Review of Literature

Forest biomass estimation

In global carbon cycle, tropical forests play major role as they storing near about 46% world’s terrestrial carbon pool and function as constant sink for atmospheric carbon and act as a major carbon reservoir of earth (Brown et al., 1982; Medina et al., 1983; Kira, 1987; Soepadmo, 1993). Brown et al. (1989) developed the allometric regression equations for calculating above ground biomass of individual tree with the help of diameter at breast height (DBH), total tree height, wood density and Holdridge life zone (Holdridge, 1967) for tropical forests. Henrique et al. (2004) assessed dynamics of above ground biomass in Amazonian forests with the help of combining long term (10-19 years) data on mortality, damage, growth and recruitment of ≥ 10 cm DBH live and dead trees measurement with the help of moist tropical forest allometric equations. André et al. (2011) found that disturbance history of plant communities had highest biomass (313±48 Mg ha\(^{-1}\)) in national park followed by from former clear cut site (297±83 Mg ha\(^{-1}\)) and from past selective logging site (204±38 Mg ha\(^{-1}\)) of Atlantic forest of Rio de Janiro, Brazil.

Based on national forest inventory data collected in 1994-1998 and 1999 – 2003, Chen et al. (2012) estimated above ground biomass carbon (\(T_{ABC}\)) and net carbon accumulation rate (\(T_{NEP}\)) for trees in major forest types in south China. A plenty of allometric equations are available to estimate above ground biomass with the help of measurable parameters such as DBH, basal area, tree height etc. (Whittaker and Wood well, 1968; Hashimoto, 1990; Niklas, 1994; Gower et al., 1999; Porté et al., 2002; Pretzsch and Schütze, 2005; Pretzsch, 2006). Results obtained by Grant et al. (2011) revealed that in United States,
decay and structural loss in standing dead trees significantly results in decreased tree and carbon stock estimation in forest. Chave et al. (2005) proposed a proportional relationship between AGB and product of wood density, trunk cross section and total height. They also developed a regression model between stem diameter and wood density. This model was tested up on many types of forests such as dry, wet, low land, mountain and mangrove forests. Hernández – Stefanoni et al. (2011) concluded that landscape structure and spatial variables influence species density more than stand age and can be the main predictor of above ground biomass.

Jing et al. (2001) estimated forest biomass at regional and global level with special reference to China. Estimations show 4.6 Pg C biomass carbon and 38.4 Mg ha\(^{-1}\) carbon density with the help of biomass expansion factor method. Alamgir and Al-Amin (2008) analyzed biomass organic carbon stock in forest vegetation of Chittagong, Bangladesh, with the help of allometric model. They concluded that the basal area was a significantly predictor of biomass organic carbon stock. Using aerial photograph and 146 plot inventory data, Hiura (2005) analyzed vegetation and estimated AGB in carbon equivalent as 480-5,615 g cm\(^{-2}\) showing strong dependency of AGB up on the size structure of forest. Zhang et al. (2012) analyzed stem, branch and leaf biomass density relationship in forest communities of China. Across most of these communities, stem biomass line were steeper than corresponding branch and leaf line. Achard et al. (2004) estimated the global carbon net emission in tropics as 1.1±0.3 Gt C y\(^{-1}\) from land use change. These emissions represent 71% from conversion of forest, 20% from loss of soil carbon and deforestation, 4.4% from forest degradation, 8.3% from fire and -3.3% from re-growth respectively. With respect to the global carbon net flux from land use and land cover change.
(LULCC), Houghton et al. (2012) estimated anthropogenic carbon emission that accounted for 12.5% from 1990 to 2010. The mean global emission from LULCC from 1990-2009 was 1.14±0.18 Pg C y⁻¹. They concluded that in the global carbon budget, the net flux is most uncertain term not only due to uncertainties of forestation and deforestation, but also because of undergoing land change and carbon density.

