Study of Vegetation And Sampling Using Ecological Quadrat

Dr. Debabrata Das
Associate Professor and Head, Dept of Botany
Ecology Laboratory, Govt. General Degree College Lalgarh, Binpur-I, Jhargram-721516, West Bengal, India

Abstract- *Since time immemorial people are very much interesting to study the vegetation to mapping the resource and their management. But crucially we know that any type, any kind or any means, measurement of characters by scientific way give us data for discussion in laboratory. That's why we are going to field and use different formula even different methodology to get result. In field the collection of data is very hard s the nature of vegetation vary from site to site due to change its microclimate even for topographical change. The stiffness and gradient of habitat make unsuitable towards data collection. So, people use alternatives to make it easy and convenience. Therefore, collectors should know how to use parameters before going to field. Here, the paper represents quadrat size, quadrat shape, and biomass collection to study the diversity of species of static kind.*

Keywords- Vegetation study, quadrats, biomass, diversity of species and discussion

I. INTRODUCTION

Vegetation is recognized as a cover of flora upon ground that changes its characters time to time due to change of seasons. Therefore, vegetation is a general term for the plant life of a region; it refers to the ground cover provided by plants, and is, by far, the most abundant biotic element of the biosphere. It serves several critical functions in the biosphere, at all possible spatial scales. Flora is a systematic enumeration of species of plants. Therefore, it is very interesting that we need study of flora, study of vegetation and study of diversity, even study of comparative aspects of vegetation in nearby two varied ecosystem. These may be forests, grassland, degraded land, plantation stand etc. Therefore, before going to study we should take care that, what are the recommended quadrat size to study the static organisms. Scientists suggested us a special quadart size for each kind of study. But, during study we always feel some problems, and need idea to establish view on the working principles. It is indeed true that, each and every habitat needs standardized size of quadart to study the vegetation even study of animal species exists in the same habitat.

II. METHODOLOGY

Any specific size of area (round, quadrangular, rectangular, pentangular or any other kind) is considered as quadart. But most of the workers use quadrangular area on land or habitat as quadrat. Size should be determined by the diversity of the organisms in the surrounding area and the type of plant or animal under investigation. For example `it is not good using a small quadrat (0.5m x 0.5m) to estimate tree diversity in woodland, instead a 10m x 10m or 20m x 20m would be recommended. Similarly, a 5m x 5m quadrat would be too big to study the lichen covers on a rocky shore, but 0.25m x 0.25m is enough to make it complete (Table 1). Recommended size of the quadrat is unique i.e. in forest one can study 1m x 1m for herbs, 5m x 5m for shrubs and 10m x 10m for tree species in lateritic forest of southwest Bengal, India (Das, 2007). In North Bengal of West Bengal same pattern may be followed though in dooars, we can use 20m x 20m for trees, whereas for herbs and shrubs the same size is already recommended by many authors, even we had work same for a forestry project with forest department under Medicinal Plants Conservation Area (MPCA) study. Woodland canopies suggested 20m x 20m to 50m x 50 m also recommended by International system of forestry study. Large heathers or long tall vegetation, always involved with 1m x 1m to 4m x 4m size quadrat .

Animal species need special attention. Here, small animals like barnacles (a type of arthropod) and bryozoa (Aquatic invertebrate animal) where cover >50% need 2cm x 2cm to 5cm x 5cm quadrat, but if cover is <50%, these need 0.1m x 0.1m. Larger animals like periwinkles (Small sea snail) and limpets (aquatic snails with a shell that is broadly conical) study need 0.5m x 0.5m quadrat (Tabel 2).

Table 1. Recommended quadrat size for vegetation study (for static plants)

Sl. No.	Vegetation/Habitat type	Quadrat size
1.	Algae, Mosses and Lichens	0.1m x 0.1m to 0.5m x 0.5m
2.	Seaweeds, grasslands, small heathers, aquatic plants etc.	0.5m x 0.5m to 2m x 2m
3.	Large heathers or long tall vegetation	1m x 1m to 4m x 4m
4.	Scrub and woodland vegetation	10m x 10m
5.	Woodland canopies	20m x 20m to 50m x 50m
6.	Habitats (e.g. badger, setts, ponds, woodland blocks)	1 km x 1km to 10km x 10km
7.	Herbs for Lateritic forests	1m x 1m
8.	Shrubs for Lateritic foests	5m x 5m
9.	Trees for Lateritic forests	10m x 10m

