The Diversity and Richness of Vegetation of Gaddikhana Forest Beat in Darjeeling Himalaya, West Bengal, India

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Abstract: **40 plant species belonging to 36 genera of 27 families were recorded from the study area - Gaddikhana Forest, Darjeeling during present investigation. Among them 37 were dicotyledons and 3 monocotyledons. Viola bentonicifolia was found to be abundant and dominant in distribution. Plant community was found to be homogenous in nature. Several clusters were formed between plant species on the basis of their relative abundance and resource value. Principal component analysis of the different pedons revealed pH, Phosphate, conductivity were statistically significant factors affecting distribution of plant species in Gaddikhana forest range. The population pressures including the anthropogenic activities in forest regions increased significantly and in future it seems to be a major threat of biodiversity of Darjeeling.**

Key Words: diversity indices, abundance, Gaddikhana Forest

I. INTRODUCTION

The habitat is of immense value to mankind because the modern material civilization is entirely based on the exploitation and utilization of the existing resources drawn from the environment and created through human efforts. In mountain areas this is more pronounced; terrain inaccessibility, climate in hospitability, soil infertility, and transport availability, scarcity of basic amenities and facilities make life nature oriented. The controlling mechanisms of biodiversity in different ecosystems are mentioned by the theory of species richness which considers resource availability and disturbance as factors for structuring plant communities.

The plant diversity at any site is influenced by species distribution and abundance patterns. Species richness is controlled by a variety of biotic and abiotic parameters [17, 8]. A number of factors have been shown to affect the distribution and abundance of plant species, including site conditions, i.e., moisture and nutrient gradients [24, 12, 7] light availability [10].

However the investigations concerning different types of forests or similar forests located in different areas have given no concrete conclusion for pinpointing the vegetation effect since site condition are changed and it is often impossible to separate the cause from the effect .However, diversity of trees in the Darjeeling foot hill region of Eastern Himalaya was recently studied by Rai and Das[18], Chanda and Palit [2] revealed the ecological Study on plant diversity and pedological characteristics in Rangiroom forest beat, Senchal West Zone Forest Range,

Darjeeling. The main objective of the present investigation was i) to prepare a checklist of different plant species of Gaddikhana forest and contribute towards taxonomy of forests of Darjeeling-Sikkim Himalayas and ii) assessment of diversity indices that can be used as a measurement tools of the ecosystem health of Gaddikhana forest.

II. STUDY AREA

A. *Gaddikhana Forest Beat*

It is a part of Senchal Wildlife Sanctuary, situated near to Darjeeling, West Bengal The forest is having the sufficient free cover and wherever required an artificial stocking is done annually. The forest is important for black bear, panther, lesser cat, goral, red legged falcon and some herbivores point of view. This forest beat is lies between 26°N-27°N and 88°E-88°20´E longitude at an elevation of 2600m. The forest has the status of reserve forests and under the supervision of The Forest Department of Government of West Bengal. Choosing randomly selected sites an area of 5 sq km was surveyed.

III. MATERIALS AND METHODOLOGY

In this present investigation 5 sq km. area was studied by choosing sites at random in different seasons in between February and December, 2013. For laying 30 quadrates ($1m^2$) specific sites were selected. The size of the quadrat used in this study was decided based on the species area curve method following Misra [13].The structure and composition of vegetation across vegetation types have been compared in terms of frequency, density, abundance and Important value index (IVI).

Species diversity index ($H' = pi \ln pi$; where, pi= ni/N; and ni = abundance of each species, N= total abundance of all species) were derived from the primary data separately for

each layer following Misra [13] and Shannon and Weaver [20] respectively. Berger and Parker Index (D_{BP} = Nmax / N Where Nmax = is the number of individuals in the most species and N= is the total number of all individuals in all species) were weighted toward the abundance of the commonest species. For any information-statistics index, the maximum diversity of a community is found when all species are equally abundant. Community's actual diversity is measured by the formula: Evenness (E) = H / Hmax. Rank Abundance diagrams visually describe the allocation of individuals to species in communities. We ranked and represented 34 species in that forest community in a standard rank abundance diagram. Next, each species were given a number. We then grouped the species in abundance classes of $\log_{10}$.