In south Asia, Patra et al. (2013) estimated net biospheric CO₂ flux based on atmospheric CO₂ inversion as sink as -104±150 Tg C y⁻¹ during 2007-2008. While with the help of bottom up approach, it was estimated to be -191±193 Tg C y⁻¹. Wittmann et al. (2008) estimated the above ground wood biomass of riparian forest of lower Miranda river, Southern Pantanal of Brazil. The non destructive method based on DBH, height, specific gravity and BA showed that the estimated above ground wood biomass was 259.4±102 Mg ha⁻¹. Berengur et al. (2014) concluded that live vegetation was extremely sensitive to disturbance. The understory fire and selective logging depleting less above ground carbon by 40% than undisturbed forest in eastern Amazon. Huang and Asner (2010) observed long term carbon loss and recovery in selective logging of Amazon forest with the help of remote sensing data from 1999 to 2002 and estimated C emission ranging from 0.04 – 0.05 Pg C y⁻¹. They have also estimated biomass damage due to logging activities during last two to three decade from 1999 to 2002 as 89.1 Tg C y⁻¹ over the study region.

Hergoualch and Verchot (2011) studied phytomass C loss from Vegin peat swamp due to logging, fire damage, mixed crop land and shrub land, rice field, oil palm plantation and Acacia plantation forests of Southeast Asian tropical peat lands with the help of stock difference method. Estimated losses
were 116.9±39.8, 151.6±36.0, 204.1±28.6, 214.9±28.4, 188.1±29.8 and 191.7±28.5 Mg C ha⁻¹ respectively.

Based on field observation and national inventory, Tian et al. (2011) reported land sink in China with respect to carbon as 0.18 to 0.24 Pg C y⁻¹ for the period from 1961 to 2005. They also concluded that for the period 1961-2005, carbon sink reduced Ozone pollution and climate changes. Keith et al. (2009) discovered world’s highest biomass carbon density from Australian temperate moist forests as high as 1867 t ha⁻¹. They concluded that the avoidance of significant carbon emission could be possible with the help of conservation, management and restoration of deforested and degrading vegetation. According to Gheorghe et al. (2010), the stand productivity is influenced by many factors such as stand density, height, age, altitude, composition and regeneration of species. Deforestation contributes to large losses of annual biomass and carbon from young edges, where the regions dominated by older edges had lower rate of biomass loss and carbon (Izaya et al., 2010).

According to Wei et al. (2013) carbon storage in forest ecosystem increased with stand age and old growth forest showed high biomass carbon storage capacity as compared to young Boreal and Temperate forest in North Eastern China. The conversion factor of biomass affected mainly with forest types, edaphic and climatic factors (Luo et al., 2014). Jaramillo et al. (2003) calculated AGB of central coastal region of Mexican flood plain forests and the findings revealed as high as 416 Mg ha⁻¹ AGB while in dry forest, it ranged from 94 to 126 Mg ha⁻¹. Southeast Asian tropical forest ecosystem is the carbon rich vegetation. AGB in seasonal dry tropical forest in Thailand and Malaysian rain
forest were (226.3 t C ha\(^{-1}\)) and (201.5 t C ha\(^{-1}\)) respectively (Adachi et al., 2011). Terakunpisut et al. (2007) analyzed carbon stock in different forest ecosystems at Thong Pha Phum national forest, Thailand. Results showed that tropical rain forest sequestered higher carbon (137.73±48.07 t C ha\(^{-1}\)) as compared to dry evergreen forest (70.29±7.38 t C ha\(^{-1}\)) and mixed deciduous forest (48.14±16.72 t C ha\(^{-1}\)). In humid tropical forests of Costa Rica, the average forest biomass was 82.2 (±47.9) Mg ha\(^{-1}\) with mean annual increment for carbon in biomass as 4.2 mg ha\(^{-1}\) yr\(^{-1}\). Approximately 65.2% AGB was contributed by tree component out of total biomass (Fonseca et al., 2011).

**Forest biomass estimation in India**

Kale et al. (2004) developed allometric equations for estimation of bole biomass of five prominent species from dry deciduous forest in Shivpuri district, Madhya Pradesh, Central India, using non destructive method. For estimation of AGB, Bijalwan et al. (2010) used non destructive approach based on DBH, height and volume equations. They reported 78170.72 Mg, 81656.91 Mg and 7470.45 Mg C in mixed, degraded and Sal mixed forests respectively in dry tropical forest of Chhattisgarh region of central India using satellite remote sensing and GIS. In studies of carbon budget of the Indian forest ecosystems, Haripriya (2003) concluded that the Indian forest sector acted as a source of 12.8 Tg C for the year 1994. The model used in this study showed advantages of the entire factors influence carbon budget.

