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FOREST DIVERSITY AND CARBON SEQUESTRATION IN RESUNGA SACRED GROVE, GULMI, NEPAL

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ABSTRACT

Resunga forest is a store-house of diverse wildlife and wild plants ranging from sub-tropical to temperate climatic zones in the midhill physiographic region. Aiming to assess the forest diversity and sequestrated carbon, this study was conducted in Resunga religious forest. Data were collected from systematically distributed plots at the interval of 50m elevation along the altitudinal gradients from 2100–2450 m elevation. Eight circular plots of 10 m radius were used to collect information on tree level characteristics. Importance value index, Shannon-Weiner index of diversity and evenness were used to assess the forest diversity. Published allometric functions were used to examine the aboveground tree biomass. Tree carbon stocks were calculated using carbon fraction value. Nineteen tree species were recorded from Rhododendron and oak forests. Comparing the forest types, Rhododendron forest was more diverse (H = 1.0) than oak forest (H = 0.9). Similarly, tree species were more evenly distributed (0.87) in the oak forest than that of *Rhododendron* forest (0.77). The vegetation carbon stock of Rhododendron forest was lower (101.8 t/ha) than that of oak forest (153.8 t/ha). Overall, the average vegetation carbon stocks in the Resunga Sacred Grove (RSG) was 127.75 t/ha.

Keywords: importance value, Shannon-Weiner diversity index, evenness, aboveground tree biomass

INTRODUCTION

Biological diversity is the variability among living organisms in a given ecological complex (Aerts *et al*., 2006) and is important to maintain the health of ecosystems and long-term survival of the human (Boyd & Banzhaf, 2007). There are three interrelated and distinct levels of biodiversity namely species, genetic, and ecosystem (Melchias, 2001; Aerts *et al*., 2006). Biodiversity can be further categorized on the basis of the space used by the different components as alpha, beta, and gamma diversity (Harrison & Inouye, 2002; HMGN/MoFSC, 2002; GoN/MoFSC, 2014). Forest have important role for the conservation of biodiversity and other ecosystem services as to prevent soil erosion, provide water for irrigation and drinking, food and maintain wood supply (Boyd & Banzhaf, 2007).

Sacred groves or religious forest are forest patches 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). Sacred groves have received considerable attention, as a pioneer of community managed natural resource management regime in Nepal.

Resunga forest is situated in the Gulmi district and covers an area of 3400 ha between 560-2300 m elevations (Khadka & Pokharel, 1999; Acharya, 2012). Resunga is the mountains with historical, religious, cultural, touristic, environmental and archeological value. Besides forest products about 252 watersheds have been estimated in the Resunga area; which is the main source of drinking water for local people (Panthi, 1984). The forest resources are being traditionally used for timber, fodder, fuel wood, leaf litter, and medicinal plants (Khadka & Pokharel, 1999). Surrounded by eleven Village Development Committees (VDCs), Resunga is not only considered as a religious spot but also as historical pilgrimage, watershed, sources of biological diversity, in-country tourism destination, splendid recreation place with full of greenery (Panthi, 1984; Khadka & Pokharel, 1999; Acharya, 2012).

Resunga, a hill of amazing geographical setting and fascinating beauty, is rich in biodiversity. It is a store-house of diverse wild animal and plants ranging habituate in sub-tropical and temperate forests. Out of 3400 ha forest land of Resunga, 1973.93 ha is covered by eighteen community forests, 165.17 ha is covered by religious forest (sacred grove) and the remaining area is under government managed (DFO, 2014). The plant species available in this area are *Pinus roxburghii, Alnus nepalensis, Schima wallichii* and *Rhododendron arboreum*. Though the region is rich in plant diversity but due to anthropogenic disturbances some of the species are in state of extinction (DFO, 2014). This forest provides favorable habitats for wild animals like Common leopard (*Panthera pardus*), Barking deer (*Muntiacus muntjak*), Ghoral (*Naemorhedus goral*), Jungle cat (*Felis chaus*), Indian crested porcupine (*Hystrix indica*) and Hanuman langur (*Semnopithecus entellus*) (Pandey & Chalise, 2014). Once common large scavenging mammal, Himalayan black bear (*Ursus thibetanus*),is now extinct from this forest (DFO, 2014). The historical pond situated in this range also provides the suitable habitats for birds like Red jungle fowl (*Gallus gallus*), Spotted dove (*Streptopelia chinensis*), Indian nightjar (*Caprimulgus asiaticus*) and Parakeet (*Psittacula* sp.). The present study aims to assess the forest diversity and estimate the vegetation carbon stock of Resunga sacred grove (RSG) which will be a good basis to the incentive provisioned for Reducing Emission from Deforestation and Forest Degradation (REDD) mechanism.

