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Establishing Permanent Preservation Plots in Bannerghatta National Park for long-term ecological studies to monitor climate change

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Ecological studies on Forests

Tropical forests are the cradles of biodiversity. However, biodiversity varies greatly across geographical scales. Tree diversity in tropical forests is fundamental to the biodiversity of these forests as they provide resources and habitats for several organisms in these forests (Cannon *et al.,* 1998). Quantitative floristic inventories of tropical forests have been carried out in several locations (Ayyappan and Parhasarathy, 1999, Parthasarathy, 2001, Philips *et al.,* 2003, Leigh and Losos, 2004), yet there are several locations in tropics to be explored. Natural and anthropogenic disturbances are critical to the tropical forests for the maintenance of diversity, structure and dynamics (Mittelman, 2001, Sagar and Singh, 2005. Mishra *et al.,*2004, Gautham *et al.,* 2016). These disturbances alter the environment, ecosystem process, and plant-animal interactions. They can potentially determine the species composition of a given ecosystem. Anthropogenic mediated loss of biodiversity has increased the interest in estimation, function, and maintenance of biodiversity (Barlow *et al.,* 2016, Malik *et al.,* 2016).

Assessment of pattern in biodiversity in spatial and temporal scale across environmental gradients is a crucial step. Understanding the variation in diversity is essential pre-requisite for scientific management and conservation of these natural resources (Condit *et al.,* 1998).

A significant increase in anthropogenic disturbances and forces driving human-mediated climate change makes it much more empirical for the scientific community to pay attention towards understanding diversity and structure of tropical forests. Phyto-sociological investigation of vegetation serves as a primary requirement in characterizing vegetation for its parameters such as diversity, species package, primary productivity, and floristics. There are several studies that describe diversity patterns across different vegetation types in peninsular India (Pascal, 1988, Sukumar *et al.,* 1992, Ganeshan *et al.,* 1996, Muthuram Kumar *et al.,* 2002). Bannerghatta National Park (BNP) on the outskirts of

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Bengaluru city is relatively underexplored for its floral and faunal diversity. Though there are some studies (Gopalakrishna *et al.,* 2015, Varma *et al.,* 2009), there is no systematic quantitative information on the forest wealth of BNP. This article is on our efforts to provide quantitative information on the floristic diversity of BNP and also provide information on the dynamics of forests in BNP in the wake of climate change.

Monitoring Climate change

Climate change refers to change in climate that can be attributed directly or indirectly to human activity. It is beyond the natural variability in climate. Fifth assessment report (2014) of Intergovernmental Panel on Climate Change (IPCC) has concluded the rise in the global average temperature and warming of the earth's climate system is unequivocal. The global carbon dioxide concentration has increased from 280 ppm (pre-industrial revolution) to 379 ppm (in 2005). These changes could alter the weather events and impact freshwater availability, agriculture, forests and human health. India's development agenda stresses on the development with reduced climate-related vulnerability. Keeping in view the magnitude of uncertainties, the need is to identify and prioritize strategies that help to achieve developmental goals in the face of climate change. The government of India has initiated National Action Plan on Climate Change for India (NAPCC, 2008). A key objective of the plan is to create awareness in the community about the threats posed by climate change and take suitable steps to counter it. Through eight sectoral missions, the NAPCC focuses on key sectors impacted by or impacting climate change, including agriculture, water, forestry, energy and urban planning and relates to sustainable development, with focus on adaptation, mitigation, and scientific research. The National Mission on Strategic Knowledge seeks to address the inadequacy of knowledge on the impacts of climate change by establishing research networks and encouraging research on socio-economic impacts of climate change including the impact on health, demography, migration patterns and livelihoods of coastal communities. The State Action Plan on Climate Change (SAPCC) has been prepared by the state of Karnataka, wherein the challenges faced by the various sectors of the state are listed and feasible action points are earmarked.

Ministry of Environment, Forests and Climate Change (MOEFCC) has established a network, Indian Network for Climate Change Assessment (INCCA) consisting of several research institutions and industries. Important objectives of INCCA are 1) Assess the driver and implications of climate change through scientific research. 2) Preparing climate change assessments including GHG emissions. 3) Build capacity towards the management of climate change. Long-term ecological, social and economic monitoring is required in India to identify the pattern and driver of change as a sizable population of India is dependent on natural resources for their livelihoods. Monitoring is required to formulate national policies and signing international conventions and treaties such as United Nations Framework on Convention on Climate Change (UNFCCC). Proposed India's Long-term Ecological observatories (ILTEO) is the major step towards understanding the impacts of climate change on our biodiversity. It is an activity of the climate change action program of the country launched by the MOEFCC. It encompasses both ecological and social perspectives and designed to be multi-disciplinary and multi-institutional activity across different bio geographical zones of the country. Under this program, students and young scientists will also be trained through sustained long-term support for research in the area of climate change. The initiative will also help the country to have its own scientific database in this key area without depending on studies done abroad.

Permanent Preservation Plots

Establishment of Permanent Preservation Plots (PPPs) in natural forests play a significant role in assessing the impact of climate change on forests. The ecological studies would help to observe and record the changes in species diversity, composition and growth pattern due to climate change over a period of time. This article describes the initiatives of Environmental Management and Policy Research Institute (EMPRI) to understand the anthropogenic mediated climate change impacts on dry forests of Bannerghatta National Park (BNP). EMPRI, as a state nodal agency for climate change, is strengthened by a project sanctioned by Department of Science and Technology (DST) to establish a Karnataka strategic knowledge center for climate change (KSKCCC) with advanced research capabilities to take up research studies on climate change issues. To pursue long-term studies on climate change, it was decided to establish Permanent Preservation Plots (PPPs) in two major forest areas in Bengaluru. Permission is received from Principal Chief Conservator of Forest (WL) for selection of PPPs in the Bannerghatta National Park and Doresanipalya Forest campus. Discussions were held by the study team from EMPRI, scientists from Indian Institute of Science (IISc), Deputy Conservator of Forest, BNP and staff of forest department on criteria for establishment of PPPs, a methodology for laying sample plots and assessment and selection of plots based on Forest Vegetation types.

