Discussion

7.1. VEGETATION STRUCTURE AND COMMUNITY ANALYSIS

The association of species growing together in a particular habitat is known as community and analysis of community is an important basis for studying vegetation and to understand its function (Warger & Morrel, 1978). Not only that the vegetation characterization is the primary and most important step in framing conservation goal. Different plantations and natural vegetations of Terai-Duars region of west Bengal have been analysed and thereby a quantitative data have been derived.

The vegetation of Terai and Duars region of West Bengal are very rich in phytodiversity and covers all major groups of plants (Chatterjee, 1940; Das 1986; Kadir, 2001; Das, 1996, 2011). Comparison of different plantations with natural forests revealed a huge difference. Difference in the numerical strength of different taxa of plantation and natural forest were noted and has been presented in Figure 7.1.1. Thus natural vegetation of this belt appeared much more diverse and rich in floral elements than the plantations. All the three layers – tree, shrub and herb layers were populated by higher number of species, family and genera in natural vegetation. Natural forests harboured 446 species, 312 genera and 97 families whereas in plantation the number of species genera and family were 280, 197 and 77 in respective order. From all the plantations only 62.78%, 61.54% and 79.38% of species, genus and families of plant that were growing in natural vegetations were recorded. The superiority of natural forest over the plantations was observed in all the three sites (Figure 7.1.2, 7.1.3, 7.1.4). Differences in number of species occurred in natural forest and plantation was highest in Lataguri site and was measured to be 36.56% and was followed by NRVK site (27.05%) and Sevoke site (25.45%) respectively. Differences in number of genera between natural forest and plantation were 77.17%, 26.99% and 24.11% in Sevoke, NRVK and Lataguri site respectively.

Seasonal variation of occurrences of different taxa i.e. family genus and species were also notable in both the plantation and natural forest and the variations have been represented in Table 7.1.5, 7.1.6, 7.1.7 & 7.1.8. In most of the cases, winter vegetation was less diverse and poor in both plantation and natural forest. Accumulation of thick layer of litter, dry weather and very less or no rainfall at all might be the reasons behind that poorness of winter vegetation (mainly the herbaceous vegetation). Maximum number of species genus and families were recorded in Postmonsoon season in all the plantation and natural vegetation and sites. Favourable conditions during the monsoon specifically the monsoon shower led to the development of this luxurious growth of vegetation although logged water adversely affected the vegetation in some lowland during monsoon rain. But when the plantation was compared with the natural vegetation under same ecological and environmental conditions in the same site, higher magnitude of difference were noted in plantation than the natural forest and that can be explained from the view point of better stability of natural forest than the plantations throughout the year. The tree layers were more or less similar in both natural and plantation forest throughout the year except some minor changes. Whenever the changes were noted, were due to some anthropogenic activities mainly like unauthorized felling, human induced fire etc. Differences were also noted in case of family representing highest number of species. Thus the different types of plantation differed from the natural vegetations in respect of species content and compositions along with the dominant families showing highest number of families, their seasonal variations and in the pattern of variations.

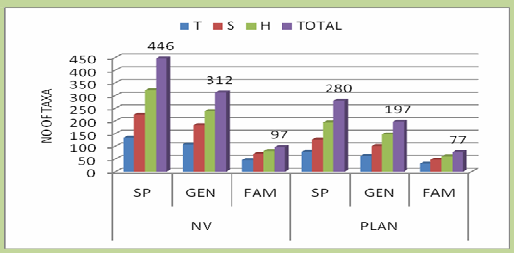

Figure 7.1.1. Number of taxa in different layer of vegetaion in Natural forests and plantation in Terai & Duars Region

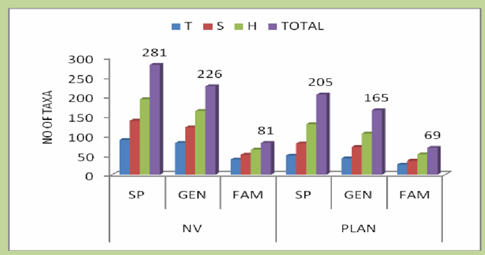

Figure 7.1.2. Number of taxa in different layer of vegetaion in Natural forests and plantation in NRVK site

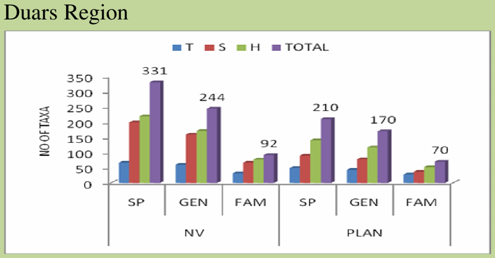

Figure 7.1.3. Number of taxa in different layer of vegetaion in Natural forests and plantation in Lataguri site

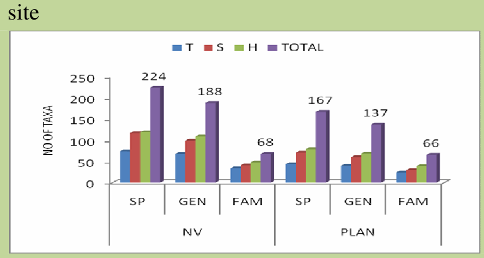

Figure 7.1.4. Number of taxa in different layer of vegetaion in Natural forests and plantation in Sevoke site

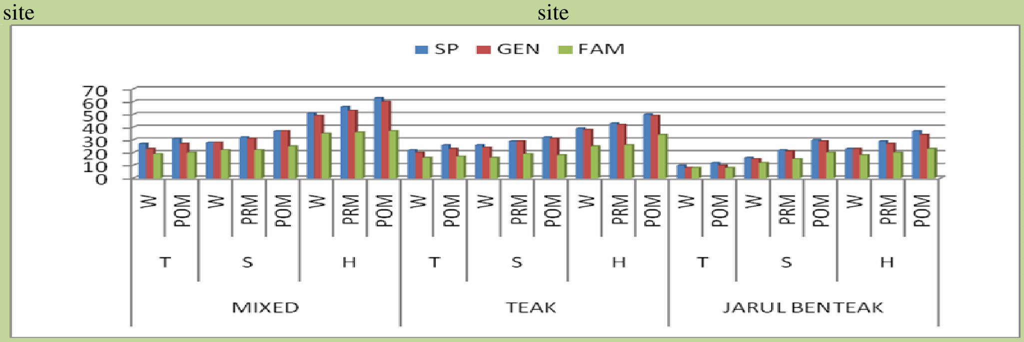

Figure 7.1.5. Seasonal variation of different taxa in various plantations of NRVK site

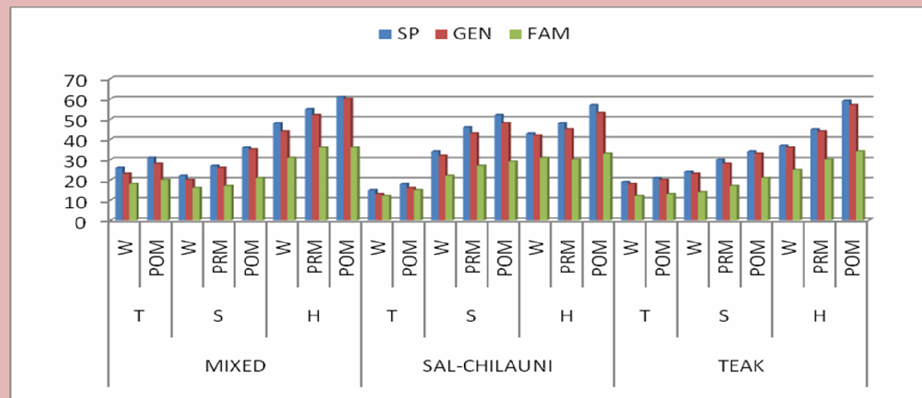

Figure 7.1.6. Seasonal variation in number of species, genera and families in different plantation of Lataguri site

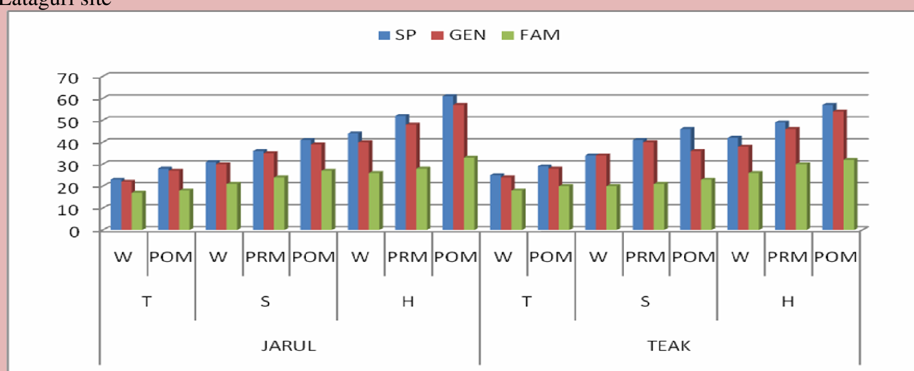

Figure 7.1.7. Seasonal variation of different taxa in different plantation of Sevoke site

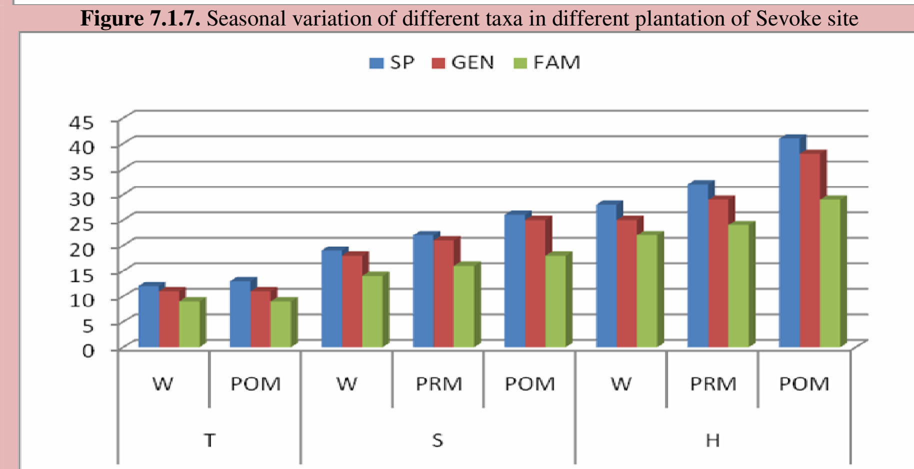

Figure 7.1.8. Seasonal variation of different taxa in Jarul plantation in Satali

7.1A. PHYTOSOCIOLOGY

Phytosociology is a branch of vegetation science which deals with plant communities, their composition and development, and the relationships between the species within them. Its principal goals are the delimitation and characterization of vegetation types based on the complete floristic composition (Dengler, 2017).

