Distribution pattern of tree species from tropical to temperate regions in Makawanpur district, central Nepal

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Tree species are the dominant component of forest ecosystems which influence most structural and functional attributes of these ecosystems. This study aims to document distribution pattern of forest types and their composition from tropical region at Hetauda (550 m asl) to temperate region above Simbhangyang (2500 m asl) of Makawanpur district, central Nepal. The carbon stock in the living biomass of tree species was estimated using an allometric equation while the biodiversity index was calculated using Shannon-Wiener Biodiversity index. A total of 62 species of trees belonging to 51 genera was recorded. *Shorea* forest was dominant in lower elevation while *Quercus* forest, *Alnus-Rhododendron*, *Quercus-Lyonia* and *Quercus-Symplocos* forests at higher elevation. Similarly, *Castanopsis tribuloides* has the widest distribution range (570 m to 2240 m asl) followed by *Shorea robusta, Lagerstroemia parviflora*, *Trichilia connaroides, Syzigium jambos*, *Castanopsis indica*, *Schima wallichii* etc. The highest number of tree species was recorded at 550 m elevation. Estimated carbon stocks were ranged from 0.85 — 53.37 t/ha with the mean value 24.98 t/ha. The values of Shannon-Wiener Biodiversity index ranged from 1.23— 2.78. There was positive relationship between carbon stock and biodiversity index (R^2 = 0.40, p = 0.03). People have been practicing community forest management to support sustainability of harvesting in the study area.

Keywords: Allometric equation, biodiversity index, Daman, forest, Hetauda, species

Vegetation is the reflection of physiographic and climatic condition of an area. Nepal is a small country in terms of area, though it is rich in floristic composition. Being a mountainous country, altitudinal gradient is quite common feature of physiography which ultimately creates microclimatic condition that supports vegetation diversity. Floristic or inventory is the systematic enumeration and documentation of all plant species in a given geographic region and ideally provides keys, description and often illustration (Naik, 1998; Simpson, 2006). Exploration is the most important step of systematic study. In montane Nepal, altitude and aspect are the paramount importance in determining the type of forest found at particular place (Stainton, 1972).

Altitude, one of the major factors determining the climatic condition, affects directly the distribution of species of an area. Along with the increasing altitudinal gradient, the temperature and rainfall differ markedly so the species should adapt to the particular condition to sustain their life. However, majority of the species cannot adapt the major change in climatic conditions and become restricted to a limited elevation.

Forests being standing stores of sequestered atmospheric carbon can serve as valuable carbon pool. It is thus, the global communities become progressively more concerned with forest ecosystem as a tool to mitigate the impacts of climate change. This study focused on the distribution pattern of forest types and their composition along altitudinal gradient.

Materials and methods

Study area

This research work was carried out from Hetauda to Simbhangyang of Makawanpur district. All

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together 12 spots were fixed at different altitude (550 m to 2500 m) and forest types from Hetauda to Simbhangyang to cover maximum tree species as far as possible. The study area comprises tropical, subtropical and temperate climatic zones (DDC, 2015). Tropical zone comprises Sal and riverine forests at southern lower belts where *Shorea robusta*, *Terminalia chebula*, *Terminalia bellirica*, *Adina cordifolia*, *Acacia catechu*, *Dalbergia sissoo*, *Bombax ceiba* etc. flourish very well. Subtropical region consists of mainly *Schima*-*Castanopsis*, Chir pine and Alder forests comprising *Schima wallichii*, *Castanopsis indica*, *Castanopsi striduloides*, *Pinus roxburghii* as dominating species. Similarly, *Rhododendron arboreum*, *Myrica esculenta*, *Lyonia ovalifolia*, *Quercus lanata* as dominating species in the temperate forests. Sample plots of the study area is given in figure 1.

Fig. 1: Dots representing the sample plots of study area

Sampling design

A stratified random sampling method was used for locating the sample plots. The forest types were considered as strata. Altogether, 12 spots were fixed at different altitude (550 m to 2500 m) and forest types from Hetauda to Simbhangyang to cover maximum tree species as far as possible. At each spot, a square quadrate of 20m×20m was set up. Then, each sample plot was characterized by altitude, slope, aspect, crown canopy cover (%) and geographic location.

