B. No C. Not sufficient D. Don’t know

16. Have there any amendments made in the existing rules?

A. Yes B. No C. Not sufficient D. Don’t know

17. Is there any income generating program of sacred grove for poor people?

A. Yes B. No C. Don’t know

18. Is there any involvement of users in conservation activities?

A. Yes B. No C. Less D. Don’t know

19. Is there any changes in the number of visitors from previous years?

A. Less B. More C. Very high D. Don’t know

20. Is there any support provided by the government for the management of the grove?

A. Budget B. Technical manpower C. Security D. No

21. What kind of support is provided by local community for the management of the grove?

A. Community participation B. Donation C. Security D. Cleaning

22. What is the perception of local people towards the conservation?

A. Positive B, Negative C. Ignore D. Hindrance

23. Is there any future planning for the sacred grove management?

A. Yes B. No C. Don't know

24. Is there any income generating program to support management from sacred grove?

A. Yes B. No C. Very high D. Don't know

25. If yes, what are the sources of income?

A. From recreational activities B. Religious activity

C. Sale of forest resource D. Others

26. Would you like to suggest any suggestions for solving conservation problems?

A. Insufficient law B. Inefficient law enforcement C. Awareness raising D. Involvement of stakeholders during planning process

Annex 7 - Plot wise regeneration of tree species of PSG.

Plot no.	Seedling /ha	Sapling /ha	Tree /ha	Status	Dist. Status	pH	OM%	N%	P_2O_5 kg/ha	K_2O kg/ha	Sandy %	Silty%	Clay%	Class%	Canopy %
1	1393	247	239	Good	MD	4.11	2.14	0.35	275.0	268.8	79	12.5	8.5	Loamy	99
2	0	48	223	Poor	MD	4.41	3.69	0.15	80.6	1102.0	67	24.5	8.5	Sandy Loam	96.8
4	0	0	167	None	MD	4.81	3.69	0.15	89.2	961.1	73	18.5	8.5	Sandy Loam	85.5
5	11346	1543	135	Good	LD	4.57	3.95	0.17	443.6	725.7	69	22.5	8.5	Sandy Loam	72.6
7	0	48	32	Poor	HD	5.6	4.31	0.21	847.3	698.8	69	22.5	8.5	Sandy Loam	77
9	0	0	40	None	HD	4.62	4.11	0.15	435.0	1276.8	61	26.5	12.5	Sandy Loam	39.6
10	0	48	111	Poor	HD	4.43	3.49	0.09	291.0	846.7	57	32.5	10.5	Sandy Loam	83.6
11	0	0	135	None	HD	5.24	3.18	0.15	330.4	994.5	69.4	22.5	8.5	Sandy Loam	66
12	0	0	103	None	LD	4.98	4.57	0.11	1200.5	1344.0	56.4	30.5	13.1	Sandy Loam	4.4
13	0	0	119	None	HD	4.34	3.74	0.10	705.8	860.1	54.4	30.5	15.1	Sandy Loam	96.8
14	0	199	95	Poor	LD	4.33	4.47	0.24	435.0	725.7	72.4	18.5	9.1	Sandy Loam	46.2
16	0	0	135	None	LD	4.5	3.43	0.06	615.9	967.6	56.4	32.5	11.1	Sandy Loam	59.4
19	199	445	493	Poor	HD	4.69	4.16	0.16	53.2	645.1	68.4	24.5	7.1	Sandy Loam	59.4
20	0	644	557	Poor	HD	4.18	3.33	0.08	42.1	672.5	64.4	24.5	11.1	Sandy Loam	72.6
23	1592	48	294	Fair	LD	4.84	0.59	0.15	49.5	1075.2	64.4	24.5	11.1	Sandy Loam	88
24	199	947	310	Fair	MD	4.65	5.4	0.07	111.6	645.1	60.4	28.5	11.1	Sandy Loam	96.8
25	1385	48	263	Fair	LD	4.92	3.02	0.12	43.9	1263.3	42.4	46.2	11.4	Loamy	57.2
29	2389	302	660	Fair	LD	4.77	5.76	0.09	190.4	1128.9	46.4	44.2	9.4	Loamy	90.2
30	0	247	231	Poor	LD	4.66	3.07	0.13	366.4	940.8	58.4	30.2	11.4	Sandy Loam	96.8

Note: *LD - Least disturbed, MD - Moderately disturbed, HD - Highly disturbed, Dist. Status – Disturbance status.*

Annex 8 - Plot wise regeneration status of tree species in BSG.

Plot No	Seedling/ha	Sapling/ha	Tree/ha	Status	Dist. status	pH	OM%	N%	P_2O_5 kg/ha	K_2O kg/ha	Sand %	Silt%	Clay%	Class%	canopy
2	199	0	438	Fair	LD	3.81	1.97	0.09	235.15	638.68	44	44.2	11.8	Loam	92.40%
3	1385	0	278	Fair	LD	4.41	0.88	0.06	212.18	760.24	46	40.2	13.8	Loam	96.80%
4	0	0	342	none	HD	3.95	3.88	0.15	98.43	652.19	32	50.2	17.8	silt loam	90.20%
5	1990	0	700	Fair	LD	4.25	0.41	0.06	53.59	328.06	48	42.2	9.8	Loam	85.50%
7	3981	0	430	Fair	UD	4.56	2.02	0.09	84.22	328	50	40.2	9.8	Loam	85.50%
8	3583	0	175	Fair	LD	3.97	2.74	0.11	65.62	449.61	42	40.2	17.8	Loam	90.20%
9	2189	103	335	Fair	LD	3.97	7.91	0.27	115.94	544.15	56	34.2	9.8	sandy loam	81.40%
11	0	0	581	none	HD	4.47	1.71	0.09	384.99	1003.33	7.2	15.4	77.4	clayey	92.40%
13	0	199	263	poor	MD	4.56	1.45	0.08	123.59	652.19	33.2	47.4	19.4	Loam	94.60%
16	0	0	525	none	LD	4.04	2.48	0.11	314.99	814.26	41.2	43.4	15.4	Loam	99%

***Note**: LD - Least disturbed, MD - Moderately disturbed, HD - Highly disturbed, Dist. Status – Disturbance status*

Annex 9 - List of tree species recorded from the study area

a. Pashupati Sacred Grove

SN	Name of tree species	Name of family	Local name	Common name
1	*Alnus nepalensis* D. Don.	Betulaceae	Utis	Alder
2	*Araucaria Basalllii* Hook.	Araucariaceae	Kande sallo	Monkey puzzle
3	*Betula alnoides* Buch.-Ham. ex D. Don.	Betulaceae	Saur	NA
4	*Castanopsis tribuloides* (Sm.) A. DC.	Fagaceae	Musure katus	NA
5	*Celtis australis* L.	Ulmaceae	Khari	Eropean neettle wood
6	*Choerospondias axillaris* (Roxb.) B.L. Brutt. & A.W. Hill.	Anacardiaceae	Lapsi	Nepalese hog plum
7	*Eurya acuminata* DC.	Theaceae	Jhingani	NA
8	*Fraxinus floribunda* Wall.	Oleaceae	Lankure	Ash
9	*Hymenodictyon excelsum* (Roxb.) Wall.	Rubiaceae	Bhurkul	NA
10	*Juglans regia* L.	Juglandaceae	Okhar	Walnut
11	*Litsea lanciffolia (Roxb.ex Nees) Hook.f*	Lauraceae	Kali paheli	Culbeb
12	*Morus serrata Roxb.*	Moraceae	Kimbu	NA
13	*Myrica esculenta* Buch. -Ham. Ex D. Don.	Myricaceae	Kaphal	Box myrtle/Bay berry
14	*Myrsine capitellata* Wall.	Myrsinaceae	Seti kath	NA
15	*Myrsine semiserrata* Wall.	Myrsinaceae	Kali kath	NA
16	*Persea odoratissima* (Nees) Kosterm.	Lauraceae	Seto kaulo	NA
17	*Prunus cerasoides* D. Don.	Rosaceae	Painyu	Himalayan cherry
18	*Pyrus pashia* Buch. -Ham. ex D. Don.	Rosaceae	Mayal	Wild pear
19	*Quercus glauca* Thunb.	Fagaceae	Phalant	Blue Japanese oak

SN	Name of tree species	Name of family	Local name	Common name
20	*Schima wallichii* (DC.) Korth.	Theaceae	Chilaune	Needle wood
21	*Stranvaesia nussia* (D. Don) Decne	Rosaceae	Jure mayal	NA
22	*Syzygium cumini* (L.) Skeels.	Myrtaceac	Jamun	Black plum
23	*Zizyphus incurva* Roxb.	Rhamnaceae	Hade vayar	Bead plum

b. Bajrabarahi Sacred Grove

SN	Name of tree species of BSG	Name of family	Local name	Common name
1	*Albizzi jubrissin* Durazz.	Leguminosae	Padkesiris	NA
2	*Albizzia lebbek* (L.) Benth.	Leguminosae	Kalo siris	Parrot tree/Black Siris
3	*Areca catechu* L.	Palmae	Supari	Areca nut/Betet nut
4	*Boehmeria rugulosa* Wedd.	Urticaceae	Getha/Thekikath	NA
5	*Cassia fistula* L.	Leguminosae	Rajbikchya	Cassia pods
6	*Castanopsis tribuloides* (Sm.) A. DC.	Fagaceae	Musure katus	NA
7	*Castanopsis indica* (Roxb.) Miq	Fagaceae	Dhale katus	Nepal or Indian chest nut
8	*Celtis australis* (L.)	Ulmaceae	Khari	Eropean neettle wood
9	*Choerospondias axillaris* (Roxb.) B.L. Brutt. And A.W. Hill	Anacardiacae	Lapsi	Nepalese hog plum
10	*Hymenodictyon excelsum* (Roxb.) Wall.	Rubiaceae	Bhurkul	NA
11	*Myrica esculenta* Buch. -Ham. ex D. Don.	Myricaceae	Kafal	Box myrtle/Bay berry
12	*Myrsine capitellata* Wall.	Myrsinaceae	Seti kath	NA
13	*Myrsine semiserrata* Wall.	Myrsinaceae	Kali kath	NA

SN	Name of tree species of BSG	Name of family	Local name	Common name
14	*Neolitsea cuipala* (Buch. -Ham. ex D. Don) Kosterm.	Lauraceae	Lakhesin	NA
15	*Persea odoratissima* (Nees) Kosterm.	Lauraceae	Seto kaulo	NA
16	*Rhus succedanea* L.	Anacardiaceae	Bhalayo	Wax tree
17	*Sapium insigne* (Royle) Benth. ex. Hook.f	Eurphorbiaceae	Khirro	Tallow tree
18	*Schima wallichii* (DC.) Korth.	Theaceae	Chilaune	Needle wood
19	*Syzygium cumini* (L.) Skeels.	Myrtaceae	Jamun	Black plum

c. Following names and family have been changed according to APGIII (2009).

Old name of species	Family	New name of species	Family
Myrsine capitellata Wall.	Myrsineceae	*Rapania capitellata* (Wall.) Mez.	Primulaceae
Myrsine semiserrata Wall.	Myrsineceae	not changed	Primulaceae

Annex 10 - List of photos

Photoplate 1 – Forest Inventory with bussol compass

Photoplate 2 – Reading height and distance by Vertex IV

Photoplate 3 – Fragmentation of Pashupati sacred grove by development activities (road)

Photoplate 4 – Forest disturbance due to access trail and garbage in BSG

Photoplate 5 – Forest of PSG

Photoplate 6 – Forest destruction due to erosion (BSG)

Photoplate 7 – Disturbance due to wildlife in deer park of Mirgasthali

Photoplate 8 – Forest floor of BSG

Photoplate 9 – Forest floor of PSG

Photoplate 10 –Cremation in Pashuptinath premises

Photoplate 11 - Devotees in Pashuptinath during Shivaratri festival 2014

a. *Castanopsis indica*

b. *Schima wallichii*

c. *Choreospondias axilaris*

d. *Quercus glauca*

e. *Myrsine capitellata*

f. *Neolitsea cuipala*

Photoplate 12 – Common tree species reported during the study

Annex 11 – List of publications

PUBLICATIONS ARISING FROM THIS THESIS

1. Shrestha L.J. and Devkota M.P. (2013). *Forest types of Pashupati Sacred Grove, Kathmandu, Nepal*. Journal of Natural History Museum. 27: 72-77.
2. Shrestha L.J., Devkota M. and Sharma B.K. (2015). Phyto-sociological assessment of sacred groves in Kathmandu Nepal. International journal of plant and soil science, *IJPSS,* 4(5): 437-444, 2015; Article no.IJPSS.2015.043
3. Shrestha L.J. and Devkota M.P. (2015). Sacred groves as important sites for biodiversity conservation in Kathmandu, Nepal. In the Proceedings of the Biodiversität und Naturausstattung im Himalaya V. (Eds. Hartmann, M. and J. Weipert). Erfurt, Germany, pp. 1-6.
4. Shrestha L.J., Devkota M.P and Sharma B.K. (2015). Tree regeneration in Kathmandu Valley Nepal. *ECOPRINT* 22: 29-38.
5. Shrestha L.J., Devkota M.P and Sharma B.K. (2016). "Are sacred groves of Kathmandu Valley efficient in carbon sequestration?" Hindawi Publishing Corporation Journal of Botany, Volume 2016, Article ID 7695154, http://dx.doi.org/10.1155/2016/7695154

PAPER PRESENTED IN CONFERENCE AND SEMINAR

1. Sacred groves as important sites for biodiversity conservation in Kathmandu, Nepal. Paper presented in the symposium on Biodiversity and Natural Heritage of the Himalayas organized by the Natural History Museum, Erfurt, Germany between 11 and 14 April, 2014.
2. How efficient are sacred landscapes of Kathmandu Valley in biodiversity conservation? Paper presented in The Sixth Global Conference of the International Partnership for the Satoyama initiative (IPSI-6), held from 12 to14 January, 2016, in Siem Reap, Cambodia.