Phytosociological studies are essential for protecting the natural plant communities and biodiversity as well as understanding the changes experienced in the past and continuing on into the future (Mishra *et al*. 2012). In the present study phytosociological data were collected from natural vegetation and different plantations of Terai and Duars region of West Bengal. Analysis of processed data revealed the characteristic features of the vegetations (both plantations and natural vegetations). Comparison of different plantations with natural vegetation expressed differences in species richness, species diversity, concentration of dominance and seasonal variations of different vegetation layers were also noted differentially in different sites and types of plantation and natural forests.

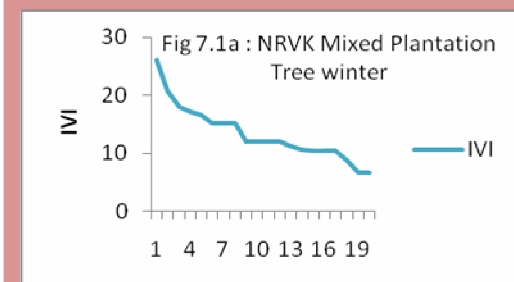

Figure 7.1a. Dominance diversity curve of tree layer of mixed plantation in winter in NRVK site

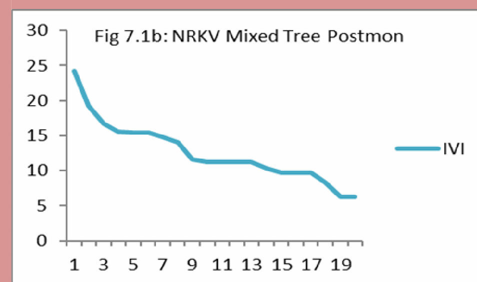

Figure 7.1b. Dominance diversity curve of tree layer of mixed plantation in Postmonsoon in NRVK site

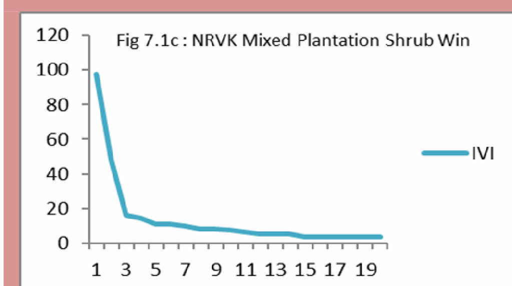

Figure 7.1c. Dominance diversity curve of Shrub layer of mixed plantation in winter in NRVK site

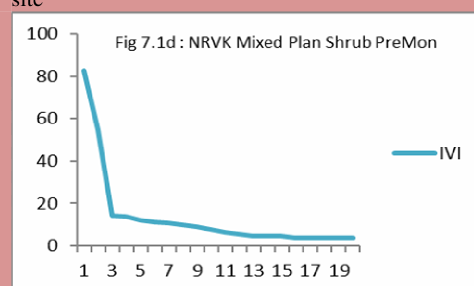

Figure 7.1d. Dominance diversity curve of Shrub layer of mixed plantation in pre monsoon in NRVK site

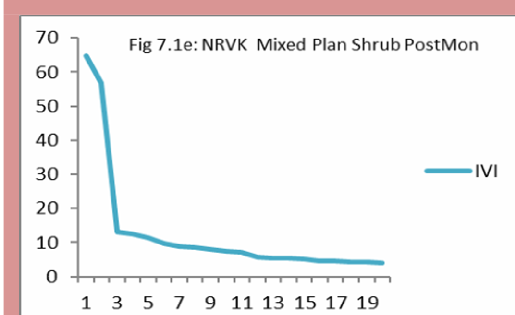

Figure 7.1e. Dominance diversity curve of Shrub layer of mixed plantation in post monsoon in NRVK site

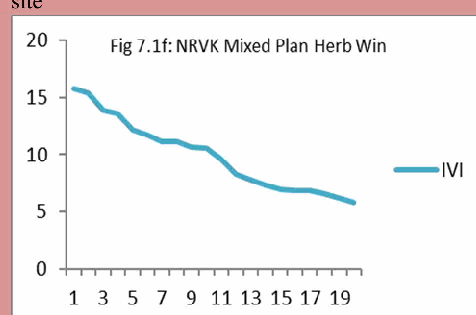

Figure 7.1f. Dominance diversity curve of Herb layer of mixed plantation in winter in NRVK site

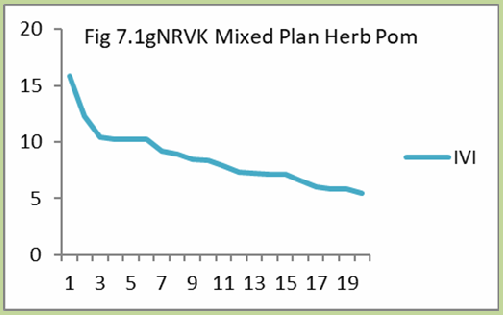

Figure 7.1g. Dominance diversity curve of Herb layer of mixed plantation in post monsoon in NRVK site

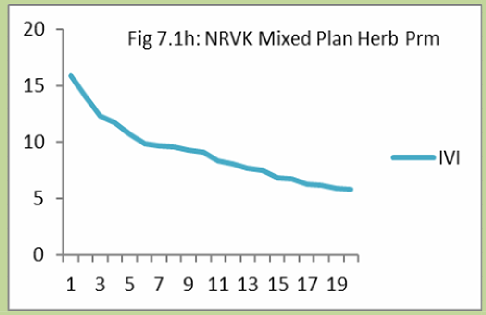

Figure 7.1h. Dominance diversity curve of Herb layer of mixed plantation in pre monsoon in NRVK site

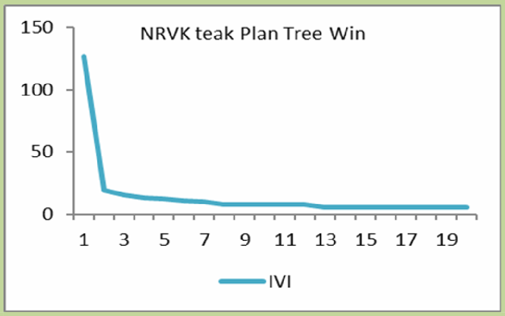

Figure 7.1i. Dominance diversity curve of Tree layer of Teak plantation in winter in NRVK site

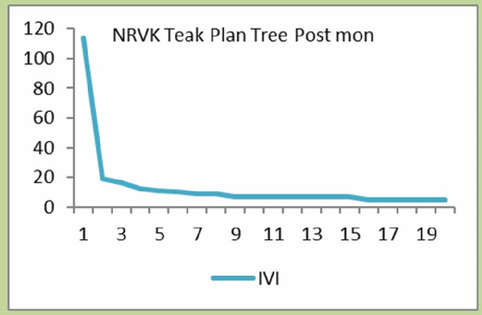

Figure 7.1j. Dominance diversity curve of Tree layer of Teak plantation in post monsoon in NRVK site

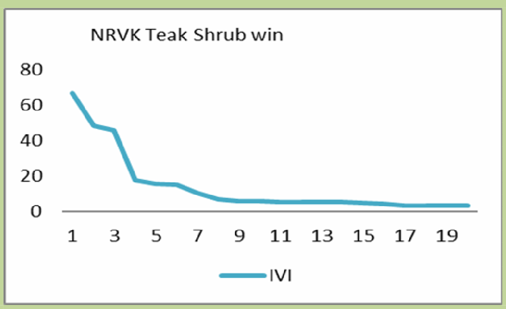

Figure 7.1k. Dominance diversity curve of Shrub layer of Teak plantation in winter in NRVK site

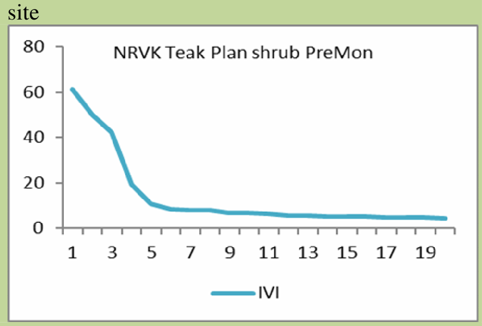

Figure 7.1l. Dominance diversity curve of Shrub layer of Teak plantation in pre monsoon in NRVK site

Mixed Plantation: Tree layer in NRVK mixed plantation in both winter and post-monsoon seasons were more or less similar in species composition. The vegetations were heterogeneous assemblage of numerous species and that was evident from nearly smooth running dominance diversity curve drawn on the basis of IVI value (Figure 7.1a & 1b).

Shrub layer showed more or less similar type of dominance pattern in all the seasonal vegetations but the vegetations were quite homogeneous or uniform and that was indicated by steeper dominance diversity curve (Figure 7.1c, d, e). Figure 7.1f, g & h revealed that the herbaceous vegetation of mixed plantation in NRVK site was heterogeneous type of assemblage of numerous species without true dominance by a single species. Detectable seasonal changes in vegetation were observed in post monsoon season which added little steepness to the dominance diversity curve (Figure 7.1g).

Teak Plantation: Tree layer of teak plantation was uniform or homogeneous growth of teak and maximum degree of dominance was shown by teak in both the winter and post-monsoon seasons and was very uniform in both the seasons. The association of top 20 species has been shown in Figure 7.1i & j. Steepness of the dominance diversity curve expressed the weaker association among them. Shrub and herb layer also showed same type of trend (Figure 7.1k & l) as in mixed plantation but the only difference is in the magnitude of dominancy of predominant species or of the predominant group of species.