MATERIALS AND METHODS

Present study was carried out in the religious forest area of Resunga hill which covers an area of about 165.17 ha (fig. 1). The altitude of the study site varies from 2000 m to 2600 masl (Subedi, 1998; DFO, 2014). The forest is rich in biodiversity with great variation in flora accompanied by sub-tropical and temperate forests encompassing floral species like *Schima wallichii, Castanopsis indica, Pinus roxburghii, Quercus semecarpifolia, Rhododendron arboreum, Pyrus pashia, Aesculus indica, Pinus roxburghi, Myrsine semiserrata* (Khadka & Pokhrel, 1999). The climatic condition of the study site is of cool and humid type of temperate climate. The average maximum and minimum temperatures of RSG are 26°C and 6°C respectively with the average annual rainfall of 1,900 mm (Pandey & Chalise, 2014).

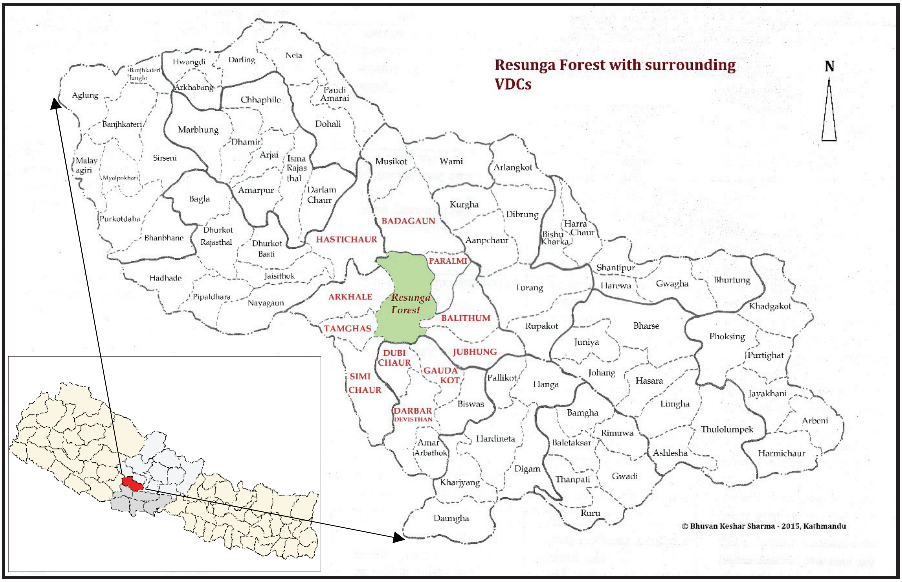

FIG. 1. Map of Gulmi district with study area and surrounding VDCs.

Forest diversity

Circular plots having 10 m radius were used to conduct forest inventory (Yadhav *et al.,* 2013). Total numbers of surveyed plots in RSG were 8 and distributed between 2100 m to 2450 m elevation. Plots were systematically distributed in transect prepared along the altitudinal gradients at the interval of 50 m between 2100–2450 m elevation. Similarly, local name, scientific name, DBH and height of trees were also collected. The specific results were determined by applying following formulae (Zobel *et al.,* 1987; Sharma *et al.,* 2012).

