Plant Science Research 36 (1&2) : 34-42, 2014

Plant Science Research

ISSN 0972-8546

Application of quantitative approach on the analysis of oak-mixed forests in India and Japan

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ARTICLE INFO

Article history:
Received : 2 August 2014
Received in revised form : 15 October 2014
Accepted : 19 November 2014

Keywords:
Oak-mixed forest
Floristic diversity
Plytosociology
Shikinomori protected forest

ABSTRACT

The present study was carried out to analyze the vegetation of Shikinomori Park Protected Forest, Japan and to find out the species composition and vegetation structure. A total of 14 tree species, 24 shrub species and 60 herb species were recorded in the forest under study. The families Liliaceae and Poaceae were best represented in the forest followed by Araliaceae, Lauraceae and Dryopteridaceae. Random distribution was most common in all the three vegetation layers. However, *Prunus grayana* exhibited weak regular distribution and *Fatsia japonica*, *Aucuba japonica* and *Pleioblastus chino* exhibited contiguous distribution. There appeared contiguous distribution among seedlings of *Quercus serrata* and random distribution among seedlings of *Q. myrsinaefolia*. There is no definite pattern of frequency distribution conforming to Raunkiaer's Law of Frequency. However, most of the species have fallen in class B for trees and herb layers and class D for shrub layer. A comparison of Oak forests of Central Himalayan region with the present Shikinomori Protected Forest indicates that in both the ecosystems the Oak species accounted for more than 30% of the IVI. Further, at genus level, some common plants are represented in both the forests. The study establishes the highly diverse habitat of Shikinomori Protected Forest is a rich gene pool of biodiversity.

1. Introduction

Forests occupy a unique natural resource position because of its non-renewable nature and have been more in demand for fuel wood, fodder, non forest produce like minerals and soil. Rapid destruction of forests has caused severe damage to natural habitats, thus threatening the very survival of several indigenous species of plants and animals. Therefore, a number of plants are in danger of extinction and many of the rare, endangered and insufficiently known plants of indigenous species are no more seen in their original habitat. To protect the depleting floristic diversity, and to rehabilitate the degraded area, proper conservation and management strategies are required through ecological management interventions such as by creating biosphere reserves, reserve forests, national parks, sanctuaries, etc. Rehabilitation of degraded areas by indigenous natural biotic population seems to be only answer in many areas where we need to re-establish the indigenous flora and flora which are facing the threat of extinction.

For the management of biodiversity, and rehabilitation of natural species, particularly in protected areas, it is essential to understand the roles of species. Species functional groups across the ecological gradients, edaphic factors; species traits acquire and utilize resources from the environment to a large extent which is central to the role of species in pattern and process of communities and ecosystems.

Tropical ecosystems with high level of biological diversity and habitat heterogeneity, are facing massive

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degradation and alteration of habitat characters due to intense development oriented anthropogenic activities (Howard and Lanly, 1975). Tropical forest environment is quite different from the temperate ones in which almost all the developed countries are located and need special attention for developing specialized individuals and institution to deal with the problems of degradation of various kinds. It is in this context that ecological knowledge, particularly on vegetation survey techniques (phytosociology) to investigate ecological structure and function of natural vegetation and to suggest strategy (on the basis of study) for rehabilitation of degraded areas with potential natural vegetation become absolutely essential .

Thus, conservation and management of forests require understanding of the composition of particular forests in relation to other forests, the effects of past impacts and the present status, the present relationship of the forest with surrounding land uses and qualitative and quantitative assessment of forest vegetation (Geldenhuys and Murray, 1993). Finding out the potential natural vegetation through phytosociological tool to use them in rehabilitation of degraded lands is essential particularly when we have to take holistic view to conserve all the biotic components of the food chain of an ecosystem. The present study is one such step towards applying ecological techniques to know potential natural vegetation which will help in ecological restoration programmes in degraded habitats.

2. Materials and methods

2.1 The study site

This phytosociological study was carried in Shikinomori park protected forests of Yokohama, Kanagawa Prefecture, Japan. The Park Forest area are located at an elevation ranging from 36 to 62 m msl and slope of site was in the range of 10-30^0. Annual mean temperature and precipitation of Yokohama is 15.8 ^{0}C and 1688.60 mm respectively (1981-2000). The park is located in warm temperate zone and includes some type of forest vegetation such as evergreen/deciduous oak forests and Japanese cedar plantation etc.

