Composition and structure of subtropical vegetation of Meghalaya, northeast India

The study was carried out in three major i.e., subtropical evergreen and semi-evergreen (broad-leaved) and pine (needle-leaved) forest types in the state of Meghalaya, northeast India by random sampling method to find out the tree composition and population structure. One representative forest stands were selected in each of the forest and 1-ha area were sampled in each of the evergreen and semi-evergreen forest and 0.3-ha in pine forest due to its homogeneity in species composition. The findings reveal that these forests experiences various level of human disturbances, pine forest was exposed to more disturbance. Concentration of soil organic matter, total Kjeldahl nitrogen and available phosphorus were higher in the evergreen forest than the semi-evergreen and pine forests. The soil of the pine forest was more acidic than the other two forests. The concentration of all these constituents was higher in the upper soil layer than the lower layer. The tree (>15cm cbh) species richness was more (76 and 77 species) in broad-leaved forests than the pine (26 species) forest; while ground species richness was more in later forest. Stratification was distinct in broad-leaved forest. Aporusa oblonga, Castanopsis tribuloides, Dysoxylum binectiferum, Duabanga grandiflora Elaeocarpus rugosus, Engelhardtia spicata and Schima wallichii in the broad-leaved and Pinus kesiya and Schima wallichii in the needle-leaved were among the most important canopy species. In broad-leaved forests, the density of tree species decreased with increase in girth-class while in the needle-leaved forest maximum density was contributed by mature (55-95cm cbh) trees which also indicates that individuals of lower girth classes were removed from the forest due to various anthropogenic activities. Basal cover distribution in different girth-class showed a reverse trend to that of the density distribution in all the stands.INTRODUCTION The tropical and subtropical forests have attracted the attention of large number of workers all over the world, who have carried out comprehensive studies on their community organization and dynamics, and have estimated species richness, biomass, and productivity (Whitmore 1984, Valencia et al. 1994, Condit et al. 1996, Aiba & Kitayama 1999, Condit et al. 2000). Forest structure and composition are strongly correlated with environmental factors, such as climate and topography (Currie 1991). Tree species diversity is an important aspect of forest ecosystem diversity (Rennolis & Laumonier 2000). Tree species inventories at defined sites and in minimum diameter classes give a reliable instrument to indicate diversity level of the stand site (Wattenberg & Breckle 1995). Quantitative floristic sampling also provides the necessary context for planning and interpreting long-term ecological research (Phillips et al. 2003). Williams-Linera (2002) had reported that the landuse systems are threatened and must be studied to understand and minimize the ecological impact of anthropogenic activities on forest ecosystems. Diversity of a community can be assessed by a variety of nonparametric measures such as Shannon, Simpson, Margalef indices, and these measures have gained a great deal of popularity in the recent past (Maguran 1988). Besides species diversity, abundance of species in community helps in determining the common and rare species (May 1975). Ecologists often use girth class distribution to indicate the health of population. Population studies in forest ecosystems have been used to infer past changes and predict future changes in species composition by examining the size class distribution of woody species (Khan et al. 1987, Read et al. 1995). Presence of less number of seedlings and saplings of a species in the forest stand is a major concern for its conservation (Foster et al. 1996). Northeast India, an extension of the eastern Himalayan complex, is a hot spot of biodiversity. About 50 % species of the Indian flora is confined to this region (Rao & Hajra 1986). The varied physiography, soil and climatic conditions of