Objectives

Important objectives of the proposed research are as follows:

1. To understand the pattern of diversity and structure of forests in BNP.
2. To understand the pattern of recruitment, mortality, and growth in various species.
3. To understand the short-term fluctuations in climate on vital parameters such as mortality, recruitment, and growth.
4. To understand the standing biomass and carbon stocks in the forests of BNP. Also, understand the changes in biomass.
5. To understand the phenology and variability of climate on the phenology of woody species of BNP.
6. To understand drivers of diversity such as soils in terms of nutrients, physical and biological properties.
7. To understand the effect of climate variability on the physiology of various species.
8. To understand the climate variability on dynamics of forests of BNP.

Study area: This study is initiated in the Bannerghatta National Park (BNP) located on the outskirts of Bengaluru city. BNP (12°34'to 12° 50' N Lat and 77° 31 to 77° 38'E Long) covers an area of 102.74 km$_2$ comprising mainly dry forests. It was elevated to the status of National Park in the year 2004 vide final notification **No. FEE 19 FWL 98, Bengaluru, dated 5th March 2004**. The total area of the park was further increased to 260.51 sq. km by appending three more reserve forests measuring 157.77 sq. km in the area drawn from the Kanakapura Range of Ramanagara Division located in the southern part of the park in the year 2011 vide notification **No. FEE 302 FWL 2011-(II), Bengaluru, dated 27th December 2011.** Administratively BNP has three wildlife ranges namely Bannerghatta, Harohalli, and Anekal. BNP is also identified as important elephant corridor which is a part of Karadikkal – Mahadeswara elephant corridor. The terrain of the park is undulating with a mean elevation of 850meters ASL (range 700 meters – 1035 meters). The climate of the park is the monsoonal type. Forester had recognized the importance of permanent plots and had recommended in their management plans (Range Gowda, 2002).

The BNP receives rainfall from both South-West and North-East monsoons. Heavy rainfall occurs during the month of September and October from North-east monsoon and torrential rains from June to August from South-west monsoon (**Fig. 1**). Annual rainfall data (based on South-West monsoon, North-East monsoon & Pre-monsoon) for the Anekal region varies from 417 mm to 1494 mm with a mean of 869± mm between the years 1960 to 2016; occasionally the area receives heavy cyclonic rains in October and November **(Fig. 2).**

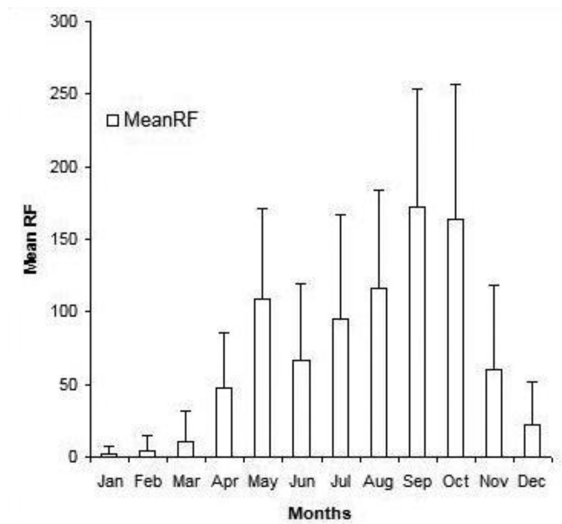
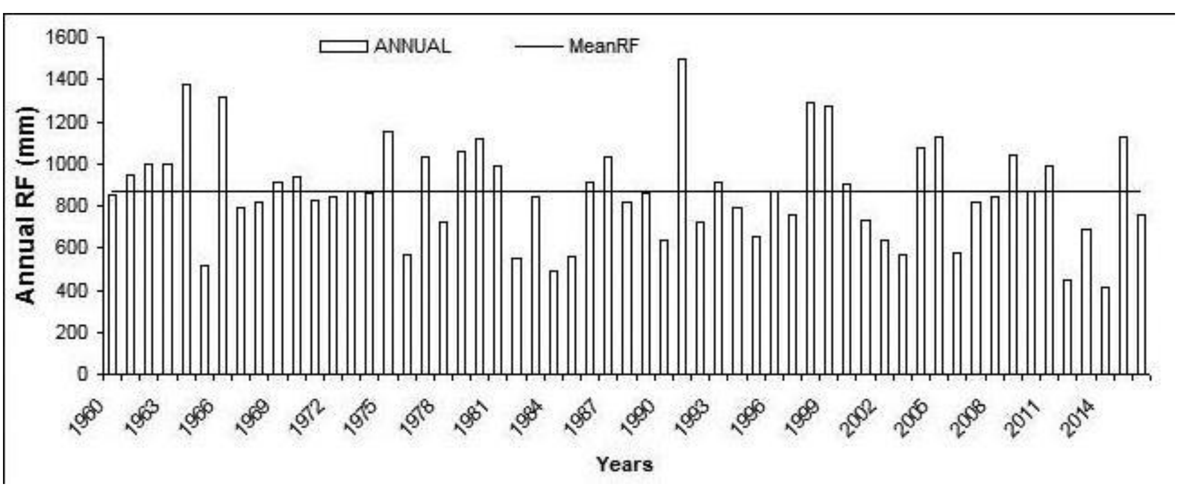
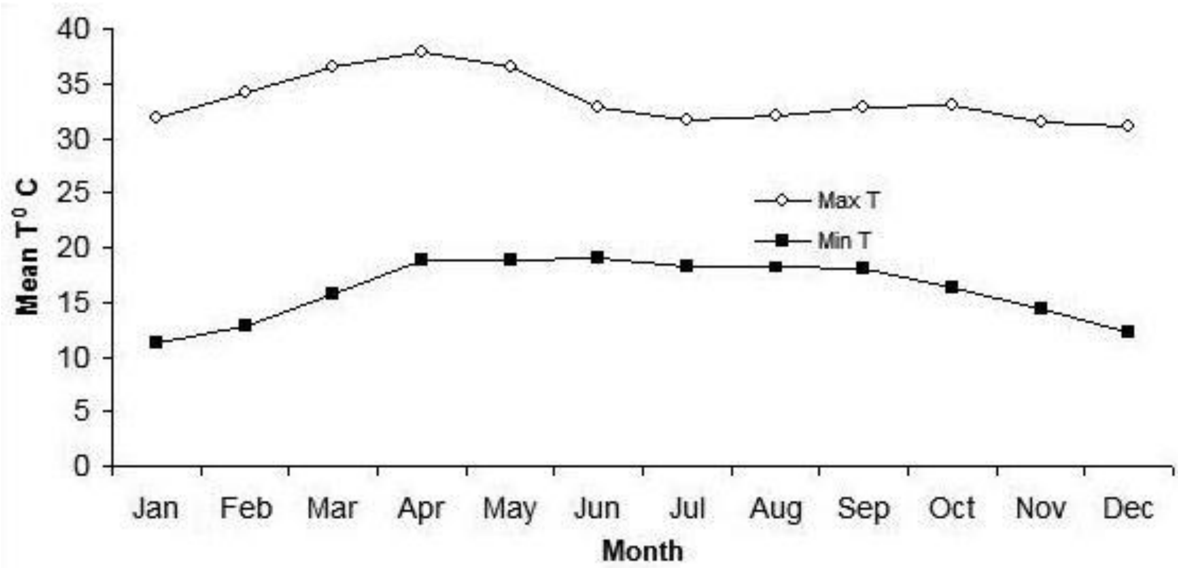