Devi and Yadava (2009) carried out study for estimation of AGB and net primary productivity of semi-evergreen tropical forest of Manipur, North Eastern India, with the help of harvest method. They analyzed total biomass in two different stands as 22.50 t ha\(^{-1}\) and 18.27 t ha\(^{-1}\) in forest stand I and II.
respectively. A positive correlation between tree species, DBH and AGB of trees was also reported. Kale et al. (2009) estimated carbon sequestration and conclude that natural plantation had highest rate (20.27 t ha\(^{-1}\)) of carbon sequestration than natural forest (mixed moist deciduous forest (8%)) in Western Ghats. Using carbon density, remote sensing and growing stock data, Kaul (2011) estimated carbon pool size from 41 to 48 Mg C ha\(^{-1}\) and 39 to 47 Mg C ha\(^{-1}\) for 1992 and 2002 respectively. Sheikh et al. (2011) estimated India’s forest biomass and reported variations from 3325 to 3161 Mt during year 2003 to 2007 respectively. Net fluxes of CO\(_2\) were 372 Mt in I assessment and for II assessment period it was 288 Mt with annual emission of 186 and 114 Mt of CO\(_2\) respectively. Since 2003, the carbon stock in Indian forests biomass decreased continuously.

In sacred forest of Tehri of Garhwal Himalaya, Uttarakhand, India, biomass and total carbon density of different species based on non destructive method were 1549.704 Mg ha\(^{-1}\) and 774.77 Mg ha\(^{-1}\) respectively (Pala et al., 2013). Phytomass of moist deciduous forest of Gujarat, India, estimated with the help of spectral modeling showed a range from 6.13 t ha\(^{-1}\) to 389.166 t ha\(^{-1}\) while it was 5.534 to 134.082 t ha\(^{-1}\) using area weights for 250×250 m sites. The mean biomass of study area was 40.50 t ha\(^{-1}\) with mean C density of 19.44 t C ha\(^{-1}\) respectively (Patil et al., 2012).

Forest of Himachal Pradesh in Himalayan range had 1158 t ha\(^{-1}\) as mean AGB (Sharma et al., 2008). In Garhwal Himalaya of Uttrakhand, India, the total live tree biomass density ranged from 215.5 to 486.2 Mg ha\(^{-1}\) and live C density varied from 107.8 to 234.1 mg C ha\(^{-1}\) (Gairola et al., 2011). Mani and Parthasarthy (2007) estimated AGB in inland and costal tropical dry evergreen
forests of Peninsular India. Using basal area method, AGB ranged from 39.69 to 170.02 Mg ha\(^{-1}\) while based on basal area and height method, it ranged from 73.06 to 173.10 Mg ha\(^{-1}\). In both the forests types BA and AGB showed positive relationship. Kumar et al. (2011) estimated mean AGB of Northern Haryana which varied from 30.46 Mg ha\(^{-1}\) to 310.10 Mg ha\(^{-1}\) across in all forest types. While the total AGB and C stock accounted for 26.99 Tg and 12.96 Tg.