the region are responsible for the luxuriant growth of various types of forest. The state of Meghalaya being a part of the northeastern Indian bio-geographic zone, constitutes the junction meeting place of paleo-arctic, Indo-Malayan and Indo-Chinese bio-geographic realms. Owing to the diverse ecological conditions such as wide variation in rainfall, temperature, altitude as well as soil conditions, the inaccessible humid areas of the state, support luxuriant growth of tropical and subtropical vegetation, which is rich in angiospermic flora. The subtropical evergreen and semi-evergreen forests of the state cover large areas and the forest patches were confined to remote areas with complex terrain and are less influenced by humans. However, pine forests were secondary in nature, where further succession has been arrested due to complex interaction of biotic and edaphic factors. These forests are mostly confined to higher reaches of Khasi and Jaintia hills district of the state and are highly fragmented. The impact of shifting cultivation is less in evergreen forests than the semi-evergreen forests as these forests were confined to less complex terrain (Tripathi 2002). The primary reason of forest destruction is habitat destruction due to cattle grazing, overexploitation for medicinal and ornamental purposes and encroachment in forested area for cultivation. The objectives of the present study was to analyze and investigate the soil characteristics, plant diversity status, community organization and population structure in subtropical evergreen, semi-evergreen and pine forests of the state. STUDY SITES AND METHODOLOGY The study was conducted in each of the three selected forests to characterize its floristic composition and population structure. Representative forest stands i.e., subtropical evergreen (250 27 N and 900 19 E, 1425 m asl), semi-evergreen (250 14 N and 910 43 E, 1475 m asl) and pine (250 32 N and 910 53 E, 1900 m asl) were selected in each of the three forests. Soil samples were collected randomly from two (0-10cm and 10-20cm) depths at ten places on annual basis from the selected forest stands and were mixed thoroughly to obtain a composite sample. These samples were used to determine the pH, soil organic carbon, total Kjeldahl nitrogen and available phosphorus using the methods given by Allen et al. (1974) and Anderson & Ingram (1993). Twenty five quadrats of 20 m x ?20 m size were randomly laid in each of the evergreen and semi-evergreen and thirty quadrats of 10m x 10m size in the pine forests and all individuals (>15cm cbh) were recorded. Tree seedlings (15m height), sub-canopy (8-15m) and tree-let (2-8m) layer. However, there was no clear stratification in the pine forest. Canopy layer was composed of 13 species in both evergreen and semi-evergreen forests, where as it was almost exclusively composed of Pinus kesiya in the pine forest. However, a few trees of broad-leaved species like, Quercus sp., Schima wallichii, Myrica esculenta and Exbucklandia populnea were found scattered in this forest (Tripathi 2002). Under-canopy (2-15m tree height) was poor in the pine forest while this layer was the most species rich in the evergreen and semi-evergreen forests and has contributed about 80% of the total species richness. Elaeocarpus rugosus, Castanopsis tribuloides, Engelhardtia spicata and Duabanga grandiflora in the evergreen forest, Aporusa oblonga, Dysoxylum binectiferum, Schima wallichii and Ficus sp., in semi-evergreen forest were among the most dominant canopy species. Lauraceae was the most species rich family represented by 11, 10 and 5 species in the evergreen, semi-evergreen and pine forest, respectively. Euphorbiaceae and Pinaceae were the co-dominant family in the broad-leaved and pine forest. A large number of families were monospecious in all the forests. Dominance-distribution curves of the families showed that only a few families were dominant in broad-leaved as well as needle-leaved forests and large number of families had low FIV (Tripathi 2002). Shrub species were represented by 20, 23 and 21 species belonging to 18, 20 and 18 genera and 13, 13 and 14 families