3. Cultural heritage and tree diversity in Pashupati Sacred Grove of Kathmandu Nepal, in 2016 World Wood Day Symposium (21 – 23 March, 2016).

4. Tree Diversity Conservation Initiatives in Sacred Groves of Kathmandu Valley, Nepal, in 7^{th} National Conference organized by NAST (29 – 31 March, 2016).

5. Local perception towards conservation of sacred groves in Kathmandu Valley, Nepal. Paper presented in National conference on "Impact of Climate change on Biodiversity; applications of recent technology for conservation of threatened species" organised by Dept. Zoology Mizoram University, India, 22-24 September 2016.

POSTER PRESENTED

1. A poster entitled "Local Community Initiatives in Biodiversity Conservation by the Management and Conservation of sacred forests in Kathmandu Valley Nepal", in IPSI Conference, September, 2013, Japan.

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1. Shrestha L.J., Devkota M.P and Sharma B.K. (2016). Tree Diversity Conservation Initiatives in Sacred Groves of Kathmandu Valley, Nepal. Manuscript submitted to Nepal Academy of Science and Technology (NAST) Journal.

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FOREST TYPES OF PASHUPATI SACRED GROVE, KATHMANDU, NEPAL

L.J. Shrestha and M. Devkota

ABSTRACT

A year round phytosociological study was carried out in 2012 to study different forest types in Pashupati Sacred Grove in Kathmandu Valley. Concentric circular plots (n-19) were laid down along eight parallel transects, 100 m apart from each other, traversing north and south passing through various vegetations. Our results showed that the grove had experienced change in forest types over the time period. Three forest types namely *Schima-Pyrus*, Moist (*Myrsine-Persea*) and Mixed (*Quercus-Myrsine*) were identified based on the importance value Index (IVI) of tree species instead of *Myrsine-Schima* forest which had once dominated the grove. Tree density greatly changed in different forest types and showed strong correlation between canopy cover and tree density, supporting the results of previous studies.

Key words: phyto-sociology, Importance Value Index, correlation, diversity, conservation

INTRODUCTION

Sacred grove has been defined as “A tract of virgin forest harboring rich biodiversity, protected by the local people based on the ground of indigenous cultural and religious beliefs, and taboos”. (Khumbongmayumi *et al.* 2005) and have been proved as the repositories of rare and endemic species as the remnant of the primary forest left untouched by the local inhabitants (Anthwal *et al.* 2006). The role of sacred groves in the conservation of biodiversity has long been recognized (Gadgil and Vartak 1976, Haridasan and Rao 1985, Khan *et al*. 1997) and it has been believed that sacred virgin forests date back to several thousands of years when human society was in the primitive state and all forms of vegetation in the sacred groves were supposed to be under the protection of the reigning deity of that grove, and the removal of even a small twig is taboo.

Nepal’s Forest Act 1992 has defined a religious forest as “A forest area that has been legally handed over to a legally registered religious groups, 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 groves have received considerable attention in conserving small patches of forest from socio-cultural and religious perspective but in recent times they are facing severe threats and are in verge of destruction. In an intensive study on the sacred groves of Kathmandu Valley, Mansberger (1991) has reported that Pashupati sacred grove is facing serious forest conservation challenges. A year round phyto-ecological assessment of Pashupati Sacred Groves was conducted in 2012 to identify the existing forest types within the grove.

STUDY AREA

The study was carried out in Pashupati Sacred Grove (83.55 ha) located in the suburbs of Kathmandu City 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. Based on historical facts it has been estimated that the grove is 1400 years old (Mansberger 1991) and has been considered as a bio-cultural landscape having close relationship with religious, socio-cultural beliefs, taboos and conservation practices. Pashupati Area Development Trust (PADT) has undertaken management responsibility of the sacred forest. Long back the grove was dominated by *Choerospoandias axillaris* (Nepalese Hog Plum) tree and due to that even today it is also known as Sleshmantak Forest but since that time lots of changes have occurred in the forest composition and species diversity.

MATERIALS AND METHODS

Parallel transects (n=8) 150 m apart from each other traversing north-south direction incorporating each forest types of the study area were prepared with the help of Google earth image. Coordinates of each transects thus laid were recorded and location of the field plot measurement were also selected at the interval of 100 m in each transect. The coordinates (latitude and longitude) of selected plot were noted down separately. Distance between quadrates varied with the size of unit to be sampled, but was always a minimum of 50 paces apart. Sampling was conducted at least 25 m from the border of different forest types.

Concentric Circular Sample Plots (CCSPs) were used to collect the field data (FRA 2010). The central point of CCSP was identified by using Geographic Position System (GPS) included with already identified coordinates from Google Earth images. The circles of a CCSP with different radii and diameter thresholds were centered at the same point. The outermost plot was used for tallying bigger trees, whereas inner plots are used for measuring trees belonging into smaller size classes, respectively. The innermost circle was used for assessing shrubs and for counting natural regeneration by counting the number of seedlings by species. The CCSP consist of four circular plots: plot with the radius of 20m (A=1257.1 m^2) all big size trees with DBH ≥30 cm were measured, plot with the radius 15 m (area: 707.1 m^2) trees with DBH 20.0 cm to 30.0 cm were measured, the third plot with the radius 8 m (area: 201.1 m^2) trees with DBH from 10.0 cm to 20.0 cm were measured, fourth plot with the radius 4m (area: 50.2 m^2) trees with DBH from 5.0 cm to 10.0 cm were measured. Canopy covers of the plots were measured with the help of Densiometer. The height and DBH (diameter at breast height) of trees (woody plant with single bole, >5 cm DBH and >1.3 m height) were measured with the help of Vertex IV, Transponder T3 and DBH tape.

Importance values index (IVI) of individual trees species available in the particular vegetation were calculated by adding the relative values of frequency, density and dominance. Relative dominance of trees was determined by calculating the basal area. Name of each forest type was determined by ordering the Importance values of each tree species. The name of particular vegetation was provided from the name of plant with highest importance value.

RESULTS AND DISCUSSION

From the phyto-sociologial analysis three types of forest were recorded in Pashupati Sacred

Grove. They were *Schima-Pyrus* Forest, *Myrsine-Persea* Forest and *Quercus-Myrsine* Forest.

Schima-Pyrus (Chilaune-Mayal) Forest

This forest occupied 20.9 ha area incorporating Mirgasthali Deer park (4.8 ha). The average tree height of this forest was 15.2 m with 40.9 cm of average diameter. In this forest total 14 tree species were recorded with the density of 318 trees per ha. The height of tree in this forest was reached up to 35m (*Araucaria bidwilii)*. In this forest *Schima wallichii* was found most important tree (IVI=81.4) followed by *Pyrus pashia* (IVI = 51.5) (table 1). The canopy coverage of the tree of this forest was 55%.

Mysrine-Persea (Moist) Forest

A total of 11 tree species with the density of 593 trees per ha were recorded from this forest. It geographical area covered by this forest was 22.5 ha. The average tree height was 11.7 m with 30.7 cm of average diameter. The maximum height of tree recorded from this forest was 25.9 m. From phyto-sociological analysis the more important tree of this forest was *Myrsine capitellata* (IVI=142.9) followed by *Persea odoratissima* (IVI=41.5) (table 1). Tree canopy cover of this forest was 80.96%.

Quercus-Myrsine (Mixed) Forest

The study revealed the presence of 5 tree species with 677 trees per ha in this forest. The geographical area occupied by the forest was 40.1 ha. The average height of tree was 12.6 m with 28.5 cm of average diameter. The more important tree of this forest was *Quercus glauca* (IVI=138.5) followed by *Myrsine capitellata* (IVI=56.2). The maximum height of tree in this forest was 20m. Canopy cover of the tree in this forest was 85.8%.

Most of the previous studies regarding the Pashupati Sacred Groves mainly focused its environment and conservation of forest (Marriot 1978, Bajracharya *et al.* 1988, Tandon 1989). The area is also famous for the commercially valuable medicinal plants (Joshi *et al.* 1998).

Pashupati Sacred Grove, also known as Sleshmantak forest, used to be dominated by *Choerospoandias axillaris* trees in the past. Previously only one forest type *Myrsine–Schima* was identified by Shrestha (2001). Three forest types have been identified by the current study and *Choerospoandias axillaris* was not identified as dominant tree for none of these forest types.

Deer Park of this forest is located in Mrigasthali area. In this park 2 Barking deers (*Muntiacus muntjak*) and 10 Chitals (*Axis axis*) and 20 Blackbucks (*Antelope cervicarpa*) were reintroduced in 2004 by Pashupati Area Development Trust (Shrestha 2009). The forest of Mrigasthali was considered as dying forest patch due to the heavy pressure from the reintroduced deer (Ghimire and Shrestha 2009) whose population has gone up to 150 according to Pashupati Area Development Trust. Current result also supported the negative impact of the deer park for forest cover. The tree canopy cover in this patch of forest is less (55%) than other forest types.

Current study reflected that tree density is different according to the forest types. The density of tree also related to the tree canopy coverage of the forest. So, the canopy coverage is one of the indicators of the forest degradation. There was less canopy cover and less density of tree in degraded forest of Mrigasthali (Ghimire and Shrestha 2009). Current study provided the similar result that there are strong correlation between tree canopy cover and tree density (*r* = 0.997).

The sacred groves in Kathmandu Valley are bio-cultural landscape, which have deeply rooted biological, cultural, religious and historical significances in the local communities. Regardless of strong religious beliefs which has always contributed in the conservation activities in Nepal the groves is getting pressure from local communities. Mansberger (1991) and Ingles (1994), in their extensive study, mention that due to weakening of religious beliefs in Nepal sacred groves of the country are on the way to extinction due to various threats. Registration of only 36 sacred groves covering an area of 2056 ha forest in Nepal (DoF 2013) is also an indication of inadequate conservation policy and action plan of Government of Nepal.

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Abbreviation used

DoF- Department of forest, FRA – Forest Resource Assessment, GoN – Government of Nepal, IVI - Importance value index, RD - Relative density, RDo - Relative dominance, RFr - Relative frequency.

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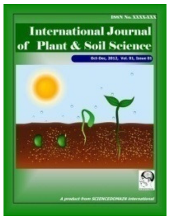
Table 1. Composition of forests in Pashupati sacred grove.