Data collection

Diameter at breast height (DBH) of tree standing at least a 1.3 m, and the height of individual trees of ≤ 5 cm DBH were measured. Species and their distribution were identified using relevant literature like Hara *et al*. (1978, 1979, 1982), Malla *et al*. (1986), Pande (1967), Press *et al*. (2000), Stainton (1988), Suwal (1969) while a few specimens were also confirmed by tallying with specimens deposited at KATH.

Data analysis

Distribution pattern of forest types and tree species along altitudinal gradient was analyzed using Detrended Correspondence Analysis (DCA) (Hill and Gauch, 1980). Since the mean annual precipitation of the study area is 2206 mm, the carbon stock in the living biomass of tree species was estimated using an allometric model for 'moist forest' (annual precipitation 1500—3500 mm) developed by Chave *et al.* (2005) while the biodiversity index was calculated using Shannon-Wiener biodiversity index as -

Allometric equation -

The aboveground biomass (kg) of a tree =

$$0.0509 \times \boldsymbol{\rho D}^2 H$$

Where, ρ is wood density (g cm^{-3}), H is height of tree (m), D is diameter of tree at breast height (cm) as proposed in forest carbon stock measurement guidelines (Subedi *et al.*, 2010). For dry wood density, the global database was used (Zanne *et al.*, 2009). The biomass stock (kg/m^2) of each sampling plot was obtained by dividing the sum of all the individual biomass by the area of sampling plot (400 m^2) and converted to tonnes per hectare. Later, biomass value was converted into carbon stock by multiplying with carbon fraction of 0.47 (IPCC, 2006).

Total biomass = Above ground biomass × 1.15

Carbon stock = Total biomass × 0.47

Shannon-Wiener biodiversity index-

$$H' = -\Sigma pi \ln pi$$

Where, H' is the diversity index, pi is the proportion of i^{th} species individuals to total species individuals, and ln is natural logarithm.

Results and discussion

Sixty two (62) tree species belonging to fifty one(51) genera was recorded. Among them, *Albizia*, *Quercus* and *Terminalia* were the largest genera with three species each followed by *Castanopsis*, *Pinus*, *Premna*, *Rhus* and *Vibernum* with two species each while remaining genera were monotypic ones (Fig. 2).