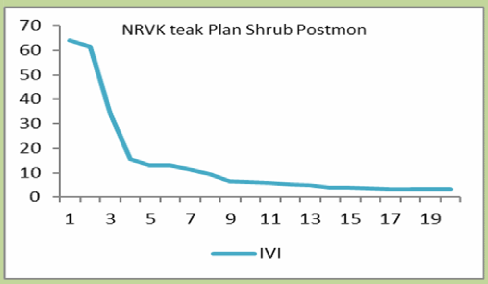

Figure 7.1m. Dominance diversity curve of Shrub layer of Teak plantation in post monsoon in NRVK site

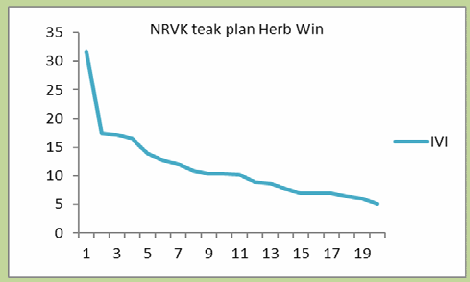

Figure 7.1n. Dominance diversity curve of Herb layer of Teak plantation in winter in NRVK site

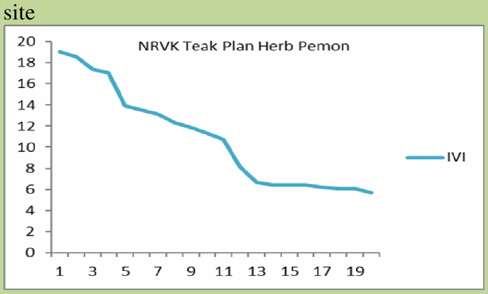

Figure 7.1o. Dominance diversity curve of Herb layer of Teak plantation in pre monsoon in NRVK site

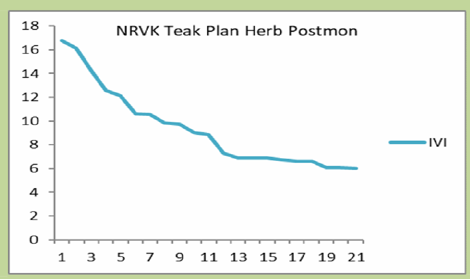

Figure 7.1p. Dominance diversity curve of Herb layer of Teak plantation in post monsoon in NRVK site

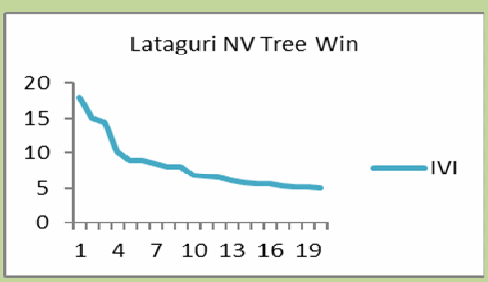

Figure 7.1q. Dominance diversity curve of Tree layer of Natural vegetation in winter in Lataguri site

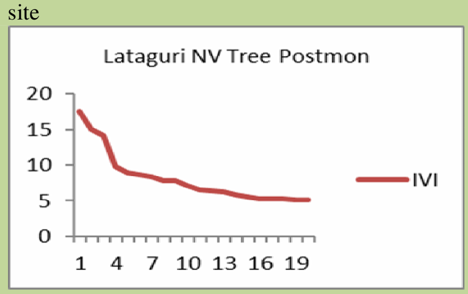

Figure 7.1r. Dominance diversity curve of Tree layer of Natural vegetation in post monsoon in NRVK site

Jarul Benteak plantation: Jarul Benteak plantations in NRVK site also exhibited same type of features of its different layers of vegetation in different seasons. In mixed plantation of Lataguri site the situation was little different from the other plantations. Tree layer in both winter and post-monsoon were quite diverse and dominance diversity curve revealed better association of component tree species than in other type of plantations. Shrub and herb layer were also different in to some extent. It was more diverse than the monoclonal plantation like teak or jarul-Benteak or sal-chilauni plantation. But all the tree shrub and herb layers were less diversified than the natural forests. Similar types of findings were noted in plantations of Sevoke site. Thus the general trend in different types of plantations in all the three sites were traced as less diverse tree layers (except mixed plantation) with minimum alliance among the associated species, lower to moderately diversified shrub layer with some seasonal changes especially in post monsoon season; and moderately diverse herb layer with higher degree of seasonal variation.

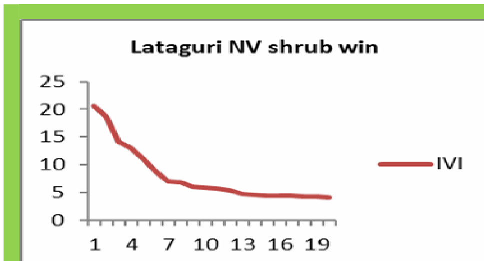

Figure 7.1s. Dominance diversity curve of Shrub layer of Natural vegetation in winter in Lataguri site

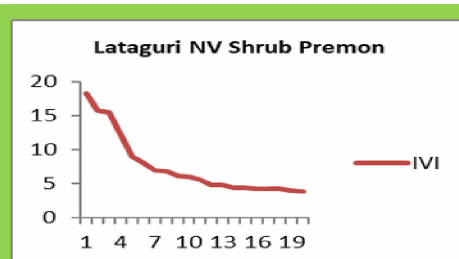

Figure 7.1t. Dominance diversity curve of Shrub layer of Natural vegetation in pre monsoon in Lataguri site

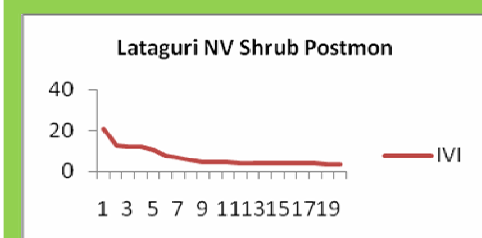

Figure 7.1u. Dominance diversity curve of Shrub layer of Natural vegetation in post monsoon in Lataguri site

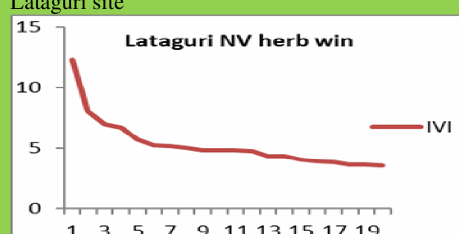

Figure 7.1v. Dominance diversity curve of Herb layer of natural vegetation in winter in Lataguri site

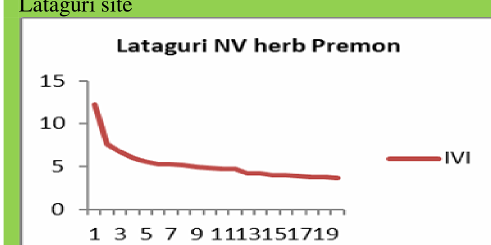

Figure 7.1w. Dominance diversity curve of Herb layer of Natural vegetation in pre monsoon in Lataguri site

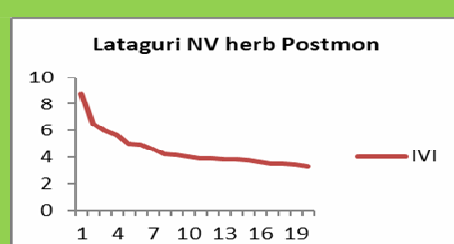

Figure 7.1x. Dominance diversity curve of Herb layer of Natural vegetation in post monsoon in Lataguri site

Seasonal variations were found mainly in post monsoon period when the dominance pattern got rapid change due to luxurious growth of pre-dominant herbs in the plantation floor. In natural vegetation all the tree shrub and herb layers were much more diverse than the plantations and the seasonal variation of different layer of vegetation were found to be symmetric. The dominant species with co-dominant one or co-dominant group of species were found to be well associated. General trend of the natural vegetation in other 2 sites were similar but only difference was in dominant species and /or dominant group of species, and in magnitude of dominancy.

7.2. BIODIVERSITY INDICES

Determination of different diversity indices for both the plantations and natural forests and their analysis revealed the actual picture of vegetation structure, diversity and dominance pattern, richness of the vegetation and the association of constituent species of the plant community.

Natural Vegetation

Lataguri Site: In natural vegetation of Lataguri site all the tree shrub and herb layers were diverse enough and were established by higher value of Shannon-Weiner index of species diversity. The layer wise comparison of vegetation revealed the superiority of herb layer over trees and shrubs. But, the winter shrubby community was the exception where maximum diversity was found (Figure 7.2.1).

Regarding the magnitude of dominancy of most abundant and predominant species, tree layer were with lower value of Simpson index or the concentration of dominance (Figure 7.2.2) that meant the tree layer was a heterogeneous assemblage of component species. It also indirectly indicated the higher diversity of tree layer. Higher value of Menhinick's index in case of tree layer (Figure 7.2.3) also supported the richness of the tree layer.

NRVK site: In NRVK site highest diversity was found in case of herb layer and then in tree layer. Shrub layer was least diverse (Figure 7.2.4). Concentration of dominance was highest in shrub layer which implied the high magnitude of dominant species. In herb layer lower value of concentration of dominance and moderately high value of Menhinick's index revealed richness of the herb layer (Figure 7.2.5).

Sevoke site: In Sevoke site tree layer in both winter and post monsoon season were rich in species diversity with lower concentration of dominance (lesser magnitude of dominancy of predominant species or group of species) and richness of species content as revealed by Menhinick's index of species richness (Figure 7.2.6 & 7.2.7). Thus the natural vegetation in all three sites were rich in species content, with less magnitude of dominance (heterogeneous community) and widely diversified.