SN	Species	*Schima-Pyrus* forest				*Quercus-Myrsine* forest				*Myrsine-Persea* forest			
		RFr	RD	RDo	IVI	RFr	RD	RDo	IVI	RFr	RD	RDo	IVI
1.	*Schima wallichii* (DC.) Korth	18.92	38.4	24.1	81.4	25.0	15.5	14.4	54.9	16.7	3.9	4.0	24.6
2.	*Eurya acuminata* DC.	2.70	0.3	0.4	3.4	-	-	-	-	-	-	-	-
3.	*Zizyphus incurva* Roxb.	5.41	2.2	1.2	8.8	-	-	-	-	-	-	-	-
4.	*Syzygium cumini* (L.) Skeels.	5.41	1.1	1.4	8.0	20.0	12.7	11.6	44.3	12.5	3.4	3.4	19.3
5.	*Stranvaesia nussia* (D.Don) Decne.	5.41	0.6	1.3	7.2	-	-	-	-	4.2	1.7	1.6	7.5

6.	*Myrsine semiserrata* Wall.	-	-	-	-	-	-	-	-	4.2	8.3	8.2	20.7
7.	*Myrica esculenta* Buch-Ham. ex. D. Don.	-	-	-	-	-	-	-	-	4.2	0.3	0.3	4.8
8.	*Persea odoratissima* Ness in Wall.	13.51	5.3	8.1	26.9	5.0	0.7	0.6	6.3	16.7	12.4	12.4	41.5
9.	*Celtis australis* L.	5.41	0.6	0.9	6.8	-	-	-	-	-	-	-	-
10.	*Choerospondias axillaris* (Roxb.) Burtt & Hill.	-	-	-	-	-	-	-	-	4.2	1.9	1.8	7.9
11.	*Pyrus pashia* Buch-Ham. ex. D. Don.	13.51	19.5	18.5	51.5	-	-	-	-	4.2	0.8	0.8	5.8
12.	*Araucaria bidwilli* Hook.	2.70	2.5	4.1	9.3	-	-	-	-	-	-	-	-
13.	*Castanopsis tribuloides* (Sm.) A. DC.	2.70	0.6	0.2	3.5	-	-	-	-	8.3	3.6	3.7	15.6
14.	*Myrsine capitellata* Wall.	13.51	4.2	4.3	21.9	25.0	14.6	16.6	56.2	16.7	63.1	63.1	142.9
15.	*Quercus glauca* Thunb.	5.41	1.1	1.7	8.2	25.0	56.6	56.9	138.5	8.3	0.8	0.8	9.9
16.	*Hymenodictyon excelsum* (Roxb.) Wall.	2.7	6.9	6.7	16.3	-	-	-	-	-	-	-	-
17.	*Alnus nepalensis* D. Don.	2.70	17.0	27.2	46.9	-	-	-	-	-	-	-	-

AUTHOR'S ADDRESS
Laxmi J. Shrestha and Mohan Devkota
Department of Botany, Amrit Campus, Tribhuvan University, Kathmandu, Nepal
(email: joshilaxmi@hotmail.com)



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Phyto-sociological Assessment of Sacred Groves in Kathmandu, Nepal

Laxmi Joshi Shrestha[1*], Mohan Devkota[1] and Bhuvan Keshar Sharma[2]

[1]Department of Botany, Amrit Campus, Institute of Science and Technology, Tribhuvan University, Kathmandu, Nepal.
[2]Department of Natural Resource Management, Phokhara University, Kathmandu, Nepal.

Authors' contributions

This work was carried out in collaboration between all authors. Authors LJS and MD designed the study, wrote the protocol, and wrote the first draft of the manuscript. Author BKS managed the literature searches, analyses of the study performed and identified the species of plant. All authors read and approved the final manuscript.

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ABSTRACT

Phyto-sociological studies were conducted in Bajrabarahi and Pashupati Sacred Groves of Kathmandu, Nepal for the comparative analysis of tree species diversity in the year 2012-2013. Concentric circular plots with radius of 20m were used to collect necessary information along four and eight parallel transects in Bajrabarahi and Pashupati Sacred Groves, respectively. Similarity Index showed that more than 57% tree species are shared by both the groves whereas Maturity Index showed that Bajrabarahi Sacred Grove has more mature trees (33.9) than Pashupati Scared Grove (26). Based on Importance Value Index three different forest types, namely - Schima-Pyrus, Myrsine-Persea and Quercus-Myrsine, were identified in Pashupati Sacred Grove whereas, Bajrabarahi Sacred Grove incorporated only one forest type of Neolitsea cuipala. The Shannon-Weiner Species Diversity Index, Evenness and number of tree species of Pashupati Sacred Grove was higher than that of Bajrabarahi Sacred Grove, whereas the canopy coverage of Bajrabarahi Sacred Grove was higher than Pashupati Sacred Grove. Local community initiations are more effective management system than the government management system for tree diversity conservation, in sacred groves of Kathmandu.

**Corresponding author: E-mail: himalayanforum@gmail.com, joshi.laxmi.shrestha@gmail.com;*

Keywords: Bajrabarahi; pashupati; diversity index; similarity index; maturity index.

1. INTRODUCTION

Sacred groves have very long and diverse history in human cultures and had shown ancient link between peoples and their environments, as a result sacred groves are conserved primarily for spiritual reasons across the world. Harming the forest is forbidden by tradition and it is typically believed that any alteration of the forest, such as cutting wood for construction or firewood, hunting animals or other forms of resource extraction, will result in negative consequences to the person taking the resources and this is the main reason that leads towards the conservation of biodiversity of sacred groves [1,2,3]. Sacred groves have been defined as a patch of religious forest that are rich in biodiversity and are conserved by local people on the basis of their cultural and religious belief and taboos [4]. Sacred groves are universal human phenomenon not connected with any specific religion or world view, but they have a very strong religious context and influenced by traditional local beliefs [5]. Sacred groves have been shown to have a major effect on conservation, ecology and environment due to the special precautions and restrictions taken by the community. As a result of limited human activity due to taboos and prohibitions, sacred groves frequently possess old growth vegetation, integrated nutrient cycling with high soil fertility and many ecologically and socially valuable plant species [6]. So, sacred groves have been proved as the repositories of rare and endemic species as the remnant of the primary forest left untouched by the local inhabitants [7]. Societies have been practicing in conserving the environment of these sacred groves through traditional and stewardship practices for long time and have complement the more recent approaches to protected area management based on scientific knowledge [6]. It is increasingly clear that social context plays a major role in the success of conservation of sacred grove.

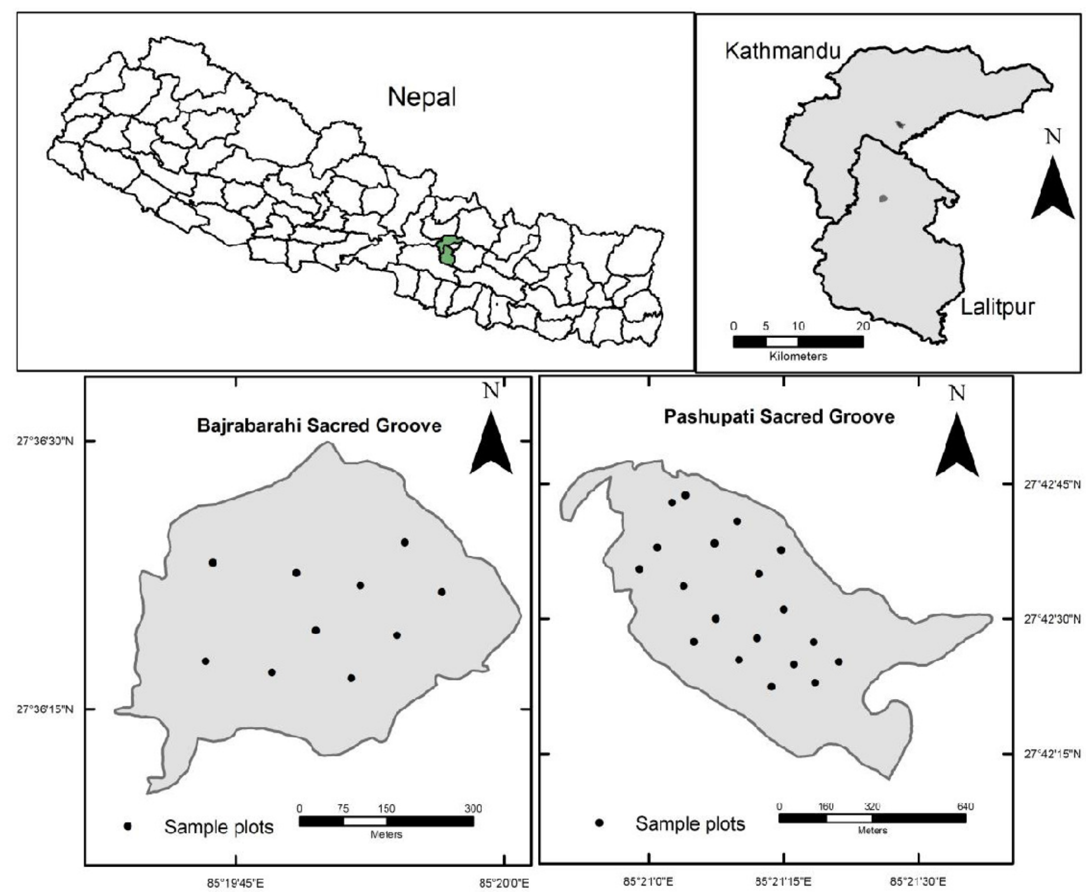
The importance of sacred groves in the conservation of biodiversity has been recognized long time back [1,8,9]. It has been believed that sacred groves have been protected due to deity of that grove and removal of even a small twig is supposed to be a taboos.

Nepal is rich in its ethnic diversity so there are diverse human societies with different religious customs, myths and beliefs [10]. Nepalese societies are intricately interconnected with their religion and customs and have been practicing generation old religious traditions by establishing various sized sacred groves devoted for their deities. Understanding the values of sacred groves among various ethnic groups, Government of Nepal has identified and categorized religious forests as one of the forest types in its Forest Act 1992. Nepal's Forest Act (1992) has defined a religious forest as "a forest area that has been legally handed over to a legally registered religious group, community or organization to carry out and continue traditional religious activities by sustainably utilizing its resources as described in its management plan". In Nepal, sacred groves have received considerable attention, to conserve small patches of forest from socio-cultural and religious perspective but now a day they are facing severe threats and are losing its biodiversity rapidly. According to the statistics of Department of Forest (2013), only 36 sacred groves covering an area of 2056 ha, have been legally registered in Nepal which clearly indicates that the role of sacred groves is still unrecognized system in biodiversity conservation. There are inadequate conservation policies and plans of Government of Nepal towards conserving the plant diversity possessed by sacred groves. Sacred groves of the Kathmandu valley, a capital city of Nepal, have also remained overlooked in the past and have never been studied in detail to assess their role in biodiversity conservation. Therefore, this paper is aimed to assess tree diversity of Pashupati and Bajrabarahi Sacred Groves of Kathmandu Valley and to evaluate the effectiveness of different management systems applied for biodiversity conservation of sacred groves.

1.2 Study Sites

The sacred grove, popularly known as Bajrabarahi Sacred Grove (BSG) (named after its presiding folk deity "Bajrabarahi") is located at south-east corner of Kathmandu Valley, in Chapagaun Village Development Committee (VDC) of Lalitpur district at an elevation of 1440 m between 27°36'15.88" to 27°36'24.62" N, and 85°19'40.58" to 85°19'50.59" E, covering 18.29 ha area (Map 1). The forest represents 900 years old relict vegetation consisting of evergreen and deciduous trees [11]. Major tree species found in the grove are *Schima wallichii, Castanopsis* *tribuloides, Albizia lebbeck, Alnus nepalensis*, *Choerospondias axillaris*, *Neolitsea cuipala*, *Myrica esculenta*, *Myrsine semiserrata*, *Pyrus pashia*, *Quercus glauca* and *Zizyphus incurva* [12]. Joytidaya Sangh, a local social organization has undertaken management responsibility of the sacred forest since 1994, after the grove has been handed over to this organization from Ministry of Forest and Soil Conservation (MoFSC). Current forest management practices include public awareness programs, appointment of forest guards, barbed wire fencing around the boundaries, and construction of walking trails, public trails and parking lots. Money generated by parking lot is used for various conservation activities.

Pashupati Sacred Grove (PSG) is located in the suburb of Kathmandu City 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. Pashupati area is renowned as one of the most sacred places in Hindu religion and is inscribed as world heritage site by UNESCO in 1979. This sacred grove is the centers of pilgrimage and is a centre of faith of all Hindu devotees. The forest represents 1400 years old relict vegetation consisting of evergreen and deciduous trees [11]. Pashupati Area Development Trust (PADT), a government organization, has undertaken management responsibility of this grove. About 85 tree species were recorded from PSG dominated by *Schima wallichii, Rapanea capitellata, Acer oblongum, Fraxinus floribunda, Osmanthus fragrans* and *Quercus glauca* [13]. Currently, PADT is contributing to manage the forest by awareness programs, appointing forest guards, fencing around the boundaries, replanting the lost tree species, and controlling grazing and human movements inside the grove.



Map 1. Location of study area

2. MATERIALS AND METHODS

Data for comparative assessment were collected from circular plots made in parallel transects (n=4 in BSG and n=8 in PSG) of 150 m apart from each other traversing north-south direction with the help of Google earth image. Plots were constructed at 100m interval in each transects. Distance between quadrates varied with the size of unit to be sampled, but was always a minimum of 50 paces apart. Plots were laid down 25 m inside from the forest margin to reduce the edge effect.

Concentric Circular Sample Plots (CCSPs) were used to collect the field data [14]. The central point of CCSP was identified by using Geographic Position System (GPS) incorporated already identified coordinates from Google Earth images. The circles of a CCSP with different radii and diameter thresholds were centered at the same point. The outermost plot was used for tallying bigger trees, whereas inner plots were used for measuring trees belonging to smaller size classes, respectively.

