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Study of Various Plant Communities' Profiles in Yamuna Biodiversity Park, Delhi, India

Azis Kemal Fauzie[1], Sreenivasa[2]

[1]School of Environmental Studies, University of Delhi, Delhi, India – 110007
Department of Studies in Environmental Science, University of Mysore, Mysore, India – 570006

[2]Department of Studies in Environmental Science, University of Mysore, Mysore, India – 570006

Abstract: ***The purpose of research was to study various plant communities' profiles and to compare with the earlier condition. The stratified random sampling method was taken by selecting 15 plots in quadrat size to measure density, diversity, richness, abundance, and girth at breast height (GBH). Results showed that more species richness will have less diversity. The homogeneity of sites correlate with their species abundance. Inversely proportional relationship between GBH and density indicates that plant density does not relate to the maturity of forests. Comparison with last five-year data showed that most of the sites have improved their density and diversity.***

Keywords: biodiversity park, girth-at-breast-height, plant community, shannon-wiener index, vegetation sampling

1. Introduction

Plants play a vital role in mitigating the ill effects of environmental degradation vis-a-vis enhancing the land productivity. To restore an ecological balance and to enhance the productivity of lands, it has become essential to bring large areas under tree cover. Some of the potential areas for the purpose are the salt-affected lands, which are treated as wastelands. Afforestation has been recommended as one way to reclaim saline-sodic lands. Plants tend to improve the degraded site by changing the chemical properties, physical structure, microclimate, infiltration capacity and moisture regime of the soil. With time, process such as litter fall, nitrogen fixation, root extension, crown expansion and nutrient cycling contribute to nutrient and organic matter build-up in the top soil leading to physical, chemical and biological improvement in the critical rooting zone [1].

Yamuna Biodiversity Park (YBP) which lies on river basin, or often Khadar, area of Yamuna flood plain in the semi-arid region of Delhi has many types of different plant communities. When the park first developed in 2002, the soil was found to be highly saline. The land was covered by a crust of salt deposition on its surface. This saline-sodic characteristic of the soil that revealed to have pH of up to 9.8 makes it extremely difficult for the wild plant species to survive in the park [2].

Many types of plants, most initially grasses and legumes, have been introduced to the park to reduce the soil pH and salinity and to enrich its nutrient content, so other sensitive plants can also share the habitats. Legume plants such as *Leucaena leucocephala*, *Sesbania aegyptica* and *Sesbania sesban* are some of the examples. Some indigenous plant species like *Syzygium cumini* and *Punica granatum* as well as native species like *Tectona grandis* are also introduced. Presently, after almost eight years operation, the plant communities in YBP have increased remarkably due to suitable condition of soil profile and nutrients required for plant growth.

The aim of this study is to measure the different variation of plant communities in Yamuna Biodiversity Park and to compare it with the earlier condition ever recorded in the same sites. The study is also intended to see how floral diversity grows at different type of habitats by developing the information about the growth, maturity, density and diversity of plant species. To achieve that, following objectives have been laid down: (i) vegetation sampling across the designated plant communities, (ii) calculation of vegetation profiles including plant diversity and density as well as species richness and abundance, and (iii) comparison of present condition of vegetation profiles with the earlier condition described in any available secondary data.

2. Study Area

Study was conducted in Yamuna Biodiversity Park, which is located in the region of Delhi, extended from 28º25'N to 28º53'N and 76º50'E to 77º22'E. The park itself is located at 28º44'N and 77º12'E on northern part of Delhi, specifically in Jharoda Majra Burari, near Jagatpur village, Wazirabad on western side of River Yamuna. Therefore, this park was originally a floodplain area and often experienced flooding in every monsoon season at about 3-4 decades ago [3]. YBP is located in an elevation of 682 ft above sea level and spread over an area of 437 acres. The park features two major areas i.e. the Visitor Area and the Nature Reserve Area.

Of all forests and communities provided in YBP, fifteen sites were selected as sampling locations among designated biotic communities, nine plots were in the Visitor Area and the remaining six were in Nature Reserve Area. All sites in both areas are protected and managed by joint-collaboration project between Delhi Development Authority (DDA) and the Centre for Environmental Management of Degraded Ecosystems (CEMDE), University of Delhi [3]. Most of the plots in Visitor Area were mounds ranging from 480 to 1764 m^2. The map and geographical locations of these 15 plots are described in Figure 1 and Table 1 respectively.