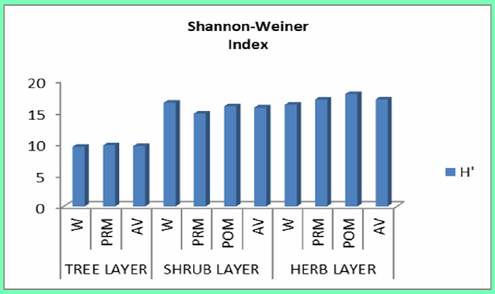

Figure 7.2.1. Shannon-Weiner Index of natural vegetation in Lataguri site

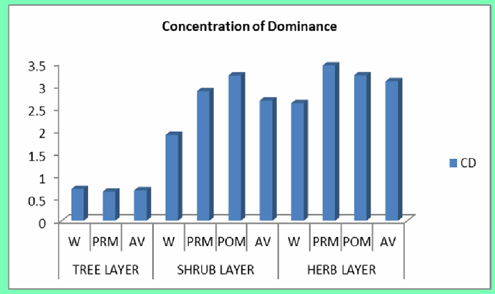

Figure 7.2.2. Concentration of Dominance of natural forest in Lataguri site

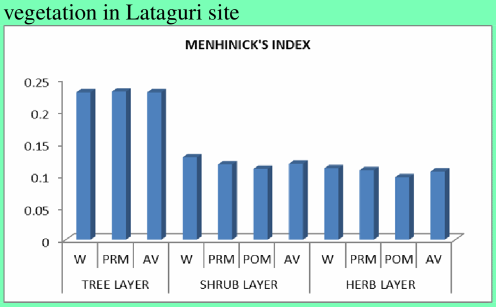

Figure 7.2.3. Menhinick's Index of natural forest in Lataguri site

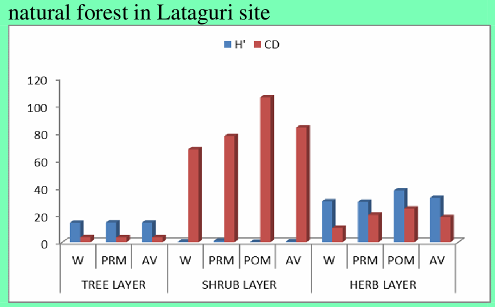

Figure 7.2.4. Shannon-Weiner Index & Concentration of Dominance of natural vegetation in NRVK site

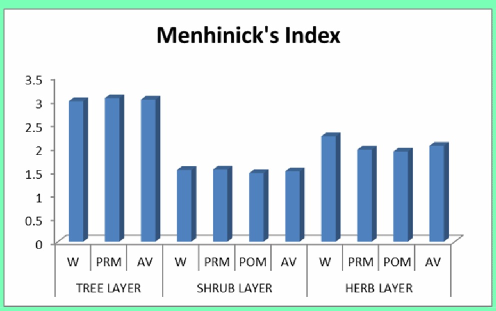

Figure 7.2.5. Menhinick's Index of natural forest in NRVK site

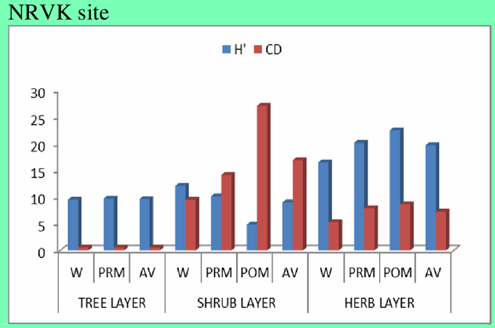

Figure 7.2.6. Shannon-Weiner Index & Concentration of Dominance of natural vegetation in Sevoke site

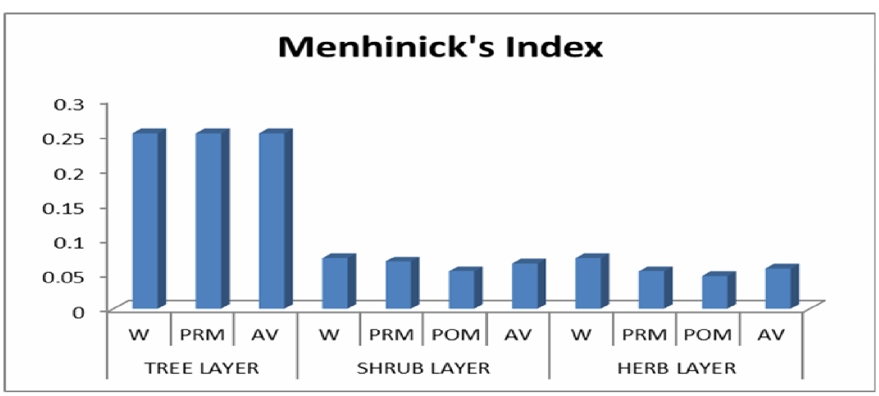

Figure 7.2.7. Menhinick's Index of natural forest in Sevoke site

***Plantation*:**

***NRVK Site*:** Determination of different diversity indices for different plantation, revealed Jarul – Benteak plantation (mainly the tree and shrub layers) as least diverse community, with higher concentration of dominance and moderate richness of species contents (Figure 7.2.8, 7.2.9 & 7.2.10). In other two types of plantation studied - mixed plantation and teak plantation the situation was more or less similar. But the herb layer was little more diverse.

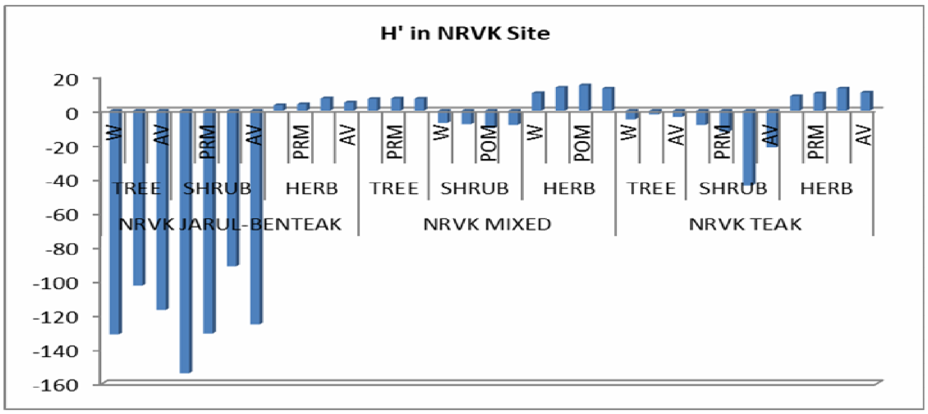

Figure 7.2.8. Shannon-Weiner Index of plantation in NRVK site

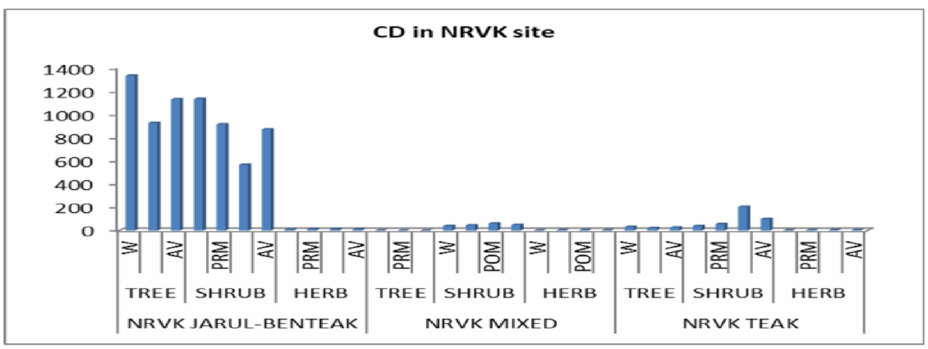

Figure 7.2.9. Concentration of Dominance of different plantations in NRVK site

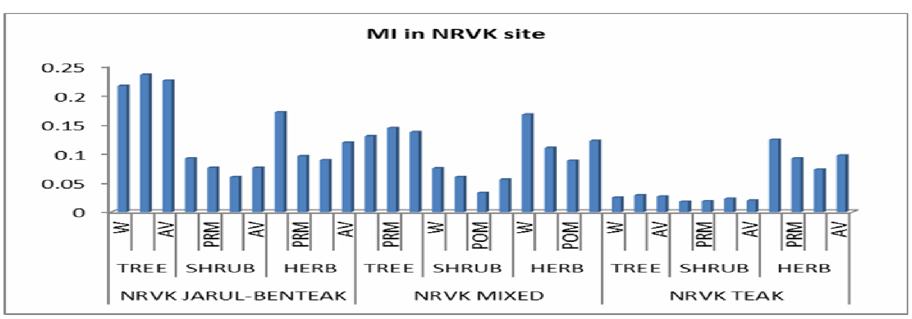

Figure 7.2.10. Menhinick's Index of plantations in NRVK site

Lataguri site: Figures 7.2.11, 7.2.12 & 7.2.13 summarised the main features of plantations in Lataguri site. Mixed plantation showed diversified shrub layer, less diverse tree or canopy layer and moderately diverse herb layer. Sal-chilauni plantation showed more or less similar type of tree, shrub and herb community with low to moderate species diversity, less concentration and moderate richness of species contents. Teak plantation in this site showed lowest diversity, highest concentration of dominance and lower richness of species contents in tree and shrub layer. But herb layer exhibited diversified species contents, lower concentration of dominance and moderately rich species composition. The situation was little different from the *Teak* plantations in other sites.

