CHAPTER 2

REVIEW OF LITERATURE

2.1 TREE SPECIES COMPOSITION AND DIVERSITY

Tree species diversity is an important aspect to determine the structural and functional components of an ecosystem. Stand composition, structure and dynamics are important elements to consider for proper management considering on forest resources use, biodiversity conservation and providing useful information for sustainable management to environment changes (Spies et al., 2006; Carvalho, 2011). McNaughton (1977) reported ecosystems with greater species diversity are more resilient to environmental disturbances. Tropical countries are the world’s most species richness and contain a majority of the world’s endemic plant species (Joppa et al., 2011; Gibson et al., 2011), and this biodiversity enhances the productivity of the forest that could sustains many people (Cardinale et al., 2012). Altitudinal gradient has an effect on pattern of diversity of the plant species, which creates variation in climatic pattern and soil differentiation (Lomolino, 2001). The reasons for decreasing of species are numerous, but the most important is the human interference in the form of burning and clearing for cultivation, fuelwood, fodder etc. Habitat destruction is the leading cause of species extinction and biodiversity loss in natural ecosystems (Koh et al., 2004; Pimm and Raven 2000). The relationship between disturbance and diversity has received increasing attention from ecologists and natural resource managers in recent years (Oliver, 1981; Miller, 1982; Rykiel, 1985; Petraitis et al., 1989; Pickett et al., 1989; Ehrlich and Wilson, 1991; Hansen et al., 1991; Roberts and Gilliam, 1995; Peltzer et al 2000). However, some authors studied the variation in species diversity in relation to latitudinal gradient, soil and climate variables (Harrison and Bruna, 1999; Schemske, 2002; Willig et al., 2003; Lortie et al., 2004; Gaston, 2007; Slot and Poorter, 2007; Kumar and Mathur, 2014 and Barthelemy et al., 2015). The vegetation structure, composition and plant species diversity change along the forest interior-edge-exterior gradient (Oosterhoom and Kapelle, 2000). Connell and Lowman (1989) suggested that species poor or low diversity
forest may be defined as forests in which 50-80% of the canopy trees are represented by only one tree species.

Landscape level tree diversity in tropical forest of Eastern Ghats was studied by Pragasan and Parthasarathy (2010). Tree diversity and species richness were greater as the stand grew older (Perkulis et al., 1997). Silva (2014) had reported a similar structural attributes between novel and native forest of similar age. Many forest configurations are possible depending on the forest history, age and ecology of the species present even there was similar native species composition (Ewel, 1980). In north east Uttar Pradesh of India, natural sal and mixed forests have higher species diversity than plantations and other secondary scrub forests (Shukla, 2009). The expanding of mangroves forest to sustain a mature forest in Sunderban Biosphere reserve was reported by Joshi and Ghose, (2014) as a result of high density and species compositions.