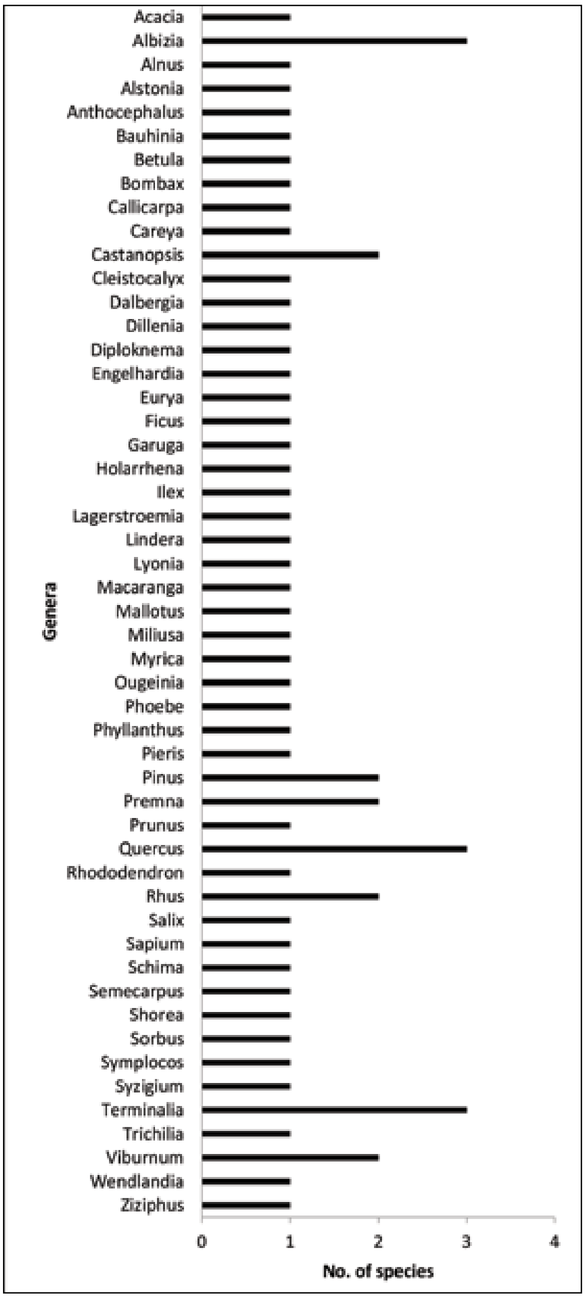

Fig. 2. Number of species per genera

Distribution pattern of forest along altitudinal gradient

The DCA axis I and II represent elevation and forest type, respectively. Species found towards the left and negative end of DCA axis I like *Albizia procrea, S. robusta, Trichilia connaroides* are highly abundant at lower elevation representing *Shorea* dominant forest (Fig. 3). The positive and right end of DCA axis I represents species abundant at high elevation. *Quercus* forest, *Alnus*-*Rhododendron*, *Quercus*-*Lyonia* and *Quercus*-*Symplocos* forest were dominant at higher elevation. Similarly, *Pinus* and *Alnus*-*Macaranga* were common at middle elevation (Fig. 3).

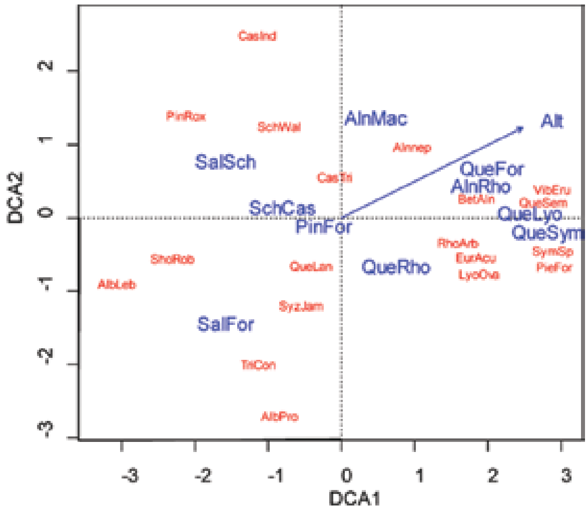

Fig. 3: DCA diagram showing environmental variation (elevation) represented by arrow and nominal variable (forest types) represented by bold words

Diversity index, carbon stock and altitude

The carbon stock in this study ranged from 0.85 — 53.37 t/ha with the mean value 24.98 t/ha. Similarly, Shannon's diversity index ranged from 1.23 — 2.78. The diversity index of species and carbon stock significantly decreased along altitudinal gradient (Fig. 4 and Fig. 5). However, there was no significant difference in density along elevational gradient.

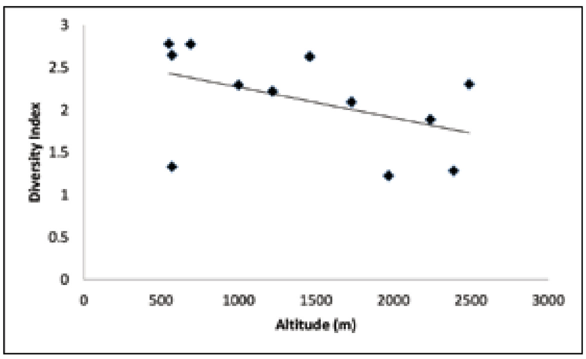

Fig. 4: Relationship between altitude and species diversity index

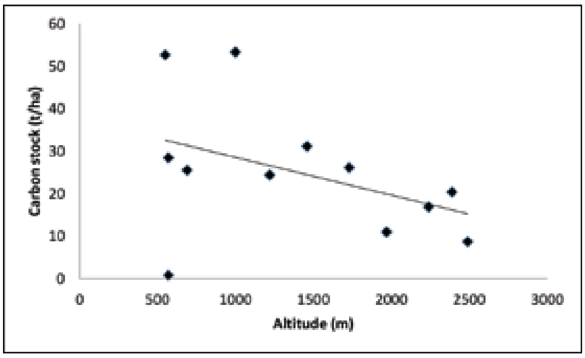

Fig 5: Relationship between altitude and carbon stock

Forest carbon stock and diversity index

The relationship between Shannon's diversity index and carbon stock in these plant communities was significant with a positive linear relationship (R^2 = 0.40, p = 0.03). Both carbon stock and Shannon-Weiner diversity index were gradually decreased with increase in elevation (Fig. 6).

