*Indian Forester,* 140 (4) : 354-362, 2014
http://www.indianforester.co.in
ISSN No. 0019-4816 (Print)
ISSN No. 2321-094X (Online)

# CAUSE, PATTERN AND CONSEQUENCE OF UNDERSTORY HERBACEOUS VEGETATION AT A FOOTHILL FOREST IN INDIAN EASTERN HIMALAYA

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ABSTRACT

Herbaceous flora is the dynamic layer in a forest stratum that protects the soil and water regimes and improves productivity and soil fertility. Thus a study was conducted at Chilapatta Reserve Forest, West Bengal India to document the status of herb diversity, biomass and carbon accumulation. Stratified random nested quadrate sampling was adopted for analyzing the qualitative and quantitative characters. Forty nine herb species were recorded, of which seven are yet to be identified. Identified species were of 21 families and 36 genera. The herb diversity index, concentration of dominance, Shannon and Wiener index and evenness index was estimated as 0.62, 0.028, 4.46 and 2.27, respectively. Highest and lowest frequency was recorded 49.12 and 1.75 while relative frequency varied from 0.09 to 1.87. Herb density ranged from 2 to 11193 individuals ha$^{-1}$ and relative density ranged from 0.05 to 1.76%. Most of the species were widely distributed and its abundance ranged from 0.80 to 12.76 while relative abundance ranged from 0.16 to 1.73%. IVI values ranged from 0.47 to 5.27. The above ground portion of herbs accumulated the major portion of biomass and carbon.

*Key words* : Chilapatta Forest, Herb, Diversity, Biomass, Carbon accumulation

## Introduction

Tropical forests are one of the most structurally and functionally complex systems on earth. Species diversity in tropical areas varies greatly from place to place mainly due to variation in biogeography, habitat and disturbance (Whittaker, 1972). They are important for reducing atmospheric $CO_2$. Herbaceous flora though constitutes only a small proportion but substantially contributes to the species diversity of a forest ecosystem and plays an important role in ecological characteristics as well as dynamic layer for forest stratum because they responds relatively quickly to changes in the environment (Whittaker, 1966; Gilliam and Christensen, 1986; Sagar *et al.*, 2012). Under story vegetation offer better protection to the soil and water regimes and also improve productivity and nutrient status (Gilliam, 1988). Quantification of understory vegetation helps in understanding the dynamics of forest (Moore and Allen, 1999). It influences nutrient cycling and energy flow which may also provide a clue regarding resources availability (Scheller and Mlandenoff, 2002). Studies on biomass of this stratum are essential for determining storage of carbon in the forest.

Chilapatta Reserve Forest under Terai Duars region in the Indo-Malayan Biodiversity Hotspot (Myers and Mittermeier, 2000) is one of the most biodiversity rich areas in Indian eastern Himalayas (Anon., 2001). The forests in the Himalayas and its foothills are degrading day by day and this forest is no exception. Study of natural plant community is basic and prerequisite for understanding the structural and functional attributes specific to locate for better landscape management. Thus the present study with this objective documented the herbal stratum diversity pattern in the forest along with its biomass and carbon storage.

## Material and Methods

The study was carried out from March 2007 to March 2009 at Chilapatta Reserve Forest under Cooch Behar Wildlife Division (Anon., 2001) which is located in the northern fringe of West Bengal state in the foothills of the sub-Himalayan mountain belts. The forest type ranges from tropical wet evergreen to tropical moist deciduous forest (Champion and Seth, 1968). The study area was located at 26°32.85'N and 89°22.99' E measured with GPS (Garmin-72). Altitude of the area was 47 m amsl. The soil in the forest was high in organic carbon and available nitrogen, medium in phosphorus and potash with acidic reaction. The soil structure at 0-30 cm has 70% sand, 19% silt and 11% clay (Paul, 2004).

Adopting random nested quadrate sampling, 285 quadrates measuring 1 m × 1 m were marked for analyzing herb qualitative and quantitative parameters in the forest with an area of 22 km$^2$. Identification of herb specimens was done in the field as far as possible with the help of local name. The unidentified voucher specimens were taken for identification either to

Herb density index, concentration of dominance, Shannon and Wiener index were estimated as 0.62, 0.028 and 4.46 respectively at Chilapatta Reserve Forest.

Taxonomy and Environment Biology Laboratory, Department of Botany, University of North Bengal, Siliguri or to National Herbarium, Shibpur Howrah. For each quadrate, the herb community was studied following standard methods (Raunkiaer, 1934; Cottam and Curtis, 1956; Mishra, 1968; Sagwal, 1995). Qualitative characters like structure and composition (stratification, sociability, occurrence/presence, function, leaf shape and texture) were described by visual observation.Visually the sociability or the nature of grouping of species in the forest was categorized as species growing singly, in patches, in colonies and intermixed. Species were also classified according to their leaf shape and texture.