in the evergreen, semi-evergreen and pine forests, respectively (Table 2). Bridelia retusa, Callicarpa rubella and Helicia excelsa in evergreen forest, Psychotria erratica, Symplocos paniculata, Adenia trilobata, Rhus javanica and Achronychia pedunculata in the semi-evergreen and Eupatorium adenophorum, Osbeckia crinita, Thysaenolaena agrostis and Rubus sp. in the pine forests were among the common shrub species (Tripathi 2002). The tree seedlings, annual and perennial flowering plants and ferns constituted the ground layer in the forest. The ground vegetation was most (57 species) species rich in the pine forest than the evergreen (44 species) and semi-evergreen (47 species) forests (Table 2). Colquhounia coccinea, Hypericum laxum, Senecio cappa, Gleichenia sp. and Asplenium sp. in the evergreen forest, Anotis oxyphylla, Hemiphragma heterophyllum, Davaellia sp., Crysopogon aciculatus and Asplenium sp in the semi-evergreen forest and Asplenium sp. and Davaellia sp. in the pine forest were among the common species of the ground vegetation (Tripathi 2002). Dominance and distribution pattern of species: Life form spectra showed preponderance of phanerophytes in broad-leaved forests followed by chamaephytes and therophytes. Pine forests showed low dominance of phanerophytes (28.4%) (Tripathi 2002). Dominance-distribution pattern was similar in evergreen and semi-evergreen forest and showed a log-normal distribution pattern, signifying high equitability and low dominance in the community. However, the pattern was broken-stick in the pine forest indicating low equitability in the dispersion of dominance of tree species (Fig.1). Values of Shannon diversity index (4.2), was more in the broad-leaved forests than the pine (2.19) forest, while Simpson dominance index showed a reverse trend to that of diversity index. The diversity index for shrub and herbaceous layer showed a similar trend to that of the woody species richness (Table 2). Majority (53% to 95%) of the plant species in the forest showed contagious/clumped distribution pattern (Table 3). There were only a few species which showed either regular or random distribution. Greater proportion of contagious distribution pattern revealed that the species were distributed in patches in the community it was further supported by the frequency distribution pattern which results that most of the species had low frequency. Stand density and basal cover: The Stand density of tree species was high in the evergreen forest and pine forest (1023 and 1050 individuals per hectare) than the semi-evergreen forest (838 individuals per hectare). Although, stand density of semi-evergreen forest was less than other two forests but contribution to the basal cover was more (Table 1). Distribution of stand density in different girth classes revealed that young individuals (95 cm cbh) were represented by a few individuals in the broad-leaved forests and it was completely absent in the pine forest. However, in pine forest mature trees (55-95cm cbh) had contributed to maximum stand density. Distribution of basal cover showed a reverse trend to that of stand density, that is, mature and adult trees, though less in number contribute maximum to the basal cover (Fig. 2). Population structure: Mean seedling density (plants 100 m2) was 494, 1341 and 501 individuals in the evergreen, semi-evergreen and pine forests, respectively. Seedlings of Ostodes paniculata, Persea duthiei, Macaranga denticulata and Engelhardtia spicata in evergreen forest, Cinnamomum tamala, Aporusa oblonga, Celtis tetranda, Callicarpa arborea and Ficus racemosa in semi-evergreen forest and Eurya acuminata, Combretum acuminatum, Lyonia ovalifolia and Zanthoxylum alatum in pine forest were among the common (Tripathi 2002). The mean sapling density was 3813 stem ha-1 in evergreen forest, 4056 stem ha-1 in semi-evergreen forest and 2212 stem ha-1 in the pine forest. Cinnamomum tamala, Citrus medica, Glochidion assamicum and Callicarpa vestita in evergreen forest, Camellia cauduca, Celtis tetranda, Glochidion acuminatum, Garcinia pedunculata and Persea duthiei in semi-evergreen forest and Myrica esculenta, Quercus