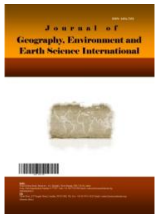

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Carbon Sequestration Potential of Urban Green Spaces (PMC Gardens) in Pune City, India

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Aim: To estimate the Carbon sequestration potential of trees in Urban green spaces of Pune city.
Study Design: The methods suggested by Ravindranath and Ostwald were used for measuring the above and belowground biomass and estimation of carbon pool. Random sampling technique was used to collect soil samples. As the study area were one acre and above, each and every tree was sampled for various parameters. The GPS instrument was used for measuring latitude and longitude of each and every tree.
Place and Duration of Study: The gardens developed by Pune Municipal Corporation (total 66 having an area one acre and above) Pune, Three years(from January 2015 to December 2015, January 2016 to December 2016, January 2017 to December 2017)
Methodology: The gardens having an area one acre and above were selected for the work. Each and every tree is sampled along with its position on ground by using GPS instrument. Sampling of tree includes measuring Height and Girth at breast height (GBH). Later, the parameters like Volume, Mass, Wood density, Above and Below ground biomass, Total biomass and Total carbon were

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calculated as per the standard methods given by Ravindranath and Ostwald [1] Soil samples were collected randomly from a depth of 30 cm as it is a zone of highest microbial activity. Walkley□Black Wet Oxidation method was used to find out soil organic carbon.

Results: Total amount of above and belowground carbon sequestered was estimated to be 7,00,507.83 tonnes; litter and deadwood 24,904.05, and soil organic carbon 1879.905; and the sum of all were 7,27,291.785 tonnes. The exotic species sequester 2,69,287.4 tonnes and native sequester 80,966.55 tonnes of carbon. The rates of carbon in active markets are US$ 30 (Thirty dollars) per tonne.

Conclusion: Putting a conservative value of US$ 30 per tonne of CO_2 locked in these sampled gardens, this carbon sink of about 7,27,291.785 tonnes of CO_2 is worth of US $ 21818753.55 or Indian Rs. 1606733011.422/-It will help in Climate mitigation and reducing the carbon footprints of Pune city.

Keywords: Above ground biomass; below ground biomass; carbon sinks; green house gases; soil organic carbon.

1. INTRODUCTION

The basic characteristic of the world is that it is constantly evolving. The climate in any place, at any time, is in a constant state of change. Nature is constantly evolving in every place, and change is a basic / fundamental characteristic of the world. However, numerous anthropogenic activities are currently disrupting nature's equilibrium and causing an unparalleled pace of changes in all aspects of the environment. Scientific societies believe that the earth's atmosphere is shifting based on a variety of scientific evidence [2-4]. The atmosphere is warming, and if current trends continue, scientists expect that by 2050, the earth would have warmed by an average of 1.5 to 4.50 degrees Celsius. [5] Carbon-dioxide, which has existed in the atmosphere for about 200 years due to its peculiar properties, is responsible for more than 55 percent of current global warming caused by Green House Gases created by human activities. Its concentration has risen by more than 30% since pre-industrial times (around 1750), and it is currently growing at a rate of 1% per year [6,7].

To cope with the increasing carbon dioxide problem, the emerging trend is to reduce the excess carbon level in the environment and its sequestration by using the natural sources like forest ecosystems [8,9]. Carbon sequestration in soils, grasslands and woody perennials, and the transfer of carbon credits among the countries (Developed and under developed or developing) through carbon market represent win-win opportunity (it is beneficial and rewarding to everyone involved) It helps in protecting the natural vegetation cover and also providing various ecological services for humanity, preserving indirectly the biological diversity of the place. Among the alternatives, tree planting and the sustainable management and protection of trees / vegetation offers perhaps the greatest potential. There is also considerable evidence that urban gardens including trees planted in educational institutes and large landscaping projects in developing countries provide substantial benefits to the environment and national economies [10,11]. The outcomes of recent Paris Agreement have also emphasized on reducing the Green House Gases, more use of renewable energy, energy efficiency and working together for greener future and to attain a goal of below 1.5 degree centigrade for the rise of temperature.

The vegetation provides a wide variety of ecological services and a range of services to communities, also contributing to human health and environmental quality. They can also help to reduce the higher ambient air temperatures that occur in urban areas as a result of the abundance of heat-absorbing materials. The Heat Island Effect is well known. Trees are amongst the most significant component and feature of any landscape, both due to biomass and diversity. The importance of urban forested areas in carbon sequestration is well recognised and documented (FSI, 1988; Tiwari and Singh, 1987). Moving toward more sustainable green cities in the near future should be a top priority and critical need in today's rapidly urbanizing world. The sacred groves act as a carbon sink and has great potential of carbon sequestration. The urban managed gardens also play crucial role in biomass carbon sequestration [12-15].