Fig. 2 – Yearly rainfall in BNP (1960-2016). Line represents mean rainfall during that period.



The mean annual temperature of the park is around 24.7°C with a maximum 39.4°C and minimum of 10.2°C (**Fig. 3**).

Fig. 3 – Mean maximum and minimum temperature in BNP (2012-2015)



The geology of the park shows that the rocks are of the oldest formation revealing cryptocrystalline to coarse granites and complex gneiss. The rocks are light to dark grey or whitish muscovite granite gneiss or biotitic granite gneiss which varies considerably from place to place in structure, texture, and appearance. According to the fineness or coarseness of the constituent grains and the relative abundance or scarcity and mode of deposition of the darker Ferro minerals, their complex gneiss masses have been styled "Peninsular Gneiss."

The soil on the upper regions is red and gravely, which it is generally deep or shallow mixed with metamorphic forms of rocks on undulating grounds. The soil in the valleys is sandy loam and is formed with finer particles of the decomposed rocks washed down and deposited during rains. The soil is shallow on the hilltops and deep in the valleys and low-lying areas (Raju, 2014).

Vegetation

Bannerghatta National Park has two major types of vegetation viz. scrub and deciduous vegetation. The scrub vegetation is seen mostly along the fringes of the park and experiences heavy biotic pressures by the local communities for reasons such as fuelwood collection and cattle grazing. The upper regions of the park are covered by mixed deciduous vegetation type whereas the valleys, watercourses and low lying areas are covered by mixed deciduous vegetation which is relatively less disturbed and degraded as it is inaccessible due to the highly undulating terrain (Verma *et al.,* 2009, Gopalakrishn *et al*., 2015).

Establishment of permanent forest dynamics plot or permanent preservation plots (PPP)

Two one-hectare plots (100 X 100 meters) were established in Bugarikallu (12°42'47" N and 77° 32'25" E) and Thalewood house

(12° 45’52” N and 77° 33’33” E) area of BNP. Both these forests represent different forest types in BNP. Thalewood house plot represents relatively moist forest and Bugarikallu forest plot represents drier forest with stunted trees. Establishment and enumeration of the plot follow Centre for Tropical Forest Sciences (CTFS) protocol which is standardized in par with international monitoring of forest resources. CTFS protocol is described briefly. The plot was gridded into blocks of 20 x 20 meters after taking slope into account with help of theodolite. Each corner was planted with a semi-permanent pole. For the ease of enumeration, each block was further subdivided into blocks of 10 x 10 meters temporarily with the help of ropes.

All woody individuals >1 cm dbh (diameter at breast height) were tagged, identified to species and measured for size. If the stems are branched they were given the same number but sizes were measured independently. They were classified as either stem branches (branching of each stem was between 1 and 1.3 meters) or root branches (stems branching from the ground). If such stems are at least 50 cm apart they are given different number otherwise they are considered as branches from the same stem. Point of measurement was marked with yellow paint on every stem. This would help to reduce subsequent measurement errors. Ocular estimate of the height was made for each individual. Spatial location of each tagged individual was plotted by measuring x and y coordinates to nearest 10 cm accuracy. In addition to woody species, lianas (woody climbers) are also being marked and mapped. Sizes of the lianas are also measured.