Quantitative characters including frequency, relative frequency, Raunkiaer's law of frequency, density, relative density, abundance, relative abundance, importance value index (IVI) and distribution pattern were estimated. Abundance is ratio of total number of individuals of a species recorded to the number of quadrates in which the species occurred. The Raunkiaer's law of frequency states that numbers of species of a community in five 20% classes (A, B, C, D and E) distributed as 0-20%, 20-40%, 40-60%, 60-80% and 80-100%, respectively (Raunkiaer, 1934). Commonly used diversity indices were like species richness and species diversity index (Menhinick, 1964) concentration of dominance (Simpson, 1949), Shannon-Wiener diversity index (Shannon and Weaver, 1949; Shannon and Weiner, 1963) and species evenness index (Pielou, 1975) were adopted. All the herbs from 1m×1m quadrates were uprooted to measure their fresh weight separately for roots and above ground parts (foliage). The total biomass was converted into carbon content by multiplying by a factor of 0.45 (Woomer, 1999).

## Result and Discussion

The visual observations for qualitative characters like stratification, occurrence/presence, function, sociability, leaf shape and texture are presented in Table 1. On the basis of occurrence/presence it was confirmed

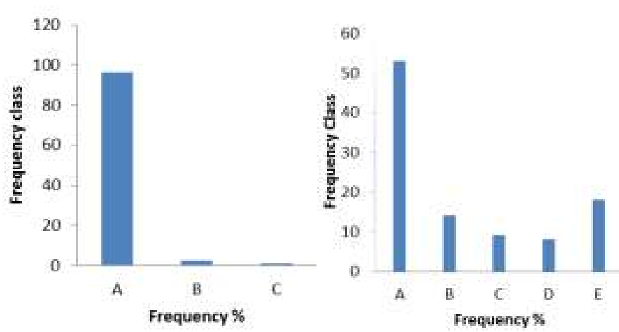


Fig. 1 : Comparision of Raunkiaer's normal frequency distribution with observed herbal frequency distribution

that all the herbs were very less or were less frequent in forest. Herb species herbs like Ageratum conyzoides, Rhaphidophora calophylla and R. hookeri which were represented by 38.78% of total recorded herbs were very less frequent while the remaining like *Amorphophallus bulbifer*, *Phlogacanthus thysiformis* and *Rungiapectinata* were less frequent herbs. All the herbs were observed as evergreen. Among the herbs, *Phaus flavus*, a terrestrial orchid and an unidentified species of genus Cyprus (sl. No. 17 Table.1) were growing singly while 51.02 and 44.89% of total herb species were observed growing in colonies and patches, respectively. The herbs growing in colonies were like *Mimosa pudica*, all species of *Rhaphidophora*, *Digitaria cillialis*, *Aegeratum conyzoides* and *Colocasia esculenta* and those growing in patches were like *Amorphophallus bulbifer*, *Globba racemosa*, *G. macroelada*, *Alpinia nigra*, *Solanum khasianum* and *S. xanthocarpum*.

Leaves of the herbs were classified as medium/small (26.53%), graminoids (51.02%), broad/large (18.37%) and compound (4.08%) on the basis of leaf size. Herbs with medium/small leaves were like *Rungia pectinata*, *Acmella calva*, *Ageratum conyzoides* and *Solanum xanthocarpum*. Herbs with broad/large leaves were like *Solanum khasianum*, *Colocasia esculenta* and all species of *Rhaphidophora*. Herbs with graminoids leaves found in the forest were like *Floscopascandens*, all the species of *Cyprus* and *Murdannia nudiflora*. *Amorphophallus bulbifer* and *Mimosa pudica* were only two herbs having compound leaves. Except for *Plectranthus barbatus,* a shrub whose leaves are succulent all the species had membranous leaf texture.

A total of 49 species of herbs were recorded from the forest but 7 of these species could not be identified (Table 1 and 2). The identified species were represented by 21 families and 37 genera (Table 1 and 3). The species richness recorded in the present study is comparable with other studies reporting species richness specifically form tropical forests in Southeast Asia and other parts of the country like that reported by Chandra *et al.* (2010) from Garhwal Himalayas with a total of 209 plant species out of which 102 were herbs. High species richness of various forests at different geographic locations in India like 329 species of plants (79 herbs) from sacred groves in Kanyakumari district, Tamil Nadu and 372 species (177 herbs) from Bhitarkanika National Park, Orissa (Sukumaran *et al.*, 2005; Reddy *et al.*, 2006) was also reported. Species diversity in tropical areas varies greatly from place to place mainly due to variation in biogeography or local landscape conditions (e.g., soil type, topography), habitat and disturbance (Whitmore, 1998; Fajardo and Alaback, 2005). The local landscape was dominated by trees and herbs inhabiting sites below gaps in the tree canopy and under the partially shaded sites below the tree canopies.