2.2 Phytosociological analysis

We selected study sites at different locations by laying three quadrats. The quadrat size and number of quadrats to be laid during survey was also discussed with experts before sampling. All the trees, shrubs and herbs species in quadrats were enumerated and indentified by Dr. Shigetoshi Okuda. All the trees occurring inside the quadrat were recorded and measured for girth at breast level (1.37 m). Quantitative data collected during field survey were subjected to various statistical calculations to derive results and standard methods of calculations and formulae were used (Curtis and McIntosh, 1951; Tuxen, 1956; Curtis, 1959; Philips, 1959; Kershaw, 1973; Misra, 1968). Data of the quadrats were also used for calculation of structural parameters of vegetation).

The frequency values obtained were grouped in frequency classes to study the homogenous/ heterogeneous nature of vegetation (Raunkiaer, 1934). The Law of Frequency states that the numbers of species of a community in the 5 percentage frequency classes are distributed as-

$$A > B > C \geq D < E$$

Where, A = frequency class- 0 to 20; B = frequency class- 21 to 40; C = frequency class- 41 to 60; D = frequency class-61 to 80; and E = frequency class- 81 to 100.

Relative frequency, relative density, relative basal area and the aivi were calculated following standard methods (Curtis and McIntosh,1951). The A/F value was calculated from the data of abundance and frequency of individual species (Cottam and Curtis, 1956). Species diversity of trees, and seedlings were determined with the Shannon-Wiener diversity index (Shannon and Wiener, 1963). Concentration of Dominance was calculated to evaluate the level of dominance of a species within a community and was expressed by Simpson's Index (1949). Species Evenness Index (EI) was calculated as per Pielou (1975). Species Richness Index (RI) was calculated as per Margalef (1958). Similarity Index/ Community Co-efficient was calculated by Jaccard (1912) to compare two plant communities to find out resemblance between each other in appearance. Sorensen's (1948) formula for similarity index was used for the present study.

3. Results and discussion

3.1 Study site characteristics

We examined the dominance and constancy of each plant species (tree, shrub, herb, climber and seedlings of trees) as per the methodology given by Braun- Blanquet (1964). Average height of upper tree canopy was recorded 17-30 m with canopy cover ranging from 80-95%. Average height of shrub and herb layers was 1.5-3.0 m and 0.3-0.8 m and cover ranging from 10-40 and 30-90%, respectively, across all quadrats.

3.2 Floristic composition

The study explored the presence of 98 different naturalised plant species belonging to 55 families and representing a three storeyed floristic composition at these sites. Different storeys, observed, were 1) Upper canopy or upper strata, tree 2) Middle storey or under storey consisting of shrubs and saplings and 3) Under growth consisting of shrubs, seedlings and herbs of seasonal and perennial type. In addition to these storeys more than 5 climber species were also recorded growing in association with different shrubs and tree species. Trees comprising 14 species were from different families (Table 1). The respective numbers of species belonging to shrubs and herbs recorded were 24 and 60, respectively (Table 2 and 3). A majority of the families across all vegetation layers were represented by only two or less species. The best represented families were Liliaceae and Gramineae (each 7 species), Araliaceae, ,Lauraceae and Dryopteridaceae (each with with 5 species) followed by family caprifoliaceae,Cornaceae, and Compositeae.

3.3 Distribution pattern of species

Of the 14 tree species recorded in the study area (Table 1), nearly all species exhibited random distribution (7 species) or contiguous distribution (6 species). Only one species *Prunus grayana* exhibited weak regular distribution (nearing random). Among 24 species of shrubs, similar trend like trees was observed; Random (11 species),Contiguous (9 species) and Regular (4 species). Contiguous distribution was more pronounced in *Fatsia japonica, Aucuba japonioca*, and *Pleioblastus chino* among shrub species. The herb layer species exhibited pronounced random distribution followed by contiguous distribution and weak regular distribution. Whereas the seedlings of *Q, serrata* were observed in patches (contiguous), the seedlings of *Q. myrsinaefolia* exhibited random distribution.