PPP 1: Thalewood house plot

The initial details of Thale woodhouse plot is given in this article. Data is being validated and cleaned up for typographical errors, species identity, and size discrepancies. Thalewood house plot has 1588 individuals above 1cm dbh belonging to 85 different woody species including lianas. Most dominant species is *Olea dioica* (Oleaceae) with 291 individuals that accounts for 18.3% of abundance followed by *Cipadessa baccifera* (Meliaceae), a shrub (157 individuals and 9.8% abundance) and *Ziziphus oenoplea* (Rhamnaceae), a liana (138 individuals, 8.6% abundance). List of the species is provided in **Appendix 1.** A community-wide measure of heterogeneity (Shannon’s index) was 3.132 while Simpson’s index (picking two individuals randomly belonging to two different species) was 0.925. Fisher’s alpha, an index that is not sensitive to plot dimensions was 18.05.

Though the plot was 1 ha in size, there was a considerable variation in species package and diversity across the plot. Mean number of species in a block of 20 x 20 (400 m_2) was 16.54±6.34 (6 – 28 species, N = 25). Mean Simpson’s index was 0.851±0.069 (0.556 – 0.931, N = 25) and Shannon’s H was 2.30±0.37 (1.24 – 2.99, N = 25). Fisher’s alpha was 8.25±3.07 (3.04 -16.26, N = 25). The variation in species package is considerable, can vary as low as 6 (quadrat no. 1) species in a block to as high as 28 (quadrat no. 5) species in a block. There were 9 quadrats that had 20 or more species. A similar variation is also depicted in diversity estimates. The density of stems >1 cm dbh in the plot was 1588 and total basal area of the plot was 31.55m_2. However, density and basal area varied considerably across the plot. Mean density of stems >1 cm dbh in the plot (20 meters x 20 meter) was 63.5±31.5 (range = 10 to 110, N= 25) and mean basal area of the block was 1.26±0.9 m_2 (0.30 to 4.81 m_2, N = 25). The highest density of individuals was in quadrat 23 and least density was seen in quadrat no 1.

Appendix 1 – Plant species reported from Thalewood house vegetation plot

Species (Family)	Number of Individuals
Olea dioica (Oleaceae)	291
Cipadessa baccifera (Meliaceae)	157
Ziziphus oenoplia (Rhamnaceae)	138
Acacia dividivi (Fabaceae)	127
Ventilago maderaspatana (Rhamnaceae)	119
Ixora nigricans (Rubiaceae)	107
Polyalthia cerasoides (Annonaceae)	73
Ardisia solanacea (Myrsinaceae)	57
Glochidion velutinum (Euphorbiaceae)	45
Jasminum Sp. (Oleaceae)	40
Randia dumetorum (Rubiaceae)	37
Terminalia bellirica (Combretaceae)	34
Syzygium cumini (Myrtaceae)	33
Terminalia arjuna (Combretaceae)	29
Cordia willichii (Boraginaceae)	26
Cassia fistula (Fabaceae)	21
Glochidion zeylanicum (Euphorbiaceae)	18
Shorea roxburghii (Dipterocarpaceae)	17
Diospyros montana (Ebenaceae)	15
Black ambu	13
Mimosa rubicaulis (Fabaceae)	13
Mallotus phillipensis (Euphorbiaceae)	13
Pavetta indica (Rubiaceae)	12
Polyalthia coffeoides (Annonaceae)	10
Phyllanthus emblica (Euphorbiaceae)	9
Vitex altissima (Verbenaceae)	9
Acacia sp (Fabaceae)	8
Canthium parviflorumum (Rubiaceae)	8
Allophylus cobbe (Sapindaceae)	8
Annonaceae	7

Species (Family)	Number of Individuals
Dalbergia lanceolaria (Fabaceae)	7
Schleichera oleosa (Sapindaceae)	6
Viburnum Sp. (Caprifoliaceae)	5
Ziziphus rugosa (Rhamnaceae)	4
Mitragyna parvifolia (Rubiaceae)	4
Acacia concina (Fabaceae)	4
Ervatamia heyneana (Apocynaceae)	3
Apocynaceae climber	3
Erythroxylum monogynum (Erythroxylaceae)	3
Pterocarpus marsupium (Fabaceae)	3
Breynia retusa (Euphorbiaceae)	3
Dendrocalamus strictus (Poaceae)	3
Premna tomentosa (Verbenaceae)	2
Bauhinia racemosa (Fabaceae)	2
Wrightia tinctoria (Apocynaceae)	2
Mimosa rubicaulis (Fabaceae)	2
Uvaria narum (Annonaceae)	2
Climber 1	2
Gmelina arborea (Verbenaceae)	2
Diospyros melanoxylon (Ebenaceae)	2
Butea frondosa (Fabaceae)	2
Careya arborea (Lecythidaceae)	2
Toddalia asiatica (Rutaceae)	2
Helicteres isora (Sterculiaceae)	2
Caesarea sp (Flacourtiaceae)	1
Terminalia chebula (Combretaceae)	1
Cassia spectabilis (Fabaceae)	1
Canthium dicoccum (Rubiaceae)	1
Ugani hambu	1
Albizia odoratissima (Fabaceae)	1
Dimocarpus longan (Sapindaceae)	1