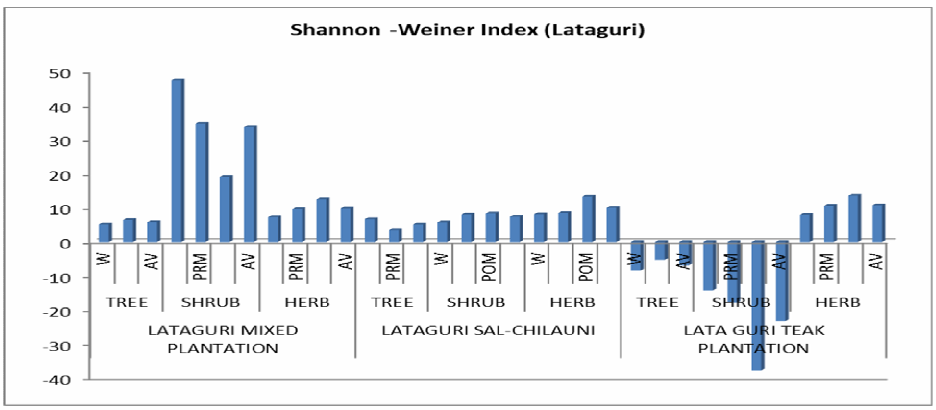

Figure 7.2.11 Shannon-Weiner Index of plantation in Lataguri site

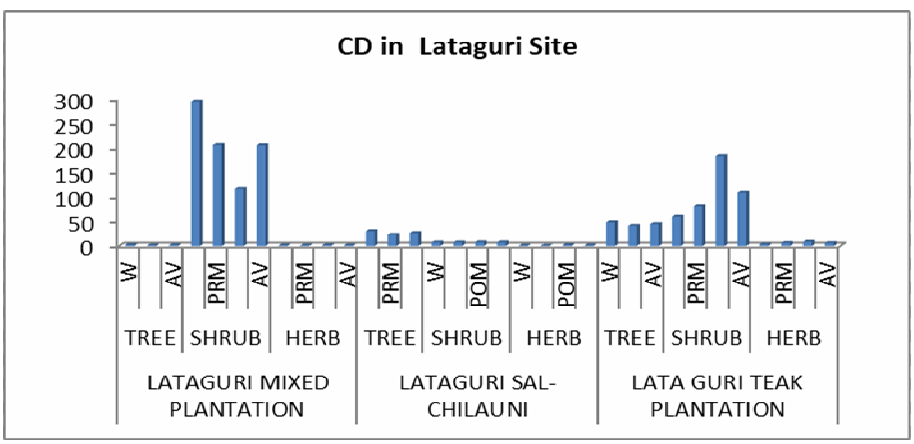

Figure 7.2.12. Concentration of Dominance of plantation in Lataguri site

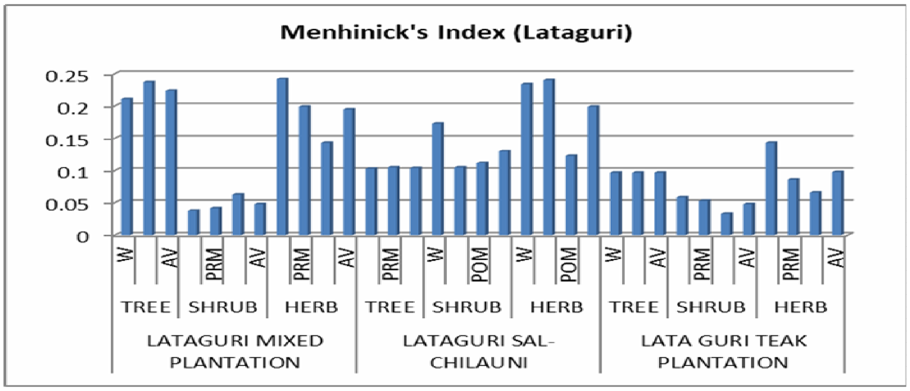

Figure 7.2.13. Menhinick's Index of plantations in Lataguri site

Sevoke site: Figures 7.2.14, 7.2.15 & 7.2.16 represent the biodiversity indices of different plantations in Sevoke site. Tree and shrub layers in both jarul and teak plantations were less diverse than herb layer as well as than the natural vegetation in the same area. But the herb layers were quite diverse and rich but not as in natural vegetation. Concentration of dominance was higher in tree and shrub layer that indicated the unevenness of the vegetation.

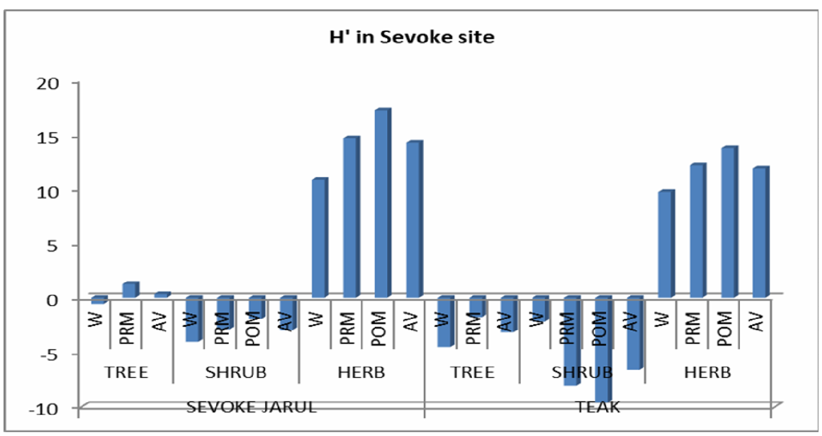

Figure 7.2.14. Shannon-Weiner Index of plantation in Sevoke site

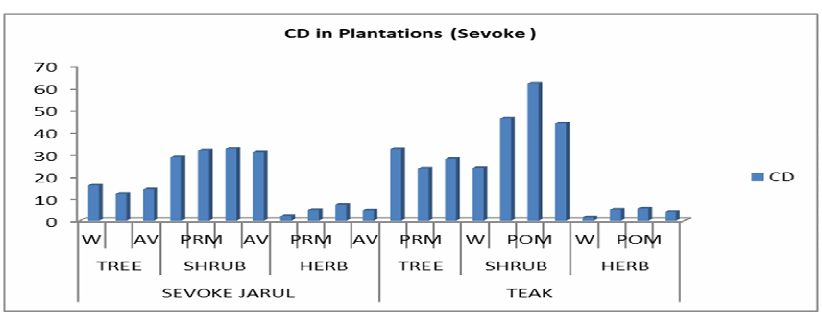

Figure 7.2.15. Concentration of Dominance of plantation in Sevoke site

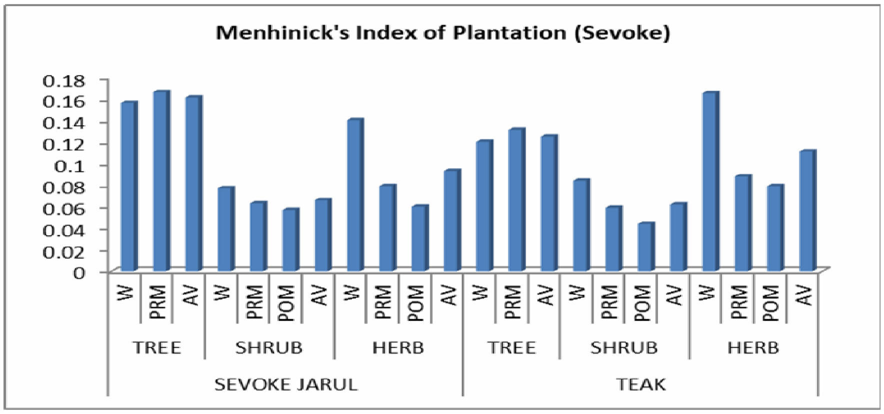

Figure 7.2.16. Menhinick's Index of plantation in Sevoke site

Similarity index: Figure 7.2.17, 7.2.18 & 7.2.19 revealed the measure of similarity and differences (Sorensen similarity indices) between different plantations and natural vegetation in different sites. Similarity was measured layer wise. Tree and herb layer of mixed plantation in Lataguri site, was more or less similar with that of natural vegetation whereas the other plantations differed from the natural forest. Jarul-Benteak plantation in NRVK site showed lesser similarity and higher differences. Teak plantation in the same site showed little higher similarity value in tree layer than the other layer of vegetation and also from other plantation as well. That may be due to the young age of teak plantation at that site. In Sevoke site also teak plantation showed some similarity in herb layer, shrub layer and tree layer but the similarity values were not more than 40%. Jarul plantation in Satali showed higher differences in all the three layers of vegetations.

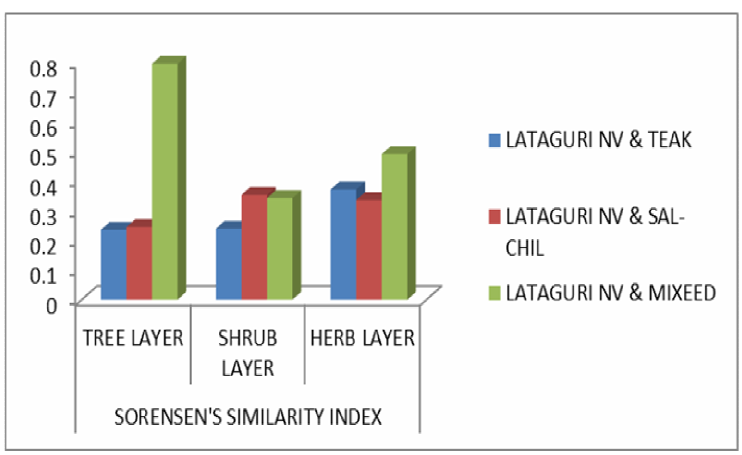

Figure 7.2.17. Sorensen's Similarity Index between natural vegetation & plantation in Lataguri site.

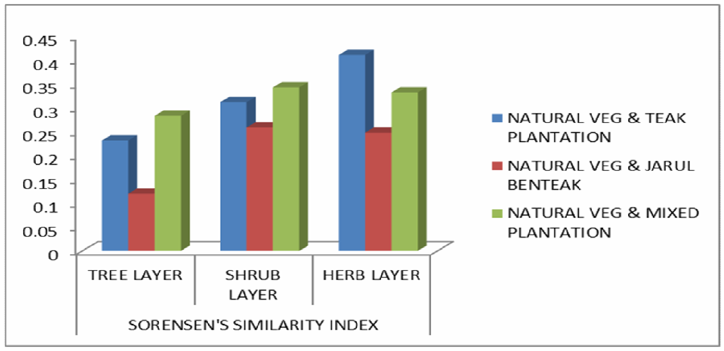

Figure 7.2.18. Sorensen's Similarity Index between natural vegetation & plantation in NRVK site.

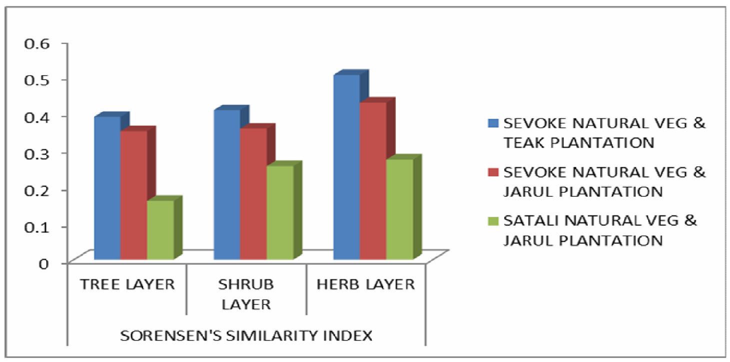

Figure 7.2.19. Sorensen's Similarity Index between natural vegetation & plantation in Sevoke and Satali site.

7.3. IMPACT OF AGGRESSIVE EXOTIC WEEDS

Impact of aggressive and exotic weeds on native biodiversity and ecosystem is already established (Carlton, 2003; Boot *et al.* 2003; Raghubanshi *et al.* 2005). In the present study, phytosociological attributes, different diversity indices for the vegetation of invaded and non invaded area, and their comparison outlined impacts of some exotic alien weed on the plant diversity of study area. Invaded area was inhabitated by lesser number of species, genera and families than the non-invaded area. As both the invaded and non invaded area were situated under same types of environmental conditions, it may be inferred that the difference in number of taxa (Species, genus and family) of invaded and non invaded area was due to the invasion of those exotic elements. Difference was also found in family distribution pattern and their frequency. But it has little correlation with invasion of alien weeds.