3.4 Raunkiaer's frequency class distribution

Raunkiaer's law of frequency (also known as the law of homogeneity) was expressed as A> B > C ≤ ≥ D < E, wherein, A to E are frequency classes suggested by Raunkiaer's from 0 to 100 (Raunkiaer, 1934). There is no definite pattern of frequency distribution conforming to above order probably because sample size is too small to derive frequency class (Fig.1). However, most of the species have fallen in class B for trees and herb layers and class D for shrub layer. The increase in class E reflects the theoretical infinite range of density and contrasts with the more strictly defined limits for classes A, B, C, and D (Kershaw 1973).

Table 1

Phytosociological data for the tree layer species of Shikinomori Protected forest

Name of tree species	F	D	A	A/F	H	Cd (%)	RD	RF	RBA	IVI
Quercus myrsinaefolia Blum.	100	5.33	5.33	0.05	0.363	18.70	43.24	17.65	40.69	101.58
Chamaecyparis obtusa (Siebold & Zucc.) Endl.	33.33	0.33	1	0.03	0.098	0.07	2.70	5.88	0.50	9.09
Quercus serrata Roxb.	33.33	0.67	2	0.06	0.158	0.29	5.41	5.88	12.05	23.33
Cornus macrophylla Wall.	33.33	0.67	2	0.06	0.158	0.29	5.41	5.88	9.46	20.75
Kalopanax pictus (Thunb.) Nakai	33.33	0.67	2	0.06	0.158	0.29	5.41	5.88	1.57	12.86
Prunus grayana Maxim.	66.67	1.00	1.5	0.02	0.204	0.66	8.10	11.77	10.21	30.08
Prunus jamasakura Siebold	33.33	0.67	2	0.06	0.158	0.29	5.41	5.88	12.10	23.39
Styrax japonicus Siebold & Zucc.	33.33	0.67	2	0.06	0.158	0.29	5.41	5.88	2.28	13.56
Cornus controversa Hemsl.	33.33	0.67	2	0.06	0.158	0.29	5.41	5.88	9.03	20.32
Machilus thunbergii Siebold & Zucc.	33.33	0.33	1	0.03	0.097	0.07	2.70	5.88	0.78	9.37
Ligustrum lucidum W.T.Aiton	33.33	0.33	1	0.03	0.098	0.07	2.70	5.88	0.35	8.93
Stachyurus praecox Siebold & Zucc	33.33	0.33	1	0.03	0.098	0.07	2.70	5.88	0.42	9.01
Celtis sinensis var. japonica (Planch.) Nakai	33.33	0.33	1	0.03	0.098	0.07	2.70	5.88	0.35	8.93
Viburnum plicatum var. tomentosum Miq.	33.33	0.33	1	0.03	0.098	0.07	2.70	5.88	0.22	8.81
		12.33			2.098	21.55				

F= Frequency; D= density; A= Abundance ;A/F = Abundance/Frequency; H/= Species Diversity; Cd= Concentration of Dominance, *RD= relative density; RF= relative Frequency; RBA= Relative Basal Area;* E.I. (Evenness index)= 1.83058

Table 2

Phytosociological parameters for the shrub layer species of Shikinomori Protected forest