Species (Family)	Number of Individuals
Breynia vitis-idaea (Euphorbiaceae)	1
Celastaceae member (Celastraceae)	1
Ficus microcarpa (Moraceae)	1
Mende ambu (red bark)	1
Scutia myrtina (Rhmnaceae)	1
Garuga pinnata (Burseraceae)	1
Maytenus emarginata (Celastraceae)	1
Vitaceae shrub (Vitaceae)	1

Species (Family)	Number of Individuals
Sooleballi	1
Vitis Sp. (Vitaceae)	1
Meiogyne cylindrocarpa (Annonaceae)	1
Grewia (Tiliaceae)	1
Memecylon umbellatum (Melastomataceae)	1
Holarrhena antidysenterica (Apocynaceae)	1
Flueggea leucopyrus (Euphorbiaceae)	1
Grand Total	**1588**

The size class distribution of individuals show a typical inverted "J" shaped curve suggesting that a large number of individuals are represented in lower size class, In fact, there were 75% of the individuals below 5 cm dbh and 2.73% of individuals were >30 cm dbh. Though plot had 2.73% individuals >30cm dbh, they accounted for 75% of the total basal area in the plot (**Fig. 4**).

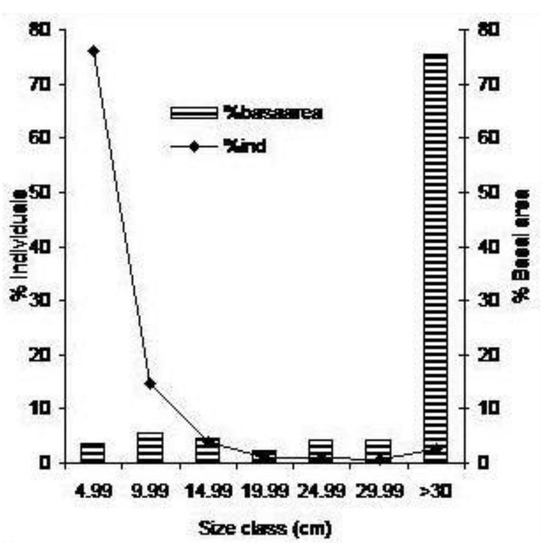


Fig. 4 – Size class and basal area distribution of individuals in Thalewood house plot. BNP

Spatial distribution of several species was analyzed. Most species show significant aggregated dispersion suggesting clumping dispersion. Canopy species such as *Olea dioica, Schleichera oleosa, Shorea roxburghii* and *Syzygium cumini* showed significant aggregated dispersion (**Fig. 5a**) while species such as *Terminalia arjuna*, *Terminalia bellirica,* and *Phyllanthus emblica* showed random dispersion (**Fig. 5b**). Most of the species that showed random dispersion was not statistically significant (**Appendix 2**).

Additional parameters to be monitored

In addition to monitoring the forests for dynamics, EMPRI is planning to take up following research studies on a long-term basis. They include monitoring of Climate, Phenology, Soil characteristics, Biometrics using Dendrometer bands, diversity of Invasive species and physiological parameters.

Climate data: On-site weather data is important information to understand the response of vegetation to natural variability in climate. An Automatic Weather Station (AWS) is installed near Bugarikallu Forest station

Appendix 2 – Spatial distribution of species enumerated in Thalewood house permanent plot

Species	Variance	Mean	Chi-sq	d.f.	Probability	Aggregation
Acacia divi divi	46.7433	5.08	220.8346	24	0	Aggregated
Acacia sp.	1.06	0.32	79.5	24	1.00E-07	Aggregated
Allophylus cobbe	0.56	0.32	42	24	0.012961	Aggregated
Apocynaceae climber	0.36	0.12	72	24	1.40E-06	Aggregated
Ardisia solanacea	13.0433	2.28	137.2982	24	0	Aggregated
Black ambu	2.76	0.52	127.3846	24	0	Aggregated
Cipadessa baccifera	53.2933	6.28	203.6688	24	0	Aggregated
Cordia wallichii	5.4567	1.04	125.9231	24	0	Aggregated
Dalbergia lanceolaria	0.7933	0.28	68	24	5.20E-06	Aggregated
Glochidion velutinum	6.5	1.8	86.6667	24	0	Aggregated
Glochidion zeylanicum	6.5433	0.72	218.1111	24	0	Aggregated
Ixora nigricans	25.46	4.28	142.7663	24	0	Aggregated
Jasminum sp.	5	1.6	75	24	5.00E-07	Aggregated
Mallotus philippensis	2.8433	0.52	131.2308	24	0	Aggregated
Mende ambu	23.19	4.76	116.9244	24	0	Aggregated
Mitragyna parvifolia	0.3067	0.16	46	24	0.004488	Aggregated
Olea dioica	74.9067	11.64	154.4467	24	0	Aggregated
Pavetta indica	1.5933	0.48	79.6667	24	1.00E-07	Aggregated
Polyalthia cerasoides	11.8267	2.92	97.2055	24	0	Aggregated
Randia dumetorum	5.51	1.48	89.3514	24	0	Aggregated
Schleichera oleosa	0.5233	0.24	52.3333	24	0.000736	Aggregated
Shorea roxburghii	6.2267	0.68	219.7647	24	0	Aggregated
Syzygium cumini	2.3933	1.32	43.5152	24	0.008746	Aggregated
Uvaria narum	0.16	0.08	48	24	0.002576	Aggregated
Viburnum Sp.	0.3333	0.2	40	24	0.021415	Aggregated
Ziziphus oenoplia	20.1767	5.52	87.7246	24	0	Aggregated
Acacia concinna	0.14	0.16	21	24	0.639154	Random
Albizia odoratissima	0.04	0.04	24	24	0.461671	Random