The dominating families were Poaceae (7), Areceae and Zingiberaceae (4 each), Asteraceae and Cyperaceae (3 each) and Acanthaceae, Orchidaceae, Rubiaceae and Solanaceae (2 each) while remaining

Table 1 : Qualitative characters of herb communities of Chilapatta Reserve Forest

| Sl. no. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| 1. | *Phlogacanthus thysiformis* (Hardwicke) Mabber | Acanthaceae | H | C | S | e | h | Z |
| 2. | *Rungia pectinata* (L.) Ness | Acanthaceae | H | C | S | e | a | Z |
| 3. | *Amorphophallus bulbifer* (Schott) Blume | Arecaceae | H | C | S | e | v | Z |
| 4. | *Colocasia esculenta* (L.) Schott | Areceae | H | C | S | e | h | Z |
| 5. | *Rhaphidophora calophylla* Schott | Areceae | H | C | R | e | h | Z |
| 6. | *Rhaphidophora glauca* (Wall) Schott. | Areceae | H | C | S | e | h | Z |
| 7. | *Rhaphidophora hookeri* (Schott) | Areceae | H | C | R | e | h | Z |
| 8. | *Acmella calva* (DC.) Jansen | Asteraceae | H | C | S | e | a | Z |
| 9. | *Ageratum conyzoides* L. | Asteraceae | H | C | R | e | a | Z |
| 10. | *Elepanthropus scaber* | Asteraceae | H | C | S | e | a | Z |
| 11. | *Chloranthus sp* | Chloranthaceae | H | C | R | e | a | Z |
| 12. | *Floscopa scandens* Loureiro | Commelinaceae | H | C | R | e | g | Z |
| 13. | *Murdannia nudiflora (L.) Brennan* | Commelinaceae | H | C | R | e | g | Z |
| 14. | *Ophiopogon wallichianus* (Kunth) Hook. f. | Convallariaceae | H | C | S | e | g | Z |
| 15. | *Cyperus cuspidatus* (Kunth) | Cyperaceae | H | C | S | e | g | Z |
| 16. | *Cyperus rotandus* L. | Cyperaceae | H | C | S | e | g | Z |
| 17. | *Cyperus sp.* | Cyperaceae | H | $ | R | e | g | Z |
| 18. | *Mimosa pudica* L. | Fabaceae | H | C | R | e | v | Z |
| 19. | *Pogostemon benghalensis* (Burman f.) Kuntze | Lamiaceae | H | C | R | e | a | Z |
| 20. | *Schumannianthus dichotomous* (Roxb.) Gagnepain | Marantaceae | H | P | R | e | h | Z |
| 21. | *Maesa indica* Roxb . A. DC. | Myrsinaceae | H | P | S | e | a | Z |
| 22. | *Bulbophyllum bailegi* | Orchidaceae | $O^e$ | C | S | e | a | Z |
| 23. | *Phaus flavus* (Bl.) Lindl. | Orchidaceae | O | $ | R | e | h | Z |
| 24. | *Lindernia crustacean* (L.) F. Muell. | Plantaginaceae | H | C | S | e | a | Z |
| 25. | *Acroceras zizanioides* | Poaceae | H | P | S | e | g | Z |
| 26. | *Axonopus compressus* (Sw.) P. Beauv. | Poaceae | H | C | S | e | g | Z |
| 27. | *Brachiaria milliformis* | Poaceae | H | P | S | e | g | Z |
| 28. | *Capillipedium assimile* (Steudel) A. camus | Poaceae | H | C | S | e | g | Z |
| 29. | *Saccharum spontaneum* Linn. | Poaceae | H | C | R | e | g | Z |
| 30. | *Degitaria cilliaris* | Poaceae | H | C | S | e | g | Z |
| 31. | *Pennisetum purpureum* Schum. | Poaceae | H | P | S | e | g | Z |
| 32. | *Polygata glomerata* Lour. | Polygonaceae | H | P | S | e | a | Z |
| 33. | *Borreria ocimoides* f. bisepala (Bremek.) Steyerm. | Rubiaceae | H | C | S | e | a | Z |
| 34. | *Oldenlandia stipulacea* L. | Rubiaceae | H | P | R | e | a | Z |
| 35. | *Lindernia ciliata* (Colsm.) Pennell | Scrophulariaceae | H | P | S | e | a | Z |
| 36. | *Solanum khasianum* L. | Solanaceae | H | P | S | e | h | Z |
| 37. | *Solanum xanthocarpum* L. | Solanaceae | H | P | S | e | a | Z |
| 38. | *Cissus repens* Lam. | Vitaceae | H | P | S | e | a | Z |
| 39. | *Alpinia nigra* (Gaertn.) B. L. Burtt | Zingiberaceae | H | P | S | e | h | Z |
| 40. | *Globba macroclada* Gagnepain | Zingiberaceae | H | P | R | e | g | Z |
| 41. | *Globba racemosa* Smith | Zingiberaceae | H | P | S | e | g | Z |
| 42. | *Hedychium coccineum* Smith | Zingiberaceae | H | P | S | e | g | Z |
| 43. | *Un -1* | | H | P | S | e | g | Z |
| 44. | *Un -2* | | H | P | S | e | g | Z |
| 45. | *Un -3* | | H | P | S | e | g | Z |
| 46. | *Un -4* | | H | P | S | e | g | Z |
| 47. | *Un -5* | | H | P | R | e | g | Z |
| 48. | *Un -6* | | H | P | R | e | a | Z |
| 49. | *Un -7* | | H | P | R | e | a | Z |