Name of species of shrubs	F	D	A	A/F	RF	RD	RA	IVI	F Class
Acanthopanax spinosus	33.33	1	3.0	0.09	3.03	1.89	2.52	7.44	B
Aucuba japonica	66.67	15.667	23.5	0.35	6.06	29.56	19.75	55.37	D
Broussonetia kazinoki	33.33	0.33	1.0	0.03	3.03	0.63	0.84	4.50	B
Callicarpa japonica	66.67	1.00	1.5	0.02	6.06	1.89	1.26	9.21	D
Cocculus orbiculatus	33.33	0.33	1.0	0.03	3.03	0.63	0.84	4.50	B
Daphne pseudo-mezereum	33.33	0.33	1.0	0.03	3.03	0.63	0.84	4.50	B
Dendropanax trifidus	33.33	0.33	1.0	0.03	3.03	0.63	0.84	4.50	B
Eurya japonica	33.33	0.33	1.0	0.03	3.03	0.63	0.84	4.50	B
Fatsia japonica	33.33	2.67	8.0	0.24	3.03	5.03	6.72	14.79	B
Hedera rhombea	33.33	0.33	1.0	0.03	3.03	0.63	0.84	4.50	B
Helwingia japonica	66.67	1.33	2.0	0.03	6.06	2.52	1.68	10.26	D
Ilex crenata	66.67	0.67	1.0	0.02	6.06	1.26	0.84	8.16	D
Ligustrum japonicum	66.67	1.67	2.5	0.04	6.06	3.15	2.10	11.31	D
Lindera umbellata	33.33	0.67	2.0	0.06	3.03	1.26	1.68	5.97	B
Osmanthus heterophyllus	33.33	0.67	2.0	0.06	3.03	1.26	1.68	5.97	B
Pleioblastus chino	33.33	16.67	50.0	1.50	3.03	31.45	42.02	76.49	B
Quercus myrsinaefolia	33.33	1.33	4.0	0.12	3.03	2.52	3.36	8.91	B
Stachyurus praecox	66.67	1.33	2.0	0.03	6.06	2.52	1.68	10.26	D
Stephanandra incisa	66.67	0.67	1.0	0.02	6.06	1.26	0.84	8.16	D
Thea sinensis	33.33	0.33	1.0	0.03	3.03	0.63	0.84	4.50	B
Trachelospermum asiaticum	33.33	0. 67	2.0	0.06	3.03	1.26	1.68	5.97	B
Trachycarpus fortunei	66.67	3.67	5.5	0.08	6.06	6.92	4.62	17.60	D
Viburnum erosum	33.33	0.33	1.0	0.03	3.03	0.63	0.84	4.50	B
Wisteria floribunda	66.67	0.67	1.0	0.02	6.06	1.26	0.84	8.16	D
Total	1100	53	119		100	100	100	300	

F= Frequency; D= density; A= Abundance; RF= Relative frequency; D= relative Density; RA= Relative Abundance; IVI= Importance Value Index.

Concentration of Dominance= 0.19845; Species Diversity= 2.18109

This fifth class has a possible density range greatly exceeding that occurring in the remainder of the frequency classes A to D. Accordingly many more species fall into this class, despite the general tendency for 'common' species to be relatively few in number in a community".

3.5 Species diversity and concentration of dominance

The species diversity depends upon adaptation of species and increases with stability of community (Singh *et al.,* 1994). Shannon Wiener species diversity was 3.287, 3.423, and 2.699, respectively, for tree, shrub and herb layers of the Shikinomori Park (Table 4). The tree, shrub and herb layer species of the Shikinomori Park are highly diverse. The dominance is more pronounced in shrub layer. The Concentration of Dominance was 0.197, 0.237 and 0.198, respectively, for tree, shrub and herb layer species. Species richness and equitability is higher in shrub species and low in tree species. Similarity index value shows that the species of three quadrats of tree layer of Shikinomori Park has only less than 25% similarity, perhaps indicating the influence of microclimate on the species distribution. The study quadrats were laid on different aspects with differences in altitude.

Table 3

Importance value Index (IVI) for the herb layer species of Shikinomori Protected forest