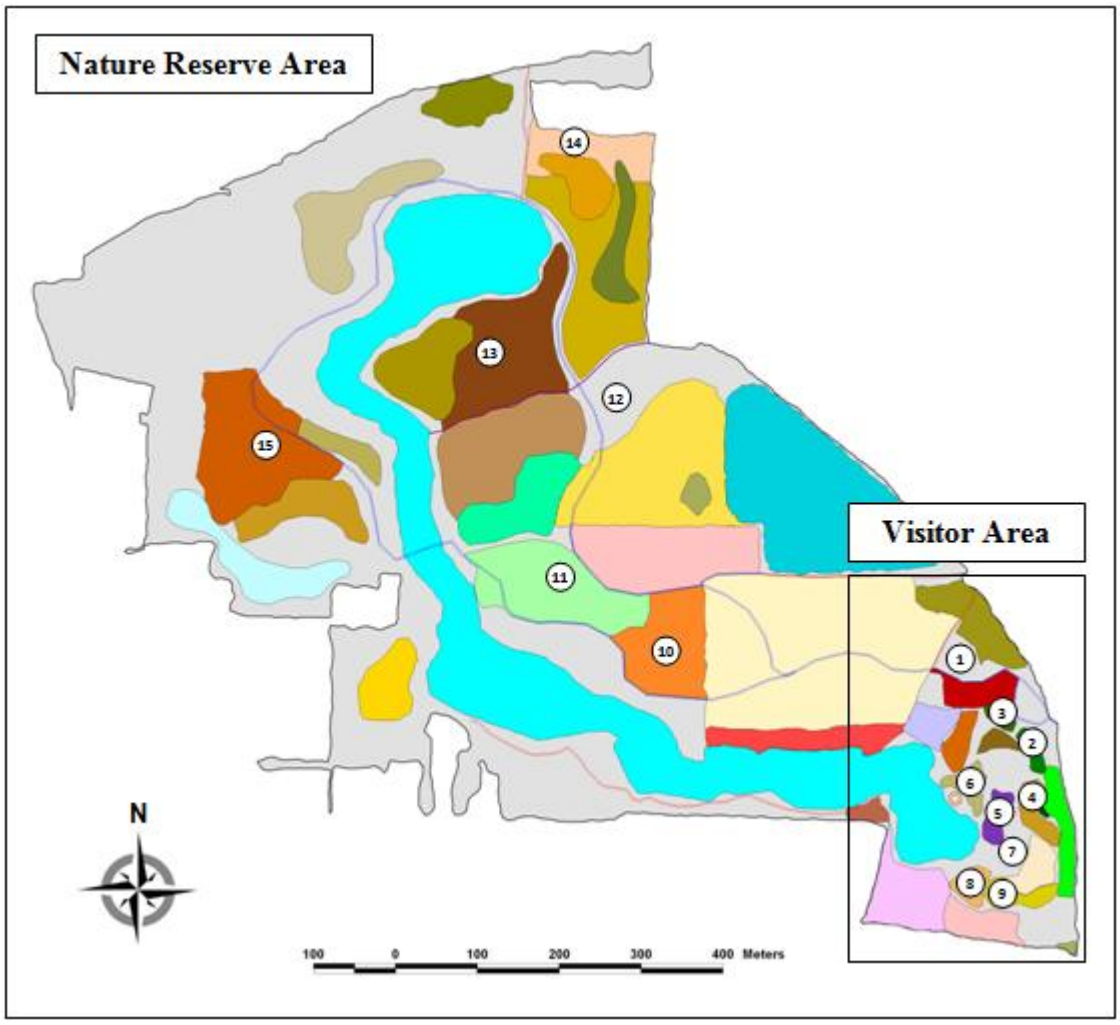

Figure 1: Map of Yamuna Biodiversity Park showing location of 15 sampling sites.

Tabel 1: Geographical locations of the plots.

No.	Names of Plant Community	Geographical Location		Area Location
1.	Mixed deciduous forest	N 28º 43' 55.8"	E 77º 13' 07.9"	
2.	Subtropical mixed evergreen forest	N 28º 43' 53.9"	E 77º 13' 09.3"	
3.	Subtropical mixed semi-evergreen forest	N 28º 43' 54.6"	E 77º 13' 08.4"	
4.	Tropical thorn forest	N 28º 43' 51.4"	E 77º 13' 09.6"	
5.	Tropical moist deciduous forest with teak	N 28º 43' 51.3"	E 77º 13' 08.3"	in Visitor Area
6.	Tropical dry deciduous forest with sal	N 28º 43' 52.2"	E 77º 13' 07.1"	
7.	Rangeland	N 28º 43' 49.0"	E 77º 13' 09.1"	
8.	Tropical mixed dry deciduous forest with bamboo	N 28º 43' 48.0"	E 77º 13' 06.9"	
9.	Tropical dry deciduous forest with teak	N 28º 43' 47.5"	E 77º 13' 08.2"	
10.	Hardwickia community	N 28º 43' 58.2"	E 77º 12' 55.6"	
11.	Grassland	N 28º 44' 00.7"	E 77º 12' 50.3"	
12.	Teak community	N 28º 44' 05.9"	E 77º 12' 52.9"	in Nature Reserve Area
13.	Tropical dry deciduous forest (Malwa forest)	N 28º 44' 06.1"	E 77º 12' 49.2"	
14.	Sal community	N 28º 44' 16.7"	E 77º 12' 53.2"	
15.	Mixed dry deciduous forest (Kuno forest)	N 28º 44' 04.7"	E 77º 12' 40.7"	