According to Bhat and Ravindranath (2011), stand AGB in tropical rain forest of Uttara Kannada district of Western Ghats, India, ranged from 6.40 to 144.47 t ha\(^{-1}\) while the basal area increased from 0.98 to 22.19 m\(^2\) ha\(^{-1}\). With the help of DLR-ESAR multi frequency data, Nizalapur et al. (2010) estimated the AGB of Indian tropical forests in Gujarat, India. They reported that C-band ESAR data predict 70 Mg ha\(^{-1}\), L-band up to 150 Mg ha\(^{-1}\) and P-band up to 200 Mg ha\(^{-1}\). Pragasan (2014) determined AGB of tree species in the Pachaimalai forest of the Eastern Ghats in India. The per transect biomass value was 25.3±5.6 t ha\(^{-1}\) ranging from 4.2 to 103.5 t 0.5 ha\(^{-1}\) with the stock of total AGB for 12 ha sampled as 608.5 t. Giri et al. (2014) did the assessment of biomass and carbon stock in *Tectona grandis* plantation in Dehradun forest division. The whole ecosystem biomass was 218.22 t ha\(^{-1}\) of which total biomass of *Tectona grandis* was calculated as 147.50 t ha\(^{-1}\), total biomass of five associated species as 65.62 t ha\(^{-1}\), total biomass of shrub and herb species as 2.218 and 0.773 t ha\(^{-1}\) respectively. According to Kumar et al. (2011), the biomass of tree ranged according to age from 183.7±3.21 to 298.3±3.57 t ha\(^{-1}\). All the values of biomass were low in 5-year-old, moderate in 10-year old and high in 15 year old forest stands in *Butea* forest ecosystem in Western India, Rajasthan.
Bijalwan et al. (2010) estimated biomass and carbon in dry tropical forest of Chhattisgarh region in India with the help of satellite remote sensing and GIS technology. The results of standing volume, AGB and C storage varied from 35.59 to 64.31 m$^2$ ha$^{-1}$, 45.94 to 78.31 Mg ha$^{-1}$ and 22.97 to 33.27 Mg ha$^{-1}$ respectively. Regarding types of forests mixed forest had maximum volume, AGB and C as compared to degraded forest. The total biomass carbon pool production of an old growth *Pinus kesiya* Royle ex Gordon forest in north eastern India was 460.5 Mg ha$^{-1}$ of which 91.20% was AGB and 8.8% below ground biomass. Out of total biomass, 77% contribution was that of *P. kesiya*, 13.5% of broad leaved tree species, 0.12% of shrub, 0.03% of herb and 0.5% of litter (Baishya and Barik, 2011). According to Sundarapandian et al. (2014), total carbon stock of Pondicherry University campus forest was 14.9 Mg ha$^{-1}$ estimated using allometric equation. Fast growing tree plantation under Agro forestry system adopting strategies for sustainable tree-crop production and C sequestration improvement in sub humid tropics of Chhattisgarh, India, was workout by Swami and Mishra (2014). In *Ceiba pentandra* of 5 year age; total biomass varied from 12.9 Mg ha$^{-1}$ to 25.1 Mg ha$^{-1}$, in *Gmelina arborea* 9.9 Mg ha$^{-1}$ to 21.4 Mg ha$^{-1}$, in *Populus deltoids* clones, total biomass ranged from 48.5 Mg ha$^{-1}$ to 62.2 Mg ha$^{-1}$. Sundarapandian et al. (2013) estimated biomass in five study sites- four plantation and a natural forest at Puthupet, Tamil Nadu, India. The AGB at study site for *Anacardium occidentale*, *Casuarina equisetifolia*, *Mangifera indica*, *Coccus nucifera* and natural forest were 32.7, 38.1, 121.1, 143.2 and 227.2 Mg ha$^{-1}$ respectively. The maximum carbon stock was reported in natural forest site (131.8 Mg ha$^{-1}$). They also concluded that for reducing atmospheric CO2 concentration more and managed plantation is helpful.
**Vegetation Analysis**

Vegetation is a vast unit of plants composed of different communities. Since plants do not grow in isolation, a number of species exist in varying combination and patterns. Further, the occurrence changes with changing habitat and environmental conditions. Forest communities consist of a few dominants in combination with a large number of rare plants determining diversity and exhibiting a definite structure. Community structure is the resultant of both community and species level attributes like analytical and synthetic characters. Important parameters such as degree of distribution, dispersion, cover, dominance, diversity, physiognomy and others, in combinations with varying degree constitute structure of a stand. It is the stand that is sampled for different qualitative and quantitative characters.

Methods for sampling the vegetation depend up on the approach being undertaken. Approaches such as completely subjective and complete random designs have their own shortcomings for statistical analysis and coverage of the area.