In shrub layer of non invaded area *Clerodendrum infortunatum* dominated the community with IVI value of 26.69 and relative diversity of 13.41. But differences in IVI value of dominant species and the species following the dominant one were less. There was a association *Coffea benghalensis*, *Triumfetta rhomboidea*, *Urea lobata*, *Mikania micrantha* etc with the dominant one. Dominance diversity curve of those species appeared smooth and it indicated the stability of the associated species in the community. But in invaded shrub layer where *Mimosa invisa* became dominant species with index value 61.43 and RD of 35.74. The high differences of IVI values of dominant species with others associated ones are the reason behind the steeper dominance diversity curve that indicated to the unstable situation of the community. Thus the invasion of *Mimosa invisa* disturbed the stable associated of species in native ecosystem.

In herb layer of non invaded area also number of species recorded was highest than the invaded area and thus the invasion of exotic *Mimosa*, affected the herbaceous layer also. It seemed to be happened due to the dense mat forming nature of young *Mimosa* plants. In herb layer of non invaded area *Ageratum conyzoides* was the dominant species. And it was associated with *Chromolaena odorata*, *Sida acuta*, *Diplazium esculenta*, *Clerodendrum infortunatum* etc. Smoothness of the dominance diversity curve of the species associated to the dominant one revealed the stability of their association. The invaded herb community was uniform and homogeneous.

Dominant diversity Indies also indicated the bad impact of those noxious weeds. Higher value of species diversity index or Shannon-Weiner index in non-invaded area was the indicator of higher species diversity in that site and it was farther established by the lesser value of concentration of dominance (Simpson's index). That meant in the non invaded area dominance of the species (mainly the predominant species) was less intense. Species richness index or Menhinick's index by it higher value revealed the species richness of non invaded native land use area. The situation was just opposite in the invaded area – i.e. species diversity was less, concentration of dominance was high and poor in species richness. Thus the invasion of exotic weeds resulted in the low species diversity, high dominance and poor species richness. This two type of vegetation i.e. vegetation in invaded and non invaded areas was different by 30% revealed by 0.70 of Sorensen's similarity index.

Invasion of *Parthenium* also caused same types of modification to the local plant community. Its invasion affected occurrences of species family and genera in invaded area. Steep dominance diversity curve revealed the higher magnitude of dominancy of the predominant species in invaded area whereas smoother one in case of non-invaded area revealed lower magnitude of dominancy of associated species in non invaded areas. Different biodiversity indices indicated the impact of *Parthenium* on local flora and floral community. Its invasion reduced the species diversity and richness in invaded area and increased the uniformity of community i.e. higher concentration of dominance was found.

Thus the invasive alien species exerted adverse effect on the plant diversity of Terai-Duars region. They reduced diversity of species and species richness and made the community uniform or homogeneous and replaced the native or local species by the huge aggression of non-native ones, alter the association of species in invaded area and ultimately disturb the stability of the ecosystem of this area. Similar type of impact was also reported by some other workers (Holway *et al.* 2002; Carlton, 2003, Raizada *et al.* 2008).

7.4. ABOVEGROUND HERBACEOUS BIOMASS PRODUCTION

Above ground biomass is an important and useful measure for assessing changes in forest structure (Brown *et al.* 1999). Comparision of Natural forest with plantations in respect of above ground herbaceous biomass production revealed that Natural vegetation (NV) produced higher amount of above ground herbaceous biomass than plantations (Figure 7.4.1). Both, in plantation and natural vegetation Maximum amount of biomass was harvested during the post monsoon period and notable difference was found in the amount of living and litter part of AGHB. The difference of litter and living biomass gradually reduced and became least during post monsoon period. Dry winter, low moisture content in the surface soil and leaf fall from deciduous tree species seemed to be the reasons for the production of high litter content during the winter. Favourable temperature, high precipitations during monsoon and addition of nutrients due to the degraded biomass in surface soil, lead to rapid flash of herb layer that ultimately contributed to the production of maximum amount of living part of AGHB. It was mentioned earlier that the degradation pattern of litter masses on the floor of plantations (teak and Sal-chilauni plantation) and natural forests both, in NRVK and Lataguri sites, as well as the biomass turnover, followed the same trends. But the differences were in the rates and their magnitudes.

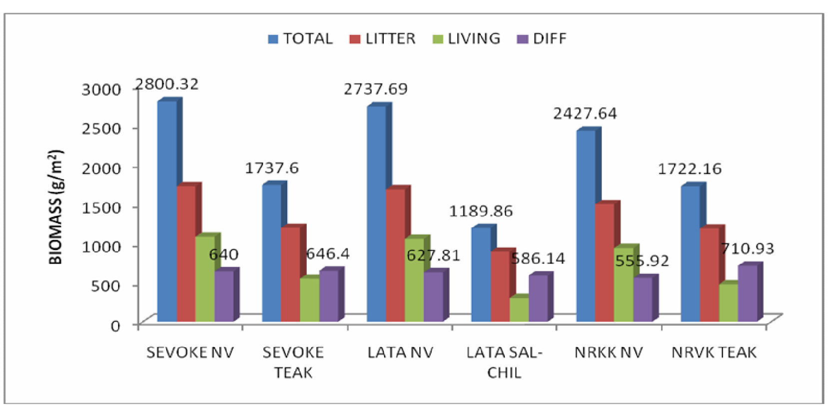

Figure 7.4.1. AGHB production under different plantations and natural vegetation (NV)

The differences in living and litter parts of AGHB were quite high under teak plantation than that of natural vegetation. Fallen leaves from teak plant during winter formed a dense carpet on the floor of plantation that prevented both, the upward and downwards penetration by the germinating seeds and seedlings of herbaceous species and ultimately reduced the production of living parts of AGHB. On the other hand slow rate of degradation of litter components lead to build up the huge difference in between litter and living parts of biomass and finally the total AGHB also.

The biomass and productivity in any ecosystem are governed by climatic and edaphic factors (Das et al. 2008). In the present study, growth of herbaceous vegetations under different land use pattern – natural vegetation, sal-chilauni plantation and teak plantation, were accelerated by the monsoon shower and AGHB production reached at peak during the post monsoon seasons reflecting better growth conditions, whereas in winter seasons the biomass production was lowest due to dry winter and low sunlight intensity. When the AGHB was splitted into living and litter contents and their production and degradation pattern were studied, litter part of AGHB showed the opposite trend of the living parts as well as the total AGHB production. Litter content were highest during winter and lowest during the post monsoon period. Large amount of above ground dead materials actually prevented the living part of AGHB during winter. That made the differences between litter contents and living parts of AGHB. This type of finding was corroborated by previous report also (Cornet, 1981; Das, 2008; Castro & Freitas, 2008; Facelli & Pickett, 1991; Grime, 2001). Present study also revealed that biomass (AGHB) production was comparatively higher in natural forests than that of tree plantations, and spatial variations of AGHB were found in different sites of Terai – Duars belt and that were governed by the climatic, edaphic, and biotic factors of the particular sites. Under natural vegetations, there were a balance between the rates of accumulation/degradation of litter contents and the production of living part of AGHB and that was indicated by the smaller differences in between living and litter parts. Thus the natural vegetations were in an ecologically balanced and stable condition but the plantations were somewhat different. The teak plantations were less efficient in the production of above ground herbaceous biomass than the natural vegetations. Terai region produced more AGHB than the Duars. AGHB production was influenced by the favourable conditions during monsoon, especially by the monsoon shower. As under the influences of same sort of climatic, edaphic and biotic factors, plantations produced lesser amount of AGHB than that of natural vegetation, it can be concluded that plantation had a negative impact on the above ground herbaceous biomass production – especially the teak plantation under which suppression of AGHB production was highest. This type of suppression is due to the accumulation of large amount of above ground dead material (Castro & Freitas, 2008), low rate of degradation due to low moisture contents in soil and lower microbial activity (Cornet, 1981).

7.5. RARE, ENDEMIC AND THREATENED ELEMENTS

Indian phytochorian is renowned for its relict species content (Sharma, 2000). Darjeeling Himalaya which is an important part of Himalaya Biodiversity Hotspot of conservation, is rich in endemic floral elements (Nayar, 1996; Das, 2004) as well as in other category of threatened plants (Nayar & Sastry 1987, 1988. 1990; Rao, 1994). Being located at the foot of Himalaya and contiguous with the Darjeeling Himalaya, Terai and Duars region also apeared to be populated by a number of endemics and other category of threatened plants (Das, 2011). Out of the total recorded plant of RET category 22 were endemic to the Darjeeling Himalayan region or Eastern Himalaya region. As the present study was not a purely florist work, extensive study of the floral elements were not done. Only the elements encounter during the present survey, were considered for determination of RET elements.

Uncontrolled increase in anthropogenic activity that led to the destruction and fragmentation of vegetations and invasion of exotic aggressive species were detected to be the major threats to the flora and vegetation of upper and lower past of Darjeeling Himalaya (Das, 1995, 2004). Similar types of threats were also applicable in the study area also. In addition to that, burning of forest floor to facilitate illegal poaching, excessive collection of NTFPs, medicinal plants, grazing in forest floor etc were some other worst from of threats to the flora, vegetation and ecosystem of the study area. Presently replacement of natural forest by economically potent exotic species and their huge plantation has also started to threaten the plant wealth and diverse vegetation of this belt.

7.6. NON TIMBER FOREST PRODUCES AND MEDICINAL PLANTS

NTFPs which play important role in poverty alleviation, has been a part of conservation strategy of forest cover in close association with human population (Sarkar, 2014). Collection of NTFPs by the forest department, involvement of rural and tribal people for harvesting them from forest, their marketing and household uses, led to the development of a strong relationship between the man and forest. In present study, a good number of plants were found to have commercial importance (Table 7.1). Economic potential of those plants (NTFPs) were not assessed in the present study, but reported by Sarkar (2014) for Buxa Tiger Reserve. Most of the commercially important NTFPs were collected as Medicinal plants which are marketed by the department of forest either in crude condition or after processing or both crude and processed. Few of the most important commercially harvested and marketed NTFPs of this region were fruits of *Phyllanthus emblica,* fruits of *Piper* *longum*, *Terminalia arjuna*, *T. belliria*, *T. Chebula*, *Thysanolaena latifolia* etc. Recording of 319 species of NTFPs as medicinal plant indicated the dominancy of medicinal herbs and trees among the non-wood product. Many of them were also collected by the rural healer personally. Thus dependency of rural, tribal and fringe population were revealed and implies the relationship between the non-wood product (or the Forest department) and the fringe population and their knowledge system related to the forest resources. Dependency of the rural and tribal population on NTFPs was quite high in case of remote location of human settlement. Specially, the dependency for medicinal plants was notable and their excessive collection became a threat to their population (Das, 2011).