Name of herbaceous species	F	D	A	A/F	RF	RD	RA	IVI	F class
Acanthopanax nipponicus	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Achyranthes bidentata var. japonica	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Akebia quinata	66.67	1.33	2	0.03	2.53	1.17	0.783	4.484	D
Akebia trifoliata	33. 33	0.67	2	0.06	1.27	0.59	0.783	2.633	B
Aphananthe aspera	66.67	0.67	1	0.02	2.53	0.59	0.391	3.508	D
Arachniodes standishii	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Ardisia crenata	66.67	0.67	1	0.02	2.53	0.59	0.391	3.508	D
Ardisia crispa	33.33	1.67	5	0.15	1.27	1.46	1.957	4.685	B
Ardisia japonica	66.67	1.33	2	0.03	2.53	1.17	0.783	4.484	D
Berberis thunbergii	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Carex duvaliana	33.33	10	30	0.90	1.27	8.77	11.742	21.779	B
Carex lenta	33.33	0.67	2	0.06	1.27	0.59	0.783	2.633	B
Cephalanthera longibracteata	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Cimicifuga japonica	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Coniogramme japonica	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Cryptomeria japonica	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Cymbidium goeringii	66.67	0.67	1	0.02	2.53	0.59	0.391	3.508	D
Cyrtomium fortunei	33.33	1	3	0.09	1.27	0.88	1.1742	3.317	B
Daphne pseudo-mezereum	33. 33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Desmodium podocarpium ssp. oxyphyllum	66.67	1.67	2.5	0.04	2.53	1.46	0.979	4.972	D
Dioscorea japonica	33.33	0. 33	1	0.03	1.27	0.29	0.391	1.950	B
Dioscorea tokoro	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Disporum sessile	66.67	0.67	1	0.02	2.53	0.59	0.391	3.508	D
Dryopteris erythrosora	100	5	5	0.05	3.80	4.39	1.957	10.140	E
Dryopteris uniformis	66. 67	1.33	2	0.03	2.53	1.17	0.783	4.484	D
Dryopteris varia var. setosa	33.33	0.67	2	0.06	1.27	0.59	0.783	2.633	B
Elaeagnus macrophylla	33.33	1.33	4	0.12	1.27	1.17	1.566	4.001	B
Euonymus sieboldianus	33.33	0.67	2	0.06	1.27	0.59	0.783	2.633	B
Euscaphis japonica	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Fatsia japonica	33.33	1	3	0.09	1.27	0.88	1.174	3.317	B
Gynostemma pentaphyllum	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Hedera rhombea	100	10	10	0.1	3.80	8.77	3.914	16.483	E
Hosta sieboldiana	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Houttuynia cordata	33.33	0.67	2	0.06	1.27	0.59	0.783	2.633	B
Kalopanax pictus	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Lindera glauca	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Lindera umbellata	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Liparis nervosa	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B

Liriope muscari	66.67	2.33	3.5	0.05	2.53	2.05	1.370	5.948	D
Lonicera japonica	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Mahonia japonica	33. 33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Morus Australis	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Neolitsea sericea	66.67	0.67	1	0.02	2.53	0.59	0.391	3.508	D
Ophiopogon japonicus	66.67	1.33	2	0.03	2.53	1.17	0.783	4.484	D
Ophiopogon ohwii	33.33	13.33	40	1.2	1.27	11.70	15.656	28.617	B
Oplismenus undulatifolius	66.67	2	3	0.05	2.53	1.75	1.174	5.460	D
Osmunda japonica	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Parthenocissus tricuspidata	33.33	0.67	2	0.06	1.27	0.59	0.783	2.633	B
Pertya scandens	33.33	2.33	7	0.21	1.27	2.05	2.740	6.052	B
Pleioblastus chino	33.33	2.33	7	0.21	1.27	2.05	2.740	6.052	B
Quercus myrsinaefolia	66.67	18.67	28	0.42	2.53	16.37	10.9589	29.865	D
Quercus serrata	33.33	3.33	10	0.3	1.27	2.92	3.914	8.104	B
Smilax china	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Stegnogramma pozoi ssp. mollissima	66.67	0.67	1	0.01	2.53	0.59	0.391	3.508	D
Syneilesis palmata	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Trachelospermum asiaticum f. intermedium	33.33	12	36	1.08	1.27	10.53	14.090	25.882	B
Viburnum dilatatum	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Viola grypoceras	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Viola hondoensis	33.33	0.33	1	0.03	1.27	0.29	0.391	1.950	B
Wisteria floribunda	66.67	3.67	5.5	0.083	2.53	3.22	2.153	7.901	D

F= Frequency; D= density; A= Abundance; RF= Relative frequency; D= relative Density; RA= Relative Abundance; IVI= Importance Value Index.