Urban parks, gardens in the city and vegetation on hilly region around the city are considered as lungs of the cities. Urban and Suburban vegetation can reduce atmospheric CO_2 directly and indirectly. As long as trees grow, they remove CO_2 from the atmosphere through a process known as carbon sequestration, which involves converting CO2 into carbon and using it to build living matter such as roots, stems, branches, leaves, flowers, fruits, and seeds. Furthermore, urban vegetation has an indirect effect on CO_2 and other greenhouse gases in the atmosphere [16,17]. Trees around buildings/ constructed areas can reduce heating and air conditioning use (Abdollahi et.al. 2000) thereby decreasing emissions of GHGs associated with the consumption of electricity, natural gas, and fuel oil. Urban trees and shrubs have the ability to remove significant amounts of air pollutants, therefore improving environmental quality [18]." Green plants have a positive impact on moods, can promote health, mental peace and relieve stress (Ulrich, 1984; Hull, 1992). These unintended consequences can be quantified and reported as co-benefits.

This study is going to focus on quantifying the amount of baseline biomass carbon pool specifically in terms of aboveground and below ground biomass, litter biomass, dead wood, and soil organic carbon of the Pune city gardens. Also, the study helped in estimating the potentiality of annual carbon sequestration by existing garden vegetation. This vegetation in the gardens inculcates a sense of environmental responsibility, awareness among the common masses and helps to know various socio-economic and ecological benefits to population.

2. MATERIALS AND METHODOLOGY

2.1 Study Area

2.1.1 About Pune City

Pune is known as Maharashtra's cultural hub. It was once known as Poona, one of Western India's most important towns. Pune has developed itself as a major manufacturing hub. It is now widely acknowledged as the country's information technology and education hub. The city has a population of more than 4 million people and is 243.84 square kilometres in size. Rapid development has transformed the city from a retirement community to an educational and administrative hub, and now to a thriving economic hub. The city is regarded as the Oxford of the East and the cultural hub of Maharashtra. Pune is also one of Maharashtra's most well-known tourist destinations. Because of its educational institutions, research institutes, training centres, exchange programmes, and the presence of a diverse range of industries and branches, Pune is a prosperous region.

Pune is situated at 18 degrees 32 minutes north latitude and 73 degrees 51 minutes east longitude. The total area of the city is 15.642 square kilometres. Pune is located at an elevation of 560 metres (1,840 feet) above sea level on the western edge of the Deccan plateau. It's on the leeward side of the Sahyadri mountain range, which serves as a natural barrier between India and the Arabian Sea. Vetal Hill rises 800 metres (2600 feet) above sea level, making it a hilly area. The old city of Pune is situated at the confluence of the Mula and Mutha rivers. The Pavana, a Mula river tributary, and the Indrayani, a Bhima River tributary, flow through Pune's northwest suburbs. With average temperatures ranging between 20 and 28 degrees Celsius, Pune has a hot semi-arid climate bordering on tropical wet and dry (type Aw) (68- and 82-degrees Fahrenheit). The Cretaceous-Eocene Deccan Trap Basalts cover the region. Rivers flow deeply into the basalt or, in some cases, into areas of late Quaternary alluvium. The majority of the rocky outcrops are Basalt, which is commonly used for building and roads. The city is underlain by basaltic lava flows of upper cretaceous age associated with basic intrusive. Along the banks of the rivers, alluvial deposits of sand, gravel, fine silts, and clays make up the soil texture. This type of soil has a thickness ranging from 8 to 18 metres. The remaining city's soil texture is made up of silicates, phyllosilicates, and the okenite group, as well as basalts with dykes and laterites.

2.1.2 Climate

Pune has a tropical wet and dry climate with three distinct seasons: summer, rainy season, and mild winter. The elevation above sea level and the leeward location in relation to the Western Ghats. As a result, the city's climate has become mild and pleasant. Between June and September, the city receives 722 mm (28.4 inches) of annual rainfall as a result of the southwest monsoon. The month of July is the wettest of the year. The city's average temperature ranges from 20°C to 30°C. Summer months are typically from March to May, with maximum temperatures ranging from 35°C to 38°C. In November, a mild winter begins.