The CCSP consist of four circular plots: plot with the radius of 20 m (area:1257.1 m^2) all big size trees with DBH ≥30 cm were measured; plot with the radius 15 m (area: 707.1 m^2) trees with DBH 20.0 cm to 30.0 cm were measured; the third plot with the radius 8 m (area: 201.1 m^2) trees with DBH from 10.0 cm to 20.0 cm were measured; and fourth plot with the radius 4 m (area: 50.2 m^2) trees with DBH from 5.0 cm to 10.0 cm were measured. Percentage canopy cover of the plots were measured with the help of a Spherical Densiometer, 20 m away from the center at four cardinal directions and one at the plot center. The height and DBH (diameter at breast height) of trees (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 DBH tape, respectively.

Importance values index (IVI) of individual trees species available in the particular vegetation were calculated by adding the relative values of frequency, density and dominance. Relative dominance of trees was determined by calculating the basal area. Name of each forest type was determined by ordering the Importance values of each tree species recorded.

Similarity index was calculated to compare similarity between two sacred groves by using Sorensen's index of similarity [15]. The similarity index is the ratio of total common species and total number of species in both sacred groves.

Maturity of the forest was identified by using maturity index [16]. Maturity index was the ratio of sum of frequencies of individual species in the habitat and total number of species in the habitat.

The Shannon-Weiner species diversity index was calculated by using the following formula:

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

H = Shannon index of species diversity
Pi = Proportion of total number of individual of species I
S = Number of species

Evenness was calculated by dividing Shannon-Weiner diversity index with the log value of total number of species found in the area.

3. RESULTS AND DISCUSSION

From the phyto-sociological analysis, only one forest type was recognized in the BSG dominated by *Neolitsea cuipala* having highest IVI (111.3). Among the tree species *Schima wallichii* was reported to have maximum height of 35 m and the maximum DBH of 111 cm. Whereas, the average tree height was18.6±12.7 cm and the average DBH of tree was 36.6±19.44 m (Tab. 1) and the average tree density per ha was 430. The canopy cover of this grove was 90.8%. In this sacred grove a similar type of study carried out by IUCN (1996) has also reported only one forest type dominated by *Neolitsea cuipala* having 30 tree species with the density of 348 per ha. Same study also reported *Neolitsea ciupala* incorporated highest number of stem per ha with maximum DBH 114 cm and *Schima wallichii* having maximum height of 38 m [12].

In PSG three forest types were identified namely, *Schima-Pyrus* forest, *Myrsine-Persea* forest and *Quercus-Myrsine* forest on the basis of importance value [17,18]. In *Schima-Pyrus* forest, *Schima wallichii* had the highest IVI (81.4) followed by *Pyrus pashia* (51.5). Similarly, in *Myrsine-Persea* (moist) forest *Rapanea capitellata* had the highest IVI (142.9) followed by *Persea odoratissima* (41.5) and in *Quercus-Myrsine* (mixed) forest *Quercus glauca* had the highest IVI (138.5) followed by *Rapanea capitellata* (56.2) [18; Fig. 1]. In this grove, the maximum height of tree was 35 m (*Araucaria bidwillii*) and the maximum DBH of tree was 106 cm (*Choerospondias axillaris*). Similarly, the average tree height in this grove was 13.3±6.3 m and the average DBH of tree was 33.6±17.4 cm. The percentage canopy cover of this grove was 73.1%. Shrestha (2001) reported 24 trees species from only one forest type (*Myrsine-Schima*) with the density of 601 per ha, higher than present study having maximum tree height of *Schima wallichii* (18.6 m) from this grove. The study area covered by Shrestha in 2001 was only a part of entire grove thus the forest type identified was also only one. But the present study has covered the entire forest area of the PSG recording three forest types.

In Bajrabarahi Sacred Grove, 18 species of trees were recorded with the density of 430 tree per ha, Whereas, Pashupati sacred grove had 17 tree species with their per hector density of 533 stems. Both groves shared ten common tree species such as *Schima wallichii, Syzygium cumini, Myrica esculenta, Myrsine semiserrata, Choerospondias axillaris, Castanopsis tribuloides, Rapanea capitellata, Persea odoratissima, Celtis australis* and *Hymenodictyon orixense*. From the index of similarity (IS), more than 57% of tree species were found to be similar between BSG and PSG. Similarly, the analysis of maturity indices (MI) indicated that BSG forest incorporated more mature (MI = 33.9) trees than that of PSG (MI = 26.0). The BSG incorporated less number of stem (430 per ha) with higher crown cover than that of PSG (Fig. 2, Table 1).

Maximum dimensions of trees in terms of size and growth pattern have been reported from a community managed sacred grove of West Bengal, India [19]. Although, the present study was conducted in different physiographic region than West Bengal, India but showed the similar type of results regarding DBH and tree height from the studied groves.

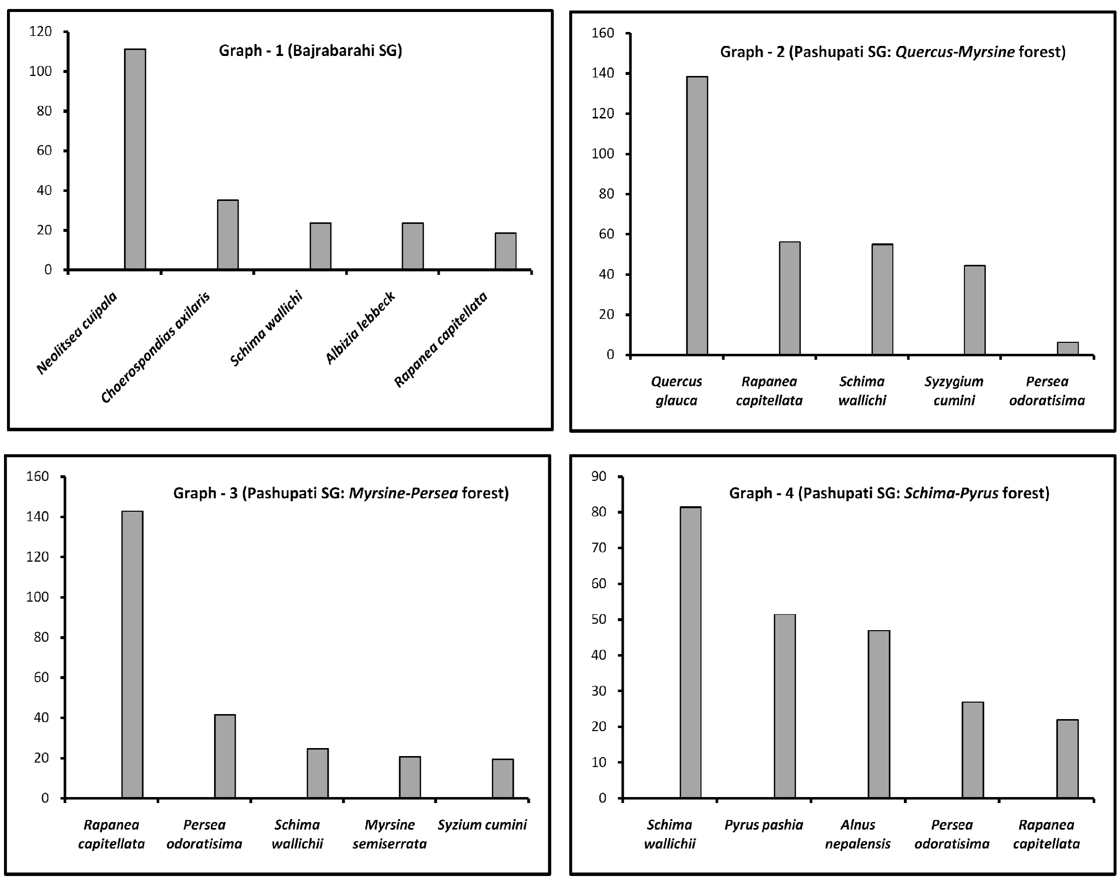


Fig. 1. Importance value of five major plant species in the study area, species are arranged in vertical axis, horizontal axis represented importance value

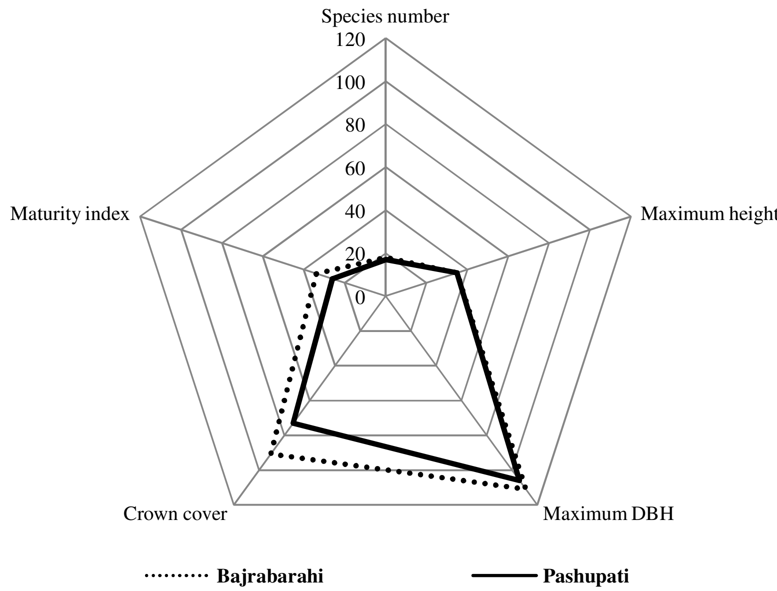


Fig. 2. Tree characteristics of the study areas

Table 1. Tree characteristics of the study areas

Characteristics/ Parameters	Bajrabarahi SG	Pashupati SG
Average tree height (m)	18.6±12.7	13.3±6.3
Average DBH (cm)	36.6±19.4	33.6±17.4
Tree density (number/ha)	430	533
Number of forest type	1	3
Species Diversity Index	1.80	1.91
Evenness	0.62	0.67

The calculated values of Shannon-Weiner species diversity index were 1.80 and 1.91 for BSG and PSG, respectively. This indicated that PSG is most diverse than BSG in term of tree diversity**.** Similarly, Evenness value indicated that tree species of Pashupati Sacred Groves (0.67) were more evenly distributed than that of Bajrabarahi Sacred Groves (0.62).

The general ecological principle in the open canopy forest, stem per unit area is highest due to having more light in the ground. In this study, forest canopy coverage in BSG was high but the density was less, where as in PSG the canopy coverage is low and density was high. This result also matches with the general ecological principle.

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 succeeding girth classes [4]. In current study, PSG incorporated higher tree density and their richness than BSG. Present study revealed that BSG has more mature trees due to community managed system supported by strong religious belief, taboos resembling the results of Manipur study. Sacred groves play a significant role in biodiversity conservation while studying the Lumbini Sacred Grove of Nepal [20]. Similarly, 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 [21].

A study conducted to assess the strength and weakness of different management system in conserving sacred groves in India found that the plant diversity is well conserved in the area managed by local community [22,23]. The current result also supports that community managed BSG is well conserved than government managed PSG. A number of factors have been identified that are negatively affecting the forest in PSG, during the study, such as - overgrazing, firewood collection, uncontrolled human access, burial ground, newly opened access road, access tracks, and lack of conservation awareness among the locals. The establishment of a deer park within the grove has been considered as a major cause of forest destruction [24] since 30% of trees were damaged by deer and 15% were dead or dying because of damage occurred by antlers and the study concluded that Mrigasthali (deer park) is a dying patch of forest.

4. CONCLUSION

Management of BSG taken over by Jyotidaya Sangh and community conservation initiative has contributed more in conservation activities that has increased tree density per hectare. The paper identified that community involvement followed by strong religious beliefs has led towards biodiversity conservation in BSG compared to PSG despite of various protection measures adopted by the government for the conservation of the forest.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Sacred groves as important sites for biodiversity conservation in Kathmandu, Nepal

Laxmi J. Shrestha & Mohan P. Devkota, Kathmandu

Abstract

In Nepal, sacred landscapes represent an important long-held tradition of conserving specific land areas and have received considerable attention in conserving biodiversity from a sociological, cultural and religious perspective. The deeply rooted religious and cultural believes, related to Hindu and Buddhist religions in Nepal, have encouraged people to establish and protect small patch of forest, dedicated to god, around the temple. This practice has begun the conservation and management of sacred forest and eventually leading towards the conservation of biodiversity. Sacred groves are not only important for the conservation of valuable biodiversity, soil and water, but are also critical in regulating weather and local climate cycles; and also providing various services. Sacred groves in Nepal are rich in biodiversity and demand a greater understanding in the conservation of biodiversity. Country contains centuries old sacred groves which have been the places of birth of strong religious and socio-cultural practices therefore, a greater focus and understanding of these groves in plant diversity conservation is definitely needed. In recent years, people's need and greed have resulted in a weakening of religious beliefs as a result sacred groves of the country are on the way to extinction due to various threats. There is an urgent need for extensive research on biodiversity for their conservation and management by developing an appropriate strategy for the conservation of sacred groves. The article discusses the role of sacred groves in conserving biodiversity in Kathmandu Valley.