Concentration of Dominance= 0.07425; Species Diversity= 3.1601

3.6 Dominance- diversity curve

Plotting 'dominance- diversity curves' is a method of exploring species abundance relationships (Whittaker 1965, 1969, 1972). By ordinating IVI (log values) against the species sequence, we can assess the community organisation in terms of resource share and niche space. This is based on the assumption that there is some correspondence between the share of community's resource a species utilizes and the share of community's niche space it occupies. Thus, degree of resource apportionment is considered as a measure of resource conservation (Pande et al. 2001). The D-D curve is log normal in shape for the study site (Fig. 2). This means, the large number of factors determine the number of species (diversity) in a community. A log normal condition represents high diversity condition. (Pande *et al.* 2002). On the other hand, species which show geometric series conform to the 'niche pre emption' hypothesis postulated by Whittaker (1975). The geometric form is often exhibited by vascular plant communities having low species diversity and it is indicative of low competition among the species because IVI of species is proportional to the amount of the resources they utilize (Whittaker 1972). It is observed from the D-D curve that *Quercus myrsinaefolia, Prunus grayana, Prunus jamasakura, Q.serrata,Cornus macrophylla* and *Cornus controversa* are the dominant species and thus use most part of the resources available in the forest and the rest 8 species use the balance of the resources. However, *Quercus myrsinaefolia* seems to enjoy highest proportion of resources and the curve shows a moderate steep downfall after this species. Balance resources are shared between the rest 13 tree species of the Shikinomori Park.

3.7 The potential natural vegetation

From vegetation analysis results, it is observed that *Quercus myrsinaefolia* is the dominant species of

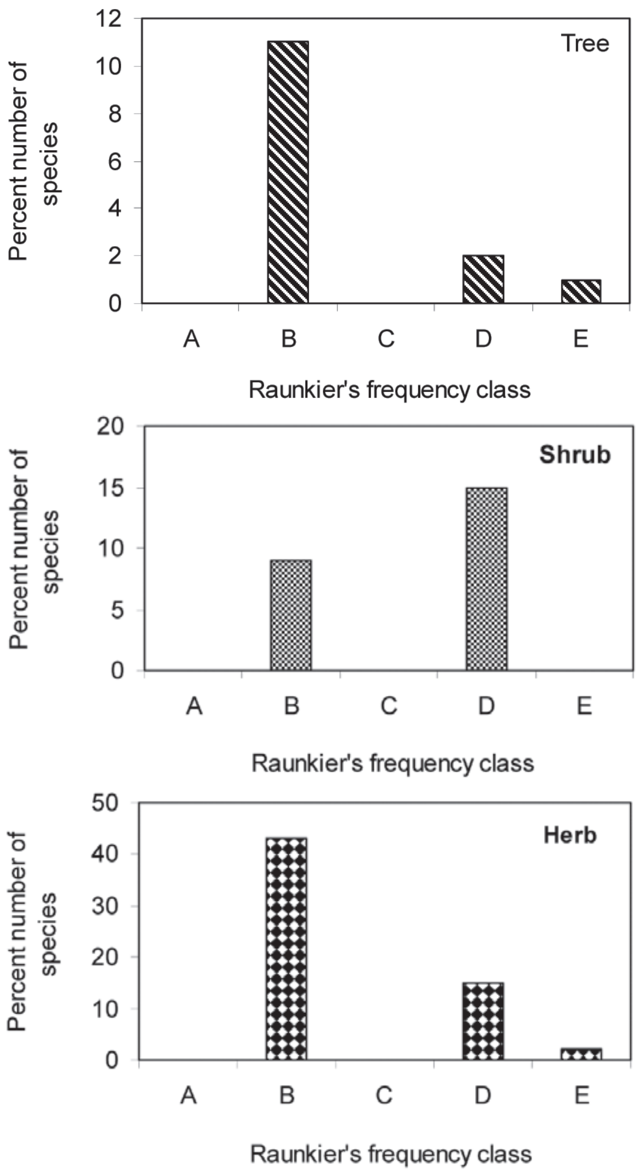

Fig.1. Raunkier's Frequency Class for Vegetation of Shikinomori Park

Shikinomori Park Forest showing nearly random distribution. It accounts for 1/3rd of the total IVI values of the forest among tree species which shows strong dominance character of this species. From D-D curve (Fig.2) it is also observed that *Q.myrsinaefolia* enjoys highest proportion of resources of the forest as it is placed at the top of the species sequence.