1. Scientific name; 2. Family; 3. Stratification (H- herb, O- orchid, e- epiphyte); 4. Sociability (c-colony; p-patch; $- singly); 5. Occurrence/presence (r-very rare/rare, s-seldom present/less frequent); 6. Function (e- evergreen); 7. Leaf shape (a- small/medium, g- graminoids, h- broad, v- compound); 8. Leaf texture (z- membranous)

families each were only represented by single species (Table 1). Family Poaceae with seven genera having a species each dominated the herbs followed by Cyperaceae with two genera and four species. Among the genera of herbs, Cyprus of family Cyperaceae and Rhaphidophora of Areceae with three species each dominated followed by Solanum of Solanaceae and Globba of Zingiberaceae with two species each (Table 1).

The values worked out for species diversity index, concentration of dominance, Shannon and Wiener index

Table 2 : Quantitative characters of herb communities of Chilapatta Reserve Forest

| Sl. no. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. | *Phlogacanthus thysiformis* (Hardwicke) Mabber | 6.14 | 0.67 | A | 2526.32 | 0.36 | 2.14 | 0.16 | 1.19 | $R_1$ |
| 2. | *Rungia pectinata* (L.) Ness | 5.96 | 0.59 | A | 2631.58 | 0.37 | 5.71 | 0.19 | 1.15 | $C_1$ |
| 3. | *Amorphophallus bulbifer* (Schott) Blume | 17.54 | 0.61 | A | 3684.21 | 0.52 | 3.50 | 0.26 | 1.40 | R |
| 4. | *Colocasia esculenta* (L.) Schott | 3.51 | 0.69 | A | 4912.28 | 0.70 | 1.00 | 0.30 | 1.70 | $R_1$ |
| 5. | *Rhaphidophora calophylla* Schott | 19.30 | 0.20 | A | 2175.44 | 0.31 | 2.82 | 0.48 | 0.98 | R |
| 6. | *Rhaphidophora glauca* (Wall) Schott. | 5.61 | 0.88 | A | 4561.40 | 0.65 | 4.75 | 0.22 | 1.75 | $C_1$ |
| 7. | *Rhaphidophora hookeri* (Schott) | 5.26 | 0.22 | A | 2561.40 | 0.36 | 4.13 | 0.50 | 1.08 | $C_1$ |
| 8. | *Acmella calva* (DC.) Jansen | 3.51 | 1.32 | A | 9192.98 | 1.31 | 3.01 | 0.30 | 2.93 | $C_1$ |
| 9. | *Ageratum conyzoides* L. | 5.96 | 0.20 | A | 3543.86 | 0.50 | 4.29 | 0.78 | 1.48 | $C_1$ |
| 10. | *Elepanthropus scaber* | 29.82 | 1.02 | B | 6175.44 | 0.88 | 6.18 | 0.26 | 2.16 | R |
| 11. | *Chloranthus* sp | 9.65 | 0.18 | A | 2807.02 | 0.40 | 2.91 | 0.66 | 1.24 | $R_1$ |
| 12. | *Floscopa scandens* Loureiro | 3.51 | 0.14 | A | 1859.65 | 0.26 | 1.50 | 0.56 | 0.96 | $R_1$ |
| 13. | *Murdannia nudiflora* (L.) Brennan | 5.26 | 0.09 | A | 1333.33 | 0.19 | 4.38 | 0.63 | 0.91 | $C_1$ |
| 14. | *Ophiopogon wallichianus* (Kunth) Hook. f. | 17.54 | 1.24 | A | 9929.82 | 1.41 | 3.50 | 0.34 | 3.00 | R |
| 15. | *Cyperus cuspidatus* (Kunth) | 6.14 | 0.44 | A | 11017.54 | 1.56 | 3.00 | 1.06 | 3.07 | $R_1$ |
| 16. | *Cyperus rotandus* L. | 3.86 | 0.47 | A | 4035.09 | 0.57 | 2.82 | 0.37 | 1.41 | $C_1$ |
| 17. | *Cyperus* sp. | 2.46 | 0.65 | A | 3614.04 | 0.51 | 1.43 | 0.24 | 1.40 | $C_1$ |
| 18. | *Mimosa pudica* L. | 16.67 | 1.78 | A | 2.02 | 1.76 | 3.26 | 1.73 | 5.27 | R |
| 19. | *Pogostemon benghalensis* (Burman f.) Kuntze | 15.79 | 0.17 | A | 807.02 | 0.11 | 4.22 | 0.20 | 0.49 | R |