Key words: Biodiversity conservation, religious beliefs, sacred groves, Nepal

Introduction

Sacred groves have long and diverse histories in human cultures and demonstrate ancient links between peoples and their environments. Sacred groves are a universal human phenomenon not associated with any specific religion or worldview (Ingles 1995), but they have a strong religious context and are influenced by traditional local beliefs. In many regions of the world, sacred sites have been shown to have a major effect on conservation, ecology and environment due to the special precautions and restrictions associated with them. Khumbongmayumi et al. (2005) define sacred grove as "A tract of virgin forest harboring rich biodiversity, protected by the local people based on the ground of indigenous cultural and religious beliefs, and taboos". The role of sacred groves in the conservation of biodiversity has long been recognized (Gadgil & Vartak 1976, Haridasan & Rao 1985, Khan et al. 1997) and has proved as the repositories of rare and endangered species (Anthwal et al. 2006). It has been believed that sacred virgin forests date back to several thousands of years when human society was in the primitive state and all forms of vegetation in the sacred groves were supposed to be under the protection of the reigning deity of that grove, and the removal of even a small twig is taboo.

Nepal's rich ethnic diversity with different religious customs, myths and beliefs has been practicing generation old religious traditions by establishing various sized sacred groves devoted for their deities (Ingles 1995). Nepal's Forest Act (1992) has defined a religious forest as "A forest area that has been legally handed over to a legally registered religious groups, 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 groves are approved and handed over to local communities, when demanded, and are monitored by the Government of Nepal but are managed jointly.

Although the sacred groves are environmentally, economically and religiously important, they are getting pressure from local communities through over harvesting of resources unsustainably. These human pressures may possibly lead to decline in the species diversity and changing in floristic composition (Fig 1.). Inventories of species preserved in the particular sacred groves may provide information about dynamics of plant communities, rational of preservation in the past, history and socio cultural values linked with particular species and societies (Bhagwat & Rutte 2006).

Recognizing the importance of sacred groves, HMGN of Nepal had committed to conserve and manage its sacred groves in its Biodiversity Strategy (2002), but was unable to include them in Nepal Biodiversity Strategy Implementation Plan (2006-2010). Only 2056 ha of forest have been registered as sacred groves in 36 districts of Nepal (Department of Forest, 2013) and it has been believed that still a large number of groves are awaiting their recognition. This amazing gap of data indicates that sacred groves are still unrecognized; their roles in conserving biodiversity are less understood, and have remained overlooked by the Government of Nepal. Despite strong religious beliefs and legal provisions of protection mentioned in Nepal's Forest Act 1992, sacred groves of Nepal are facing severe threats and are in the verge of total destruction due to various anthropogenic activities threatening the biodiversity value of the sacred groves (Shrestha & Devkota 2013). Sacred groves are hailed as models of community based conservation and storehouse of valuable biodiversity. Kathmandu Valley contains centuries old sacred groves which have been the places of birth of strong religious and socio-cultural practices therefore, a greater focus and understanding of these groves in plant diversity conservation is definitely needed. The sacred groves of Nepal are not exclusively studied in the past and their role in biodiversity conservation is understudied. Therefore, this paper has assessed and compared the existing phytosociology of tree diversity and evaluated the efficiency in biodiversity conservation of government managed (Pashupati Sacred Grove) and community managed (Bajrabarahi Sacred Groves) systems.

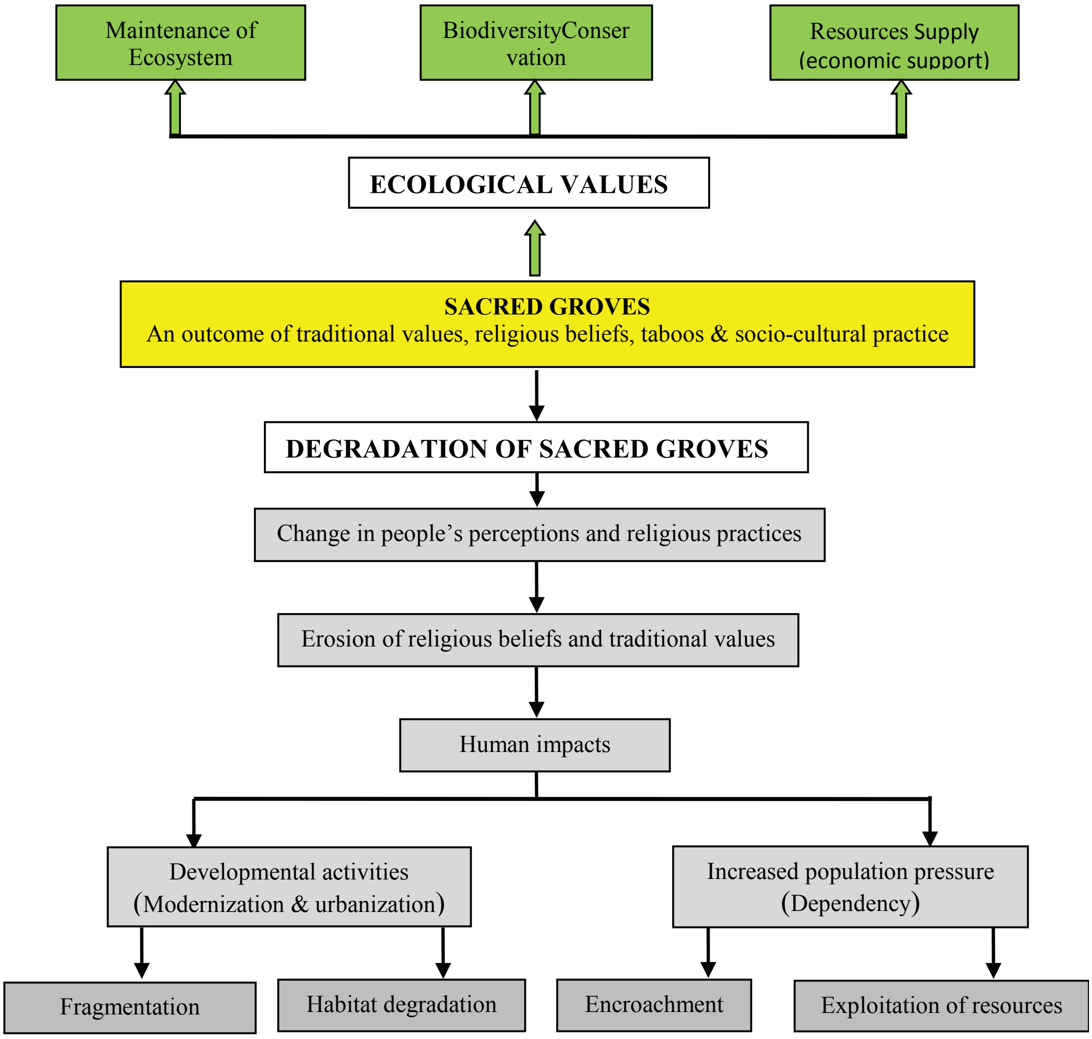

Fig 1. Diagrammatic representation of ecological value of sacred grove and relationship with changing traditional beliefs of people and impacts. (Modified from Khumbongmayumi et al., 2004)

Study area

Bajrabarahi Sacred Grove (BSG) is located at south corner of Kathmandu Valley, in Chapagaun VDC of Lalitpur District at an elevation of 1440 m. It is located between 27° 36' 15.88" to 27° 36' 24.62" N, and 85° 19' 40.58" to 85° 19' 50.59" E covering 18.29 ha area. Based on historical facts it has been estimated that the grove is 900 years old (Mansberger 1991). Joytidaya Sang, a local social organization has undertaken management responsibility of the grove from1993, after it has been handed over to this organization by the Ministry of Forest and Soil Conservation, Nepal.

The grove shows high floral (160 plant species) and faunal (48 animal species) diversity (IUCN, 1996). Major tree species found in this grove are *Albizia lebbeck, Albizia julibrissin, Alnus nepalensis*, *Castanopsis indica*, *C. tribuloides*, *Choerospondias axillaris*, *Neolitsea cuipala*, *Myrica esculenta*, *Myrsine semierrata*, *Pyrus pashia*, *Quercus glauca*, *Zizyphu sincurva* etc.

Pashupati Sacred Grove (PSG) is located in suburb of Kathmandu City between 27° 42' 25" to 27° 42' 36" N, and 85° 20' 12" to 85° 21' 29" E at an elevation of 1,300m, covering 83.55 ha area. Pashupati Temple is one of the most sacred places in Hindu religion and is inscribed as world heritage site by UNESCO in 1979. The forest represents 1400 years old relict vegetation consisting of evergreen and deciduous trees (Mansberger 1991). A government led organization named Pashupati Area Development Trust (PADT) has undertaken the management responsibility of the grove. About 85 tree species have been reported to occur (Shrestha 2001) in PSG. Dominated tree species are *Schima wallichii, Rapanea capitellata, Acer oblongum, Fraxinus floribunda, Osmanthus fragrans, Quercus glauca* etc. and has many exotic tree species such as *Araucaria bidwillii*, *Jacaranda mimosifolia*, *Grevillea robusta*, *Celtis australis* etc. introduced in the past as ornamental trees. Long back, the grove was dominated by *Choerospoandias axillaris* trees (Nepalese Hog Plum) but now there are only few planted ones.

Materials and Methods

Parallel transects (n=4, in BSG and n=8, in PSG) 150 m apart from each other traversing north-south direction were laid with the help of Google Map. A total of 16 sampling plots were laid down in BSG and 32 in PSG but due to inaccessibility of the site only 10 sampling plots in BSG and 19 in PSG were sampled for the study.

Following FRA (2010), Concentric Circular Sample Plots (CCSPs) were used to collect the data. The central point of CCSP was identified by using Geographic Position System (GPS) included with already identified coordinates from Google Earth images. The circles of a CCSP with different radii and diameter thresholds were centered at the same point. The outermost plot was used for tallying bigger trees, whereas inner plots were used for measuring trees belonging into smaller size classes, respectively. The innermost circle was used for assessing shrubs and for counting natural regeneration by counting the number of seedlings by species. The CCSP consist of four circular plots: plot with the radius of 20m (A = 1257.1m^2) all big size trees with DBH ≥30 cm were measured, plot with the radius 15m (area: 707.1m^2) trees with DBH 20.0 cm to 30.0 cm were measured, the third plot with the radius 8m (area: 201.1m^2) trees with DBH from 10.0 cm to 20.0cm were measured, fourth plot with the radius 4m (area: 50.2m^2) trees with DBH from 5.0 cm to 10.0 cm were measured. Canopy covers of the plots were measured with the help of Densiometer. The height and DBH of trees (woody plant with single bole, >5cm DBH and >1.3m height) were measured with the help of Vertex IV, Transponder T3 and DBH tape, respectively.

Importance Values Index (IVI) of individual trees species, for a particular vegetation type, were calculated by adding the relative values of frequency, density and dominance. Relative dominance of trees was determined by calculating the basal area. Name of each forest type was determined by ordering the Importance Values of each tree species. Similarity index was calculated to compare similarity between two sacred groves by using Sorensen's index of similarity (Sorensen 1948). Maturity of the forest was calculated by using maturity index (Pechi-Sermolli 1948). Shannon-Wiener Index was used to determine the diversity index.

Results and Discussions

Three forest types have been identified during the phyto-sociologial analysis in PSG and were named as *Schima-Pyrus* Forest, *Myrsine-Persea* Forest and *Quercus-Myrsine* Forest which were based upon the highest IVI calculated for individual tree species (Table 1.) whereas, Shrestha (2001) identified only one forest type *Myrsine-Schima* Forest. Long back *Choerospoandias axillaris* has dominated the forest but it was not recorded as a dominant tree in either of these forest types (Shrestha & Devkota 2013).

Schima-Pyrus Forest

This forest has occupied 20.9 ha area including Mirgasthali Deer park (4.8 ha). The average tree height in this forest was 15.2m with 40.9cm of average diameter. A total of 14 tree species were recorded with the density of 318 trees per ha. The maximum height of tree measured in this forest was 35m (*Araucaria bidwilii)*. *Schima wallichii* was found to be dominant tree species (IVI = 81.4) followed by *Pyrus pashia* (IVI = 51.5). The average canopy cover of this forest type was 55%.