Table 2. Recommended quadrat size for static Animals

Sl. No.	Static animals	Quadrat size
1.	Small Animals where cover >50%	2cm x 2cm to 5cm x 5cm
2.	Small Animals where cover <50%	0.1m x 0.1m
3.	Large animals	20m x 20m to 50m x 50m
4.	Ants' nests	20m x 20m to 50m x 50m

Above tables showed results that can be taken as a guideline. The ideal way to find out the correct size of quadrat is to repeat the survey several times, in a study field. Doubling the size of the quadrat, each time, to work out the gain in the number of species with increasing quadrat size of a study area recommended. When very few species are added to the list and upwards of 95% of the total number of species are sampled in the quadrat area, then this should be the appropriate quadrat size to use. However, this method is recommended everywhere by many authors, in practice to determine the vegetation. This is because, samples are often taken from many different vegetation types, establishing the ideal quadrat size in this way can be problematic (One way round this is to use nested quadrats). Because of statistical constraints (including variable sampling effort), it is usually best to set one size of quadrat for each of the different zones of vegetation (e.g. mosses, herbaceous layer and trees) being sampled in a study area.

Biological Spectrum study:

The ratio of the life forms of different species in terms of number of percentage in any floristic community is called the biological spectrum or phytoclimatic spectrum. Since each life-form class is related to the environment, the biological spectrum is direct indicator of its environment. So, study of environment includes study of biological spectrum. Raunkiaer made a normal spectrum (Table 3) which is a control in connection with other parameters to study the vegetation. The deviation indicates some fluctuations occur in the said vegetation that needs manipulation to make it normal for classical analysis (Das et al. 2002).

Table 3. Raunkiaer's normal biological spectrum for Phanerogamic Flora

Life form	% of Occurrence
Phanerophytes (Trees and many shrubs)	46
Hemicryptophytes (Any perennial that bears its overwintering buds at soil level)	26
Therophytes (Any annual that survives in unfavourable seasons i.e. in too cold or too dry seasons)	13
Chamaephytes (Any woody plant whose resting buds are on or near the ground)	9
Cryptphytes (A plant that forms its reproductive structure as corm, bulb, rhizomes etc.)	6

In any plant community, the ratio of the life forms of different species in terms of their numbers or percentage is called the phytoclimatic or biological spectrum. The ratio also indicates the nature of climate, prevailing in a particular region. For example, a higher percentage of chamaephytes would indicate a cold climate; where as the occurrence of higher percentage of therophytes would imply long dry seasons. Evidently, the occurrence of more or less similar biological spectra in different regions would suggest similar climatic conditions in those regions. Raunkiaer (1934) prepared a normal biological spectrum for the phanerogamic flora of the world and found the following percentage values of different life forms (Table 3). The biological spectrum of any natural ecosystem can be studied and compared with Raunkiaer's data and from this some insight can be obtained into the type of climate of the area. Raunkiaer's study was based on a large number of natural undisturbed habitats. In recent times, however the biological spectrum of any habitat has been affected by human activities, such as like agriculture, grazing, scraping, deforestation, fire, pollution, and so on. Consequently, one has to be very careful while comparing different ecosystems and drawing conclusions.

Plants: Quantitative features of the community of vegetation:

Phanerophytes: These plants may be trees, shrubs and climbers. They are found mostly in tropical regions and decrease progressively from the tropics to the temperate to the polar regions. In these plants, the growing buds, are not well protected. They are located in upright shoots much above the ground surface. Phanerophytes are usually divided into four sub-life forms depending upon the hight of mature plants. These are (a) trees more than 30 m tall, called megaphanerophytes, (b) trees between 8 and 30 m tall, called mesophanerophytes, (c) trees between 2 and 8 mt high, called microphanerophytes, and (d) shrubs less than 2 meters high, called nanophanerophytes.

Chamaephytes: In these plants the buds are located close to the ground surface or up to maximum height of 25 cm. Chamaephytes commonly occur in high altitudes and latitudes, e.g. *Trifolium repens*, found in temperate north America. It is reported from Darjeeling Himalaya also.

Hemicryptophytes: In these plants, the perennating buds are protected under the surface of soil. The plants are usually biennial herbs and grown in cold climatic regions. In the worm season the growth of aerial parts is marked.

Cryptophytes: In these plants, the buds are usually buried in the soil or in bulbs and rhizomes where food is stored to withstand long periods of adverse climatic conditions. They are called geophytes.