Species	Variance	Mean	Chi-sq	d.f.	Probability	Aggregation
Annonaceae	0.3767	0.28	32.2857	24	0.119783	Random
Bauhinia racemosa	0.0767	0.08	23	24	0.520005	Random
Breniya vitis-idaea	0.04	0.04	24	24	0.461671	Random
Breynia retusa	0.11	0.12	22	24	0.579597	Random
Butea frondosa	0.0767	0.08	23	24	0.520005	Random
Casearia sp.	0.04	0.04	24	24	0.461671	Random
Canthium dicoccum	0.04	0.04	24	24	0.461671	Random
Canthium parviflorum	0.3933	0.32	29.5	24	0.201535	Random
Careya arborea	0.0767	0.08	23	24	0.520005	Random
Cassia fistula	1.14	0.84	32.5714	24	0.113175	Random
Cassia spectabilis	0.04	0.04	24	24	0.461671	Random
Celastraceae member	0.04	0.04	24	24	0.461671	Random
Climber1	0.0767	0.08	23	24	0.520005	Random
Dimocarpus longan	0.04	0.04	24	24	0.461671	Random
Dendrocalamus strictus	0.1933	0.12	38.6667	24	0.029587	Random
Diospyros melanoxylon	0.0767	0.08	23	24	0.520005	Random
Diospyros montana	0.4167	0.6	16.6667	24	0.862844	Random
Ervatamia heyneana	0.11	0.12	22	24	0.579597	Random
Erythroxylum monogynum	0.11	0.12	22	24	0.579597	Random
Ficus microcarpa	0.04	0.04	24	24	0.461671	Random
Flueggea leucopyrus	0.04	0.04	24	24	0.461671	Random
Garuga pinnata	0.04	0.04	24	24	0.461671	Random
Gmelina arborea	0.0767	0.08	23	24	0.520005	Random
Grewia sp.	0.04	0.04	24	24	0.461671	Random
Helicteres isora	0.0767	0.08	23	24	0.520005	Random
Holarrhena antidysenterica (Kodlimurka)	0.04	0.04	24	24	0.461671	Random

Species	Variance	Mean	Chi-sq	d.f.	Probability	Aggregation
Mimosa rubicaulis	0.0767	0.08	23	24	0.520005	Random
Maytenus emarginata	0.04	0.04	24	24	0.461671	Random
Meiogyne cylindrocarpa	0.04	0.04	24	24	0.461671	Random
Memecylon umbellatum	0.04	0.04	24	24	0.461671	Random
Mende ambu (red bark)	0.04	0.04	24	24	0.461671	Random
Mimosa rubicaulis	0.6767	0.52	31.2308	24	0.14692	Random
Phyllanthus emblica	0.3233	0.36	21.5556	24	0.606153	Random
Polyalthia coffeoides	0.5	0.4	30	24	0.184409	Random
Premna tomentosa	0.0767	0.08	23	24	0.520005	Random
Pterocarpus marsupium	0.11	0.12	22	24	0.579597	Random
Scutia myrtina	0.04	0.04	24	24	0.461671	Random
Soole balli	0.04	0.04	24	24	0.461671	Random
Terminalia arjuna	1.5567	1.16	32.2069	24	0.12166	Random
Terminalia bellirica	1.3233	1.36	23.3529	24	0.500789	Random
Terminalia chebula	0.04	0.04	24	24	0.461671	Random
Toddalia asiatica	0.0767	0.08	23	24	0.520005	Random
Ugani ambu	0.04	0.04	24	24	0.461671	Random
Vitaceae shrub	0.04	0.04	24	24	0.461671	Random
Vitex altissima	0.3233	0.36	21.5556	24	0.606153	Random
Vitis sp.	0.04	0.04	24	24	0.461671	Random
Wrightia tinctoria	0.0767	0.08	23	24	0.520005	Random
Ziziphus rugosa	0.2233	0.16	33.5	24	0.09373	Random