Multivariate statistics employed, following assessment of different parameters of diversity. Cluster analysis allowed grouping of the plants based on their relative abundance as revealed in the quadrats and adding the resource value to this. Multidimensional scaling allowed a finer analysis to group plants relative to their proportional values. This portrays the value of a plant relative to other plants in the aggregate. This would help defining plant assemblage in unit habitat.

IV. RESULTS AND DISCUSSION

After taxonomic survey of the ground cover flora an analysis of the identified taxa was done which reflects the dominance of dicotyledonous plants over monocots (Table 1). The community was composed of as many as 40 species of 36 genera from 26 families. Incidentally no tree sapling / seedling could be identified within the areas covered by the quadrats laid excepting that of Acer *campbellii*. *Viola betonicifolia* was the most frequent, dominant and important species in the community. In the forest the ground vegetation was very thick and the forest floor was moist in nature. The proportions of dicotyledones to monocotyledons species are about12.99:1 (Table-1).

Table 1: A Synoptic account of forest flora

		Dicotyledons		Monocotyledons	
	Total	Total	Percentage	Total	Percentage
Families	26	23	88.88 %	3	11.12 %
Genera	36	33	87.5 %	3	12.5 %
Species	40	37	88 %	3	12 %

In order to assess ecological knowledge of the native flora in Gaddikhana forest range , a quantitative phytosociological study in different study sites was carried out. Density, Relative density, frequency, relative frequency, abundance, relative abundance, Importance value index (I.V.I.) for each plant species was determined to quantify the importance of each species.

The density value varies between 0.05 to 7.95. Higher density values were recorded by *Viola bentonicifolia* , *Pilea umbrosa*. Most of the plant species reflecting lower density values indicating single plant dominated community structure of the vegetation of Gaddikhana forest range.(Fig 1)

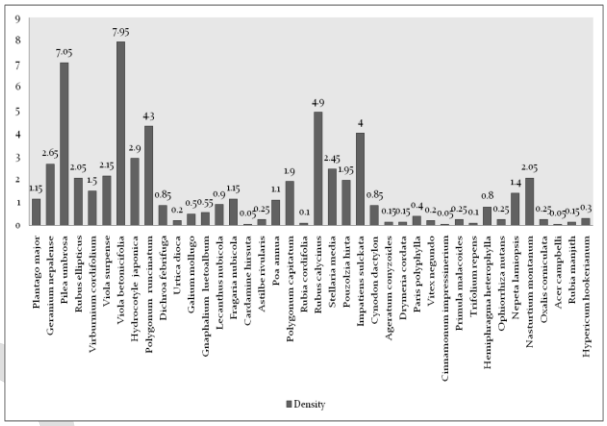

Fig 1: Variation in the Density of the studied forest Flora

Rank abundance diagrams visually describe the allocation of individuals to species in communities. A more complete description of a community could be obtained by plotting the proportional abundance of every species against its rank of abundance. Data represented in fig 2 reveals higher proportion of frequency class 1.6-2, a homogenized frequency class distribution (0-2) and lower proportion of frequency class 2.1 – 2.5 for for Gaddikhana forest range.

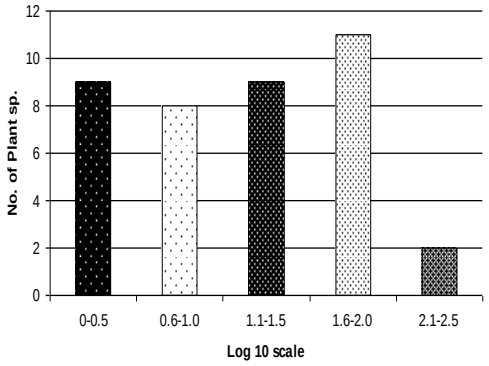

Fig 2: Log-rank abundance of plant species of Gaddikhana Forest

Data presented in fig 3 reflecting more or less homogenous abundance distribution for most of the plant species. Higher abundance value for *Nasturtium montanum* indicates higher colonization rate of this species in the respective habitat.