IV = Relative density + Relative diversity + Relative dominance

Where,

$$\text{Relatives frequency} = \frac{\text{Frequency of species i}}{\text{Sum of frequencies of all species}} *100$$

$$\text{Relatives density} = \frac{\text{Density of species i}}{\text{Sum of density of all species}} *100$$

$$\text{Relatives dominance} = \frac{\text{Dominance of species i}}{\text{Sum of dominance of all species}} *100$$

Name of each forest type was determined by ordering the Importance values of each tree species recorded (Shrestha *et al.,* 2015). Considering the physical attribute as morphological diversity tree height were measured by using Vertex IV and Transponder T3. Crown coverage of tree species were measured by using densiometer. On the basis of tree height, trees were further classified in three categories (Sharma, 2014). Tree with less than 10 m height were considered as small, 10-15 m height were considered as medium and more than 15 m height were considered as larger (Sharma, 2014).

Shannon-Weiner index of diversity was utilized to calculate tree diversity. Evenness was calculated by dividing Shannon-Weiner diversity index with the log value of total number of species found in the area (Mueller-Dombois & Ellenberg, 1974; Zobel *et al.,* 1987; Yadhav *et al.,* 2013; Shrestha *et al.,* 2015):

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

Where,

H = Shannon-Weiner index of species diversity

Pi = Proportion of total number of individual of species i

S = Number of species

Carbon sequestration

The above ground biomass of trees was calculated using published allometric functions developed by Chave *et al.* (2005). The climate of the study areas was moist, with 1500-4000 mm of annual rainfall and tropical evergreen to sub-tropical forests, the 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 = above ground 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 published literatures (Sharma & Pukkala, 1990; Zanne *et al*., 2009).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 ton ha^{-1} by multiplying it by 10 (GoN, 2011).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 in particular vegetation was calculated by summing up above ground and below ground carbon stock density of tree (Sharma *et al.,* 2014).

RESULTS AND DISCUSSION

Almost all land use type of RSG was forest. Based on topographic and LRMP land utilization maps, land use pattern of RSG are disaggregated (LRMP, 1986). Dominant land use type of RSG is forest and areas under other landuse categories are almost negligible.

Forest diversity

Based on the Importance Value Index (IVI) of canopy (pole and tree) species, forest areas of RSG were further classified into two types, Rhododendron and oak. The most important plant species in the canopy layer of Rhododendron forest was *Rhododendron arboreum* (IVI = 68.4) followed by *Lyonia ovalifolia* (IVI = 57.0) and *Schima wallichii* (IVI = 35.8) respectively. In the oak forest, *Quercus semicarpifolia* was more important tree species with higher IVI (80.6) followed by *Rhododendron arboreum* (IVI = 73.2). Based on the important value, the other important tree species found in this forest were *Myrsine semiserrata* (IVI = 21.9), *Ilex dipyrena* (IVI = 20.5), *Ilex* sp (IVI = 17.7) and *Benthamidia capitata* (IVI = 17.2) respectively (Annex 1). LRMP (1986) categorized the forest area of RSG as *Tropical Mixed Hardwood* with more than 75% species mixed with hardwood species and *Pinus roxburghii* forest either with its pure stand or mixing with other broad leaved species.

The crown coverage of the Rhododendron and oak forests of RSG were 93% and 85% respectively. In the Rhododendron forest, the maximum height of the tree was 38 m (*Schima wallichii*) and the maximum DBH was 116.2 cm (*Rhododendron arboreum*). Similarly, the average tree height of this forest was 14.6±7.6 m with 24.9±18.1 cm of average DBH. In the oak forest, *Myrsine semiserrata* was the tallest tree (25 m) and *Quercus semicarpifolia* hasthe maximum DBH (88 cm) (fig. 2). The average tree height and DBH of this forest were 11.5±4.6 m and 26.8±15.7 cm respectively (table 1). As per LRMP (1986) data the crown density of this forest was between 40-70% having immature or small timber size materials.