Rural markets in fringe areas were the meeting ground of the local villagers. They were found to sell and buy numerous products from the forests such as different vegetables – tender fronds of *Diplazium esculenta* locally known as *Dhekiaa,* leaves and petioles *of Alocasia fallax, leaves of Centella asiatica, Amorphophallus bulbifer* etc; different wild fruits, tuber of *Dioscorea spp*., different edible fungus locally known as *Cheu* and some other plant materials. Thus different NTFPs not only fulfil the household demand of the fringe people but play role vital in their income sources.

Another aspect of collection of NTFPs from the natural forest, mainly the collection of fire wood by the rural population, which was ignored by the forest department, appeared to be most frequent one. As the dead and decaying wood has important implication in the forest ecosystem, removing them by the rural population in excessive amount might have some effects on the health of natural forest. *Helminthostachys zeylania*, an endangered fern, tender frond of which is used as vegetables are collected exclusively from the forest floor and thus its population appeared to be under threat to.

Table 7.1. Some of the important marketable NTFPs

Sl No.	Botanical Names	Local Name	Habit	Uses
1	*Acorus calamus* L. [Acoraceae]	Bocho	H	Medicinal,
2	*Aegle marmelos* (L.) Corrêa [Rutaceae]	Bel	T	Food, Medicine, Religious
3	*Ailanthus integrifolia* Lam. [Simaroubaceae]	Gokul	T	Dhup and Ornamental
4	*Alstonia scholaris* (L.) R. Br. [Apocynaceae]	Chatian	T	Medicinal, decotative
5	*Asparagus racemosus* Willd. [Asparagaceae]	Satamuli	CL	Medicinal
6	*Baccaurea ramiflora* Lour. [Phyllanthaceae]	Kusum	T	Edible, Medicinal
7	*Bombax ceiba* L. [Malvaceae]	Simal	T	Medicinal, fibre
8	*Canarium sikkimense* King [Burseraceae]	Gokul dhup	T	Medicinal, Dhuna
9	*Cassia fistula* L. [Leguminosae]	Sonalu	T	Medicinal, Fodder
10	*Cheilocostus speciosus* (J.Koenig) C. D. Specht [Costaceae]	Bet larang	CL	Cordage, Rope

Sl No.	Botanical Names	Local Name	Habit	Uses
11	*Cinnamomum tamala* (Buch.-Ham.) T.Nees & Eberm.	Telpat	T	Spice, Medicinal
12	*Curcuma aromatica* Salisb. [Zingiberaceae]	Kala halud	H	Medicinal, aromatic
13	*Cymbopogon flexuosus* (Nees *ex* Steud.) W.Watson. [Poaceae]	Lebu ghass	H	Mosquto repellent
14	*Dillenia indica* L. [Dilleniaceae]	Chalta	T	Edible, Fodder
15	*Diplazium esculentum* (Retz.) Sw. [Athyriaceae]	Dheki	Fern	Edible, Medicinal
16	*Phyllanthus emblica* L. [Phyllanthaceae]	Aamla	T	Edible, Medicinal
17	*Murraya paniculata* (L.) Jack [Rutaceae]	Kamini	S	Ornamental
18	*Oroxylum indicum* (L.) Kurz [Bignoniaceae]	Totala	T	Edible, Fodder
19	*Piper longum* L. [Piperaceae]	Pipla	CL	Edible
20	*Piper nigrum* L. [Piperaceae]	Pipla	CL	Spice
21	*Pterygota alata* (Roxb.) R.Br.	Labsi	T	Ornamental
22	*Ricinus communis* L. [Euphorbiaceae]	Reri	S	Oil, Edible
23	*Bombax ceiba* L. [Malvaceae]	Simul	T	Fibre and fodder
24	*Sapindus rarak* DC. [Sapindasceae]	Ritha	T	Detergent
25	*Tamarindus indica* L. [Leguminosae]	Tetul	T	Edible
26	*Terminalia arjuna* (Roxb. ex DC.) Wight & Arn. [Combretaceae]	Arjun	T	Medicinal, ornamental
27	*Terminalia bellirica* (Gaertn.) Roxb. [Combretaceae]	Bagera	T	Edible and Medicinal
28	*Terminalia chebula* Retz. [Combretaceae]	Harra	T	Edible, Medicinal
29	*Thysanolaena latifolia* (Roxb. *ex* Hornem.) Honda [Poaceae]	Jharu	H	Broom
30	*Tinospora sinensis* (Lour.) Merr. [Menispermaceae]	Gurus	CL	Medicinal, Fodder
31	*Ziziphus jujuba* f. lageniformis (Nakai) Kitag. [Rhamnaceae]	Boer	T	Edible, Fodder and Medicinal
32	*Ziziphus oenopolia* (L.) Mill. [Rhamnaceae]	Choti boer	S	Edible

7.7. ETHNOBOTANICAL KNOWLEDGE

A good number of plants have been found to be traditionally used by rural and aboriginals of this area and the diversity of uses were also notable. Similar type of findings was also reported by Das *et al*. (2007), Ghosh & Das (2007) and Sarkar (2011). Close observation to plants under different category of use, indicated the dominancy of family Leguminosae. It represented highest number of species under edible plants, fodder, ethno-veterinary, ethno-medicinal and decorative elements with 6, 8, 11, 12 and 5 species respectively. The second frequent family was Lauraceae. Though all the habit groups were found to be used, tree dominated over the other habit classes. Under the category of ethno-veterinary plants herbs were dominant one (Figure 7.7.1). Fruit was the mostly used parts under the category of edible plants and was followed by leaves, shoot, frond, rhizome, tuber, whole plants etc (Figure 7.7.2). Twigs and leaves were mostly used as fodder (Figure 7.7.3). Figure 7.7.4 represents the diversity of different plant part used medicinally. In most of cases more than one parts of a single plant were recorded and 31 such plant were found. In other cases only a single part was used for their medicinal properties. Leaves of 16 of plants, bark, fruits, twigs, rhizomes and roots of 11, 9, 12, 6, 5 species respectively were used to heal different ailments. Decorative elements were other important category of traditionally used plants. Fruits were mostly used as decorative elements (Figure 7.7.5). During the data collection on traditional knowledge and ethno-botany it was found that most of the medicinal plants were collected either from natural forest or fringe areas. As because of the poorness of plantation floor in diversity of required plant materials, collectors didn't preferred plantations if there was natural forest nearby. But for the fodder collector plantations were the first preference.

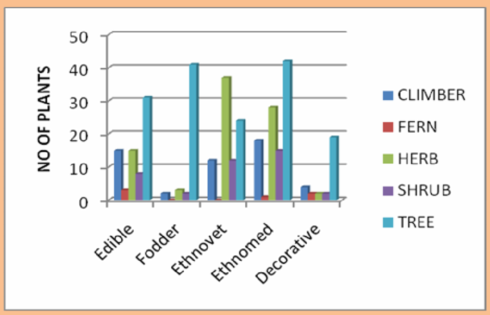

Figure 7.7.1. Distribution of recorded plants in different habit class

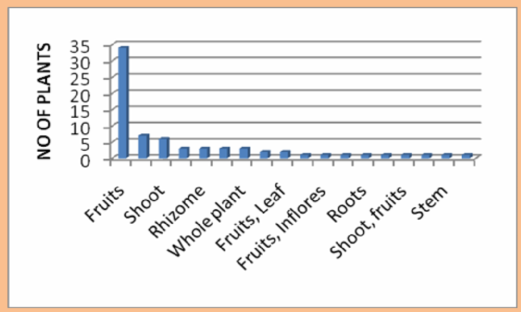

Figure 7.7.2. Diversity of plant parts used as food

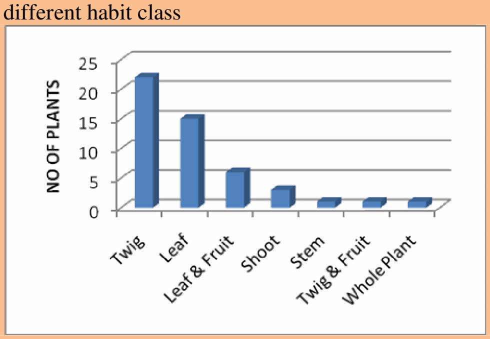

Figure 7.7.3. Diversity of plant parts used as fodder

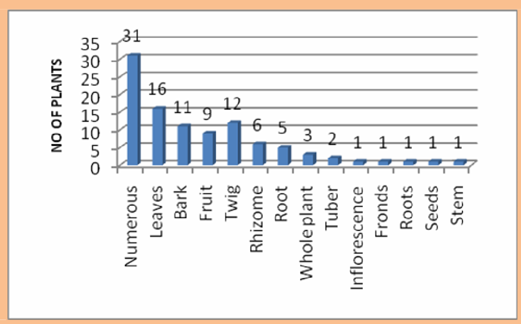

Figure 7.7.4. Diversity of plant parts used as medicines

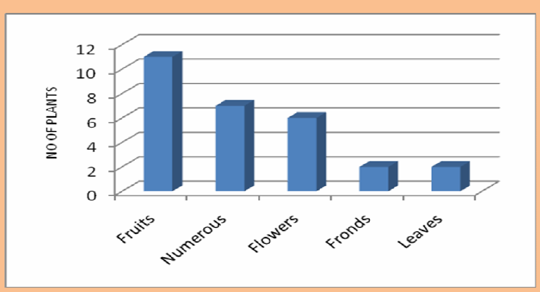

Figure 7.7.5. Diversity of plant parts used as decorative materials

The fringe villagers and tribal group were very much known about the traditional uses of plants, the forest resources and their availability. That might be developed due to their dependency on forest resources, which in turn had evolved due to the remoteness of their habitation and inaccessibility to the modern life-supports system (Sarkar, 2014) or simply for their daily life requirement. Interrelationship between the traditional knowledge system prevailed in rural and tribal population and NTFPs was also realized as the knowledgeable tribal people were preferred by the concerned authority as collector of NTFPs. Bothe the aboriginals and the rural populations were aware enough about the depletion of plant resources and in several cases they were found to grow the useful plants in their house hold garden or in kitchen garden. This tendency was more prominent among the traditional healers or the *ojhaas*. Their religious believe was also associated with the forest resources (Sarkar, 2011)**.**

7.8. IMPACT OF PLANTATIONS ON SOIL

Compassion of soil samples from different plantations and natural forest, showed some differences in its physical and chemical properties. Soil of mixed plantation was more or less similar with that of natural forest in respect of p^H. But Teak and Sal-chilauni plantations showed lesser p^H value of both top and sub soil. The difference was much more in Sal-chilauni plantation that meant soil of Sal-chilauni plantation was more acidic than the natural vegetation and even than other plantations. In all the plantation and natural vegetation, top soil showed more acidic nature than the sub soil (Figure 7.8.1) but in Sal-chilauni plantation the situation was just reverse (more acidic sub soil). Differences in p^H or acidity of top and sub soil were more or less similar in all the plantation except in mixed plantation where the differences was very less (0.037) while in other case it was 0.095 – 0.1. Regarding moisture content, soil of mixed plantation and sal-chilauni plantation was with higher moisture contents than the natural vegetation and the teak plantation showed similarity with the natural vegetation. Difference between water content of top and sub soil was highest in teak plantation (1.17%) and then in mixed plantation (1.10%) and the least in natural vegetation (0.31%).