Therophytes: In these annual plants, they produce flowers and seeds in the favourable seasons. They survive adverse conditions in seed form and are found dry, hot or cold environments.

Why do we study Vegetation?

Vegetation serves several critical functions in the biosphere, at all possible spatial scale. First, it regulates the biogeochemical cycles through different components available in the ecosphere, mostly those elements which are required for all organisms. It regulates the process and impart balance for water, carbon, nitrogen and phosphorous. It is also of great importance in local and global energy balances. Now, it regulates the green house gases and takes function to mitigate the level of green house effect.

Direct and Indirect Impact of Vegetation:

Mitigate climate change on fire regime, impact of elephant on vegetation, coverage of micro and macro animals, saver of micro flora in and around vegetation and soil flora as well as soil fauna. PLoS research journal published a paper (2018) entitled, "complexity in African savannas: direct, indirect and cascading effects of animal densities, rainfall and vegetation availability". The paper showed PLS-PM modelling using mammal and vegetation data from three different wildlife reserves in South KwaZulu-Natal. The result also showed that the processes that three separate models from three areas provided the best understanding of the importance of the different interactions. These models suggest that elephants had a negative impact on trees, but also on grass availability. This impact is stronger when elephants are not able to migrate during the dry season. Browsers and grazers were correlated with browse and grass availability, but comparison between browse and grass was not detected. This model may be made in Lalgarh or Lateritic forest of Southwest Bengal even in North Bengal forest where elephant and men conflict is a common phenomenon.

III. RESULT AND CONCLUSION

(Frequency, Density, Abundance and IVI of species study)
Frequency of species:

Frequency is the number of times a plant species occurs in a given number of quadrats. Frequency is usually expressed as a percentage and is sometimes called a frequency index. The concept of frequency indicates the probability of finding a species in a series of quadrats examined in an area of interest. It is denoted by 'f'. So,

%f = Total number of quadrats in which species present /Total number of quadrats studied.

Density of Species:

An average number of individuals of a given species over the total number of samples studied in an area. Density therefore may be calculated by the formula given below:

Density = Total number of individuals of a species present /Total number of quadrats studied. So, from the table we can write, Value of data in column number 4/value in column no. 6.

Abundance of Species:

The number of individuals of a given species per unit area (quadrat) of occurrence is called abundance. Therefore, abundance=Total number of individuals of a species/total number of quadrats of occurrence. From the table it will be-Value of data in column number 4/value in column no. 5.

Table 4. Value /data collection sheet (Quadrat size 1m x 1m for herbs, 5m x 5m for shrubs and 10m x 10m for tree species).

1	2	3					4	5	6	7	8	9
		No. of individuals per quadrat										
Sl. No.	Name of species	1	2	3	4	5	Total no. of individuals of a species	No. of quadrats in which species occurred	Total no. of quadrats studied	Density	Abundance	Frequency
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

N.B. : *please put your data here for specific study in field, you can use same sheet for use in field but keep in mind that for herb use a separate sheet, similarly for shrubs and trees use different sheet.*

Conclusion: Density gives us the numerical strength of a species in a plant community. Abundance on the other hand, gives the number of individuals of a species in a habitat. Generally, frequency and abundance are co-related to find out the distribution of species.

(a) High frequency x low abundance =Regular distribution.
(b) Low frequency x high abundance = Contagious distribution

Dominance of Species:

Dominance indices are weighted towards the abundance of the commonest species. A widely used dominance index is Simpson's diversity index. It is used widely for all cases but need to study dominance as well as diversity of species in a community. It takes into account both richness and evenness. It measures the probability that any two individuals drawn at random from and infinitely large community will belong to same species. There are two versions of the formulae for calculating Simpson's Index (D).

$$D=\sum (ni/N)^2 \qquad \text{or, } D=\sum_n \frac{n(n-1)}{} / N(N-1)$$

Where, n= the total number of individuals of ech species, N= the total number of organisms of all species. The value of D may be zero (0) or one (1). With this index zero represents infinite diversity and 1, no diversity. That is, the bigger the value of D, the lower the diversity. This does not sound the logical, so to get over this problem, D is often used and subtracted from 1 or the reciprocal of the index is taken.

Simpson's Index of Diversity 1-D:

This index represents the probability that two individuals randomly selected from a community will belong to different species. The value of this index also ranges between 0 and 1, but here, the greater the value, the greater the diversity.