Credit for developing sampling and research methods goes to Clements (1905) to pursue ecological studies in his book titled ‘Research Methods in Ecology’. Another contribution in this context was by Weaver and Clements (1938) in the form of a text book for plant ecologist. Earlier studies include small areas sampling methods (Pound and Clements, 1898) for determining abundance of secondary species. Cain (1938) propounded the concept of minimal area of quadrat standardized by species area curve method. Category distribution of frequency classes for the homogeneity and heterogeneity of vegetation was developed by Raunkiaer (1934).
Warming (1909) and Braun-Blanquet (1928, 1932) considered plant communities as the basic unit of vegetation classification, as the species is considered the basic unit in the taxonomic classification system of organism. This was followed by a study where a comparison was made between successional developments of a community from its pioneering stage to the relatively stable climax stage (Clement, 1916). Gleason (1926) compared plant communities in open and close groups of vegetation. Tansley (1920) described community as organic entity by using more appropriate term quasi-organism and the non living environment function together to form an ecosystem. Gleason (1926, 1939) proposed individualistic concept of plant community. According to him the plant community depends for its existence on the selective forces of its particular environment and the surrounding vegetation. However, the environment changes constantly in space and time. He found no two communities alike or closely related to one another. Lippma (1939) restricted the community concept to the individual horizontal strata such as shrubs, herbs or near ground level as component parts of many communities.

Daubenmire (1952, 1966) suggested to make a least relative distinction between temporary and more or less stable communities or between fast changing and slowly changing communities while the rate and direction of changes as such remains an important subject of vegetation research. The rate of change is not equally continuous in all communities. Curtis and McIntosh (1950) studied the interrelationship of certain analytical and synthetic phytosociological characters. Richard (1952) introduces profile diagram approach to describe plant communities. Goodall (1954) attempted an objective assessment of the reality of plant communities. Poore (1962) was of opinion that use of more than one vegetational parameters would lead to a less artificial
system of classification. Mac Arthur (1965), McIntosh (1967), Whittaker (1972) and Peet (1974) attempted to characterize communities in terms of some aspects of the number of taxa involved in the relative contribution of different taxa to the community. While discussing competition between species and there by its elimination, Smith and Cottam (1967) stated that if two species were found significantly positively associated with in stable environment, then these species might not be competing to the extent that one would eliminate the other, however, it is possible that associated species would have slightly different needs or the same needs at different times.

Forest classification and composition of vegetation in India have a long history of different reports made by Champion (1936), Razi (1955), Chandrasekharan (1962) and classical work of Champion and Seth (1968) is still followed throughout the Indian sub continent. For analyzing species diversity, regeneration pattern, vegetation type, population structure, structure and composition, richness, distribution, density, floristic diversity, most of the studies used sampling plot techniques (Giriraj et al., 2008; Mishra et al., 2008; Pitchairamu et al., 2008; Reddy et al., 2008; Fordjour et al., 2009; Kumar et al., 2009; Rasingam and Parthsarthy, 2009; Ahmed, 2012; Joshi, 2012; Sahu et al., 2012; Jayakumar and Nair, 2013; Gandhi and Sundarapandian, 2014). For the vegetation analysis, the sample or plot size varied from 1×1 m to 50 ha both in random and permanent plots respectively. Quantitative and qualitative characters such as frequency, density, abundance, Importance Value Index (IVI), Relative Importance Value (RIV) distribution pattern, similarity index (S), species diversity index (H'), beta diversity (BD), concentration of dominance (CD), plant community identification, dominance diversity curve (D-D curve), vegetation profile diagram etc. were worked out by Sorenson (1948), Simpson

For identification of plant communities, there are several criteria. According to Mueller-Dombios and Ellenberg (1974), with the help of homogeneity or uniformality of ecosystem or vegetation structure, identification of plant community can be easily achieved.