The general ecological principle in the open canopy forest, stem per unit area is highest due to having more light in the ground (Shrestha *et al.,* 2015). In this study, forest canopy coverage in Rhododendron forest was higher but the density was less, where as in oak forest the canopy coverage is lower and density was higher. The forest is protected due to religious belief and distant from the settlement, there is fewer disturbances from anthropogenic activities. This result also matches with the general ecological principle (Sharma, 2003). Similar result was recorded in other study conducted in the sacred groves Kathmandu valley (Shrestha *et al.,* 2015). The altitude and the physiographic condition of this study site also help to conserve the current land use.

The result showed that 21 tree species (including 2 species of shrub) were recorded from the RSG. In Rhododendron forest, 13 tree species were recorded with the density of 318 tree/ha. The number of recorded tree species from oak forest was 15 with 599 tree/ha. 7 common tree species namely *Rhododendron arboreum, Quercus lanata, Pyrus pashia, Persea duthiei, Myrsine semiserrata, Lyonia ovalifolia* and *Ilex* sp. were common in both the forest types. The similarity index showed that more than 50% of tree species were found to be similar between these forests. The calculated values of Shannon-Weiner species diversity index were 1.0 and 0.9 for *Rhododendron* and oak forests respectively. This indicated that Rhododendron forest is most diverse than oak forest in term of tree diversity. Evenness value indicated that tree species of oak forest (0.87) were more evenly distributed than that of Rhododendron forest (0.77).

TABLE 1. Tree characteristics and other parameters assessed in the RSG.

SN	Characteristics / parameters	*Rhododendron* forest	Oak forest
1	Number of species	13	15
2	Shannon-Weiner diversity index	1.0	0.9
3	Evenness	0.77	0.87
4	Average height of tree (m)	14.6±7.6	11.5±4.6
5	Average DBH (cm)	24.9±18.1	26.8±15.7
6	Area covered (%)	38	62
7	Tree density (number ha^{-1})	318	599
8	Altitudinal ranges (m)	1800-2150	2000-2600
9	Similarity index	50	

On the basis of the tree height, RSG was dominated from the small sized trees (63%). The representations of medium and large sized tree in this forest were 26% and 11% respectively. Among the 443 small size tree species of Nepal (Sharma, 2014), 12 of them were recorded from RSG. Similarly, out of 152 medium sized tree and 116 large sized tree species of Nepal (Sharma, 2014) only 5 and 2 respective tree species were recorded from RSG (table 2).

TABLE 2. Tree size and their representation in RSG.

SN	Tree height	Number of species	Representation (%)
1	Large	2	11
2	Medium	5	26
3	Small	12	63

Carbon sequestration

Average carbon stock in the forest trees of RSG was 127.75 t/ha. The carbon stock of Rhododendron forest was lower (101.8 t/ha) than that of oak forest (153.8 t/ha) (fig. 2). In Rhododendron forest higher amount of carbon was confiscated by *Rhododendron arboreum* (38.8 t/ha) followed by *Schima wallichii* (21.8 t/ha) and *Lyonia ovalifolia* (17.6 t/ha) respectively. In this forest *Ilex* sp shared the lowest amount of carbon stock (0.1 t/ha). In the oak forest higher amount of carbon was confiscated by *Rhododendron arboreum* (66.4 t/ha) followed by *Quercus semicarpifolia* (53.2 t/ha) and *Myrsine semiserrata* (8.4 t/ha) respectively. In this forest, *Rhus succedanea* shared the lowest amount of carbon stock (0.2 t/ha) (Annex 1). Resembling with the finding of this study, there is positive relationship between biodiversity and carbon stock in biodiversity hotspot areas (Midgley *et al*., 2002). The similar result was reported from the forest of low land Tarai region of Nepal (Mandal *et al.*, 2013). The significant relations between the tree species richness and carbon sequestration was also reported from studies conducted in other sacred groves of Nepal (Shrestha *et al.*, 2015).