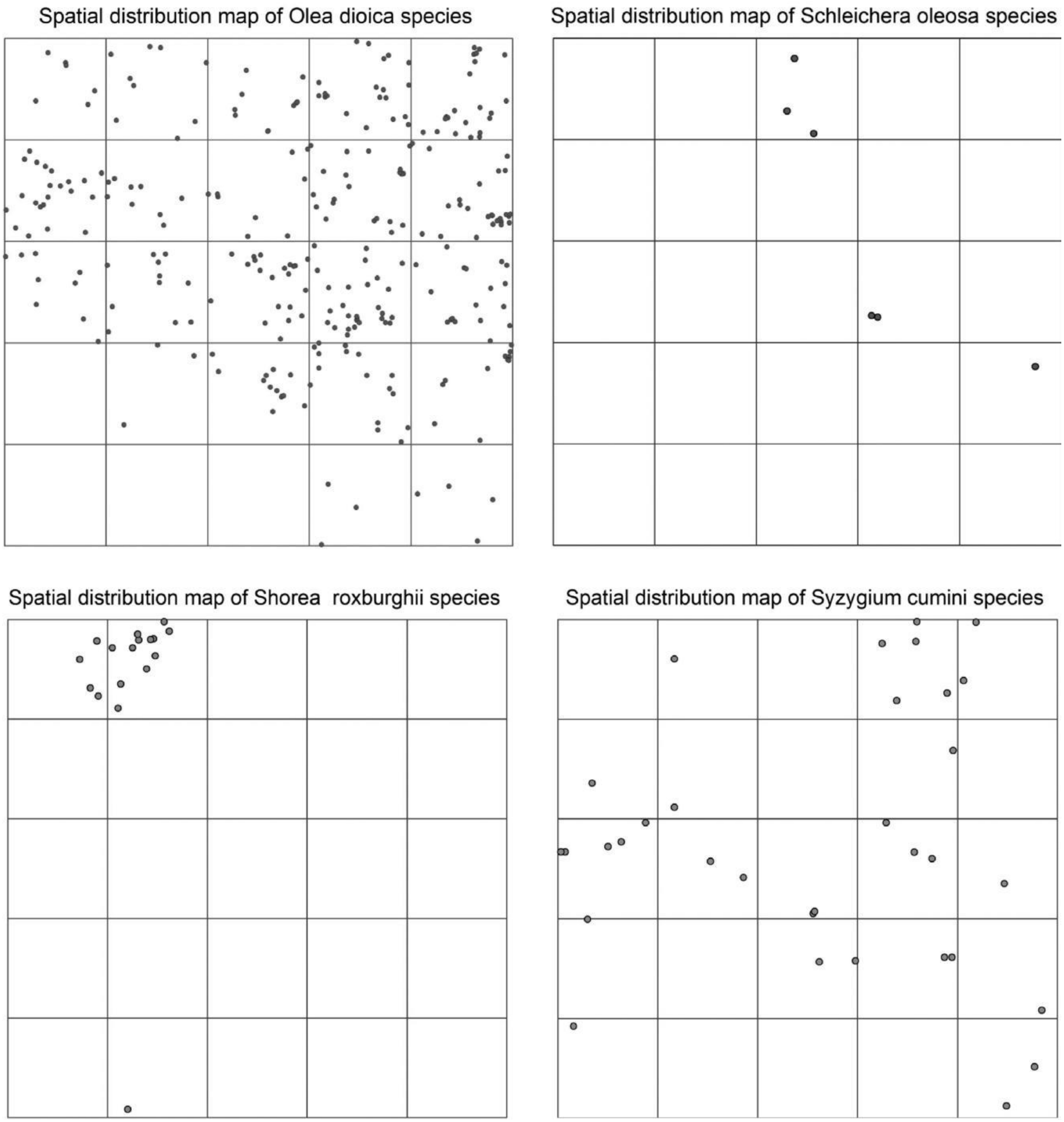


Fig. 5a – Species showing significant clumped dispersion in Thale woodhouse, BNP

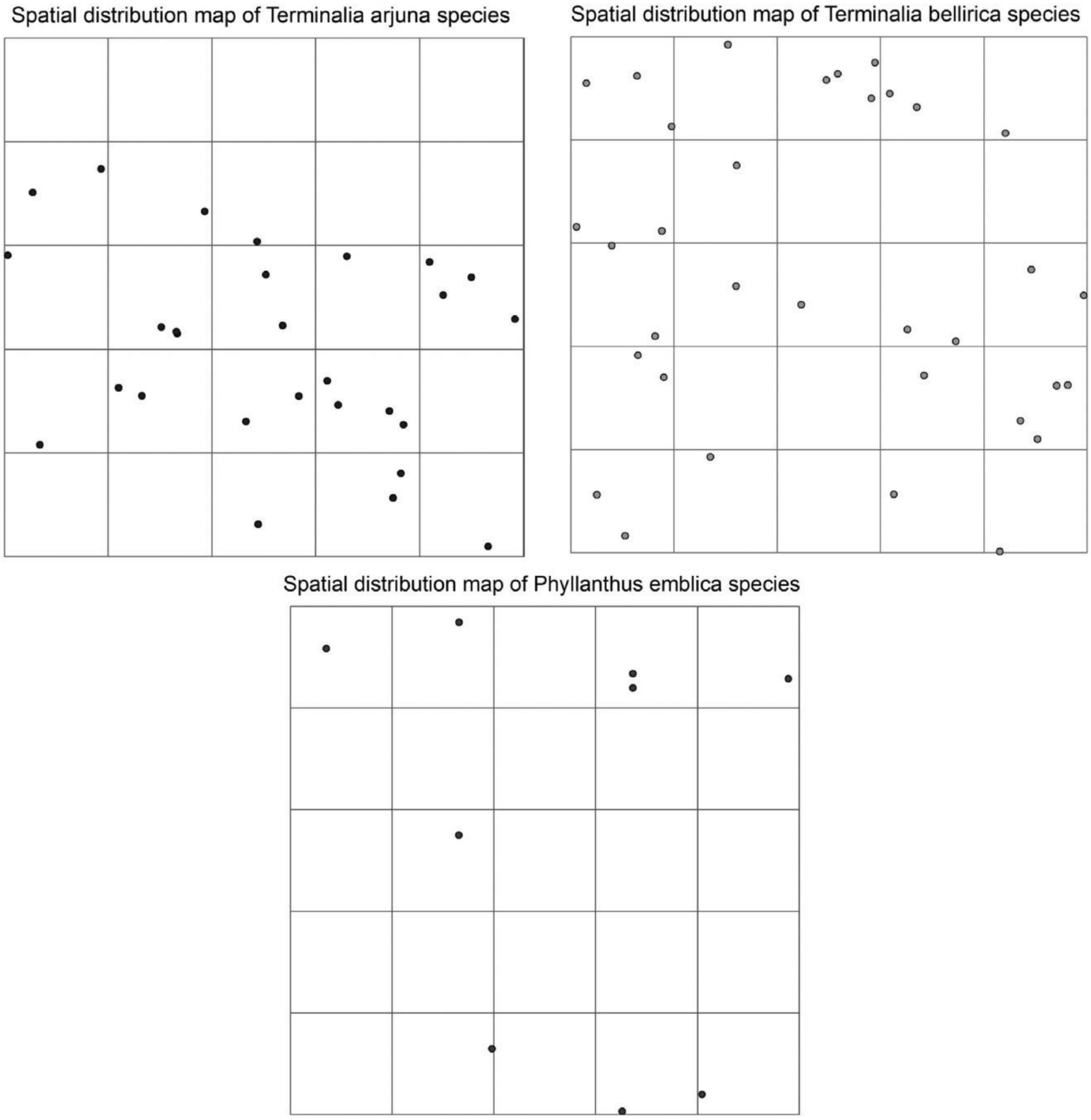


Fig. 5b – Species showing random dispersion in Thale woodhouse, BNP (Non-significant)

(12.7085 N. 77.54577 E). Parameters monitored will include rainfall, temperature, humidity, solar radiation and wind speed. Along with climate information, data on soil moisture would be obtained with help of moisture meter along different locations in the transect line.

Phenology: Phenology is the science of appearance. It is also considered to reflect the impacts of short-term fluctuation in climate. Hence it is important to study phenology to understand the long-term impacts of variability in climate. Reproductively matured trees with clearly visible canopy would be marked along a transect line. Vegetative and reproductive phenologies would be monitored regularly on a monthly interval. Vegetative phenology includes stages such as leafless, initiating leaves, expanding leaves and senescent leaves. Reproductive phenology includes both flowering and fruiting phenologies. Flowering phenology has following stages flowerless, flower buds, immature (non-pollinated) flowers, mature (pollinated) flowers and falling flowers. Fruiting stages are no fruits, fruit buds, young fruits, mature fruits and dehiscent fruits. All these stages are ranked qualitatively as the percent of extent in the canopy. Other parameters such as herbivory and frugivory would also be monitored.

Soil characteristics: Soil is an important factor that determines the association of plant communities. It also characterizes the base rock and geology of an area. The number of different nutrients and biological activity in the soil indicates the health of the ecosystem. Soil samples would be collected following systematic sampling design. Sampling design would be similar to CTFS protocol. Both macro and micronutrients would be analyzed. Maps of soil nutrients would be prepared and overlaid on the maps of spatial distribution of each species to understand the impacts of the concentration of different nutrients that drives the spatial distribution of different species in the plot. Biological activity in terms of the decomposition of litter would be assessed on a regular time frame across the plot (PPP). Microbes which are indicators of soil health (Vesicular Mycorrhizal (VAM) fungi, Plant Growth Promoting Rhizobacteria (PGPR)) and their biomass carbon (Microbial Biomass carbon (MBC)) will be estimated season wise.

Leaf analysis: Leaves play a significant role in determining physiological activity which in turn is dependent on its size and area. Leaf samples will be collected and macro & micronutrients would be estimated. Specific leaf area (SLA) and photosynthetic activity of the species will be assessed season-wise to understand the impact of climate change.