glauca, Lindera leata and Litsea sp. in the pine forest were among the common tree saplings (Tripathi 2002). The mean density of adult trees was 1023, 838 and 1050 individuals ha-1 in the evergreen, semi-evergreen and pine forests, respectively. Based on the density, all the three forests showed dominance of tree seedlings and substantially low population density of saplings and adult trees which has resulted in an upright pyramidal structure. Preponderance of tree seedlings, followed by a steep decline in population density of saplings and adult trees indicated that the period between seedlings to sapling stage was the most critical stage in the life cycle of the tree species, as maximum mortality (about 93%) occurred during this period (Fig. 3). Based on this observation, the population of the seedling phases may be considered as the most vulnerable stage in the life cycle. DISCUSSION The selected forest types were the major forest types in the state of Meghalaya and they together cover an area of about 41% of the total geographical area of the state. These forests are located between altitudinal range of 800 and 2000m asl. The climate of the area was seasonal with 7-8 month-long rainy season. The evergreen and semi-evergreen forest differs from each other depending on the dominance of evergreen and deciduous species in the canopy. Evergreen forests are found where rainfall is relatively high and soil moisture condition remains favourable for most part of the year. The areas where rainfall was low, due to coarse texture or high slope gradient or both have supported semi-evergreen vegetation (Tripathi 2002). Human intervention in these broad-leaved forests have paved the way for development of pine forests, which represent edaphic and biotic climax community on disturbed sites, which are seasonally dry and nutrient poor. The most conspicuous features of the tropical and subtropical humid forests are their species richness, heterogeneity and complex community organization. Rainfall pattern and temperature regimes strongly influence their floristic composition, which is further modified by edaphic and biotic influences (WCMC 1992). The dominance of the families like Lauraceae, Euphorbiaceae, Moraceae and Rubiaceae in the broad-leaved forests bears a good deal of similarity with Amazonian tropical rainforest and tropical forests of Sierra de Manantlan, Pasoh reserve forests of Malaysia (Gentry 1988, Vazquez & Givnish 1988, Manokaran et al. 1991) and subtropical forests/sacred forests of Meghalaya (Upadhaya et al. 2003, Mishra et al. 2004). The soil profile in broad-leaved forest is well developed, acidic and rich in organic matter and nutrients. On the contrary, the soil in the pine forest is more acidic and poor in organic matter and nutrients. The subtropical evergreen forest is richer in species content than the evergreen forest. Presence of few deciduous species, which shed their leaves during the dry months between February and April, give semi-evergreen appearance to the forest. Majority of species showed contagious/clumped distribution in all the forests which could be attributed to insufficient mode of seed dispersal (Richards 1996), topography and soil factors (Hubbell & Foster 1983). Regular dispersion pattern as observed in the present study may be the consequence of direct competition for water and nutrients, allellopathy or frequent disturbance (Armesto et al. 1986), which largely contribute to the maintenance of high level of diversity (Connel 1971). The change in dominance distribution pattern from log-normal in the broad-leaved to broken-stick in the pine forest indicate marked shift from high equitability to high dominance in the community due primarily to disturbance. The dominance of phanerophytes in broad-leaved forests is indicative of mild and moist climate as has also suggested by Archibold (1995). Dominance of therophytes followed by phanerophytes in pine forest suggested transformation of mesic habitat supporting broad-leaved forests into disturbed xeric habitat which provide more favourable condition to annuals and tolerant tree species like Pinus kesiya (Tripathi 