Simpson's Reciprocal Index 1/D:

The value of this index starts with 1 as the lowest possible figure. This figure would represent a community containing only one species. The higher the value, the greater would be the diversity. The maximum value is the number of species in the sample. For example, if there are five species in the sample (data), the then maximum value is 5.

The name Simpson's diversity index is often loosely applied and all three related indices described above (Simpson's Index, Simpson's Index of Diversity and Simpson's Reciprocal Index) have been quoted term, depending on author.

Example: let us consider the following table for forest species in Lalgarh Jungle, Jhargram, W.B. (Table 5).

Table 5. Data of forest species in 10 x 10 m^2 quadrat.

Sl. No.	Species name	Common Name	Number of Individual (n)	n(n-1)
1.	*Shorea robusta*	Sal	8	56
2.	*Terminalia bellerica*	Bahera	2	2
3.	*Terminalia chebula*	Harituki	1	0
4.	*Schleichera oleosa*	Kusum	1	0
5.	*Madhuca indica*	Mahul/Mahua	3	6
	Total (N):		15	64

Putting the value into the formula for Simpson's Index:

$$D= D=\sum (ni/N)^2 \qquad \text{or, } D=\sum_n \frac{n(n-1)}{} / N(N-1)$$

=64/(15 x 14) = 0.3 (Simpson's Index).

Then, Simpson's Index of Diversity= 1-D= 0.7 and

Simpson's reciprocal Index=1/D=1/0.3=3.33.

All these three formulae used simultaneously. The three values represent the same measurement value for biodiversity study. It is therefore, important to ascertain which index has actually been used in any comparative study of biodiversity. The disadvantage of Simpson's Index is that it is heavily weighted toward the most abundant species, as are in all dominance indices. The addition of rare species with one individual will fall to change the index. As a result, Simpson's Index is of limited value in conservation biology if an area has many rare species with just one individual

Biomass:

The total quantity of mass of biological organism or weight of organism in a given area or volume is called biomass. It is required to study abundance of species. For experimental and research purpose dry biomass is used in comparison to green or wet biomass. Generally collected plant materials were collected from standard plots (Quadrats) and studied biomass. But before going to dry mass basis we need oven dried matter collected from a special field or area (predetermined). Temperature used in drying is 70 degree centigrade for 12-24 hours in a Hot air oven. To get dry biomass from plant, drying in a woven is essential though we can use air dried biomass for a long term interval basis. This is not applicable in moist season like monsoon or pre monsoon season.

Calculation: If the plot is 25cm x 25 cm =625cm x cm. If the calculated dry biomass of a species after hot air oven treatment is y. Then the productivity of above ground biomass of a species will be = dry biomass of 25cm x 25 cm area/625 * 100*100 gm/mt^2. One can calculate total biomass hectare wise after taking the sum of all species produced biomass in the specific quadrat size.

Vegetation Cover:

Calculate average basal area by using $A = \pi r^2$, r-radius=diameter (D)/2 (Average basis); D x Average basal area = ...sq cm/sq mt

Table 6. Data sheet to be used for Basal area based coverage study in vegetation monitoring.

Sl. No.	Name of Plant species	Diameter of Individual species					Total	Average
		1	2	3	4	5		
1	A							
2	B							
3	C							
4	D							
5	E							
6	F							

Importance Value Index: It is totality of frequency, density and abundance of species (A total value will be calculated on 300 only). Therefore, frequency, density and abundance values will be 100 each basis.

IVI=RF+RD+RA (R stands for relative), for diversity study use IVI vale as ‘ni’ and sum of ‘ni’ as ‘N’

In our area i.e. in Southwest Bengal, it is better to use the method to calculate the diversity index as Shannon and Wiener (1963). Similarly for dominance of concentration Simpson’s formula (1949) is better. For the study of evenness, Pielou (1966) is used along with species richness by Margalef (1958). Similar in manner, indices of similarity in any community or simply community coefficient (IS) between any two sample sites or communities may be made by the formula Sorensen (1948) as described by Muller-Dombois and Ellenberg (1974).

All the individuals are given below:

(1) Diversity Index (H)= $-\sum[(ni/N) \times \log(ni/N)]$.

Where, ‘ni’ is the value of IVI of individual species and ‘N’ is the total IVI of all the species.

(1) Dominance of Concentration (Cd)=$(ni/N)^2$

Where ‘ni’ is the IVI of individual species and ‘N’ is the total IVI of all the species.