3. Material and Methods

3.1. Vegetation Sampling

In this study, stratified random sampling method [4] was used to assess vegetation profiles including plant diversity, plant density, species richness and species abundance [5]. To conduct stratified random sampling, all areas in Yamuna Biodiversity Park were divided into a number of plots according to their vegetation or forest type. Quadrat method was used to select a plot in each stratum which represents the vegetation characteristic of whole area of the forest

The quadrat used to sample the plant characteristics in a community or forest must be of such dimensions that almost all the species which occur in that community can be fully represented. Here 10×10 m^2 plot has been taken. First, a center point was taken where plant diversity could be seen. The geographical location (longitude and latitude) were recorded where the center point took place using GPS 60™ by Garmin. From the center point, all the four corners of the

plot were determined using a plotting compass (size 3″ diameter) to make them perpendicular each other.

Five of 60-80 cm long stakes were prepared for each plot made of wood or bamboo sticks. The stakes were kept straightly vertical to the soil right at the center point and at the four corners. The distance between the stakes was measured using measuring tape according to the quadrat size taken. The stake at the center point was labeled with a piece of paper covered by clear isolation tape. Plot numbers and names of community were written in the labels.

The presence or occurrence of all vegetations within the plots was recorded. Those found outside the plots were excluded in the counting. Plants were grouped into 3 categories: trees, saplings and grasses. Girth at breast height (GBH) of the trees was measured using the same measuring tape and noted down to the sampling data sheet together with their Latin names and number of occurrence. Trees were categorized as plants with GBH of 20 cm or more [6]. Any other plants below 20 cm GBH, including shrubs, herbs, seedlings and climbers, but not grasses, were categorized as saplings. Grasses are counted according to the number of clumps where the main roots come out.

3.2. Calculation of Vegetation Profiles

Species Abundance and Density
The term 'abundance' and 'density' refer to the number of plant species in the community (Michael, 1984). Abundance of any individual plant species is usually expressed as a percentage of the total number of species present in the community and is therefore a relative measure. In sampling the abundance of a species, the individuals of plant species were counted instead of just noting their presence. Abundance of a species is defined as the number of individuals per quadrat and density as the average number of the species per quadrat. Unit density depends on the size of the quadrat or plot used; it may be per m^2, per 100 m^2, per km^2, per ha, etc. In this work unit density per 100 m^2 is used.

$$\text{Abundance} = \frac{\text{total number of individuals of the species}}{\text{number of quadrats in which they occur}}$$

$$\text{Density} = \frac{\text{total number of individuals of the species}}{\text{total number of quadrats sampled}}$$

Species Diversity (Shannon-Wiener Index)
Species diversity can be taken to denote the number of species in a given area or as the number of species among the total number of individuals of all the species present. This relationship may be expressed numerically as the diversity index (Michael, 1984). One of the indices to calculate species diversity is the Shannon-Wiener Index (H') which uses formula:

$$H' = -\sum P_i \ln P_i$$

$$P_i = \frac{S = \text{number of individuals of one species}}{N = \text{total number of all individuals in the sample}}$$

The number of species in a community is important ecologically since the species diversity seems to increase as the community becomes more stable (Michael, 1984). A great diversity can also indicate the availability of a large number of niches.

4. Results and Discussion

Vegetation richness has been rapidly increasing in Yamuna Biodiversity Park (YBP). Number of plant species found in all communities has been continuously added every year either by plantation or natural regeneration (i.e. by animals, wind or water flows). The forests are now getting remarkably denser as compared to the earlier stages of development. The rapid change was not only in the density, but the diversity of the forests has also increased.

4.1. Vegetation Analysis across 15 sampling plots

Plant Diversity
Plant diversity was measured using Shannon-Wiener Index (H'). Result below showed that Plot No. 2 has highest plant diversity as compared to other plots, followed by Plot No. 7 and No. 8 as the second and third most diverse respectively (Table 2). Among forests in Nature Reserve Area, Mixed dry deciduous forest (Plot No. 15) performed as the most diverse, and Plot No. 10 (Hardwickia community) was the least diverse among all 15 plots (Figure 3).

Species Richness
Species richness represents number of plant species occurred in each plot. Each species may be found as only one individual or more. From 15 plots studied in Yamuna Biodiversity Park, Plot No. 6 (Tropical dry deciduous forest with sal) has the largest species richness with 39 species, and Plot No. 10 and 11 (Hardwickia community and Grassland respectivley) both have the smallest richness with 11 and 10 species occurred respectively.