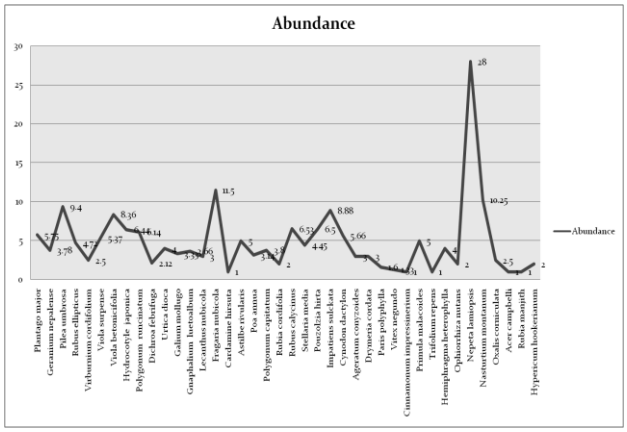

Fig 3: Variation in the Abundance of the studied forest Flora

Another important biodiversity indicator is the relative (proportional) abundance or degree of dominance of individuals among different species. This usually referred to as evenness or equitability and measures the extent to which species are equally represented in a community. There exists a strong correlation between structural diversity and species data pertaining to fig 4 reveals higher relative abundance for *Nepeta lamiopsis* and *Fragaria nubicola.*

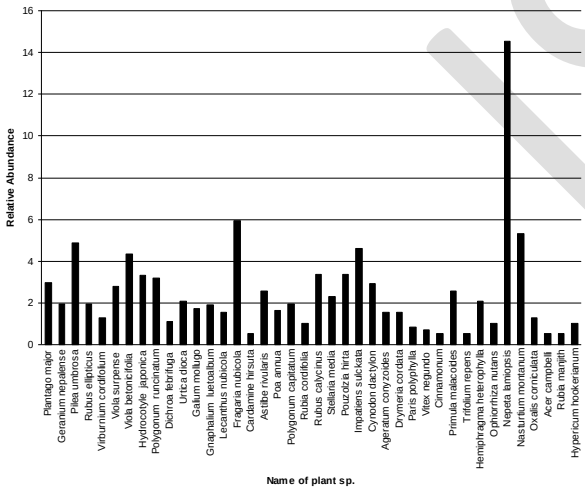

Fig 4: Relative Abundance of plant Species(n=40) in Gaddikhana Forest

Data presented in fig 5 reveals the overall frequency distribution of the studied flora of Gaddikhana forest range.The frequency value ranged between 5-95%. Most frequent forest flora appears to be *Viola bentonicifolia* , *Rubus calycynus*, *Polygonum runcinatum*,*Pilea umbrosa* . The less frequent ones includes *Primula malacoides*, *Lepeta lamiopsis* ,*Drymeria cordata* ,*Astilbe revularis*, *Urtica dioca* .

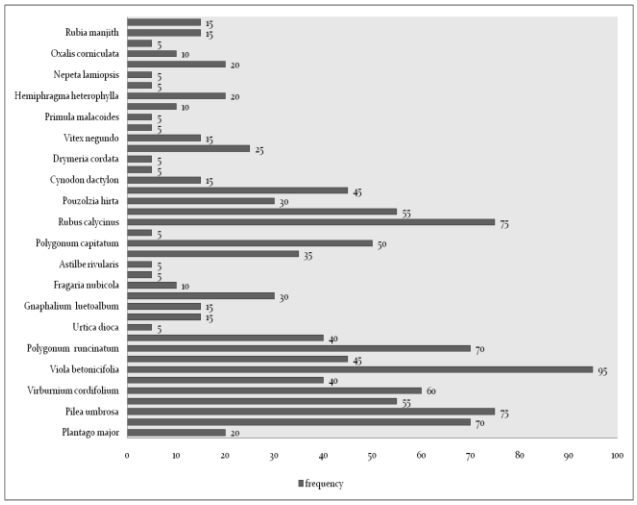

Fig 5: Variation in the frequency of the studied forest Flora

The relative frequency distribution represented in fig 6 reflects lower values .This therefore indicates that relative proportion of occurrence of species to each other is very low.