2002). In general, the higher values for therophytes, the more homogenous are the stand (Singh et al. 2006). The girth-class composition of stands at high disturbance level resembles J-shaped distribution (number increases with increasing age), indicates future decline in the population (Knight 1975). However, at low disturbance, the trend is considerably reversed due to presence of a large number of individuals in lower girth-class, an indicator of a growing population (Pandey and Shukla 2001). Selective thinning of tree-lets for firewood and their death due to surface fire seems to be major cause of loss of young individuals. The tree density in the broad-leaved forest and their reverse J-shaped distribution in different girth-classes could be related to gap phase dynamics, tree regeneration behaviour and age of the stand. In the pine forest, density distribution in different girth classes seems to be determined by the cumulative effect of natural thinning, selective cutting and surface fire as these factors cause heavy mortality of tree seedlings and saplings. ACKNOWLEDGEMENTS O.P. Tripathi is thankful to Indian Institute of Remote Sensing, Dehradun for financial assistance in the form of a research project and also to the Prof. AK Misra, Head, Department of Botany, North-Eastern Hill University, Shillong for providing the basic infrastructure for conducting the research. I am very much thankful to the referees for their valuable comments and suggestions which have strengthens the quality of our manuscript.

REFERENCES Aiba, S., & K. Kitayama. 1999. Structure, composition and species diversity in an altitude-substrate matrix of rain forest tree communities on Mount Kinabalu, Borneo. Plant Ecology 140: 139-157. Allen, F.S., Grimshaw, H.M., Parkinson, J.A., & Quarmby, C. 1974. Chemical Analysis of Ecological Materials. Blackwell Scientific Publications, Oxford. Anderson, J.M., & Ingram, J.S.P. 1993. Soil Biology and Fertility - A Handbook of Methods, 2nd edition. CAB International, Wallingford, U.K. Archibold, O.W. 1995. Ecology of World Vegetation. Chapman and Hall, London. Armesto, J.J., Mitchell, J.D., & C. Villagran. 1986. A comparison of spatial patterns of trees in some tropical and temperate forests. Biotropica 18: 1-11. Condit, R., Hubbel, S.P., LaFrankie, J.V., Sukumar, R., Manokaran, N., Foster, R.B., & P.S. Ashton. 1996. Species-area and species-individual relationships for tropical tree: a comparison of three 50 ha plots. Journal of Ecology 84: 549-562. Condit,R., Ashton,P.S. Baker,P. Bunyvejchewin, S., Gunatilleke, S., Gunatilleke, N., Hubbel, S.P., Foster, R.B., Itoh, A., LaFranki, J.V., Lee, H.S., Losos, E., Manokoran, N., Sukumar, R., & T. Yamakura. 2000. Spatial patterns in the distribution of tropical tree species. Science 288: 1414-1418. Connel, J.H. 1971. On the role of natural enemies in preventing competitive exclusion in some marine animals and in rainforest trees. In: Dynamics of populations (Den Boer, P. & Gradwell, P.R., eds.), pp. 298-312. Currie, D.J. 1991. Energy and large-scale patterns of animal- and plant- species richness. American Naturalist 137:27-49. Foster, D.R., Orwig, D.A., & J.S. Maclachalan. 1996. Ecological and conservation insights from re-constructive studies of temperate old growth forests. Trends in Ecology and Evolution 11: 419-424. Gentry, A.H. 1988. Changes in plant community diversity and floristic composition on environmental and geological gradients. Ann. Missouri Bot. Gard. 75: 1-34. Haridasan, K., & R.R. Rao. 1985-87. Forest Flora of Meghalaya. 2 Vol. Bishen Singh Mahendrapal Singh, Dehra Dun, India. Hubbell, S.P., & R.B. Foster. 1983. Diversity of canopy tree in a neotropical forest and implications for conservation. In: Tropical Rainforest: Ecology and Management (Sutton, S.L., Whitmore, T.C. & Chadwick, A.C. eds.), pp. 25-41. Blackwell Scientific Publications, Oxford. Khan, M.L., Rai, J.P.N., & R.S. Tripathi. 