High number of species, or *species richness*, found in one location did not always indicate high number of diversity. Forests which were not highest in species richness were also found to have highest species diversity or *Shannon-Wiener Index* value. Plot No. 6 (Tropical dry deciduous forest) which has highest species richness in 10×10 m^2 area (Figure 4) was not considered as the most diverse forest in the park (Figure 3). Having 39 species of plants Plot No. 6 was found to be less diverse as compared to forest in Plot No. 2 (Subtropical mixed evergreen forest) that has only 28 plant species. The heterogeneity factor was found to be the reason of this problem. Plot No. 6 with almost 700 plant individuals was relatively less heterogeneous as compared to Plot No. 2 which has almost a hundred plant individuals only in 10×10 m^2 area (Table 2). Plot No. 6 was dominated by two or three plant species which contribute more than 70% of total individuals in the site (most of them are herb and grass species), while other plant species inhabits Plot No. 2 only contributes not more than 17%.

Table 2: Distribution of vegetation in different sampling plots in Yamuna Biodiversity Park in 2011

Sampling Plots No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Shannon-Wiener Index (H')	1.33	2.85	1.89	1.75	1.81	2.00	2.54	2.24	1.55	1.08	1.41	1.69	1.39	1.38	2.20
Species richness	14	28	22	26	28	39	21	27	20	11	9	28	22	28	21
Plant density, per 100 m^2	85	98	156	430	444	698	272	271	396	579	1565	679	620	1094	310
Tree density, per 100 m^2	7	15	12	6	13	12	0	14	16	3	0	7	2	11	4
Sapling density, per 100 m^2	20	59	134	356	204	568	226	233	362	326	1004	509	511	783	278
Grass density, per 100 m^2	58	24	10	68	227	118	46	24	18	250	561	163	107	300	28
Mean GBH, cm	52.9	35.3	40.4	50.8	38.9	37.6	0.0	34.5	42.7	37.7	0.0	34.0	22.5	31.3	45.5
No. of tree GBH 20-50 cm	5	13	10	3	11	10	0	12	12	2	0	6	2	9	2
No. of tree GBH >50 cm	2	2	2	3	2	2	0	2	4	1	0	1	0	2	2

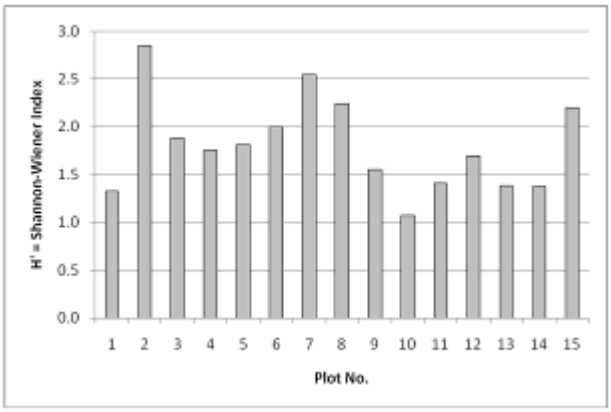

Figure 3: Plant diversity across the habitats.

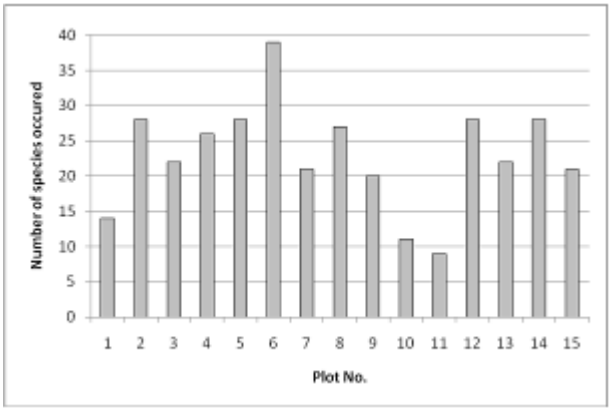

Figure 4: Species richness across the habitats.

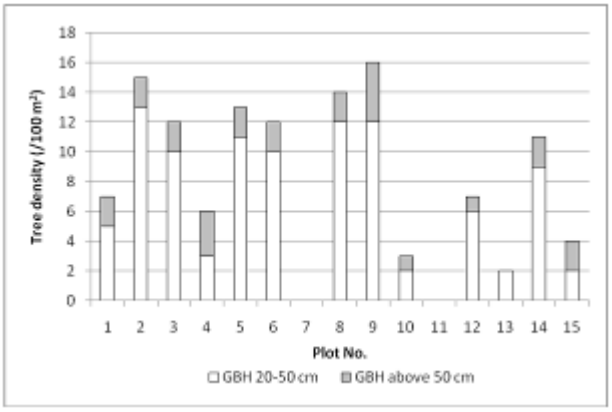

Figure 5: Tree density across the habitats.