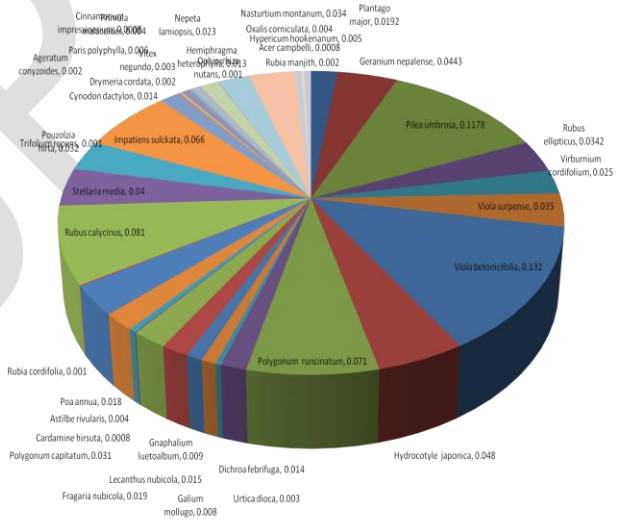

Fig 6: Relative frequency distribution of plants in the forest area

The highest IVI value of *Viola bentonicifolia* reveals that the species was most dominant in that community and the lowest IVI values of *Acer campbelli* , *Trifolium repens*,*Ophirrhiza nutans*, *Cinnamonum impressinerium* , *Rubia cordifolia* ,*Cardamine hirsuta* represent that they are the rare species of that community. Thus *Viola bentonicifolia* is the most dominant species of the study area. The IVI value ranged between 1.03 to 25.99 which is similar for trees of dry tropical forest of Vindhyan region constituted 3 to 32 IVI [21].

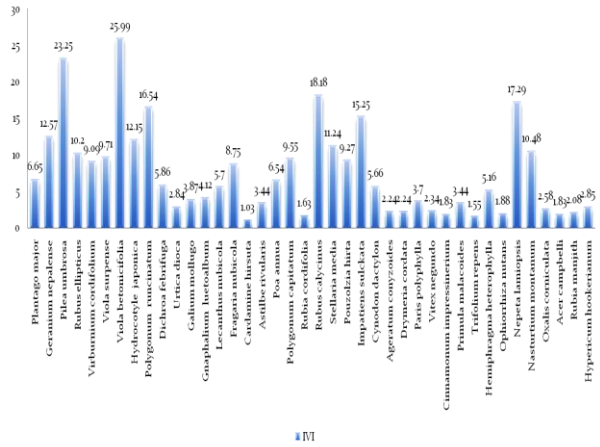

Fig 7: Variation in the IVI of the studied forest flora.

Diversity is the index of the ratio between the number of species and the important value of an individual. Shannon index value were highest for *Viola betonicifolia* followed by *Pilea umbrosa*, *Rubus calycinus* and lowest in *Acer campbelli*, *Cardamine hirsute* etc. (Fig 8). Thus, *Viola surpense* is the most dominant species of the study area. The Shannon index value of individual species was found to be lower reflecting lesser species diversity for the Gaddikhana forest range. Species diversity of the forest was relatively low, which might be due to anthropogenic factors such as cattle grazing, fire wood collection and logging.

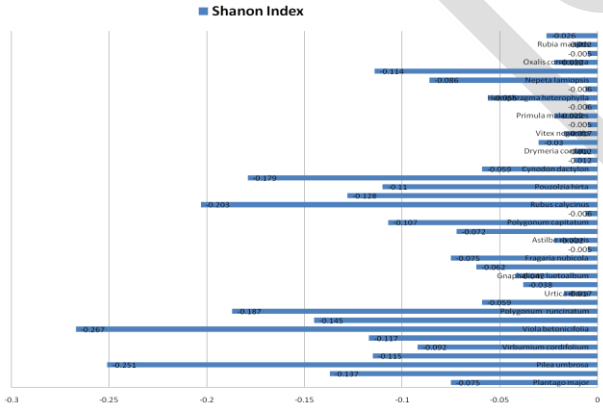

Fig 8: Variability of Shannons index of different species of Gaddikhana Forest Range

On the other hand the evenness index value is maximum in case of *Viola betonicifolia followed by Pilea umbrosa*, *Rubus calycinus*, *Polygonum capitatum* and minimum is of *Cardamine hirsute*, *Acer campbelli* etc. (Fig 9) The Eveness index value ranged between 1-53.4 which reflects that the species distribution was very even and well balanced.