1987. Population structure of some tree species in disturbed and protected sub-tropical forests of north-east India. Acta Oecologia 8: 247-255. Knight, D.H. 1975. A phytosociological analysis of species-rich tropical forest at Barro Colorado Island, Panama. Ecological Monograph 45: 259-284. Magurran, A.E. 1988. Ecological Diversity and its Measurement. University Press, Cambridge. Manokaran, N., La frankie, J.V., Kochumman, K.M., Quah, E.S., Klahn, J., Ashton, P.S., & S.P. Hubbell. 1991. Stand table and distribution of species in the 50 ha reserve plot at Pasoh forest reserve. Forest Research Institute of Malaysia, Reserve data. May, R.M. 1975. Patterns of species abundance and diversity. In: Ecology and Evolution of Communities (Cody, M.L. & J.M. Dimond. eds.) pp. 340-379. Belknap press, Harvard University, Cambridge. Mishra, B.P., Tripathi, O.P., Tripathi, R.S., & H.N. Pandey. 2004. Effects of anthropogenic disturbance on plant diversity and community structure of a sacred grove in Meghalaya, north-east India. Biodiversity and Conservation 13: 421-436. Misra, R. 1968. Ecology Work Book. Oxford-IBH Publishing Company, Calcutta. Mueller-Dombois, D., & H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley and Sons, USA. Pandey, S.K., & R.P. Shukla. 2001. Population structure of woody plants in relation to disturbances including NTFP extraction in forests of north eastern Uttar Pradesh, India. In: Tropical Ecosystems: Structure, diversity and human welfare (Ganeshaiah et al. eds.), pp. 39-44. Phillips, O.L. Hall, P., Gentry, A.H. Swayer, S.A., & R. Vazquez. 1994. Dynamics and species richness of tropical forests. Proceedings of the National Academy of Sciences, USA 91: 2805- 2809. Phillips, O.L., Martinez, R.V., Vargas, P.N., Monteagudo, A.L., Zans, M.C., Sanchez, W.Z., Cruz, A.P., Timana, M., Yli-Halla, M., & S. Rose. 2003. Efficient plot-based floristic assessment of tropical forests. Journal of Tropical Ecology 19: 629-645. Read, J., Hallam, P., & J.F. Cherrier. 1995. The anomaly of monodominant tropical rainforests: some preliminary observations in the Nothophagus-dominated rain forests of New Caledonia. Journal of Tropical Ecology 11: 359-389. Rao, R.R., & P.K. Hajara. 1986. Floristic diversity of eastern Himalaya in a conservation perspective. Proceedings Indian Academy of Sciences (Supplementary- Nov), pp. 103-125. Rao, P., Barik, S.K., Pandey, H.N., & R.S. Tripathi. 1990. Community composition and tree population structure in a sub-tropical broad-leaved forest along a disturbance gradient. Vegetatio 88: 151-162. Rennolls, K., & Y. Laumonier. 2000. Species diversity structure analyziz at two sites in the tropical rain forest of Sumatra. Journal of Tropical Ecology 16: 253-270. Richards, P.W. 1996. The Tropical Rain Forests. 2nd edition. Cambridge University Press, Cambridge. Singh, J.S, Sigh, S.P. and Gupta, S.R. 2006. Ecology, Environment and Natural Resources. Anamaya Publication, New Delhi. Tripathi, O.P. 2002. Study of distribution pattern and ecological analysis of major forest types of Meghalaya. Ph.D. Thesis. North-Eastern Hill University, Shillong. Upadhaya, K., Pandey, H.N., Law, P.S., & R.S. Tripathi. 2003. Tree diversity in sacred groves of Jaintia Hills in Meghalaya, northeast India. Biodiversity and Conservation 12: 583-597. Valencia, R., Balsley, H., Guillermo, P.Y., & C. Mino. 1994. High tree alpha diversity in Amazonian Ecuador. Biodiversity and Conservation 3: 21-28. Vazquez, J.A., & T.J. Givnish. 1998. Altitudinal gradients in tropical forest composition, structure, and diversity in the Sierra de Manantlan. Journal of Ecology 86: 999-1020. Wattenberz, I., & S.W. Breckle. 1995. Tree species diversity a premontane rain forest in the Cordillera de Tilaran, Costa Rica. Ecotropica 1: 21-30. WCMC 1992. Global Biodiversity Strategy. (Groombridge, B. ed.). World Conservation and Monitoring Centre, Chapman and Hall, London. Whitford, P.B. 1948. Distribution of woodland plants in relation to succession and clonal growth. Ecology 30: 199-208. Whitmore, T.C. 1984. Gaps in forest canopy. In: Tropical Trees as Living Systems (P.B. Tomlinson & M.H. Zimmermann, eds.), pp. 639-655. Cambridge University press, Cambridge. Williams-Linera, G. 2002. Tree species richness complementarity, disturbance and fragmentation in a Mexican tropical montane cloud forest. Biodiversity and Conservation 11: 1825-1845.