Measurement of Photosynthesis using Infrared Gas Analyser: The nutrient uptake and the photosynthetic activities will indicate the health of the species. The main parameters related to changing climate are CO_2 and temperature but other important variables may be light, humidity, pollutants, ozone, aerosols etc. Study of changes in the carbon assimilation and gaseous exchange of plants is important for understanding the effect of climate change on the plants. The quality and quantity of photosynthetic incident light (PAR), temperature and water stress, availability and utilisation of mineral nutrients, photo-respiratory losses, presence of pollutants in the atmosphere (NO_2, SO_2, O_3) and in the soil (heavy metals), etc., are some of the factors that affect plant productivity. Using Infrared Gas Analyser, the photosynthetic activities in the major tree species will be assessed on a seasonal basis.

Biometrics using Dendrometers bands: Traditional (tape) measurement of stems is subjected to many kinds of human errors. Unbiased and accurate measurement of stems is desirable for estimation of growth rates and biomass accumulation and hence carbon sequestration. Hence dendrometers which measure growth accurately would be installed on a subset of trees in the plot. Dendrometer measurements would be made twice a year (end of dry season and end of the first wet season). Dendrometer measurements would reflect the true growth, hence the biomass accumulation in a year. The measurements would also reflect the variation in growth due to fluctuation in moisture levels in the atmosphere.

Invasive species: Invasive or alien species are known to have a great impact on the native biodiversity of a community. Survival and spread of the alien species are known to be affected both by disturbance and climate change. A qualitative estimate of principal invasive species such as Lantana, Eupatorium and Parthenium would be made at the block level. The abundance class would be graded as Absent, Present, Common, Dense and Very dense. The variation in abundance of various species across successive enumerations would help us under-stand the rate of spread of invasive species and its relation to environmental factors.

Future directions

EMPRI proposes to continue to monitor these plots for recruitment, mortality, and growth of trees up to the end of the project period and beyond, provided continued financial support is obtained from the state government. EMPRI also proposes to provide quantitative data on vital parameters of several species to the forest managers which would help them to have an appropriate conservation plan and specific conservation and regeneration plans for the species that may become highly vulnerable in the face of climate change. EMPRI can also provide technical assistance and guidance to several forest divisions which have critically endangered habitats such as Myristica Swamps, Dipterocarpus forest stands pristine tropical rainforests in the Western Ghats and fire-prone deciduous forests in the peninsula.

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