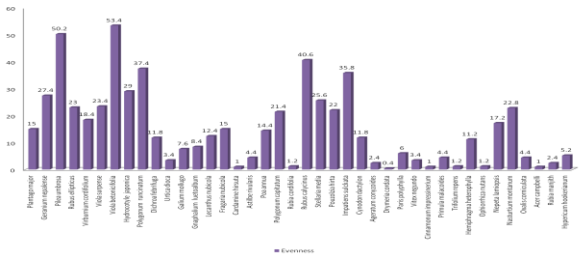

Fig 9: Variability of Eveness index of different species of Gaddikhana Forest Range[i]

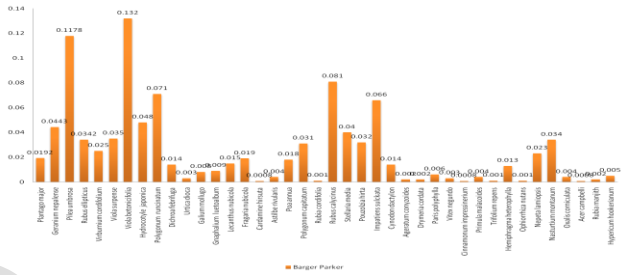

Fig 10: Variability of Berger Parker index of different species of Gaddikhana Forest Range

Data presented in fig 10 revealed the relative proportion of species to each other. Higher Berger Parker index value was recorded for *Pilea umbrosa*, *Viola bentonicifolia*, *Polygonum runcinatum*, *Hydrocotyl japonica* reflected higher relative proportion of this species in the plant community.

Hierarchical cluster analysis of plant species of Gaddikhana forest range on the basis of relative abundance and resource value reflected numerous clustering among different species indicating the closer abundance value, strong association between different plant species and homogenous distribution of species in their natural habitat. (Fig11)

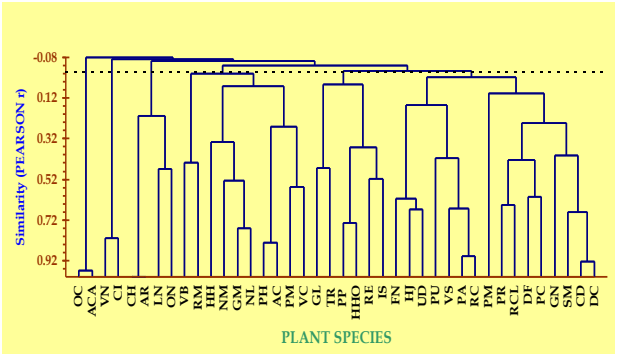

Fig 11. Cluster based on the relative abundance and resource value of the plants

Six major clusters were formed from the results of plant species during present investigation based on resource value of plants.(fig 12). The Pearson's similarity reflected statistically significant result. Among the 6 major

clustering of species cluster 2 comprising of 16 species followed by cluster 1(10 species), cluster 3 (6 species),cluster 4 (4 species), cluster 5 (2 species) and cluster 6(1 species). Distant clustering of plant species were observed between *Drymeria cordata* and *Nasturtium montanum* and *Primula malacoides* and *Nepeta lamiopsis*.

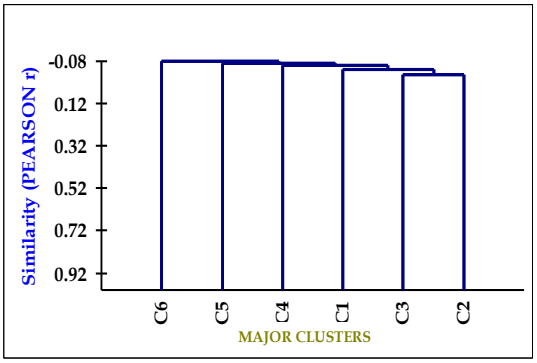

Fig 12. Major clusters based on resource value and grouping of plants

Multidimensional scaling of the different plant species on the basis of plant abundance and their resource value clearly reflects 11.12 % variability for 1st dimension and 10.32% variability for 2nd dimension, which reflects lesser variability in terms of species distribution leading to even and random distribution. The relative abundance of the plants varied with these parameters, with the dominant plants being *Viola betaicifolia*, *Pilea umbrosa*, *Rubus calycinus*, *Polygonum runcinatum* Relatively few numbers of *Cardamine hirsuta*, *Acer campbelli* were noted, which is clearly reflected in the cluster diagrams and multidimensional scaling (fig 13)