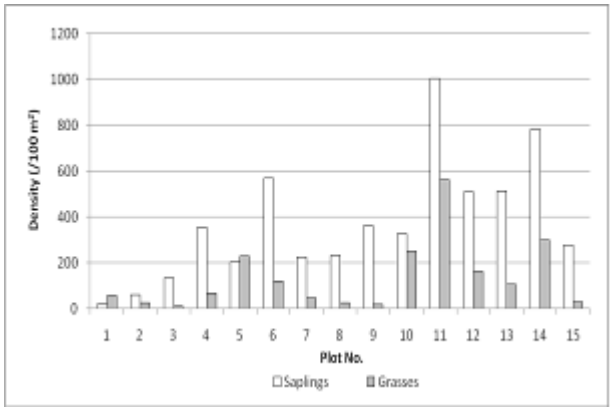

Figure 6: Sapling and grass density across the habitats.

Plant Density

Plant density was counted in two categories: tree and sapling density. Any plants having girth at breast height (GBH) 20 cm and above were counted as trees, while below that were counted as saplings. Tree density often less than sapling or grass density. Tree density of all plots reached maximum at 16 individuals per 100 m^2, while sapling density peaked to a thousand individuals per 100 m^2 (Table 2). It was also observed that majority of tree species (80%) were having girth 20-50 cm (Figure 5). Among all plots studied, Plot No. 9 has the largest tree density (Figure 5), followed by Plot No. 2 and 8. Plot No. 7 and 11 have no tree, because the sites were mostly covered by grasses, saplings, herbs and shrubs.

The sites that have less in tree density were found to have more in saplings and grass density. For example, Grassland and Sal community performed the two highest densities in saplings and grasses (Figure 6), because large number of small plants, seedlings, herbs and grasses were found there, but in tree density Grassland were the weakest together with Rangeland (Figure 5).

Relative Abundance

Abundance of a species represents how much number of individuals of that species occurred in a site. There were more than 800 plant species in Yamuna Biodiversity Park, and the study found at least 144 plant species were occurred in 15 sampling plots. Apart of them, 41 species were categorized as tree with GBH more than 20 cm. Among all trees established in the park, Indian elm tree (*Holoptelia integrifolia*) were the most abundant species followed by *Albizia lebbeck* which contribute about 12 and 10 percent respectively of total tree species in the park, while other species mostly covered below two percent (Figure 7).

Different plots may have different abundance of species. Relative abundance may also represent the homogeneity of the site. If one tree species occurred more than 50% of the area, it may be said that those area was dominated by that particular species. Even the plant species *Holoptelia integrifolia* has high relative abundance in the park, but it covered only 12% of all species counted. So the site can still be classified as heterogeneous.

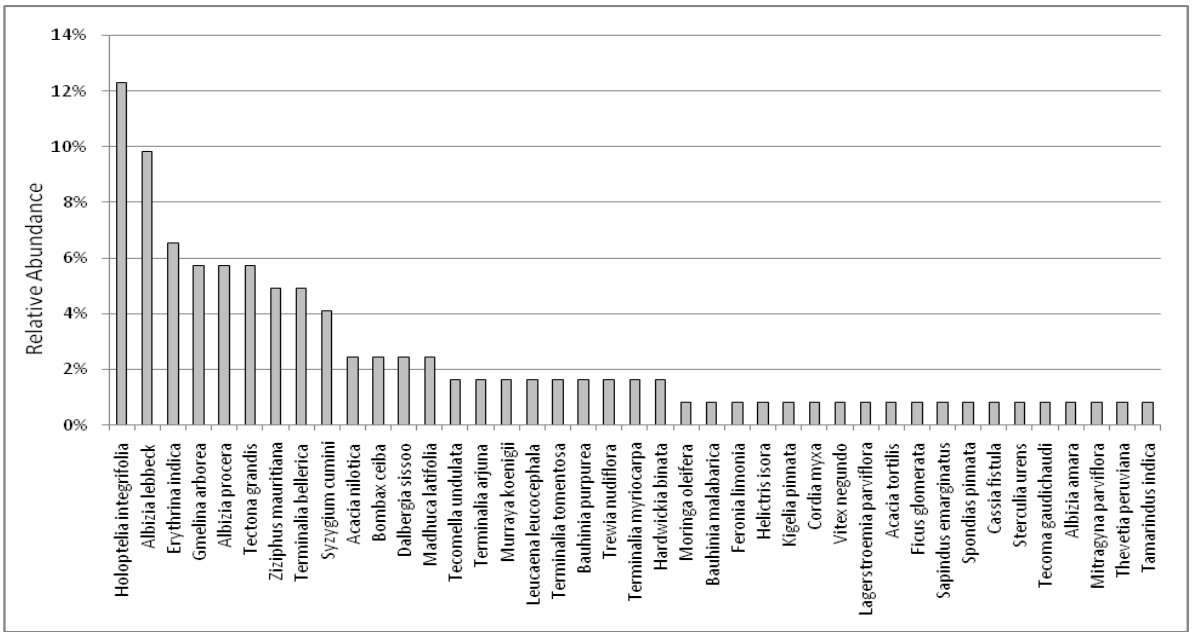

Figure 7: Relative abundance of tree species in Yamuna Biodiversity Park.