Phytosociological studies of tropical forest of Northeast India were also studied (Devi and Yadava, 2006; Kumar et al., 2006; Sahoo et al., 2008; Borah and Garkoti, 2011; Majumdar et al., 2014). The effects of disturbance on community composition and tree population structure (Rao et al., 1990) and tree fall gaps on species diversity (Barik et al., 1992) have been studied in Northeast India. Forest fire is also a main source of forest disturbance in natural ecosystems. In the Northeastern India the impact of fire on the regeneration of tree species in subtropical forests were reported by Ramakrishnan et al. (1981), Toky and Ramakrishnan, (1983), Khan and Tripathi, (1989), Kikim and Yadava, (1998) and Singh and Singh (2011). Studies on tree population structure and regeneration behavior in the natural tropical forest ecosystems of north-east India have been carried out by several workers (Bhuyan et al. 2003; Khan et al., 1987; Upadhya et al., 2009). In the Western Ghats of Peninsular India, quantitative phytodiversity were studied by Parthasarathy et al. 1992; Ganesh et al., 1996; Parthasarathy et al. 1997a; Giriraj et al., 2008; Swamy et al., 2010). The girth class distribution was also reported to decrease with the increase in girth class. The species structure and function along altitudinal regimes can provide baseline information for monitoring and better sustainable managing of the forest biodiversity (Reddy et al., 2011, Ren et al., 2012). Tripathi and Reynald (2010) have studied the effects of forest fragment size through community
disturbance by timber and fuelwood extraction as well as cattle grazing in sub tropical forest of Meghalaya. Proper lopping of trees for fuelwood and restriction on grazing in forest could also enhance the diversity and regeneration potential as well as biomass increment in sub tropical forest of Mamlay watershed, Sikkim (Sundriyal et al., 1994). The impact of insect herbivores also affects the growth and survival which is closely related to forest stand density and successional status of tree species (Khan and Tripathi, 1991). The role of light in forest regeneration have been studied as the survival rates of seedlings and sprouting was observed higher at the forest periphery than under the dense canopy (Khan et al., 1986). Nath et al., (2005) have studied the vegetation and tree population structure of tropical wet evergreen forests in and around Namdapha National Park, north-east India. Ralhan et al. (1982) and Singh & Singh (1987) conducted phytosociological analysis of forest vegetation in Kumaun Himalaya. Ramakrishnan (1992) compiled most of the studies on the vegetation of agro-ecosystems and natural communities of north-eastern India. Ganesh et al. (1996) assessed the plant biodiversity in an undisturbed, mid-elevation evergreen forest of Western Ghat.

The pattern of tree species diversity, diameter class distribution, species versus girth class relationship, evenness characteristics and similarity parameter of tree populations for different forest types of Andaman Islands was studied by Padalia et al., 2004. Community characteristics of subtropical forest with effect to disturbances and regeneration status were studied (Khan et al., 1986; Rao et al., 1990; Mishra et al., 2005; Khumbongmayum et al., 2006; Gautam et al., 2008; Shaheen et al., 2011; Singh et al., 2011; Zhang et al., 2012). Most of the studies on forest ecosystems in relation to disturbance were focused on species-rich tropical rain forests (Ashton 1993; Aravind et al. 2001; Bhuyan et al. 2001) or temperate forests (Gilliam 2002; Schumann et al. 2003). The effect of forest fragment size on plant diversity status and population structure was studied by Tripathi and Reynald (2010). The exploitation of natural resources by the local populations has resulted in depletion of the biodiversity of forest communities (Ramakrishnan, 2003).

In subtropical forests high number of species densities was reported by Mishra et al. (2005), Khumbongmayum et al. (2006), Gautam et al. (2008) Uniyal et al. (2010) and
Tripathi et al. (2010) in India and Zhang et al. (2012) in China. In India, diversity of tree species, population structure and regeneration behaviour have been studied in different subtropical forests by several workers (Khan et al., 1987; Rao et al., 1990; Barik et al., 1992; Upadhaya et al., 2003; Mishra et al., 2004; Tripathi et al., 2004).

2.2 FUELWOOD CHARACTERISTICS OF TREE SPECIES

Fuelwoods are the major forest products to meet the energy needs for developing countries. Tietema et al. (1991) has studied the characteristics of firewood of Botswana, Gaborone. Demirbas (2003) studied the fuel wood characteristics of six indigenous wood species of Eastern Black Sea Region, Turkey based on their Higher Heating Value (HHV). Wood fuel consumption in Kampong Thom Province, Cambodia was studied by Top (2004). Ramos et al., (2008) also studied the use of fuel wood of Caatinga (dry land) vegetation in N.E. Brazil. Chemical composition of biomass with proximate, ultimate and ash analyses was studied by Vassilev et al., (2010). Calorific values of native tree species, Prosopis africana and Balanites aegyptica in west African Sahel was determined and analyze its correlation with wood density and tree growth and further reported that gross caloric values are positively correlates with tree growth but negatively with wood density (Monti et al, 2011). The heating values of twelve main fuelwood species in Portugal and the variation on heating values by lignin and extractive contents was also reported by Telmo and Lousada (2011). Fuelwood quality was improved through storage (Brand et al., 2011). Shawn et al., (2012) have reported that percentage of ash content decreased with increase in age. In the sub-tropical and temperate forests of Mamlay watershed in South Sikkim, India, Rai et al. (2002) reported high FVI values in Castanopsis tribuloides, Quercus lineata and Q. lamellosa.