Plant	Cluster	Plant	Cluster
AC	1	PU	2
GM	1	RC	2
HH	1	RCL	2
NL	1	SM	2
NM	1	UD	2
PH	1	VS	2
PM	1	GL	3
RM	1	HHO	3
VB	1	IS	3
VC	1	PP	3
CD	2	RE	3
DC	2	TR	3
DF	2	AR	4
FN	2	CH	4
GN	2	LN	4
HJ	2	ON	4
PA	2	CI	5
PC	2	VN	5
PM	2	ACA	6
PR	2	OC	6

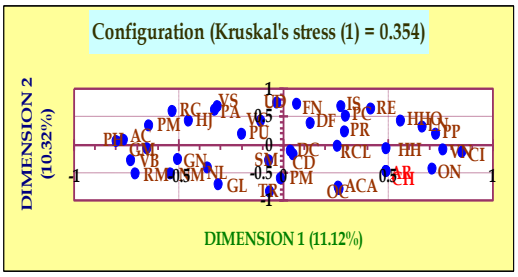

Fig 13. Multidimensional scaling based on abundance and resource value

Soil factors include all the physical, chemical and biological properties of the soil. The nature of the soil profile, soil pH and the nutrient cycle between the soil and the trees are some of the important dimensions in determining the site quality. Soils of this region does not have texture finer than loamy fine sand, have no lithic contact and its organic carbon content more or less decreases with depth. Total amount of organic matter that returns to the soil affects the soil properties which to varying degrees depends upon the rates of decomposition of the former.(Fig 14) From the Hierarchial Cluster analysis it is clearly reflected that pedons 1,9,5 and pedons 8,10,4,2,3 forming closely related cluster indicating higher similarity among them in terms of soil characteristics. Pedon 9,2,7 and 6 formed distant clusters reflecting significant variation among them in terms of soil characteristics.

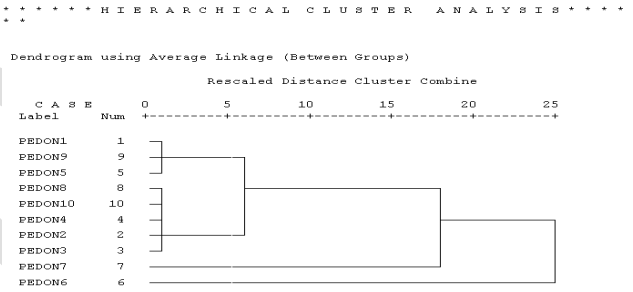

Fig-14 –Hierarchical Cluster analysis of different pedons of Gaddikhana Forest Range on

Principal component analysis of the pedological characteristics of different pedons isolated three component factors significantly affecting the species distribution of the concerned study site. (Table-5) pH(0.845) , phosphate(0.898) in the first component, nitrogen(0.958) in the second component and conductivity(0.963) in the third component was found to be statistically significant affecting species distribution.

Table-2- Principle component Analysis (3 Component extracted) with varimax rotation for pedon I-X

Rotated Component Matrix

	Component		
	1	2	3
PH	.845	-.438	.198
COND	.252	-9.18E-02	**.963**
N	-.108	**.958**	-6.35E-02
P	**.898**	.114	.246
OC	-.775	.554	-.173

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization

The habitat is of immense value to mankind because the modern material civilization is entirely based on the

exploitation and utilization of the existing resources drawn from the environment and created through human efforts. In mountain areas this is more pronounced; terrain inaccessibility, climate in hospitability, soil infertility, and transport availability, scarcity of basic amenities and facilities make life nature oriented. The controlling mechanisms of biodiversity in different ecosystems are mentioned by the theory of species richness which considers resource availability and disturbance as factors for structuring plant communities.