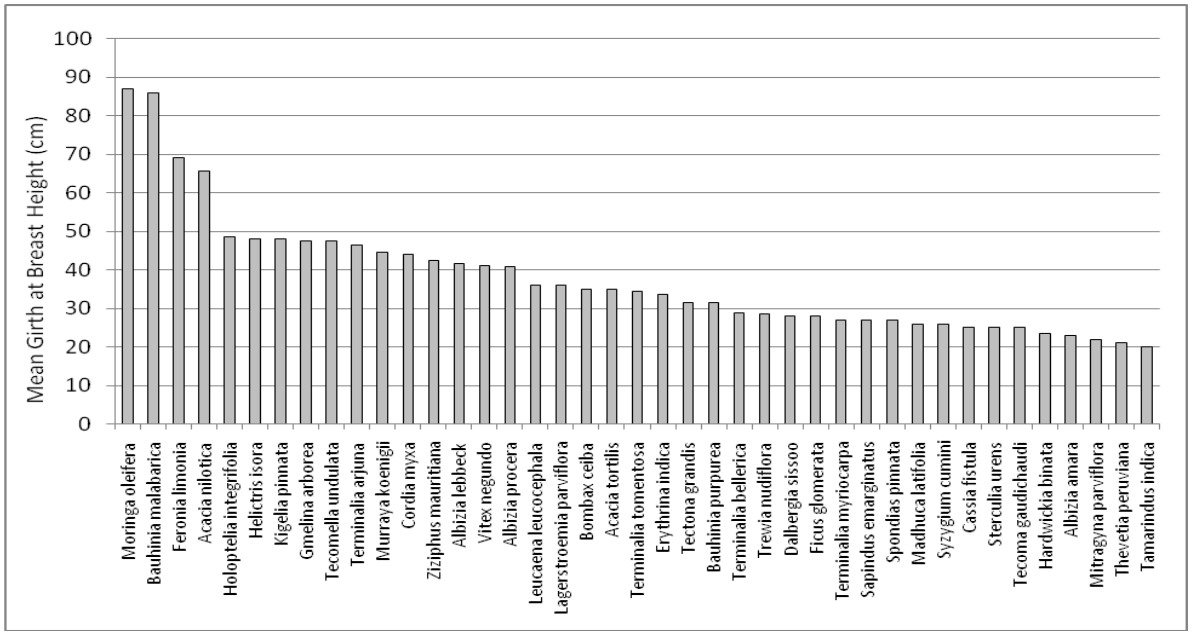

Figure 8: Mean Girth at Breast Height of tree species in Yamuna Biodiversity Park.

Mean Girth at Breast Height

Tree species found in YBP were mostly small to medium size. Most of the trees have GBH 20-50 cm. Only four species were found to have GBH more than 50 cm within the sampling plots, including *Moringa oleifera*, *Bauhinia malabarica*, *Feronia limonia* and *Acacia nilotica* (Figure 8). However, there were many species having GBH more than 30 cm, such as *Ziziphus mauritiana*, *Holoptelia integrifolia*, *Terminalia arjuna*, *Terminalia tomentosa*, *Albizia lebbeck*, *Albizia procera*, *Tecomella undulata*, *Cordia myxa*, *Leucaena leucocephala*, *Erythrina indica*, *Tectona grandis*, *Bauhinia purpurea* and *Bombax ceiba*. This indicated that forests in YBP were still young. It was due to the forests in YBP were man-made and developed mostly by the introduction/reintroduction of plant species into the park. But there are forests such as Teak community, Sal community and miscellaneous forest community were seen very close to natural forest ecosystem.

Density of forests did not only determine the quality of the environment they had, but it also determined the maturity of the forests. The maturity of the forest can be exactly estimated by looking at the tree rings, but it is not exactly the wise thing to do as the tree have to be cut down first to count how many tree rings are there. Another simple, but not exact, estimation is by measuring the girth at breast height.

Girth at breast height measurements were performed in this study. All girth were measured to identifiy the maturity of the trees as well as the forests. Mixed deciduous forest and Tropical thorn forest were found to have more number of thick trees (Figure 9), as they have more mean GBH value than other forests. Conversely, Tropical dry deciduous forest has the least number of thick trees, because most of the trees found there were young and less than 20 cm GBH. Plots No. 7 and 11 are not forests but Rangeland and Grassland respectively. So, the trees were absent in these two sites.