In the Himalayan regions several indigenous fuel wood tree species were growing extensively owing to its variability of climate, soil and topography. Bhatt and Todaria (1990) have studied 33 mountain tree and shrub species in Garhwal Himalaya for temperate and tropical species and later on reported that temperate species are better suited for fuel wood species due to its high density, low ash content and low nitrogen percentage. Negi and Todaria (1993) also studied fuel wood trees and shrubs of Himalayan region. Certain fuel woods were also investigated in alkaline soil sites with
relation to tree ages for establishing harvest rotation cycles (Goel and Behl, 1996). Bhatt and Tomar (2002) have also quantitatively analyzed the indigenous mountain fuel wood species of North eastern Himalayan region. The fuel wood consumption pattern of tribal communities in cold desert of Lahaul valley, North-Western Himalaya, for its extremely low temperature and xeric climatic conditions was also studied by Rawat et al., 2009. Chettri and Sharma (2007) analysed the traditional knowledge of firewood and fodder values corresponding to scientific assessment in Sikkim Himalaya, India.

The fuel wood characteristics of different tree species of India have been studied by Jain (1992). Jain and Singh (1999) have also studied indigenous tree species from central India and reported excellent fuel wood quality based on Fuel Value Index (FVI). The fuel wood characteristics of 45 multipurpose trees growing in Kerala, has been studied by Shanavas and Mohankumar (2003). The properties of fuel wood from trekking corridor of West Sikkim, were analyzed by Chettri and Sharma (2007). Nirmalkumar et al. (2011) have studied the fuel wood properties of 26 mountain tree and shrub species of Rajasthan, Western India based on their Fuel Value index (FVI). Kumar et al. (2011) have studied the age and height wise variability on calorific value and other properties of *Eucalyptus, Acacia auriculiformis* and *Casuarina equisetifolia* of Karnataka. In the Arunachal Pradesh, North-east India there are four tribes out of which the tribe Nishis had the highest fuel wood consumption (Maikhuri, 1991). Bhatt and Sachan (2004) studied the firewood consumption pattern of different tribal communities of Meghalaya, N.E. India under varying ecological, socioeconomic and socio-cultural conditions and reported that among the tribes Khasis contributed the highest firewood consumption. In Assam, North-east India, *Albizia lucida, Pterospermum lanceaeolatum* and *Syzygium fruticosum* were considered for plantation of energy yielding tree species in the wastelands for its highest value of Fuel Value Index (FVI) and other physico-chemical properties of fuel woods (Kataki and Konwer, 2001). Kataki and Konwer, 2002 studied 35 fuelwood tree species and reported *Acacia nilotica, Albizia lebbeck, Abizia procera, Pinus kesiya* as better fuelwood quality for energy plantation in Meghalaya, north east India. Bhatt and Tomar (2002) also studied 26 fuelwood tree species in subtropical forest of Meghalaya where *Betula nitida, Machilus bombycina, Itea macrophylla* were considered as better fuelwood tree species. Deka et al., (2007) studied ten fuelwood tree
species in tropical forest of Assam. In the temperate forest of Sikkim, Chettri and Sharma (2007) reported 39 fuelwood tree species and considered *Rhododendron arboretum*, *R. grande* and *Quercus lamellosa* as good quality fuelwood trees. In Manipur, the calorific values of biomass components (bole, branch, twig and leaf) of six oak tree species and valley based ten traditional fuel wood tree species were reported by Singh (1997,1999). Meetei *et al.* (2015) also reported the fuelwood characteristics of five indigenous oak tree species in subtropical forest of Manipur.