(2) Evenness Index (e)= Diversity Index/log S

Here, Diversity Index is Shannon Index and ‘S’is the number of species.

(3) Species Richness Index (d)= S-1/log N

Where, S= Number of species and ‘N’ is the total Importance value and ‘d’ is species richness.

Similarity Index (IS) =(2C/(A+B) x 100

Where, ‘A’ is number of species in one stand/Community, ‘B’ is number of species in another stand/ community and ‘C’ is number of species common to both the community

Abstract Community: The degree of occurrence of a species in an ecosystem, in an abstract community, along the series of stand may be adjusted by species presence in sample plots of similar nature and size. The judgement for grouping of discrete plant communities in to an abstract community may vary. However, based on common management status the classification of community has been done. This is indeed true to a natural forest where the elements are heterogeneous in comparison to the community in degraded land or plantation stand.

Diversity Study:

Several formulae used today to assess the diversity of species. But in general, Simpson’s diversity index was popular. It is a measure of diversity which takes into account the number of species present as well as the relative abundance of each species. As species richness and evenness increase so diversity increases. Here 1 value represents infinite diversity where 0 indicates no diversity. Other indices are Shannon index (Shannon-Wiener or Shannon-Weaver Index), Dominance Index, Reciprocal Index, Berger-Parker Index, Margalef Richness, Menhinick Index, Renyi Index, Gini Coefficient, Buzas and Gibson's Index, Equitability Index, Hill Number, Whittaker Index, Sorensen's Index, Routledga beta-R Index, Jaccard Index, Mountford Index, Bray Curtis, Gamma diversity, Preston Diagram, Lorenz Curves etc.

Zoologist and botanist use Shannon Index (1948) to determine the diversity of species. The formula is:

$$H= - \sum_{i=1}^{r} ni/N * log ni/N$$

Where, 'N' is total number of 'ni' and ' ni' is the proportion of characters belonging to the ith type of letter in the string of interest. In ecology, ni is often the proportion of individuals belonging to the ith species in the dataset of interest. Then the Shannon entropy (degree of surprise) quantifies the uncertainty in predicting the species identity of an individual that is taken at random from the dataset. Although the equation is here written with natural logarithms, the base of the logarithm used when calculating the Shannon entropy can be chosen freely. Shannon himself discussed logarithm base 2, 10, and e and these have since become the most popular bases in application that use the Shannon entropy. Each log base corresponds to a different measurement unit, which have been called binary digits (bits), decimal digits (decits), and natural digits (nats) for the base 2, 10 and e respectively. Comparing Shannon entropy values that were originally calculated with different log base requires converting them to the same log base: change from the base 'a' to base 'b' is obtained with multiplication by $\log_b a$.

What is evenness of Species?

Take natural logarithms of species richness 'ln(S)'. In this example, ln(3) equals 1.009. Calculate the proportion of each species 'p(i)' by dividing the number of that species by the total number of all species. The proportion of orchids is 10 divided by 140, which equals 0.072.

How to start your Study?

A field study includes some aspects of study i.e. standardization of instruments, standardization of methodology associated with specific type of study. The study field and grid standardization may be fixed by using statistical sampling. Random sampling may be considered and plots may be chosen and study may be made with the fix up of seasons as per the guideline made earlier. No change will takes place in case of trees as the data type is girth and height. So, in case of herbs and shrubs seasonal change give you data. For shrubs minute change takes place where as in case of herbs, a great change will be noticed. Take GPS readings (Latitude, longitude and altitude) to know the global position. Make a local map with the help of local people using participatory rural appraisal (PRA) technique. This would help you better understanding about the habitat to be taken for continuous field study. Study the characters of vegetation, soil, flora, fauna, soil microbes, etc. to know the condition of ecosystem on a trial basis. Standard indices may be made using different formulae. Say for example, frequency, density, abundance and importance value index (IVI) of species, biomass estimation, coverage of vegetation study and canopy cover study etc. These are required to qualify the goals and quantify the vegetation in terms of standard. Diversity index, dominance index (Concentration of dominance), richness index, evenness index, equitability index and similarity index are the various indices used till date.

Fig.1 Sal (Shorea robusta Vegetation at Lalgarh, Jhargram, West Bengal, India

IV. CONCLUSION

I conclude that go to the field with full basic knowledge and apply the methodology for proper assessment of vegetation by knowing present scenario of ecosystem based vegetation characters, not the earlier too.