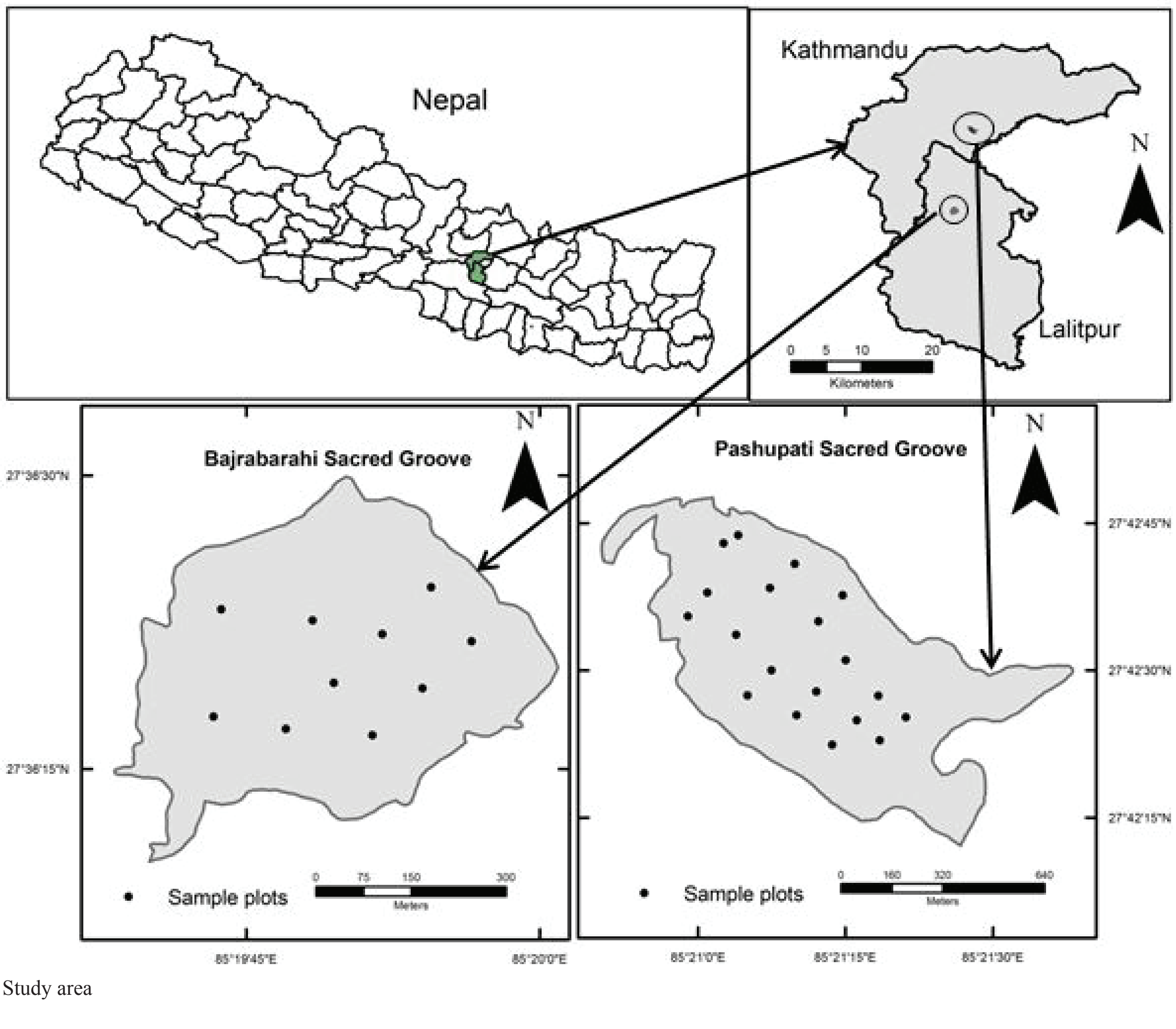

Fig 2. Study area

Table 1: Identified forest types in PSG with dominant tree species having respective IVI.

Tree species	*Schima-Pyrus* Forest	*Quercus-Myrsine* Forest	*Myrsine-Persea* Forest
Alnus nepalensis D. Don	46.9	-	-
Araucaria bidwilli Hook.	9.3	-	-
Castanopsis tribuloides (Sm.) A. DC.	3.5	-	15.6
Celtis australis L.	6.8	-	-
Choreospondias axillaris (Roxb.) B.L. Brutt. & A.W. Hill.	-	-	7.9
Eurya acuminata DC.	3.4	-	-
Hymenodictyon excelsum (Roxb.) Wall.	16.3	-	-
Myrica esculenta Buch.-Ham. Ex D. Don	-	-	4.8
Rapanea capitellata (Wall.) Mez	21.9	56.2	142.9
Myrsine semiserrata Wall.	-	-	20.7
Persea odoratissima (Nees) Kosterm.	26.9	6.3	41.3
Pyrus pashia Buch.-Ham. ex D. Don	51.5	-	5.8
Quercus glauca Thunb.	8.2	138.5	9.9
Schima wallichii (DC.) Korth.	81.4	54.9	24.6
Stranvaesia nussia (D. Don) Decne	7.2	-	7.5
Syzygium cumini (L.) Skeels.	8	44.3	19.3
Zizyphus incurva Roxb.	8.8	-	-

Quercus-Myrsine Forest
The study found only 5 tree species with 677 trees per ha in this forest and has covered an area of 40.1 ha. The average height of tree was 12.6m with 28.5cm of average diameter. Dominant tree species in this forest type was *Quercus glauca* (IVI = 138.5) followed by *Rapanea capitellata* (IVI = 56.2). The maximum height of tree in this forest was 20m. The average canopy cover of this forest type was 85.8%.

Mysrine-Persea Forest
A total of 11 tree species with the density of 593 trees per ha was recorded from this forest covering an area of 22.5 ha. The average tree height was 11.7m with 30.7cm of average diameter. The maximum height of tree recorded from this forest was 25.9m. From phyto-sociological analysis the dominant tree species was *Rapanea capitellata* (IVI = 142.9) followed by *Persea odoratissima* (IVI = 41.5) and the measured average canopy cover in this forest was 80.96%.

Only one forest type was identified in BSG and was named as *Neolitsea cuipala* forest based upon its highest IVI (111.31). A total of 18 tree species with the density of 430 trees per ha was recorded from this forest type. The average tree height was 18.6m with 36.6cm of average diameter. The maximum height of tree recorded from this forest was 35m. The dominant tree species was *Neolitsea cuipala* (IVI = 111.31) followed by *Choerospoandias axillaris* (IVI = 35.3). The average canopy cover in this forest type was 90.8 (Table 2) higher than that of PSG.

Table 2: Identified forest types in BSG with dominant tree species having respective IVI.

Tree species	*Neolitsea cuipala* Forest
Neolitsea cuipala (Buch.-Ham. ex D. Don) Kosterm.	111.3
Choerospondias axillaris (Roxb.) B.L. Brutt. & A.W. Hill	35.3
Schima wallichii (DC.) Korth.	23.7
Albizia lebbeck (L.) Benth.	23.7
Rapanea capitellata (Wall.) Mez	18.5
Castanopsis indica (Roxb.) Miq	15.1
Castanopsis tribuloides (Sm.) A. DC.	15.1
Cassia fistula L.	11.6
Areca catechu L.	8.8
Albizia julibrissin Durazz.	7
Syzygium cumini (L.) Skeels.	6.8
Hymenodictyon excelsum (Roxb.) Wall.	6.4
Myrsine semiserrata Wall.	4.3
Rhus succedanea L.	4.1
Myrica esculenta Buch.-Ham. ex D. Don	2.4
Celtis australis (L.)	2
Sapium insigne (Royle) Benth. ex. Hook.	2
Persea odoratissima (Nees) Kosterm.	1.9

While comparing the community structure of BSG and PSG (Table 3) it was found that Maturity Index, total number of tree species, average crown cover, maximum DBH and average height of BSG was higher than of PSG. Plant community characteristics of BSG clearly indicate that the forest was more mature than PSG. Similarly, slightly higher diversity index value and evenness value of PSG showed that tree diversity is more diverse and evenly distributed than BSG. The study showed the similar type of results regarding DBH and tree height from the studied groves of Kathmandu with Bhakat et al. (2008) who have also reported maximum dimensions of trees in terms of size and growth pattern from a community managed sacred grove of India.

Unlike in PSG, BSG showed higher forest canopy cover with less tree density, following the general ecological principal found in the open canopy forest. Higher tree density and species richness in PSG resembled the results of density-diameter distribution class in a study carried out in sacred groves of Manipur, India (Khumbongmayum et al. 2005). Community contribution in managing the forest of BSG has contributed

Table. 3: Comparison of plant community structure and diversity in both sacred groves

Community structure	Bajrabarahi SG	Pashupati SG
Maturity Index	33.9	26.0
Diversity Index	1.81	1.91
No. of species	18	17
Crown cover (%)	90.8	73.1
Density per ha.	430	532.3
Maximum DBH (cm)	111	106
Average tree height (m)	18.6	13.3
Evenness	0.61	0.67
Maximum height (m)	35	35
Forest types	1	3
Average DBH (cm)	36.6	33.6

in forest conservation as a result the tree density has increased to 430 per/ha from 348 per/ha (IUCN, 1996). Role of sacred grove in biodiversity conservation are also reported from other parts of Nepal, as well. Bhattarai & Baral (2008) have reported that the sacred grove of Lumbini in Nepal has played a significant role in conserving the local biodiversity. Similarly, Devkota (2013) has shown that sacred groves of Kathmandu are important in providing habitat for mistletoes and harbor 45% of mistletoe diversity reported from Nepal.

Threats to sacred groves

Sacred groves are not only important in conserving the local biodiversity but are also equally important in providing various types of ecosystem services. Despite strong religious beliefs and taboos, poverty in local communities of Nepal has forced them to depend upon the local forest resources resulting to biodiversity and habitat loss. Bajracharya et al. (1987) and Shrestha (1987), in an exclusive seminar on the Environmental Issues of Pashupati Area, have reported that the forest of Pahupati Area is losing its glory, from the past decades, due to various anthropogenic disturbances such as erosion, landslide, pollution, habitat degradation and deforestation. Similar threats have been identified, by the present study, in both sacred groves, adversely affecting the local biodiversity. The most significant identified threats included various anthropogenic activities like use of sacred groves as picnic spots resulting to garbage production, uncontrolled access tracks, forest fire, biomass removal resulting to erosion and landslides, uncontrolled grazing leading to poor regeneration, use as cemetery, fragmentation of forest etc.

Conclusion

Sacred groves are part of the cultural heritage of Nepal and provide important sites for forest conservation. If managed and conserved properly sacred groves can play a significant role in conserving the local biodiversity. Management practices adopted by Jyotidaya Sangh and supported by community conservation initiative have proved as a better practice in conserving the local biodiversity of Bajrabarahi Sacred Grove. The paper has concluded that community involvement followed by strong religious beliefs and taboos has led towards biodiversity conservation in Bajrabarahi Sacred Grove compared to Pashupati Sacred Grove despite of various protection measures adopted by the government for the conservation of the forest. Nepalese sacred groves are threatened due to various anthropogenic activities and losing biodiversity at an alarming rate. There is an urgent need of recognition of these sacred groves as important sites of biodiversity conservation and a separate policy is required to conserve the biodiversity of sacred groves.

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Authors address:

Laxmi J. Shresta* & Prof. Dr. Mohan P. Devkota
Amrit Campus, PO Box 102
Tribhuvan University, Kathmandu, Nepal

Corresponding author: *joshilaxmi@hotmail.com*

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TREE REGENERATION IN SACRED GROVES OF KATHMANDU VALLEY, NEPAL

L.J. Shrestha[1*], M.P. Devkota[1] and **B.K. Sharma[2]**
[1]Botany Department, Amrit Campus
Institute of Science and Technology, Tribhuvan University, Kathmandu
[2]Green Governance Nepal, Kathmandu
*Email: joshi.laxmi.shrestha@gmail.com

ABSTRACT

Population structure and regeneration status of tree species were studied in two sacred groves of Kathmandu valley, Pashupati (PSG) and Bajrabarahi (BSG) by sampling in concentric circular plots of 20 m radius. The dominant tree species of PSG are *Schima wallichii, Pyrus pashia, Myrsine capitellata, Persea odoratissima and Quercus glauca*, where as those in BSG are *Neolitsea cuipala, Castanopsis indica,, Choerospondias axillaris, Schima wallichii* and, *Myrsine capitellata*. On the basis of biomass removal, tree cutting, livestock and wildlife grazing and other anthropogenic activities, disturbance levels were classified as undisturbed, least disturbed, moderately disturbed and highly disturbed. The highest number of seedlings, saplings and adults were found in the least disturbed areas of the studied groves showing good to fair regeneration of tree species. In this study *Pyrus pashia, Myrsine capitellata, Castanopsis indica, Neolitsea cuipala* are found in good and fair state of regeneration. Management authority should address the prevalent factors affecting natural regeneration of the tree species.