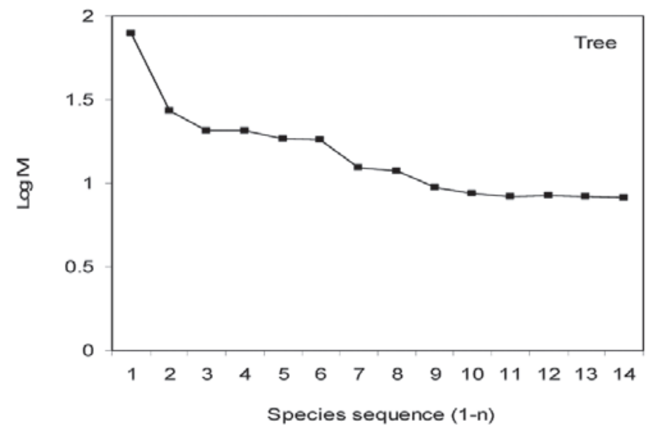

Fig 2. Dominance-Diversity curve for tree layer of Shikinomori park protected site on the basis of IVI Values.

Thus, *Q.myrsinaefolia* qualifies for being 'Potential Natural Species" (PNS) of the Shikinomori Park. Among the shrub layer species, *Pleioblastus chino* and *Aucuba japonica* are the 1st and 2nd dominant species. The Seedlings of *Q.myrsinaefolia* also exhibited highest IVI values among ground flora species with density of >18%. Among herb layer species, *Carex duvaliana, Dryopteris erythrosora, Hedera rhombia, Ophiopogan ohwii* and *Tracheospermum asiaticaum* are the dominant species enjoying higher proportion of resources and these species are natural associations of Potential Natural Vegetation (PNV) dominated by *Q.myrsinaefolia.* It was observed that a total of 55 families were represented across all sites located in Kanagawa Prefecture. Therefore, it is concluded that the flora of the Kanagawa Prefecture is extremely diverse and seems to be one of the richest of the protected ecosystems in the area. Presence of 55 families indicates richness in biodiversity and these habitats are gene banks of the majority of important keystone species.

We have attempted to compare species composition of Oak and Mixed Oak Forest of Central Himalaya and Shikinomori Protected Forest of Japan. Table 5 provides list of trees, shrub and herb species of Central Himalaya. It is observed that *Quercus* species is associated with genus *Prunus, Machilus, Celtris* and *Viburnum* in both the ecosystems. There are shrubs like *Viburnum* and *Daphne* and herbaceous plants with genus like *Achyranthes, Carex,*

Table 4

Species diversity and related parameters of tree, shrub and herb layer species of Shikinomori Park

Vegetation	Shannon Index (H')	Simpson's Index (Cd)	Species richness(d)	Equitability (e)
Tree layer	3.287	0.197	2.070	1.246
Shrub Layer	3.423	0.237	2.918	3.135
Herb Layer	2.699	0.198	1.448	2.485

Table 5

Composition of Oak and Mixed Oak- Conifer Forest of Himalaya (Singh, 1999, Upadhyay, 1995)