The sequestrated carbon in the forest varied according to the forest type and stem density. Species composition of the forest also differ the average amount of assimilated carbon in the particular forest type. In the study area *Rhododendron arboretum* (66.4 t/ha) was highest carbon sequestrating tree species. 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.

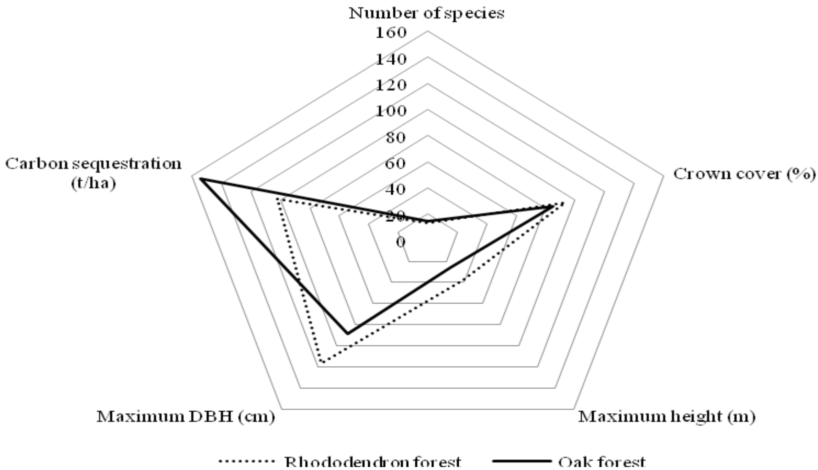

FIG. 2. Forest and tree characteristics of Resunga religious forest.

In RSG 21 species of tree, including two species of shrub, were distributed in two different types of forests, Rhododendron and oak. Seven tree species were common in both of the forests. RSG was dominated from the small sized tree (n = 12). Average carbon stock was 127.75 t/ha in RSG. The carbon stock in the trees of Rhododendron forest was lower (101.8 t/ha) than that of oak forest (153.8 t/ha). The determinant factors for the carbon stock in the RSG were species richness and wood density of the tree species.

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ANNEX 1. Tree species, importance value, forest types and sequestered carbon in RSG.

SN	Species	Rhododendron forest		Oak forest		Tree height
		IV	Carbon stock t/ha	IV	Carbon stock t/ha	
1	*Benthamidia capitata*	--	--	8.6	2.1	Small
2	*Castanopsis indica*	7.05	3.3	--	--	Medium
3	*Cinnamomum glaucescens*	--	--	4.7	0.7	Medium
4	*Engelhardia spicata*	4.65	1.1	--	--	Small
5	*Eurya acuminata*	39.25	3.5	--	--	Small
6	*Ilex dipyrena*	--	--	23.65	5.5	Small
7	*Ilex* sp.	17.1	0.1	8.85	1.4	Small
8	*Lindera pulcherrima*	--	--	14.8	0.3	Small
9	*Luculia gratissima*	--	--	2.55	0.7	Shrub
10	*Lyonia ovalifolia*	28.5	17.6	5.55	1.8	Medium
11	*Myrica esculenta*	32.8	4.3	--	--	Medium
12	*Myrsine semiserrata*	29	0.5	80.35	8.4	Shrub
13	*Persea duthiei*	33.4	1.5	4.3	1.5	Small
14	*Pyrus pashia*	29.3	2.4	29.9	3.3	Small
15	*Quercus lanata*	20.4	0.3	21.5	7.9	Large
16	*Quercus semecarpifolia*	--	--	40.3	53.2	Large
17	*Rhododendron arboreum*	34.2	38.8	36.6	66.4	Small
18	*Rhus succedanea*	--	--	2.25	0.2	Small
19	*Schima wallichii*	17.9	21.8	--	--	Medium
20	*Stranvaesia nussia*	6.35	6.6	--	--	Small
21	*Viburnum erubescens*	--	--	16	0.4	Small
Total		**300**	**101.8**	**300**	**153.8**	