Key words: Importance value index, disturbance index, sapling, seedling.

INTRODUCTION

A tract of virgin forest with rich biodiversity that has been traditionally managed by the local community based on the ground of indigenous cultural and religious beliefs, and taboos is considered as scared groves (Khumbongmayum *et al.* 2006). The groves are a universal human phenomenon not associated with any specific religion or worldview, but have a strong religious perspective and are influenced by traditional local beliefs. Sacred groves have significant effects on environment conservation due to the special precautions and exclusion from social fencing - a management by local communities applying their religious faith and belief - associated with them (Singh 2012). With limited human activity due to taboos and prohibition of resource utilization, sacred groves frequently possess old growth vegetation, integrated nutrient cycling with high soil fertility, and many ecologically and socially valuable biotic species (Ramakrishnan 1996, Godbole and Sarnaik 2004). Sacred groves function as natural gene pool reserve and set an example of environment conservation by community participation (Gadgil and Vartak 1975) to ensure benefits to human societies in various ways.

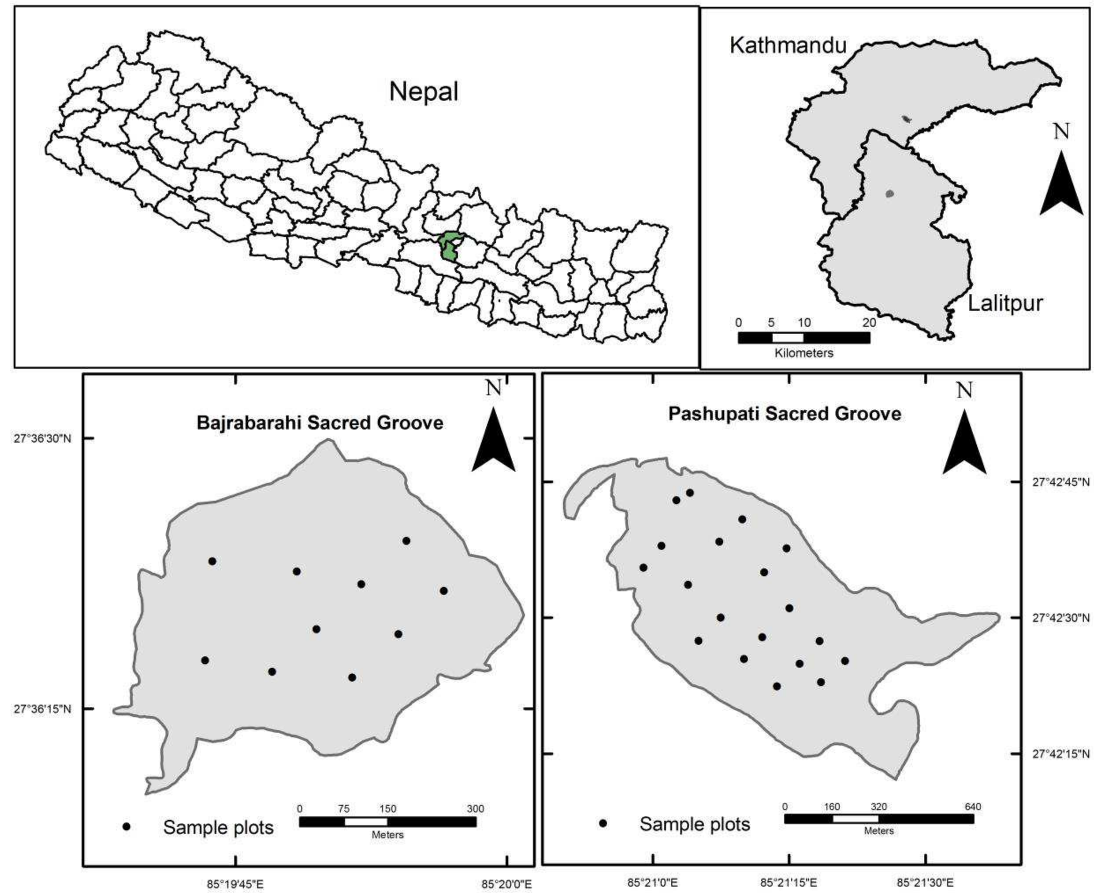
Different growth forms of woody plant species is the main constituent for the formation of community structures of forest and the ecological characteristics of sites, species diversity and regeneration status (Khumbongmayum *et al.* 2006). Growth stages of trees in the plant community are affected by micro-environmental conditions and help to maintain the population structure of the forest. Hence, the population structure of a species in forest community can express its regeneration behavior (Saxena and Singh 1984). The population structure characterized by the presence of sufficient number of seedlings, saplings and adults indicates successful regeneration of forest species (Saxena and Singh 1984). Regeneration status of tree species depends on the maturity and diameter structure of their population (Bhuyan *et al.* 2003). Characteristics of the forest floor, micro-environmental conditions under the forest canopy and anthropogenic activities influence the regeneration status of trees (Mishra *et al.* 2003). An increased availability of light stimulates germination of seeds in several forest trees and inhibits it in a few. The tree fall gaps cause increase in seedling recruitment and establishment of seedlings as well as saplings. Growth of seedlings is often limited by the availability of soil nutrients, especially N and P (Mishra *et al.* 2003).

The study of regeneration of forest trees has important implications for the biodiversity conservation and forest management. Sacred groves are hailed as models of community based conservation and storehouse of valuable biodiversity. Their importance to forest conservation from community based model becomes even more significant in Nepal. The main criterions used for the study area selection are size of the sacred groves, their location, legality and duration of the forest management practices from the local community. Based on the mentioned criterion two sites Pashupati (government managed) and Bajrabari (community managed) were selected to evaluate the management system. This study attempts to understand the population structure and regeneration status of tree species in those sacred groves of Kathmandu valley.

STUDY AREA

The study was conducted during 2012-2013 in two sacred groves of Kathmandu valley from the midhil physiographic zone of Central Development Region of Nepal (Map 1). Pashupati is one of the important pilgrimage site of Hindu called as Pashupati Sacred Grove (PSG) that belongs to the Lord Pashupatinath temple in Kathmandu valley, the capital city of Nepal. The area was inscribed as world heritage site by UNESCO in 1979. It is located at 27°42'25" to 27°42'36" N latitude and 85°20'12" to 85°21'29" E longitude at an average elevation of 1,300 m and covering an area of 83.55 ha. Based on historical facts it has been estimated that the grove is 1400 years old (Mansberger 1991) and has been considered as a bio-cultural landscape having close relationship with religious, socio-cultural beliefs, taboos and conservation practices. Pashupati Area Development Trust (PADT), a government organization, has undertaken management responsibility of this grove.

The other study site was Bajrabarahi Sacred Grove (BSG) located at south-east corner of Kathmandu valley, in Chapagaun of Lalitpur district. It is located at an elevation of 1440 m between 27°36'15.88" and 27°36'24.62" N latitude and 85°19'40.58" and 85°19'50.59" E longitude with 18.29 ha area. This grove represents 900 years old (Mansberger 1991) and Jyotidaya Sangh, a community based organization is managing this forest since 1994.



Map 1. Location of study area and distribution of surveyed plots.

MATERIALS AND METHODS

Parallel transects in the north-south directions with 150 m interval were laid down on which concentric circular plot at an interval of 100 m were set for the inventory of tree species Concentric Circular Sample Plots (CCSPs) were used to collect the field data following FRA/DFRS (2014). The central point of CCP was identified by using Geographic Position System (GPS) incorporated already identified coordinates from Google Earth images. Nineteen plots were laid down in PSG and 10 plots in BSG. The CCSP consist of four circular plots: plot with the radius of 20 m (area:1257.1 m^2) for trees with diameter at breast height (DBH) ≥ 30 cm; plot with the radius 15m (area: 707.1 m^2) for trees with DBH 20.0 to 30.0 cm; the third plot with the radius 8m (area: 201.1 m^2) for trees with DBH from 10.0 to 20.0 cm; and fourth plot with the radius 4m (area: 50.2 m^2) for trees with DBH from 5.0 cm to 10.0 cm. Similarly, with the help of Spherical Densiometer, percentage crown cover was measured at five points on the plot, i.e., at the plot centre and at the four cardinal directions (N, E, S and W) 20 meters apart from the plot centre. Plot wise crown cover percentages was calculated by multiplying the number of crown-covered grid points by 2.2 (FRA/DFRS 2014).The height and DBH of trees (woody plant with single bole, > 5cm DBH and > 1.3 m height) were measured with the help of

Vertex IV with Transponder T3 and diameter tape, respectively. Data regarding the seedling and sapling were collected from four subplots with the radius of 2 m (12.6 m^2) located 10 meters from the plot center of the CCSP in four cardinal directions. Soil samples were collected from each plot to measure soil pH and analyze total organic matter, available Nitrogen, Potassium and Phosphorus. Soil samples were collected from five soil pits (15 cm *15 cm * 5 cm), one in each four cardinal directions (N, E, W and S) 20 m far from plot center and one in the plot center of the CCPS. The collected soil samples (200 gm from each pit) were mixed together and one kg of soil was packed in a polythene bag. Standard methods were used to measure soil pH (soil:water ratio is 1:2), organic matter content was done by volumetric method, total Nitrogen analysis by Kjeldahl method, available phosphorus by Bray and Kurt, available potassium by flame photometer method and soil texture by hydrometer method (Bouyoucos 1962). The analysis of soil was done in soil science laboratory of Nepal Agricultural Research Council, Lalitpur, Nepal. The analyzed soil nutrients were classified in to five categories: very low, low, medium, high and very high (GoN 2010).

The density (number per ha) of saplings and seedlings were considered as the indicator of regeneration status of each dominant tree species in each grove. Regeneration status of tree species was analyzed on the basis of population size of seedlings and sapling following Shankar (2001) and Khumbongmayum *et al.* (2006) in the following categories: (a) good: if seedling > sapling > adult; (b) fair: if seedling > sapling ≤ adult; (c) poor: if a species survives in only sapling stage, but not as seedling (though saplings may be less, more or equal to adults), (d) none: if a species is absent both in sapling and seedling stages, but present as adults; and (e) new: if a species has no adults, but only saplings and/or seedlings. Species importance value was used to classify the existing forests in the study area (Sharma *et al.* 2012, Shrestha *et al.* 2014).

To assess the disturbances physical conditions of every tallied tree individual within CCSPs were noted. The disturbances of living trees were categorized as healthy, partly broken at the top or partly dry. The disturbances of dead trees included standing dead, completely dry, and fallen (green or dry). The anthropogenic disturbances of tree and vegetation in each CCSP were assessed by counting the individual tree which was lopped, logged, cut or burnt. Besides the disturbance on vegetation, other disturbances like erosion, access track, drain, rubbish dumping, picnic spot, permanent structure, cemetery, grazing (livestock and wildlife), litter collection, fencing, access road within each CCSP were also assessed.

On the basis of biomass removal, tree cutting, livestock and wildlife grazing and other anthropogenic activities disturbance levels were classified in four categories like undisturbed, least disturbed, moderately disturbed and highly 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). Paired *t*-tests were used to compare soil parameters with tree regeneration and drivers of deforestation with tree regeneration (Johnson and Bhattacharya 1996).

RESULTS

The study sites belongs to *Schima-Castanopsis* forest (Stainton 1972) of subtropical climatic region of mid-hill physiographic region Nepal (Sharma 2014). However, some vegetation of these sites have been changed to its secondary forms. On the basis of importance value of trees three types of forest were identified from PSG and only one from BSG. The forest types of PSG were *Schima-Pyrus*, *Myrsine-Persea* and *Quercus-Myrsine* and that of BSG was *Neolitsea cuipala* (Shrestha *et al.* 2014). The average canopy cover of PSG was 55% and that of BSG was 90.8%.

The identified anthropogenic disturbances in PSG were freshly cut trees, dead or rotten trees, coppice re-growth, erosion, access track, rubbish dumping, picnic spot, cemetery, sport activities (badminton court), livestock and wildlife grazing, water point, earth work, fence lines, construction of permanent structures like buildings as well as army camp (Fig. 1a). In PSG 42% area were least disturbed, 37% were highly disturbed and 21% were moderately disturbed.

In the least disturbed areas of PSG, numbers of seedlings were 2089 individual ha^{-1}, saplings were 298 individuals ha^{-1} and adult trees were 240 individuals ha^{-1}, which showed good regeneration status. In moderately disturbed plots the numbers of seedlings were 398 individuals ha^{-1}, saplings were 311 individuals ha^{-1} and adults were 227 individuals ha^{-1}, which showed good regeneration. In highly disturbed plots the numbers of seedlings were 28 individuals ha^{-1}, saplings were 169 individuals ha^{-1} and adults were 212 individuals ha^{-1}, with poor regeneration status (Table 1). In the study area there was significant effect of disturbances in tree regeneration (t = 1.82, p<0.05, df = 18).