| 20. | *Schumannianthus dichotomous* (Roxb.) Gagnepain | 14.91 | 0.18 | A | 1929.82 | 0.27 | 3.24 | 0.45 | 0.91 | R |
| 21. | *Maesa indica* Roxb . A. DC. | 17.54 | 0.64 | A | 5543.86 | 0.79 | 0.80 | 0.37 | 1.80 | R |
| 22. | *Bulbophyllum bailegi* | 1.75 | 0.42 | A | 3052.63 | 0.43 | 1.00 | 0.31 | 1.17 | $C_1$ |
| 23. | *Phaus flavus* (Bl.) Lindl. | 7.02 | 0.17 | A | 947.37 | 0.13 | 4.55 | 0.24 | 0.54 | $C_1$ |
| 24. | *Lindernia crustacean* (L.) F. Muell. | 28.95 | 0.93 | B | 8771.93 | 1.25 | 4.00 | 0.41 | 2.58 | R |
| 25. | *Acroceras zizanioides* | 7.72 | 1.02 | A | 6175.44 | 0.88 | 7.18 | 0.26 | 2.16 | $C_1$ |
| 26. | *Axonopus compressus* (Sw.) P. Beauv. | 11.23 | 1.32 | A | 11192.98 | 1.59 | 5.50 | 0.36 | 3.27 | $R_1$ |
| 27. | *Brachiaria milliformis* | 8.77 | 1.36 | A | 6280.70 | 0.89 | 12.76 | 0.20 | 2.45 | $C_1$ |
| 28. | *Capillipedium assimile* (Steudel) A. camus | 11.23 | 0.48 | A | 2771.93 | 0.39 | 5.59 | 0.25 | 1.12 | $R_1$ |
| 29. | *Saccharum spontaneum* Linn. | 8.07 | 0.14 | A | 912.28 | 0.13 | 3.43 | 0.27 | 0.55 | $R_1$ |
| 30. | *Degitaria cilliaris* | 5.05 | 0.13 | A | 4.39 | 0.05 | 3.60 | 0.58 | 0.76 | $C_1$ |
| 31. | *Pennisetum purpureum* Schum. | 17.54 | 0.52 | A | 2877.19 | 0.41 | 3.90 | 0.24 | 1.17 | R |
| 32. | *Polygata glomerata* Lour. | 9.47 | 0.97 | A | 6666.67 | 0.95 | 7.04 | 0.30 | 2.21 | $C_1$ |
| 33. | *Borreria ocimoides* f. bisepala (Bremek.) Steyerm. | 4.56 | 1.43 | A | 5719.30 | 0.81 | 12.54 | 0.17 | 2.41 | $C_1$ |
| 34. | *Oldenlandia stipulacea* L. | 6.32 | 0.10 | A | 666.67 | 0.09 | 3.56 | 0.27 | 0.47 | $C_1$ |
| 35. | *Lindernia ciliata* (Colsm.) Pennell | 3.51 | 1.87 | A | 7859.65 | 1.12 | 1.00 | 0.18 | 3.17 | $R_1$ |
| 36. | *Solanum khasianum* L. | 4.75 | 0.73 | A | 7929.82 | 1.13 | 3.80 | 0.47 | 2.32 | $C_1$ |
| 37. | *Solanum xanthocarpum* L. | 49.12 | 1.03 | C | 8280.70 | 1.18 | 3.36 | 0.34 | 2.55 | R |
| 38. | *Cissus repens* Lam. | 3.16 | 1.27 | A | 6666.67 | 0.95 | 2.78 | 0.23 | 2.44 | $C_1$ |
| 39. | *Alpinia nigra* (Gaertn.) B. L. Burtt | 6.67 | 0.48 | A | 1824.56 | 0.26 | 3.74 | 0.16 | 0.91 | $C_1$ |
| 40. | *Globba macroclada* Gagnepain | 7.37 | 0.25 | A | 2491.23 | 0.35 | 6.00 | 0.43 | 1.03 | $C_1$ |
| 41. | *Globba racemosa* Smith | 10.18 | 0.71 | A | 4421.05 | 0.63 | 5.45 | 0.27 | 1.60 | $C_1$ |
| 42. | *Hedychium coccineum* Smith | 5.61 | 0.95 | A | 5543.86 | 0.79 | 4.81 | 0.25 | 1.99 | $C_1$ |
| 43. | *Un -1* | 3.51 | 0.51 | A | 3263.16 | 0.46 | 2.90 | 0.27 | 1.25 | $C_1$ |
| 44. | *Un -2* | 3.81 | 0.38 | A | 3403.51 | 0.48 | 2.88 | 0.39 | 1.25 | $C_1$ |
| 45. | *Un -3* | 3.51 | 1.41 | A | 7087.72 | 1.01 | 2.86 | 0.22 | 2.63 | $C_1$ |
| 46. | *Un -4* | 2.46 | 0.90 | A | 4315.79 | 0.61 | 1.29 | 0.21 | 1.72 | $R_1$ |
| 47. | *Un -5* | 3.86 | 0.27 | A | 2666.67 | 0.38 | 2.59 | 0.42 | 1.07 | $C_1$ |
| 48. | *Un -6* | 7.02 | 0.24 | A | 2245.61 | 0.32 | 4.55 | 0.41 | 0.96 | $C_1$ |
| 49. | *Un -7* | 3.16 | 0.26 | A | 3192.98 | 0.45 | 3.00 | 0.52 | 1.24 | $C_1$ |