Broadleaf Forests	Broadleaf mixed with Conifer Forest	Conifers Mixed with Broadleaf Forest
Trees		
Acer acuminatum, A. cappadocicum, Ainsliea aptera, Berginia ciliate, Bidens pilosa, Carex nubegina Celtris australis, Desmodium triflorum, Galium aprine, Hedera nepalensis, Impatiens sulcata, Lyonia, valifolia, Phacelurus speciosus, Polygonum affinis, Prunus cornuta, Quercus floribunda, Q. eucotrocophora, Q. semicarpifolia, Rhododendron barbatum, Senecio chrysanthenoides, S. rufinervis, Taxus wallichiana, Viburnum nervosum	*Abies pindrew, Acer acuminatum, Aesculus indica, Carpinus viminea, Engelhardtia colebrookiana, Eugenia frondosa, Euonymus tingens, Eurya acuminate, Ilex dipyrena, Juglans regia, Lyonia ovalifolia, Machilus duthiei, Myrica esculenta, Myrsine, emiserrata, Picea smithiana, Pinus roxburghii, P. allichii, Prunus cornuta, Pyrus pashia, Quercus eucotrichophora, Q. semecarpifolia, Randia etrasperam, Symplocos crataegoides, Syzigium cumini*	*Abies pindrew, Acer acuminatum, Acer caeseum , A. cappadocium, Cedrus deodara, Picea smithiana, Quercus floribunda, Q. glauca, Q. semicarpifolia, Rhododendron arboretum, Taxus wallichiana*
Shrubs		
Adiantum venustum, Astible rivularis, Berberis chitra, Coniogramme affinis, Cotoneaster affinis, Cynoglossum lochidiatum, Desmodium elegans, Erigeron, anadensis, Indigofera heterantha, Iris milesii, Oplimenus undulatifolius, Pilea umbrosa, Polygonum amplexicaulis, Prinsepia utilis, Pyrus pashia, Rosa serecia, Rubus niveus, Saussurea graciliforus, Viburnum nervosum	*Viburnum nervosum*	*Daphne papyracea, Jusminum humile, Lonicera purpuresence, Principia utilis, Rosa webbiana, Viburnum nervosum*
Herbs		
Achyranthus aspera, Anaphalis busua, Artemisia vulgaris, Arundineria fulcata, Carex nubigena, Centella asiatica, Clematis montana, Diplazium esculantum, Fragaria vesca, Gallium aprine, Girardinia diversifolia, Helictotrichon viresceus, Iris milesii, Onichyum cryptogrammoides, O. japonicum, Oplismenus composites, Parochetus communis, Polygala crotolariodes, Salvia nubicol, Scutellaria angulosa, Smilex parviflora, Stachys aspara, Themeda anther, Valeriaga wallichii, Viola biflora , V. serpens	*Aconitum tetrasepala, A. venutum, Apluda mutica, Asparagus filicina, Calanthe tricarinata, Cappilidium assimile, Carex condensate, Chrysopogon serrulatus, Clematis barbata, Coniogramme fraxinea, Cyperus iria, Cyrtomium caryotideum, Diplazium fieldinzianum, Dryopteris sparsa, Erigeron bonariensis, Fragaria vesca, Lastrea divida, Leucas lanata, Malva verticillata, Muhlenbergia himalensis, Nicus argericanthus, Oplismenus composites, Oxalis acetosa, Pouzolzia hirta, Pteris critica, Remusatia hookeriana, Senecio graciliflorus, Smilacena purpurea, Urtica dioca, Urtica sp*	*Adiantum venustum, Ainsiliaea aptera, Anemone rivularis, Astrobilanthus atropurpures, Commelina paludosa, Crotolaria cytosoidies, Cymbopogon distans, Desmodium tiliaefolium, Dryopetris sparsa, Flemengia fruticulosa, Fragaria vesca, Geranium nepalensis, G. wallichiana, Goldfusia dalhousiana, Grardiana diversifolia, Habeneria marginata, Hedera nepalensis, Impatience sulcuta, Iris mellessi, Murdannia divergence, Onychium japonicum, Ophiopogan intermedia, Oplismenus composites, Oxalis acetosa, O. corniculata, Pilea umbrosa, Polygonum affinis, Potentilla microphylla, Roscoea alpine, Rubia cordifolia, Smilicena purpurea, Stipa roylei, Strobilanthes dalhausianus, Thelictrum foetidum, Viola biflora, Vitis himalayana*

Dryopteris, Hedera, Oplismenus, Ophiopogan, Smilax and *Viola* that represent both the Central Himalaya and Shikinomori habitats. Further it is observed that middle elevation ranges show IVI value of more than 100 of *Q. leucotrichophora* (Singh and Singh, 1987). The Shiknomori Protected Forest also has been represented by *Q. myrsinaefolia* with IVI value of more than 100. The Oak forests of both the ecosystems therefore, indicate that *Quercus* species with high IVI values are potential natural species.

Acknowledgements

The work was carried out as a part of JICA Sponsored training course. We thank all the staff and trainees of the course *"Rehabilitation of Degraded Lands in Asia and Africa"* viz., Dr. S. Veophet, Mr. S. H. Aung, Ms. I. Syphavanh, Mr. S. N. Njihia, Mr. R.K. Srivastava, Mr. A.N. Nyabuti and Mr. A. Z. Moe and all the experts for their guidance during field. Our special thanks are also due to Ms. A. K. Akhmetova who helped in data arrangement of the field analysis results. The help extended by the authorities of Shikinomori Park Protected Forest is gratefully acknowledged. The help received for calculation of the ecological parameters from Dr. S. S. Bargali, Kumaun University,Nainital India and Dr R. K. Mishra, North Orissa Univ. Mayrbhanj, Odisha India is also gratefully acknowledged. The present paper is dedicated to Professor Akira Miyawaki from whom we got all inspirations for the study report.

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