Giriraj et al. (2008) studied the vegetation composition, structure and patterns of diversity of tropical wet evergreen forests of the Western Ghats, India. The results showed that tree mean density and basal area of were 1875 trees ha\(^{-1}\) and 47.01 m\(^2\) ha\(^{-1}\) respectively and Shannon and Simpson diversity indices were 4.89 and 0.95 respectively. Studies on natural regeneration, structure and floristic composition of Tinte Bepo forest reserve Ashanti region, Ghana, showed higher plant species diversity in undisturbed forest (\(H'= 3.6\)). Mean basal area, canopy cover were also higher in undisturbed forest as compared to disturbed – invaded and disturbed forest (Fordjour et al., 2009). In Kumaon Himalays, Uttarakhand, India, density was 136.1 ha\(^{-1}\) and the concentration of dominance of species varied between 0.237-0.561 Ahmed (2012). Study also concluded that lower rate of diversification and evolution might be due to lower density and greater concentration of dominance. Edaphic and environmental conditions and anthropogenic disturbances are the factors affecting the diversity and richness of species (Kumar et al., 2009). Reddy et al. (2008) analyzed quantitative structure and composition of tropical forests at Mudumalai wildlife sanctuary, Western Ghats, India. Results showed that stand density of tree species varied from 112-406.8 ha\(^{-1}\) with the average basal area as 26.25 m\(^2\) ha\(^{-1}\) \(H'\) index ranged from 3.96-4.90, while Simpson index of
concentration of dominance varied between 0.86-0.94. Authors opined that with the help of measurable parameter effect of changing environmental conditions on vegetation can be easily analyzed.

At Sathanur reserved forest in Eastern Ghats, India, Gandhi and Sundarapandian, (2014) determined mean density of understory plant species between 659676 to 712490 plants ha\(^{-1}\). Species richness ranged from 66 to 79 (16-21 for shrub and 50-58 for herb). Shannon index of shrub and herb community ranged between 1.74-1.92 and 3.04-3.22 respectively. Results clearly indicate that in tropical dry forests, there is a need for restoration and conservation of understory vegetation to manage the native biodiversity. In a study of tropical moist deciduous Sal forest of Nagaon, Assam, Dutta and Devi (2013) reported 89 plant species with *Shorea robusta* having highest IVI followed by *Dillenia pentagyna*. Stand density and basal area of tree species were 422 individual ha\(^{-1}\) and 88.87 m\(^2\) ha\(^{-1}\) respectively. Higher tree density was found in lower girth class i.e. 30-60 cm. Shannon-Wiener index of diversity ranged from 2.02-2.43. According to Joshi (2012), in three sites of tropical dry deciduous forests of West Bengal, tree density varied from 500-1700 stems ha\(^{-1}\) and basal area ranged from 7.66-19.55 m\(^2\) ha\(^{-1}\). Shannon-Wiener and Simpson indices ranged from 0 to 1.28 and 0.51 to 1. DBH class of 10-15 cm showed higher proportion of tree species. In tropical forest of Rajasthan, Western India, Kumar *et al.* (2011) worked out the structure and species composition. The mean canopy height and average stands were 10 m and 995 stems ha\(^{-1}\) (≥ 3.0 cm DBH), total BA was 46.35 m\(^2\) ha\(^{-1}\), out of which *Tectona grandis* contributed 48%. The H', J' and S' index were 1.08, 0.71 and 5.57 respectively.
Lovett et al. (2006) described woody vegetation of Mwaninana forest Udzungwa mountains National Park, Tanzania. They used fixed and variable area plot method to analyze altitudinal variation in tropical forest structure. The results showed that 2143 woody stem were found in six 25 m×100 m fixed area plot and 1560 stems in 9.1 ha of variable area plot method. The species diversity is highest was high elevations. Rasingam and Parthasarathy (2009) compared species diversity and damage by 'Tsunami’ at eight sites in little Andaman Island, India. A total 4252 tree ≥30 cm GBH were recorded within these sites. Tree density (79-935 trees ha⁻¹) and BA (14-59.10 m² ha⁻¹) showed that when girth class increased, density and richness of species decreased. Cattle grazing effect on structure and composition of forest was determined by Stern et al. (2002), at Northwestern, Costa Rica. They reported that fewer plant species were found in area with intermittent cattle grazing as compared to no grazing area. Also Shannon index of diversity and Fishers alpha value of these two habitats was different. The results also indicated that impact of cattle grazing on the dry forest reduced the relative abundance and density of older and large tree species and had a bearing on structure and composition. In tropical dry deciduous forest of Piranmalai, Eastern Ghats of Tamil Nadu, Pitchairamu et al. (2008) determined tree diversity, species richness, basal area, structure of population and distribution patterns. The disturbance index for disturbed, moderately disturbed and undisturbed stands were 60%, 30% and 10% respectively. In different stands, disturbance gradient varied in relation to tree species richness which was highest (11-9) for undisturbed, and lowest (5-4) for disturbed stands. H' index for tree species ranged from 1.33 to 2.184 in all stands. The results also showed that tree species composition differed with respect to family and generic level.
Bijalwan (2010) estimated patterns of structure, composition and diversity of woody vegetation of degraded dry tropical forest in Balamdi watershed of Chhattisgarh plain, India. The results showed that Shannon, Simpson index, species richness, equitability and beta diversity value were highest in over storey as compared to understory.