1. Scientific name (Un- unidentified); 2. Frequency; 3. Relative frequency; 4. Frequency class (A: 0-20, B: 20-40, C: 40-60%); 5. Density (individuals/ha); 6. Relative density; 7. Abundance; 8. Relative abundance; 9. Importance value index; 10. Distribution pattern (R-regular, $R_1$-random $C_1$-contagious)

and evenness are given in table 3. The herb diversity index or Menhinick's index of herb community was 0.62 which are comparable to that reported for tropical forests of Garo Hills in Meghalaya (Kumar *et al.*, 2006; Sagar *et al.,* 2012). The index considers the total number of species and total number of individuals of all the herb species. Based on this index it can be stated that the herb assemblages found in this forest were low in diversity but individuals were frequently present. The concentration of dominance was 0.028. This represents the probability of a species being encountered during sampling (lower value means the chance of encounter is higher). The Shannon-Wiener index is inversely proportional to concentration of dominance and the corresponding value was 4.46. This index is also an expression of community structure and complexity of a habitat. A high index value suggests a more diverse and stable herb community. Herb species in the forest were distributed evenly with a high value of 2.27. The evenness or equitability recorded in this study matched with the results got by Varghese and Menon (1999); Dash *et al.* (2009) and Padalia *et al.* (2004) but lower than that reported by Kumar *et al.* (2004) and Newaz (2006).

Density of herbs was sometimes high and widely variable at 7,628 individuals $ha^{-1}$. Plant density varies with forest community type, forest age class, tree species and size class, site history, site condition and other factors (Kumar *et al.*, 2006). Evaluation of density-dependent status of a species in a study site is important for conservation and management of forests. Overall the herb density of the forest is high because of lesser disturbance owing to its protection from the law as a Reserve Forest or Protected Forest for wildlife. Relative density ranged from 0.05 to 1.76% i.e. *Mimosa pudica* had the highest representation while *Neomicrocalamus andropogonifolius* had the lowest relative to all other species. Newaz (2006) also reported relative density from secondary forests of Chittagong, Bangladesh is comparative to the present study.

Pande *et al.* (2002), Galav *et al.* (2005), Srivastava *et al.* (2005) and Dash *et al.* (2009) have also reported the inverse relationship between concentration of dominance and the Shannon-Wiener index as observed in this study. Moreover, concentration of dominance reported by the above workers and Kumar *et al.* (2004) were higher than what was recorded in this study but was similar to those reported for other Indian tropical forests (Pande *et al.*, 2000; Newaz, 2006). Concentration of dominance recorded in this study was low which was accordance with higher diversity and related inversely to the index of dominance (Odum, 1971). The lower concentration of dominance recorded in this study can be attributed to the fact that in the Chilapatta Reserve Forest, dominance of herbs was shared by more than one species which was otherwise higher due to single or few species dominance as was reported by Dash *et al.* (2009) and other workers.

Species diversity index or Shannon and Wiener index of diversity is generally higher for tropical forests (Knight, 1975). But for Indian tropical forests the value of this index was found between 0.83 and 4.0 (Singh *et al.*, 1981, 1984). The index recorded in this study was quite high than those reported in the range between 0.001 and 2.69 (Sundarapandian and Swamy, 2000; Padalia *et al.*, 2004; Khurana, 2009; Sapkota *et al.*, 2009; Galanes and Thomlinson, 2009) but was comparable to those reported between 2.47 and 4.86 (Knight, 1975; Singh *et al.*, 1984; Parthasarathy *et al.*, 1992; Adekunle, 2006; Kumar *et al.*, 2006; Onyekwelu *et al.*, 2008; Dash *et al.*, 2009). However it would be inappropriate to draw quantitative comparisons among these studies because of significant differences in sample size, plot size and dimensions along with the differences in the environmental conditions and other site factors. Chilapatta Reserve Forest is a diverse community in which the species are evenly distributed with higher chances of encountering a species during sampling. This was confirmed by the higher values of the species diversity index, concentration of dominance, Shannon-Wiener index, evenness and density. This was because the forest is protected under law as a Reserve Forest or Protected Forest for wildlife and there is little anthropogenic disturbance.