In PSG the seedling density was greater than that of the sapling and tree and there were equal number of saplings and trees individuals per hectare. So, the status of tree regeneration in Pashupati sacred grove was good (Table 1). Out of 23 (Table 5) tree species recorded in PSG, number of species (23) is greater in seedling level and few (17 species) in tree level. The regeneration of two species, namely *Myrsine capitellata* and *Pyrus pashia* was found good, seven species of trees were fairly regenerating, three species of trees were poorly regenerating, three species of trees were not regenerating and eight species trees were newly arising at seedling and sapling stages (Table 3). The regeneration status of the tree was good in *Schima-Pyrus* forest. There was fair regeneration of tree species in *Myrsine-Persea* and *Quercus-Myrsine* forests of PSG.

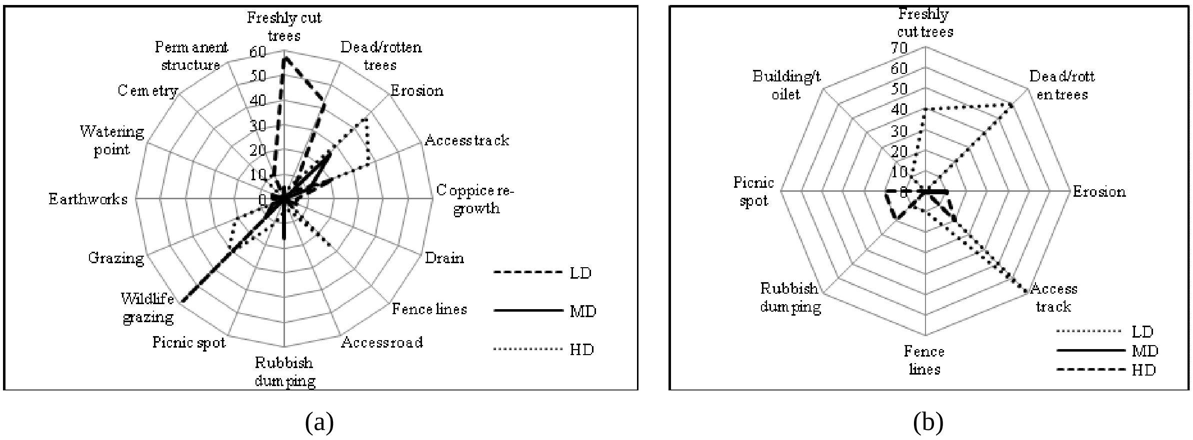


Fig. 1. Types of disturbances and their intensity in PSG (a) and BSG (b). (LD–least disturbed, MD–moderately disturbed, HD–highly disturbed)

Table 1. Regeneration status of forest in PSG.

Disturbance Status	Seedling ha^{-1}	Sapling ha^{-1}	Tree ha^{-1}	Regeneration status
Least disturbed	2089	298	240	Good
Moderately disturbed	398	311	237	Good
Highly disturbed	28	169	212	Poor

Table 2. Soil characteristics of PSG and BSG.

Soil characters	Sacred Grove	
	PSG	BSG
pH	4.70	4.20
Nitrogen (%)	0.15	0.11
Organic matters (%)	3.70	2.54
Potassium (kg ha^{-1})	902.00	617.07
Phosphorus (kg ha^{-1})	348.00	168.87

Table 3. Regeneration status of forest in BSG.

Disturbance Status	Seedling ha^{-1}	Sapling ha^{-1}	Tree ha^{-1}	Regeneration status
Undisturbed	3981	0	430	Fair
Least disturbed	1558	17	409	Fair
Moderately disturbed	0	199	263	Poor
Highly disturbed	0	0	462	None

Different types of anthropogenic and natural 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 spot, fence lines, and construction of permanent structures like buildings and toilets (Fig. 1b).

The study revealed that 10% of the study area were undisturbed, 10% were moderately disturbed 20% were highly disturbed, and 60% were least disturbed. The highest number of seedlings (3,981 ha^{-1}) and adult trees (430 ha^{-1}) were recorded from the undisturbed forest areas. The sapling stage of tree were absent in these areas and indicated the fair regeneration status. In least disturbed areas, the recorded numbers of seedlings were 1558 ha^{-1}, saplings were 17 ha^{-1} and trees were 409 ha^{-1} with fair regeneration status. In the moderately disturbed forest seedlings were absent (Table 3) numbers of saplings were 199 ha^{-1} and the numbers of adult trees were found 263 ha^{-1} with poor status of regeneration. In highly disturbed forest areas the seedlings and sapling stage of tree were absent and the numbers of adults were 462 ha^{-1} which showed no regeneration status. There was significant effect of disturbances in tree regeneration ($t = 2.80$, $p<0.05$, $df = 9$).

The regeneration status of available tree species in Bajrabarahi sacred grove was fair. Out of 19 recorded tree species from BSG (Table 5), 26.3% tree species showed fair regeneration, 68.4% trees were not regenerating and a new species, *Boehmeria rugulosa* was regenerating in seedling stage. In this forest the most dominant tree species *Neolitsea cuipala, Castanopsis tribuloides*, and *Castanopsis indica* including other two tree species, *Albizia lebbeck* and *Celtis australis*, showed fair regeneration. The sapling stage of these tree species was absent. In BSG *Castanopsis tribuloides* had good population of seedlings, but these were not maturing enough as saplings and adult stages. Thirteen tree species were not regenerating in BSG (Table 4).

Table 4. Regeneration status of tree species in study area.

Regeneration status	Number of species	
	PSG	BSG
Fair	7	5
Good	2	0
New	8	1
None	3	13
Poor	3	0
Total	23	19

The average pH found in the soil of BSG was acidic (4.2). The average level of nitrogen content found in the BSG was 0.11% which was in medium range. There was significant effect of Nitrogen in tree regeneration of BSG (t = 2.80, $p<0.05$, df = 9). The average level of phosphorus content recorded in the soil of BSG was 168.87 kg ha^{-1} which in very high range. There was significant effect of Phosphorus in tree regeneration in BSG (t = 2.45, $p<0.05$, df = 9). The average level of potassium content recorded in the soil of BSG was 617.07 which was in very high range. There was no significant effect of Potassium in tree regeneration of BSG (t = 1.52, $p<0.05$, df = 9). The average level of organic matters content found in the soil of BSG was 2.54% was in medium range (Table 2). There was significant effect of organic matters in tree regeneration of BSG (t = 2.79, $p<0.05$, df = 9).

Table 5. Tree species and their regeneration status.

SN	Tree species	Family	Regeneration status	
			PSG	BSG
1	*Choreospondias axilaris (*Roxb.) B.L. Brutt. and A.W. Hill.	Anacardiaceae	Poor	None
2	*Rhus succedanea* L.	Anacardiaceae	-	None
3	*Araucaria bidwill* Hook.	Araucariaceae	None	-
4	*Alnus nepalensis* D. Don	Betulaceae	New	-
5	*Betula alnoides*Buch.-Ham. ex D. Don	Betulaceae	New	-
6	*Sapium insigne* (Royle) Benth. ex. Hook.f	Eurphorbiaceae	-	None
7	*Castonopsis indica (*Roxb.) Miq	Fagaceae	-	Fair
8	*Castanopsis tribuloides (*Sm.) A. DC.	Fagaceae	None	Fair
9	*Quercus glauca* Thunb.	Fagaceae	Fair	-
10	*Juglans regia* L.	Juglandaceae	New	-
11	*Litsea lanciffolia* (Roxb.ex Nees) Hook.f	Lauraceae	New	-
12	*Neolitsea cuipala (*Buch.-Ham. ex D. Don) Kosterm.	Lauraceae	-	Fair
13	*Persea odoratissima (*Nees) Kosterm.	Lauraceae	Fair	None
14	*Albizia julibrissin* Durazz.	Leguminosae	-	None
15	*Albizia lebbeck (*L.) Benth.	Leguminosae	-	Fair
16	*Cassia fistula* L.	Leguminosae	-	None
17	*Morus alba*	Moraceae	New	-
18	*Myrica esculenta* Buch.-Ham. Ex D. Don	Myricaceae	None	None
19	*Myrsine capitellata* Wall.	Myrsinaceae	Good	None
20	*Myrsine semiserrata* Wall.	Myrsinaceae	Poor	None
21	*Syzygium cumini (*L.) Skeels.	Myrtaceac	Fair	None
22	*Fraxinus floribunda* Wall.	Oleaceae	New	-
23	*Areca catechu* L.	Palmae	-	None
24	*Zizyphus incurva* Roxb.	Rhamnaceae	Poor	-
25	*Prunus cerasoides D. Don*	Rosaceae	New	-

26	*Pyrus pashia* Buch.-Ham. ex D. Don	Rosaceae	Good	-
27	*Stranvaesia nussia (*D. Don) Decne	Rosaceae	Fair	-
28	*Hymenodictyon excelsum (*Roxb.) Wall.	Rubiaceae	New	None
29	*Eurya acuminata* DC.	Theaceae	Fair	-
30	*Schima wallichii (*DC.) Korth.	Theaceae	Fair	None
31	*Celtis asutralis* L.	Ulmaceae	Fair	Fair
32	*Boehmeria rugulosa* Wedd.	Urticaceae	-	New

DISCUSSIONS

The regeneration status of tree species in the study area were recognized as good (PSG) and fair (BSG). This study has identified that the density of seedling, sapling and adult was found higher in least disturbed forest stand than moderately disturbed stand and no regeneration in highly disturbed forest stand. It has also reported that higher numbers of adult trees were available in undisturbed and were found least in disturbed forest stands.

Stem density was found higher in the open canopy forest with less anthropogenic activities where greater density of seedling than the adult trees. This finding favor the general ecological principle that the open canopy forest with less anthropogenic disturbances favor plant regeneration. Open canopy of the forest provide sufficient light in the forest floor and is useful for the plant regeneration. Thus, there is possibilities to regenerate new plant species which ultimately effect on species richness of the particular area. A similar kind of study conducted in the wet evergreen *Dipteracarpus* forests of Assam Valley, tropical evergreen forest of Arunachal Pradesh, India (Bhuyan *et al.* 2002), Uttara Khanda and Western Ghats of India (Murthy *et al.* 2002) provided the similar findings about the regeneration of tree species. The study conducted in Garhwal Himalaya of India also identified higher numbers of adult trees density in undisturbed and least disturbed stand (Uniyal *et al.* 2010). Another study conducted in Manipur of India, identified highest stand density and species richness in the lowest girth class (30-60 cm) and decreased in the succeeding girth classes (Khumbongmayum *et al.* 2006). A study conducted in tropical forest in Garo Hills of Northeast India identified that primary forests were more tree-rich and diverse than secondary forests or Sal plantations (Kumar *et al.* 2006).

During the study tree cutting, lopping, fire, erosion, access track and roads, fence lines, high tension lines, rubbish dumping, picnic spot, wildlife and livestock grazing; litter collection, earthworks, and permanent structures were directly observed as major drivers of deforestation and forest degradation. In the studied groves, forest areas were either replaced or fragmented due to road and trail construction (PSG) and construction of picnic spots (BSG) to attract tourists. Both sacred groves have a large influx of people, from all over the country and neighboring India. The number of visitor will be higher during religious festivals like Maha Shivaratri, Teej, Bala Chaturdashi and Janai Purnima in PSG and various local festivals (*Jatras*) in BSG. Both groves also offer both religious spots and open place for city dwellers and offer large number visitors during holidays. Being a UNESCO's World Heritage Site, PSG is also an attraction for international visitors to observe Hindu rituals. Local traditions and customs have been challenged by westernized urban cultures learned from large number of tourist visiting the area. Modern education system has also failed to respect the local traditions and customs. As a result, sacred groves have been losing its cultural importance for the younger generation of local people.

The Pashupati Sacred Grove is fragmented by road construction leading to loss of species composition and interruption in ecological function. The forest areas of PSG were also found encroached from government line agencies for the extension of International Airport and construction of religious permanent structures. These drivers of deforestation recorded in current study areas resembled with the study conducted in the sacred groves of Karnataka, India. In Karnataka the recorded threats for the conservation of sacred groves were development projects, commercial forestry, and shift in belief system, sanskritilisation, 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 groves (Sharma and Devi 2014).

CONCLUSION

The population structure of tree species showed seedling populations dominate tree populations and which provided good to fair regeneration status. Presence of new species in the groves may be due to the invasion through dispersal from other areas and the prevailing favorable micro environmental conditions contributed to their establishment and growth in the groves. Richness of tree species and stand density were found higher in open canopy forest with no anthropogenic disturbances. Management authority should be aware to address the prevalent factors affecting natural regeneration of the tree species.

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