Darjeeling is one of the biodiversity hotspot within Himalayas. It is floristically akin to other parts of the Eastern Himalayas in general and Sikkim Himalaya in particular. Darjeeling hill appears as the matrix encompassing some features of boreal and temperate flora of the eastern and western hemispheres together with certain unique features of Asia in addition to its own unique features.

The patterns and role of species richness in ecosystem function are important in terms of land-use and climate change concerns [1, 19, 14]. While there is still debate on the role of species diversity and ecosystem function [5, 15] species richness is a frequently measured ecosystem attributes [11] because it characterizes the biodiversity of an area at any scale. Species richness is controlled by a variety of biotic and a biotic parameters [16, 3,8, 16].

The plant diversity at any site is influenced by species distribution and abundance patterns. A number of factors have been shown to affect the distribution and abundance of plant species, including site conditions, i.e., moisture and nutrient gradients [4, 24, 12, 7] and canopy coverage, i.e., light availability [10]. However the investigations concerning different types of forests or similar forests located in different areas have given no concrete conclusion for pinpointing the vegetation effect since site condition are changed and it is often impossible to separate the cause from the effect .However, diversity of trees in the Darjeeling foot hill region of Eastern Himalaya was recently studied by Rai and Das[18], Chanda and Palit [2] revealed the ecological study on plant diversity and pedological characteristics in Rangiroom forest beat, Senchal West Zone Forest Range, Darjeeling.

The present investigation reveals that dicotyledonous plants have the major contribution towards the flora of Sikkim- Darjeeling Himalayan forest.

The variable rate of frequency class distribution at Gaddikhana forest range of Senchel wildlife sanctuary may be explained by a common biological explanation pattern which implies most dominant species appeared to colonize a new area appropriates a fraction of the available resources and by competitive interaction, preempts that fraction. The second species then preempts a similar fraction of the remaining resource and so on with further colonists.

The concept of species diversity relates simply to "richness" of a community or geographical area in species. At the simplest level of examination, species diversity corresponds to the number of species present. Species diversity is considered to be an important attribute of community organization and allowed comparison of the structural characteristics of the communities. It is often related to community dynamics stability, productivity, integration, evolution, structure and competition. The idea of displacement of one species through competition with other is net prime importance. The ecology of different plant communities of Gaddikhana forest range of Senchel wildlife sanctuary showed variation in nature, structure, composition of vegetation and soil characteristics. Most of the species were evergreen in nature. The majority of individuals of plant population were seen in danger. Various types of activities have modified the plant cover over wide areas. There is a need to develop plant-protected areas. Scientific information relating to the composition of vegetation can be helpful for proper rehabilitation of the affected area because this forms the basic element for the conservation of important and endangered flora and fauna of any region. Protection of the natural flora from overgrazing is necessary, especially during the time when the desirable plants set their seeds. Protection is essential to maintain the desirable forage plant species in a good proportion, to avoid invader plant species and to rehabilitate the destroyed natural flora .We must carry out our efforts to make a list of the plant species, which can be lost from the natural environment, otherwise it will leads to desertification. Desertification associated with human activities has been recognized over the past two decades as one of the important facets of ongoing global environmental change [23, 22, 9] and species loss can alter the goods and services provided by ecosystems [6].

V. CONCLUSIONS

The community is diverse, so it has the potentiality to receive high degree of diversity if prevailing environmental conditions are most advantageous. A more intensive study would surely result in identifying many more species. But at present various stress factors like extensive cutting of tress for fuel and fodder and other plants, overgrazing and other biotic interferences declining the trend of species density. So, impact of anthropogenic alteration of habitats in Senchal forest would be taken into account and on the other hand it will important to make a further study on the change of plant diversity in relation with physico-chemical character of soil in Gaddikhana forest. Since this forest is likely to have generous impact on socio-economics of local stakeholders, its ecorestoration and protection is of utmost importance.

ACKNOWLEDGEMENT

We do hereby Acknowledge our most beloved and respected Professor Ambarish Mukherjee, Professor , Dept. of Botany,The University of Burdwan , West Bengal, India for his constant support, enthusiasm and

technical advice during the entire work as well as during the preparation of this writing.

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