Mani and Parthasarathy (2009) investigated tree population and AGB changes in two disturbed tropical dry evergreen forest of Peninsular, India. They concluded that the observable changes in basal area, density of stems and total AGB can be due to cumulative effect of site quality and anthropogenic disturbances. They also stated that for good understanding and predicting present status of tropical forest, quantitative parameters of changes of tree population played a key role.

Bhuyan et al. (2003) investigated species richness, tree density, BA, population structure and distribution patterns in undisturbed, mildly, moderately and highly disturbed stands of tropical wet evergreen forest of Arunachal Pradesh, India. Highest species richness was recorded in mildly disturbed stands (54-51 genera) and lowest in highly disturbed stands (16 -16). H’ index for tree species ranged from 0.7 to 2.02 in all stands. Stand density was highest (5452 stems ha\(^{-1}\)) in undisturbed and lowest (33 stems ha\(^{-1}\)) in highly disturbed stands. In all stands, highest species richness and density were reported in the medium girth class (51-110 cm).

Jayakumar and Nair (2013) estimated species diversity and tree regeneration pattern of different vegetation types of Western Ghats, India. Their results envisaged that different vegetation types of the forest landscape differ in regeneration patterns of trees. Heterogeneous distribution of species was found
in all vegetation types of study area. In mature and regeneration phase, change in species composition was more frequent in disturbed forest as compared to less disturbed or undisturbed forest. Study of vegetation analysis of Similipal Biosphere reserve forest ecosystem, Orissa, India (Mishra et al., 2008) indicate that core area had less number of trees as compared to herb and shrub as an impact of anthropogenic disturbance. Basal area of buffer and core zone varied from 48.7 to 78.61 m$^2$ ha$^{-1}$ and 81.4 to 104.9 m$^2$ ha$^{-1}$. Few individuals with large diameter class and more in lower diameter classes in buffer area indicated disturbed and regenerating plant community stage (Mishra et al., 2008). Sahu et al., (2012) studies tree species diversity, distributional and population structure of tropical dry deciduous forest of Malyagiri hill ranges of Eastern Ghats, India. In 20×20 m 60 quadrats total 1063 tree was recorded. The mean tree density, BA, H' index and C' index value were 443 trees ha$^{-1}$, 13.73 m$^2$ ha$^{-1}$, 3.38 and 1.0 showed high tree species diversity. The results also showed that with increasing girth class, there was a decrease in species richness and density.


Rao and Mishra (1994) studied the floristic composition, diversity of species as well as quantitative characters in Chitrakoot and Ghunghuti forests.
of Madhya Pradesh. Thakur and Khare (2008) investigated composition and species diversity of forest ecosystem of Sagar district in central India. They identified six types of vegetation with dominance of or association of *Tectona grandis*. The beta diversity and Shannon-Wiener index varied from 0.69-1.83 and 18 to 50 respectively. Thakur and Khare (2010) studied comparative changing status of forest vegetation during fifty years in the forest complex of Patharia hills, Sagar, India. Results showed that *Acacia leucophloea*, *Diospyros melanoxylon* and *Butea monosperma* were the dominant tree species showing highest IVI. Most of the species found with contagious distribution and vegetation structure showed heterogeneous distribution. The similarity index varied between 35.89 and 57.69%.