The parameters for vegetation analysis i.e. frequency, relative frequency, Raunkiaer's law of frequency, density, relative density, abundance, relative abundance, important value index and distribution pattern are presented in table 2. Frequency or the degree of dispersion of the herb species in the forest ranged from 1.75-49.12% i.e. the chance of occurrence of *Bulbophyllum bailegi*was lowest while *Solanum xanthocarpum* occurred most. Similarly Negi and Nautiyal (2005) reported frequency of herbaceous layer between 10 and 100% from *Central* Himalayan forest which is more than the present study. This can be attributed to the lesser diversity/species richness of temperate forest than the tropical or sub-tropical forest (Odum, 1971). The relative chance of occurrence of herbs ranged between 0.09 and 1.87% (*Murdannia nudiflora-Lindernia ciliata*). The relative frequency of herbaceous layer from Central Himalayan forest reported by Negi and Nautiyal (2005) was higher than that was estimated in the present study which may be attributed to lower species richness in the temperate forests than the tropical or sub-tropical forests as discussed earlier for frequency.

The herb communities of forest was grouped into three frequency classes as A, B and C following Raunkiaer's law of frequency (Raunkiaer, 1934) in which 96.32, 2.45 and 1.23% respectively of species were distributed. The law of frequency states that the number of species in a community in the five per cent classes is A, B, C, D and E distributed as 0-20, 20-40, 40-60, 60-80 and 80-100%, respectively. This clearly indicate that the law holds good for herb communities of Chilapatta Reserve Forest also because the distribution of frequency classes was exactly similar to what was described in the law as A > B > C. But unlikely the law where five classes was described; this forest had only three classes of herbs (Fig. 1) which may be due to its higher heterogeneous nature and also due to the deviation from the normal frequency distribution as described by Raunkiaer (1934). Raunkiaer's normal frequency distribution was 53, 14, 9, 8 and 18% of species in frequency classes A, B, C, D and E where as in Chilapatta Reserve Forest it is 96.32, 2.45 and 1.23%, respectively (Fig. 2). This means that the species with poor dispersion of frequencies were higher in number than the number of species with higher frequency values. The trend of species falling in the frequency classes reflects the higher heterogeneous nature of herbs. A decreasing number of species in successive 20% frequency class intervals but an increase in the 80-100% class intervals has been widely interpreted as being a fundamental community characteristics indicating homogeneity (McIntosh, 1975) but contrary to this in the present study the forest exhibited reverse trend showing heterogeneity.

Herb species abundance is numerical strength of species in sampled area and in the present study it ranged from 0.80 to 12.76 i.e. Maesa indica had least while Brachiaria milliformis had highest number of individuals in the forest, respectively. The abundance for shrubs reported by Khurana (2009) in disturbed dry deciduous tropical forest of Hastinapur and Central Himalayan forest (Negi and Nautiyal, 2005) was comparatively lower than what was estimated in the present study because of lesser disturbance owing to its protection from law as Reserve Forest and also due to higher species richness and higher number of individuals of each species than the temperate forests. Abundance, however did not give a total picture of the numerical strength of a species because it considers only the quadrats of occurrence of a species. Therefore the abundance of a species relative to total abundance of all the species in all sampled quadrats is indicative of actual numerical strength of a species and in the present study, it was found that *Phlogacanthus thysiformis* had the lowest with 0.16% while *Mimosa pudica* had highest numerical strength of 1.73% relative to all the herb species found in the forest. Relative abundance reported by Newaz (2006) for secondary forests of Chittagong does not widely vary between the species (2.44-5.29) where as in present study it varied comparatively lower.

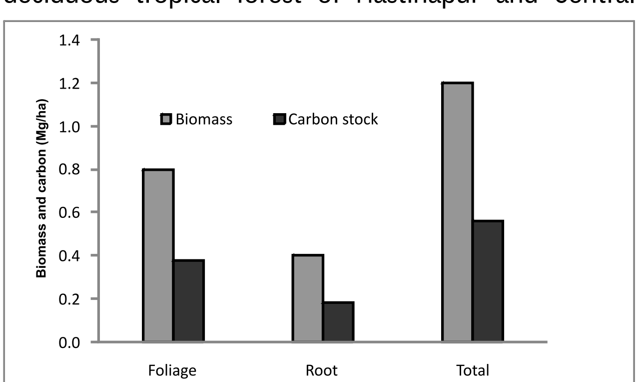


Fig. 2: Herb biomass and carbon stock ($Mgha^{-1}$)

Herbal IVI ranged between 0.47 and 5.27 (*Oldenlandia stipulacea-Mimosa pudica*). The large deviation of IVI values between this study and others was because of different estimation methods used, for instance in this study relative frequency, relative density and relative abundance was used while others workers used relative dominance instead of relative abundance and even some used only relative density and relative dominance. Whatever the method of estimation, calculation of IVI help in understanding the ecological significance of the species irrespective of vegetation types and more the IVI value the more ecological significance of the species is in that particular ecosystem. The distribution pattern of herb species in the forest was regular (12 species), random (10 species) and contagious (27 species). Contiguous distribution is the commonest pattern in nature; random distribution is found in very uniform environment and regular distribution occurs when severe competition exists between individuals (Odum, 1971; Dash *et al.,* 2009).