Higher density of a forest did not always indicate its higher maturity index. The maturity might be indicated by its mean GBH. For example, Plot No. 1 showed as the most mature forest in YBP as it has highest mean GBH among the trees occurred inside the plot. Though Plot No. 9 has higher plant density (Figure 5), but forest in Plot No. 1 was assumed to have been established earlier than all other forests. So, most of the trees were there in that forest were estimated to be older in age. But, overall, forests in YBP were young in age. Only 20 percent of 122 trees were found to have GBH more than 50 cm at all sampling plots, the rests have 20-50 cm GBH (Figure 5), because the park came into existence originally in the year 2002 [2].

4.2. Comparison of 2006 and 2011 Vegetation Profiles

Plant Diversity

Shannon-Wiener Index, an index for measuring plant diversity, showed a variation in the result (Table 3). Vegetation sampling showed increasing profiles in some communities (VA, G, TC and K) from 2006 to 2011, while the remaining communities (HC and SC) perform declining features (Figure 10). Increase in Shannon-Wiener Index indicated that the forests were more heterogeneous, while forests which have decreased their Shannon-Wiener Index values tend to get closer to homogeneity.

Species Richness

Number of species (or species richness) found in six plant communities of YBP showed rise and decline patterns from 2006 to 2011 (Figure 11). Species richness in Grassland (G), Teak Community (TC) and Kuno Forest (K) were increasing, while in other communities they were decreasing during this five-year period. The difference of species richness pattern (rise and decline) was mainly caused by the difference in selecting number of plots or quadrats in each community studied. The vegetation sampling conducted in 2006 used five quadrats per each plant community sized 5×5 m^2 [2], while in 2011 took only one quadrat sized 10×10 m^2. Therefore, technically in field, selecting more number of quadrats or plots in a vegetation sampling will lead to more species richness obtained than using only one quadrat, because selection of the plots was basically due to their high plant diversity.

Table 3: Comparison of vegetation in different plant communities in YBP during 2006 and 2011

Parameter	2006						2011					
	VA	HC	G	TC	SC	K	VA	HC	G	TC	SC	K
Shannon-Wiener Index (H')	1.63	1.11	0.98	0.56	1.52	0.59	2.00	1.08	1.41	1.69	1.38	2.20
Species richness	29	14	8	16	29	20	25	11	9	28	28	21
Plant density, /100 m^2	168	470	198	176	678	227	317	579	1565	679	1094	310

VA=Visitor Area, HC=Hardwickia Community, G=Grassland, TC=Teak Community, SC=Sal Community, K=Kuno.

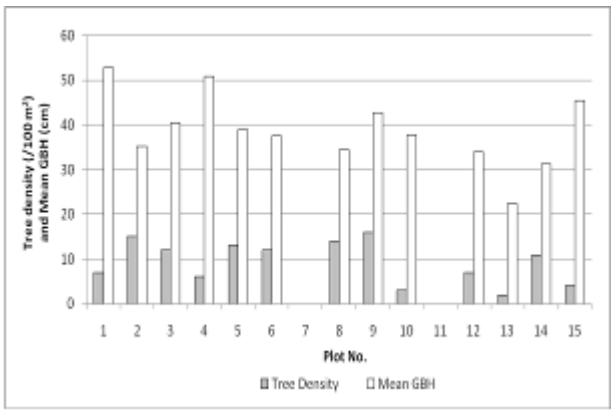

Figure 9: Density and mean GBH across the habitats.

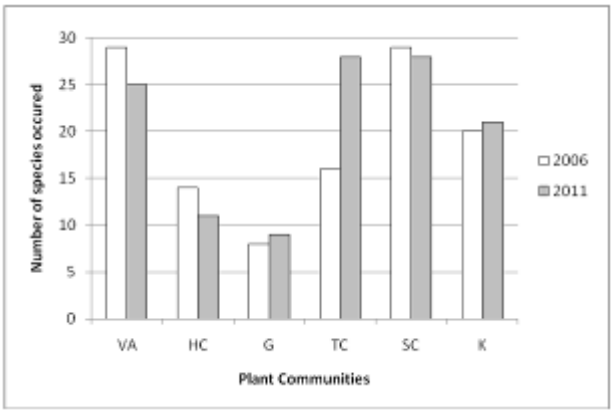

Figure 10: Plant diversity profiles in 2006 and 2011.

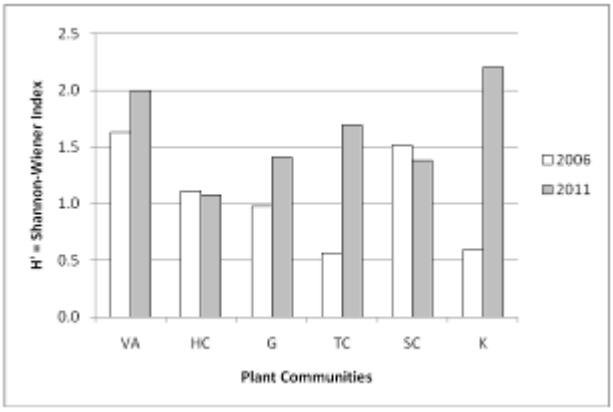

Figure 11: Species richness profiles in 2006 and 2011.