### 2.3 GROWTH OF TREES

The growth dominance pattern has been supported by several studies in stands of *Eucalyptus saligna* (Binkley *et al*., 2003; Doi *et al*., 2010), *Facaltaria moluccana* (Binkley *et al*., 2003), native forest co-dominated by *Pseudotsuga menziesii*, *Tsuga heterophylla*, *Picea sitchensis* and *Alnus rubra* (Binkley, 2004), *Pinus elliottii* and *Pinus taeda* (Martin and Jokela, 2004) and *Pinus resinosa* (Bradford *et al*., 2010). However, the magnitude and pattern of growth dominance have been different between species (Binkley *et al*., 2006; Fernández and Gyeenge, 2009; Fernández *et al*., 2011). In addition, once growth dominance has been established in *Eucalyptus* spp. stands, larger trees were more efficient in the use of light, water and nitrogen than smaller trees, and also had higher growth efficiency (the ratio between stem growth and leaf area; Waring, 1983) (Binkley *et al*., 2002). These differences did not exist in young stands (open canopy) of *Eucalyptus* spp. (Binkley *et al*., 2002). Contrarily, differences in Water Use Efficiency (WUE) between different size-trees have been observed in *Pinus ponderosa* stands; nonetheless, growth dominance was null or very low in those stands (Fernández and Gyeenge, 2009). Naidu *et al.* (1998) also found that dominant trees of *P. taeda* have higher growth efficiency than suppressed trees. According to Ryan *et al.* (2004) and Drake *et al.* (2011) growth decline is mainly caused by a decline in gross primary productivity (GPP). This general decline in GPP may be related to stomata closure promoted by tree height (Yoder *et al*., 1994) or more complex branching patterns, other limits to photosynthesis (Barnard and Ryan, 2003), decline in leaf area index (Ryan *et al*., 1997), change in stand structure (Binkley, 2004), limits to the plasticity of allocation, or changes in leaf demography to an older average population (Ryan *et al*., 2004). It is important to mention that diameter increment of a given tree varies considerably over its
life span. There is a general tendency for mean growth rate to increase with a typical species size (Alder et al., 2002). The use of sigmoidal growth models viz. logistic, gompertz etc. has been discussed by Gore and Paranjpe (2002) for describing the growth of single species population.

Binkley et al. (2002) suggested that changes in stand structure contribute to the decline in stand growth by increasing differences in Resource Use Efficiency (RUE, defined as wood production per unit of resource use) between dominant and nondominant trees. In agreement with this idea, Binkley (2004) proposed that the decline in stand growth near canopy closure is driven by increasing dominance of site resources by larger trees and to declining efficiency of resource use by smaller ones. Thus, growth decline is related to the establishment of growth dominance and declining resource use efficiency of smaller trees, leading to an overall decline in stand level resource use efficiency (Binkley, 2004). According to these ideas, stands gradually go through four phases of growth dominance – from an early phase of null growth dominance through an increasing growth dominance phase and to a phase of ‘‘reverse growth dominance’’ – during their development (Binkley et al., 2002, 2006; Binkley, 2004). Different size trees have always different growth efficiency (and may be resource use efficiency) during the stand development, that is, it is not dependent on growth dominance.

Stem diameter increments are strongly affected by climatic constraints such as precipitation and temperature (Fritts, 1976; Orwig and Abrams, 1997). This great influence of water availability on stem radial growth has also been observed in the Mediterranean regions (Zhang and Romane, 1991; Mayor and Roda, 1994; Oliveira et al., 1994; Caritat et al., 1996, 2000; Boreux et al., 1998; Borghetti et al., 1998; Costa et al., 2001). Diameter increment was also affected by drought condition (Ogaya et al., 2003). Many studies have demonstrated how climate-growth relationships can change over the life of a tree (Briffa et al., 1998; Carrer and Urbinati, 2006; D’Arrigo et al., 2008). However, a non-significant or a weak positive relationship between wood density and growth has also been observed previously in Scots pine (Mörling 2002), and in other tree species such as lodgepole pine (Pinus contorta), Wang et al. (2000), black spruce (Picea mariana) (Zhang and Morgenstern 1995, Zhang et al. 1996), and Norway spruce (Picea abies) Bujold et al., 1996, Zubizarreta Gerendiain et al., 2007). Moreover, in Scots pine,
overall wood density generally correlates strongly with latewood percentage (Hannrup et al., 2001), which is significantly affected by tree age and growth rate (Hakkila 1966, 1968, Tyrväinen 1995).