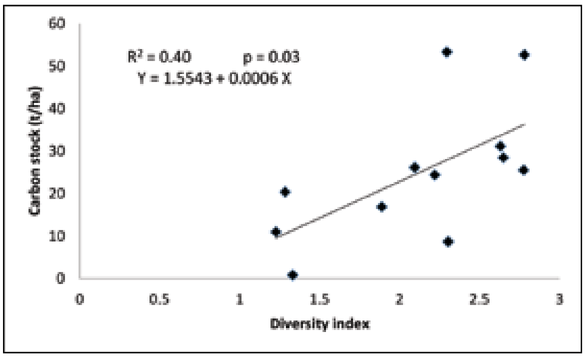

Fig. 6: Relationship between carbon stock and diversity index

Vegetation of an area is largely affected by various factors including temperature, rainfall, humidity, and soil characters, etc. which in turn get affected by altitude. The study area ranging altitudinal gradient from 550 — 2500 m provides a unique habitat for both flowering and non-flowering plants. In this study, *Albizia*, *Alstonia*, *Mallotus*, *Shorea*, *Garuga*, *Terminalia*, *Holarrhena,* etc. were the common species at lower elevation whereas *Acacia*, *Dalbergia*, *Bombax,* etc. were common along river side. Similarly, *Betula*, *Quercus*, *Pinus*, *Sorbus*, *Rhus*, *Macaranga*, *Prunus*, *Symplocos*, etc. represented the Mid-hill forests. Makawanpur district comprises 1068 species of flowering plants consisting of 210 tree species, 211 shrubs and remaining herbs (Chapagain *et al*., 2016). The study area represents a total number of 62 tree species belonging to 51 genera *i.e.* about one third of the total number of tree species of Makawanpur district. *Shorea* forest is dominant at lower elevation followed by *Pinus* and *Alnus-Macaranga* forest at the middle elevation and *Quercus*, *Alnus-Rhododendron* and *Quercus-Lyonia* forest at the higher elevation. Similarly, *C. tribuloids* had the widest distribution range (570 m to 2240 m asl) followed by *S. robusta*, *L. parviflora*, *T. connaroides*, *S. jambos*, *C. indica*, *S. wallichii*, *Wendlandia coriacea*, *L. ovalifolia* and *Alnus nepalensis.*

Though the standing biomass of tree species tended to concentrate in species of large trees, it seems that overall biomass values differed more due to species richness than species composition. A positive relation was found between Shannon's diversity index and carbon stock (R^2 = 0.40, p = 0.03). The lower belt was suitable for biodiversity to flourish well thus preserving much biomass and also carbon stock. The result showed that both biodiversity index and carbon stock were significantly higher in lower elevation and decreased along altitudinal gradient. The diversity-biomass relationship is affected by the environment (Guo and Berry, 1998). When environments are homogeneous, linear relationships are present, and when environments are heterogeneous, inverted U-type curvilinear relationships occur. Although hump-shaped or unimodal relationships between biomass and species diversity (Waide *et al*., 1999; Roy, 2001; Alhamad *et al*., 2010) have been frequently observed in mature vegetation, recent findings show positive relationship in establishing vegetation (Hooper *et al*., 2005; Spehn *et al*., 2005). This mechanism of changing relationship has been mainly discussed in terms of facilitation and competition i. e. when biomass is relatively low, diversity increases due to interspecific facilitation; whereas when biomass accumulates to a certain level, competition leads to lower diversity (Guo and Berry, 1998; Weiner and Thomas, 2001; Guo, 2007).

Conclusion

In the present study, the tropical forest represents the greatest value of both diversity index and carbon stock whereas these values get decreased along elevational gradient. This also indicates that species richness is positively related with biomass and carbon stock value thus conserving biodiversity is not only important in terms of conservation but also in mitigating the negative impacts of climate change issues. In other words, the present result has provided empirical support for the argument that increases in the biodiversity index could increase carbon stock if other anthropogenic and environmental factors are not limiting.

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