Biomass accumulation and partitioning

Biomass accumulation estimation and partitioning in herb communities at the time of observation are given in figure 2. The total biomass accumulated per hectare of Chilapatta Reserve Forest was 1.19 mega grams. The contribution of foliage or above ground biomass was 68.91% and rest by the roots. Biomass partitioning is an important driver of whole-plant net carbon gain and has a direct influence on future plant growth and reproduction (Evans, 1972). Knowledge of biomass allocation between vegetative and reproductive compartments will greatly improve our understanding of plant life history and strategies (Westoby *et al.*, 2002;

Table 3 : Diversity indices of herb communities of Chilapatta Reserve Forest

| Sl No. | Diversity | Value |
|---|---|---|
| 1. | Species richness | 49 |
| 2. | Family richness | 21 |
| 3. | Genera richness | 36 |
| 4. | Herb diversity index | 0.62 |
| 5. | Concentration of dominance | 0.028 |
| 6. | Shannon and Wiener index | 4.46 |
| 7. | Evenness index | 2.27 |
| 8. | Density individuals $ha^{-1}$ | 7628 |

Pickup *et al.*, 2005; Niinemets *et al.*, 2007) and will also improve the silvicultural techniques efficiently to manage a forest sustainably. The biomass of herb community can be used as a proportion of its contribution to understand the total storage of carbon and carbon cycling in the whole forest and thus can help in planning viable options to mitigate $CO_2$ increased climate change. Carbon accumulation estimates and partitioning of herbs at the time of observation are given in figure 2. Total carbon accumulation by the herbs was 0.54 mg $ha^{-1}$. The foliage or above ground portion contributed almost 80% and rest was contributed by the roots. Carbon stock is intricately linked with site quality, nature of land use, choice of species and other silivicultural practices (Swamy *et al.*, 2003). These factors ultimately influenced the plant growth which is reflected in its biomass and its proliferation as evidenced from its population density (7628 $ha^{-1}$). This is because of the site factor i.e. tropical moist deciduous with soil having high organic carbon and available nitrogen and high precipitation (2942 mm annual rainfall), high mean monthly relative humidity (69.0-91.5%) and optimum temperature (9-32°C). These site quality factors supported luxuriant growth supporting biomass accumulation and carbon storage. It is well known that many factors may affect the carbon budget of an ecosystem: biotic features including the leaf size, photosynthesisrate, plant architecture and type of forest (evergreen or deciduous), and abiotic features such as solar radiation, temperature,water supply, soil property and the length of growing season.

**भारत के पूर्वी हिमालय की तलहटी वाले वनों में अन्तर्वितानीय जड़ी वनस्पति उगने के कारण, पद्धति तथा परिणाम**

गोपाल शुक्ल तथा सुमित चØवर्ती

**सारांश**

वन स्तर पर शाकीय वनस्पति की सØय परत मृदा और जलीय प्रणाली की रक्षा करती है और उत्पादकता तथा मृदा उर्वरकता में सुधार लाती है। अत: शाकीय वैविध्य, जैवमात्र और कार्बन एकत्रीकरण की स्थिति को प्रलेखीकृत करने के लिए चिलापाट्टा आरक्षित वन, पश्चिमी बंगाल, भारत में एक अध्ययन किया गया। गुणवत्ता एवं मात्रात्मक अभिलक्षणों का विश्लेषण करने के लिए सामुहिक त्वरित नमूना सर्वेक्षण किया गया। उनचास जड़ी प्रजातियों को रिकार्ड किया गया। जिनमें 7 की पहचान करना अभी बाकी है। पहचानित प्रजातियां 21 कुलों और 36 वंशों में से थी। शाकीय वैविध्य सूची, प्रभाव की गहनता, शेन्नान तथा वीनर इंडेक्स तथा समरूपता सूची का आकलन Øम"ा: 0.62, 0.028, 4.46 तथा 2.27 किया गया। उच्चतम और न्यूनतम आवृत्तियां 49.12 तथा 1.75 रिकार्ड की गई जबकि आपेक्षिक घनत्व 0.09 से 1.87 के बीच पाया गया। शाकीय घनत्व प्रति एकड़ 2 से 11193 एकल पाया गया और आपेक्षिक घनत्व 0.05 से 1.76 प्रतिशत पाया गया। अधिका"ा प्रजातियां व्यापक रूप से फैली थी जिनकी प्रचुरता 0.80 से 13.76 और आपेक्षिक प्रचुरता 0.16 से 1.73 प्रतिशत के बीच थी। आई बी आई क्षमता 0.47 से 5.27 थी। धरातल के Åपर शाकीय वनस्पतियों में जैवमात्र और कार्बन का बाहुल्य था।

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