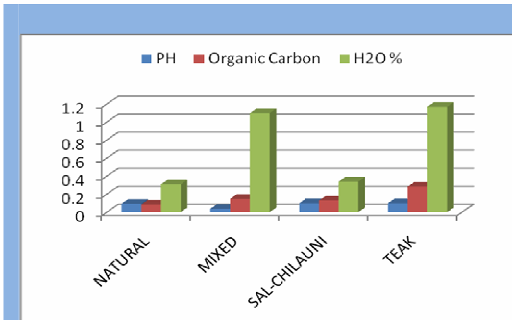

Figure **7.8.1.** Difference of p^H, Organic Carbon content and H_2O in top and sub soil

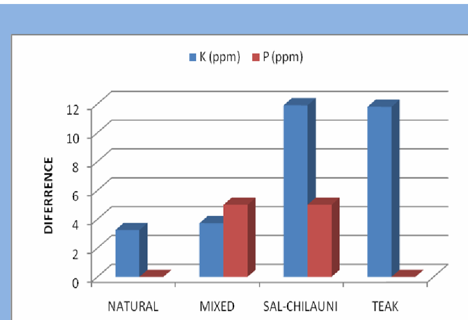

Figure **7.8.2.** Difference of Potassium and Phosphorus contents in top and sub soil

Teak plantation showed highest amount of organic carbon content in its top and sub soil and the difference was also higher than the other plantations and the natural vegetation. Difference of Organic Carbon contents between top and sub soil in teak plantation was highest measuring 0.285. In mixed and sal-chilauni plantation, that difference was slightly higher than the natural vegetation. In all plantations – mixed plantation, natural vegetation and teak plantation higher potassium content was found in top soil in comparison to sub soil, but the difference was highest in teak plantation (11.8 ppm). Sal-chilauni plantation also led to make a difference in potassium content between of top and sub soil but the sub soil was with higher potassium content and the trend was just opposite to the natural vegetation and other two types of plantation studied (Figure 7.8.2). Thus sal-chilauni and teak plantation deviated from natural forest in respect of potassium content. Phosphorus contents in both top and sub soil of plantation was reduced than the natural forest. In addition to that remarkable difference in top and sub soil phosphorus contents were found in mixed plantation and sal-chilauni plantation whereas in teak plantation and natural forest phosphorus contents was same in both top and sub layer of soil. So the plantations deviated from natural forest in respect of either phosphorus contents, or in difference of P contents in top and sub soil.

So in general, the soils of different plantations differed from that of natural vegetation in one or more aspects (Figure 7.8.3). Sal-chilauni plantation differed in lower value of pH (more acidic soil), higher moisture contents, lower potassium content and phosphorous contents and in texture of soil. Mixed plantation was different from the natural forest in respect of higher moisture content, lower potassium content and lower phosphorous contents. Soil of the teak plantation on the other hand deviated from the natural forest regarding lower pH contents or more acidic soil (top soil was too much acidic than the sub soil), higher organic carbon content, higher difference in potassium contents between top and sub soil, and in texture as the soil in teak plantation was classified as clay. Table 7.2 and 7.3 summarized the differences in different parameters in top and sub soil and differences between plantation and natural forest soil.

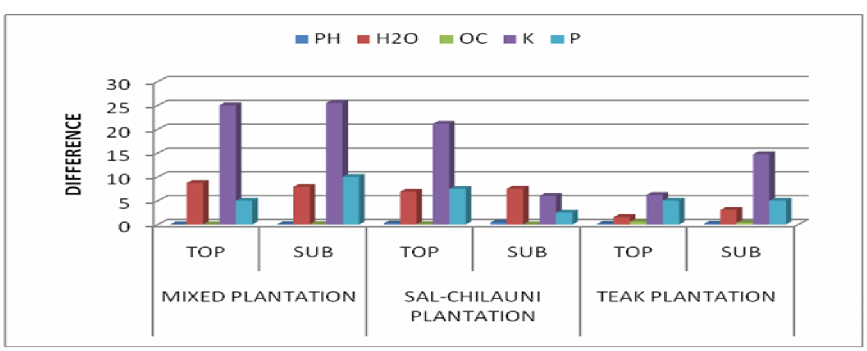

Figure 7.8.3. Comparion of different properties of plantations and natural forest

Table 7.2. Difference of P^H and of different nutrient contents in top and sub soil of natural forests and plantations

Vegetation Type	Difference Between Top And Sub Soil In				
	pH	Organic Carbon	H_2o %	Potassium Contents (Ppm)	Phosphorus (Ppm)
Natural	0.095	0.085	0.310	3.250	0
Mixed	0.037	0.148	1.100	3.725	5
Sal-Chilauni	0.100	0.130	0.340	11.900	5
Teak	0.100	0.285	1.170	11.800	0

Table 7.3. Difference of various soil parameters of Natural vegetation and plantations

Vegetation Type	Soil Layer	p^H	H_2O (%)	Organic Carbon	Potassium Contents (Ppm)	Phosphorus (Ppm)
Mixed Plantation	Top	0.018	8.7	0.0075	25.025	5
	Sub	0.04	7.91	0.055	25.5	10
Sal-Chilauni Plantation	Top	0.235	6.87	0.045	21.15	7.5
	Sub	0.43	7.52	0	6	2.5
Teak Plantation	Top	0.135	1.56	0.57	6.2	5
	Sub	0.13	3.04	0.37	14.75	5

7.9. ALLELOPATHIC EFFECTS

From the studies on three regularly planted angiospermic species of trees in the Terai-Duars region of West Bengal it is realized that *Tectona grandis*, an exotic from Myanmar region, exerted maximum effects on the randomly selected common herbs of this area, namely *Senna occidentalis, Ocimum gratissimum, Plumbago zeylanica, Oxalis corniculata* and *Andrographis paniculata.* And, the experiments also exposed that two other species under allelopathic evaluation are also having some degree of effects on these local species of plants. Extract of Sal affected the germination of *Ocimum gratisimum* and *A. paniculata*. Maximum level of inhibition of seedling mass was noted in *O. Gratisimum*. Jarul showed less inhibitory effects on the test herbs. Different chemical constituents such as nor-triterpene, dammarenolic acid, asiatic acid, dipterocarpol, triterpenic acid, tannic acid and phenolic content are present in Sal may be responsible for the allelopathic effects.

Allelopathy acts by addition of phototoxic substances to the environment and most of them inhibits germination and growths and are termed as allelochemicals (Whittaker & Feney 1971). Different phenolic acids such as salicylic acid, p-hydroxy benzoic acid, chlorogenic acid, tannic acid, caffeic acid, vanillic acid have been reported to occur in teak that are responsible for inhibitory or effects on other plants (Tripathi *et al*. 1999).

Of the selected herbs, *Ocimum gratissimum* is not a natural member of Terai-Duars vegetation but have naturalized in some regions especially around the forest villages. It is one highly aromatic plant and the present evaluation showed that it responded almost similarly like other species in the test. Similarly, the alkaloid content of *Andrographis paniculata and Senna occidentalis* are quite high. But their alkaloids could not resist the effects. *Oxalis corniculata* is one cosmopolitan species and grows in wide diversity of habitat conditions. This species was also affected, may be little less adversely. Out of the three tree-species under assessment, *Lagerstroemia* was with least effects and different test herbs also responded differentially to the extracts of different tree species.

7.10. PRESENT STATUS OF CONSERVATION

Once, the entire Terai-Duars belt of West Bengal was covered by dense forests. But introduction of tea, rapid extension of its cultivation, initiation of plantation, construction of road and rails, development of tourism industry and some other activities started to degrade the rich vegetation of this region (Das, 2011; Choudhury, 2015). And now the vegetation and ecosystem of Terai-Duars region is under severe threats. Followings are the main form of threats –

- Establishment of tea gardens and its rapid expansion
- Rapid extension of human settlement
- Cattle grazing in the natural vegetation
- Both legal and illegal extraction of timber in excess
- Fragmentations of ecosystems
- Initiation and expansion of tree plantation mainly the momoclonal plantation and rapid removal of natural forests
- Uncontrolled tourism to the reserve forests and protected areas
- Excessive collection of NTFPs, Medicinal Plants etc
- Removal of dead log for fuel wood

7.11. NOTES ON FUTURISTIC CONSERVATION STRATEGIES

Terai-Duars belt of west Bengal is concentrated in its relic contents and other category of threatened plants. On the other hand a huge pressure is being exerted on the vegetation and is increasing every day. So this unique belt of vegetation deserves very special conservational attention. The conservation strategies may be as follows:

- Creation of new plantations of introduced non-native species should be restricted.
- Monoclonal plantation should be avoided and if required a number of native species should be used to raise the plantation.
- At any cost natural forest should not be replaced with any type of plantations.
- Different cultural practice in plantation areas should be planned in such a way so that it exerts minimum or no strain on nearby natural forests.
- Unnecessary burning of forest floor in plantations and/or natural vegetation should be banned.
- Strict regulation to be strictly applied to prevent the unauthorized entry into the protected forests
- Grazing in the natural forest should be banned
- Collection of different type of NTFPs from the natural forests and even from the marginal areas should be controlled
- Rare species may be propagated by in vivo or in vitro method to increase their population very carefully.
- Tourism industry should be effectively managed, environment friendly initiative should be taken and tourist should be well aware of their activities in the natural forests
- No cultivation should be allowed inside the protected areas and already escaped species should be controlled immediately
- Emphasis should be laid on protection of the whole ecosystem instead of some rare species
- Creation of proper awareness among the common people especially among the fringe people should be emphasized.