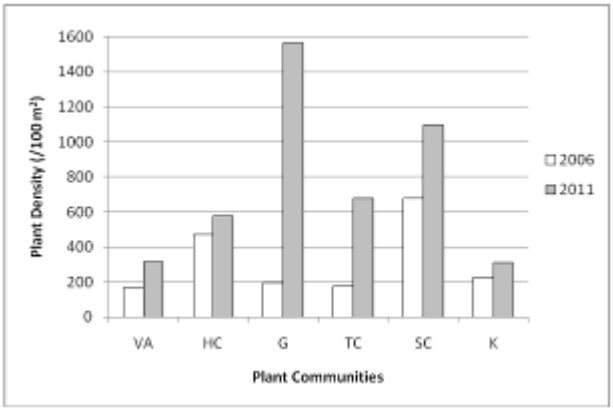

Figure 12: Plant density profiles in 2006 and 2011.

Plant Density

Plant density profiles of six different plant communities studied in YBP were increasing during the year 2006 to 2011 (Figure 12). The highest increase values of plant density during this five year periods were found in Grassland community (G), while the lowest one found in Kuno Forest (K). The difference was due to the maturity of the sites. More mature sites or forests would have less increase in plant density, because of the crowd of the area. Conversely, immature sites may have more empty space for new plants or seedlings to grow. Therefore, they may have great increase in plant density, especially sapling density. But this still depends on how good soil conditions preserve and how many nutrients available in that site. Moreover, competition in gaining nutrients, water and sunlight between plants, either deep-rooted or shallow-rooted, large canopy or small canopy, also became an important factor.

5. Conclusion

The purpose of the work was to study various profiles of plant communities in a forest-designed park. The field work was conducted in late winter to early summer 2011 in the study area of Yamuna Biodiversity Park, Delhi, India. The study was started by vegetation sampling to measure density, diversity, species richness, abundace and maturity of tree species by measuring their girth at breast height (GBH). The vegetation sampling was carried out in stratified sampling design [4] by selecting fifteen sampling plots at different plant communities across the site. For each plant community one plot was made at quadrat size 10×10 m^2 as the basis area for vegetation analysis. All plants occurred within the plots including trees, saplings and grasses were counted, and GBH of tree species sized above 20 cm were measured [6].

The important findings of this study were that high species richness did not always indicate high diversity index. In other word, forests with more number of species were found to be less diverse as compared to forests with low species richness in similar area size. The heterogeneity factor was the reason for this. Some forest was dominated by only two or three plant species which most of them are herbs and grasses, while some other have no highly specific dominant species and tend to be heterogeneous. The sites with less tree density were also found to have more sapling and grass density. Study found that according to its species abundance, the park is still categorized as heterogenous.

Another finding was that parameter of GBH was found to be inversely proportional to the number of total plant density. Forests with high mean GBH mostly have lesser density than forests with low mean GBH. This indicated the maturity of the forests in which the mature forests would have lesser density than immature forests, because their basal area was covered more by large trees than small trees. Immature forests might have more empty basal area that allowed new seedlings to grow, and hence created more number of saplings and more forest density. In this case, density of forests was not actually governed by large number of tree species. Number of saplings, including small trees, shrubs, herbs, seedlings and climbers influenced most of the density and the basal cover of the sites. But, most of the saplings, particularly herbs, were categorized as annually-growing species that abundant only in a particular season. Therefore, they cannot identify the maturity or density of the forests as they may have disappeared in the next non-growing season.

Habitat improvement was clearly shown in the comparative vegetation data of 2006 and 2011. Most of the sampling plots have shown an improvement in plant density as well as diversity. But in few communities, there was a declining feature in plant diversity and species richness due to different sampling location and different number of plots constructed. Moreover, as timing (or season) of sampling was also different, majority of plant species recorded in 2006 were annual plants with few tree species. However, the 2011 data has shown more trees and fewer annuals (herbs).

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Author Profile

Azis Kemal Fauzie received the S.T. degree in Chemical Engineering from University of Indonesia in 2001 and M.Sc. degree in Environmental Studies from University of Delhi in 2011. Since 2006, he has been working for Environmental Management Agency, Government of Karawang Regency, Indonesia. He is now pursuing Ph.D. in Environmental Science at University of Mysore.

Sreenivasa received the M.Sc. degree in Environmental Science from University of Bangalore in 2001 and M.Phil degree from Periyar University in 2009. He has passed NET, SET and 15 years of teaching and extension experience. He is now pursuing Ph.D. in Environmental Science at University of Mysore.