V. ACKNOWLEDGEMENTS

I acknowledge to my teacher Dr. M. S. Mandal, Additional Director (Retired), Botanical Survey of India, Head Quarter, Kolkata and Dr. T. K. Mishra, expert of Forest Ecology and Retired Principal, Vidyasagar College, Kolkata for their help as and when required. I am also thankful to those who are lived in Forest premises and monitoring vegetation every day without any applied scientific knowledge though full of basic knowledge.

REFERENCES

[1] Shannon, C.E. 1948. A mathematical theory of Communication, Bell System Technical Journal, 27: 379-423.
[2] Sax, D.F. 2002. Equal diversity in disparate species assemblages: a comparison of native and exotic woodlands in California, Global Ecology and Biogeography, 11: 49-57.
[3] Pandey, B.N and Kulkarni, G.K. 2006. Biodiversity and Environment, S.B. Nangia, APH Publishing Corporation.
[4] Price, P. W. 1975. Insect Ecology, John Willey and Sons.
[5] Niklaus, P.A; Leadley, P.W; Schmid, B and Korner, C. H. 2001. A long term field study on Biodiversity x elevated Co2 interactions in grassland, Ecological Monographs, 71: 341-356.
[6] Sarma, P and Das, D. 2015. Application of Shannon's Index to Study Diversity with reference to Census data of Assam, Asian Jour. of Management Research, 5(4): 620-628.
[7] Das, D. 2007. Study of Vegetation ecology of forests of Southwest Bengal with special reference to Non-timber Forest Produce Productivity, Ph.D. Thesis, Awarded from Vidyasagar University, Midnapore, Paschim Medinipur, W.B.
[8] Das, D. 2016. Ecological Studies on Jhitka Forest under Medinipur Forest division, IJSART, 2(12): 296-302.
[9] D. Das. 2017. Spectrum of Vegetation in March at Lalgarh Forest of Jhargram Disatrict in West Bengal, India, Indian J. Appl. & Pure Biol., 32(2): 217-226.
[10] Das, D. 2017. Present Day Scenario of Forest ecosystem in Lalgarh for Sustainable development in Paschim Medinipur District of West Bengal, National Conference on Nonlinear Dynamics and Its Applications (CNDA-16), Feb. 07-09, Department of Physics, Durgapur Govt. College, West Bengal.
[11] Mishra, R. 1968. Ecology Work Book, Oxford and IBH Publishing Company, New Delhi.
[12] Das, D. Study of June Vegetation at Lalgarh forest of Jhargram District in West Bengal, India, 3(7): 163-171.
[13] Das, D. 2018. *Chromolaena odorata* (*Eupatorium odoratum*)-An Exotic weed used in Lalgarh, Jhargram, West Bengal for Fuel wood purpose, IJSART, 4(11): 924-930.
[14] Leeuwis, T; Peel, M and de Boer, WF. 2018. Complexity in African savannas: direct, indirect and cascading effects of animal densities, PLoS ONE, 13(5): e0197149.doi:10.1371/journal.pone.0197 149.
[15] Anonymous. 2018. Perspectives in Plant Ecology, Evolution and Systematics, ISSN:1433-8319, Editors, Peter J. Edwards, Claus Holzapfel, Elvira Horandl, Florian Jeltsch, Diethart Matthies, Kirk A. Moloney, George Perry .Elsevier publication.
[16] Das, D; Ghosh, R. B and Mishra, T.K. 2002. Biological spectrum of the Vegetation in the Campus of Vidyasagar University, Midnapore, West Bengal, Vidyasagar University Journal of Biological Sciences, 8: 87-91
[17] Simpson, E. H. 1949. Measurement of Diversity, Nature, 163: 688-699.
[18] Pielou, C. 1966. Species diversity and pattern diversity in the study of ecological succession, Jour. of Theor. Biol, 10: 370-383.
[19] Margalef, R. 1958. Information Theory in Ecology, Gen. Syst., 3: 36-71.
[20] Sorensen, T. 1948. A method of establishing groups of equal amplitude in plant sociology based on similarity of species and its application to analyzes of the vegetation on Denish commons, Biologiske Skrifter/Kongelige Danske Videnskabernes, 5: 1-34.
[21] Muller-Dombois, D and Ellenburg, H. 1974. Aims and methods of vegetation ecology, John Willey & Sons inc., New York.