2.1.3 Flora

The vegetation pattern of the city is conducive almost for all types of tropical species indigenous and exotic both. The city has a dense canopy of trees that spans the entire cityscape. In Pune, there are approximately 380 tree species. Pune Municipal Corporation is conducting a tree census. Approximately 70% of the tree census had been completed as of June 2011. According to the tree census, there are 23.33 lakh trees in 170 square kilometres. When compared to other forest areas in the city, the Katraj and Sinhagad areas around Pune have the most forest cover.

2.1.4 Fauna

Pune City is home to a diverse range of natural habitats, including forests, plantations, grassland, water bodies, rivers, gardens, and hills, which has contributed to the city's rich fauna diversity. The native fauna of Pune has changed over time as a result of urbanisation and the introduction of exotic species. The city's development has resulted in habitat loss and posed a threat on the faunal community.

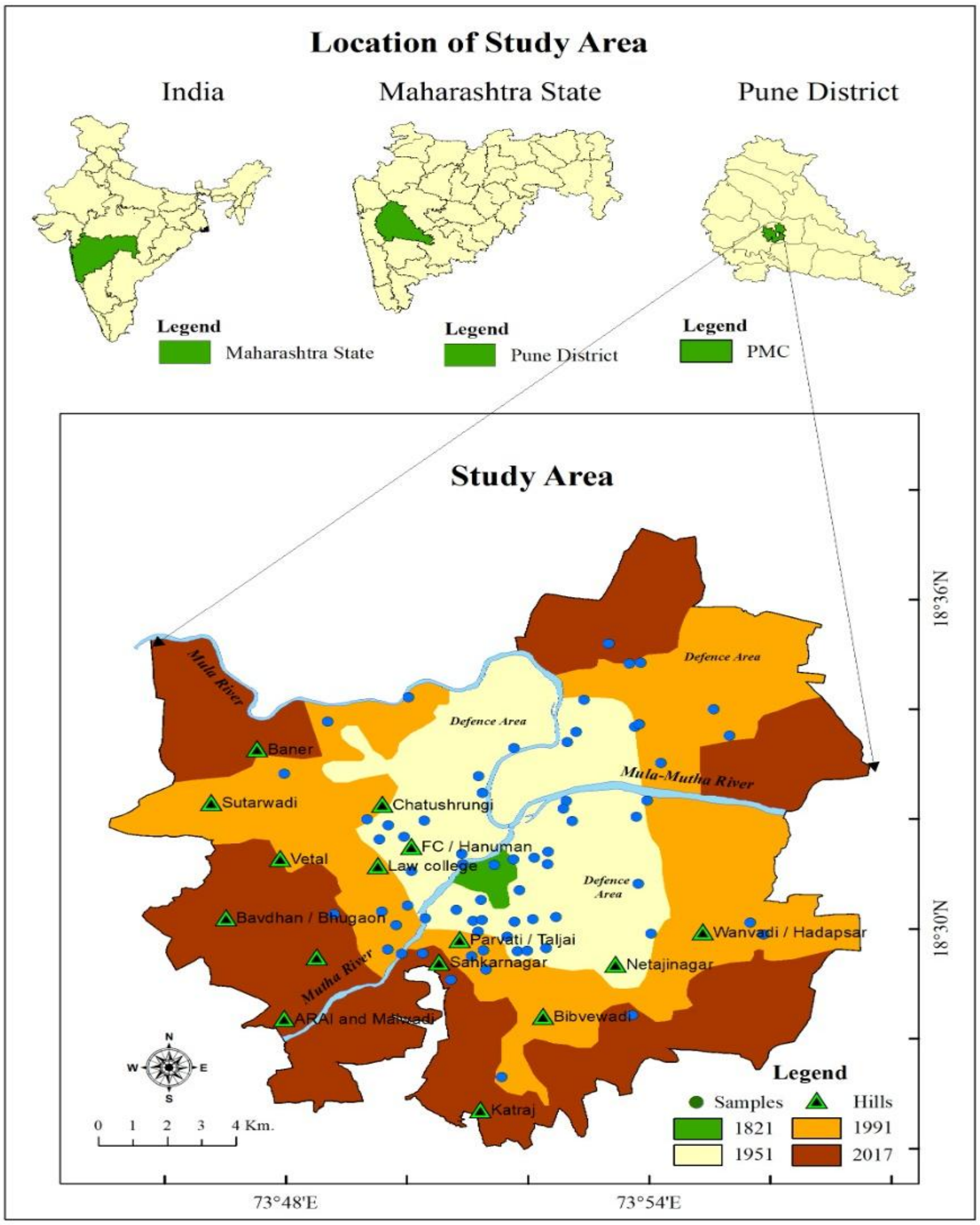


Fig. 1. Location of Study area and Sampling sites

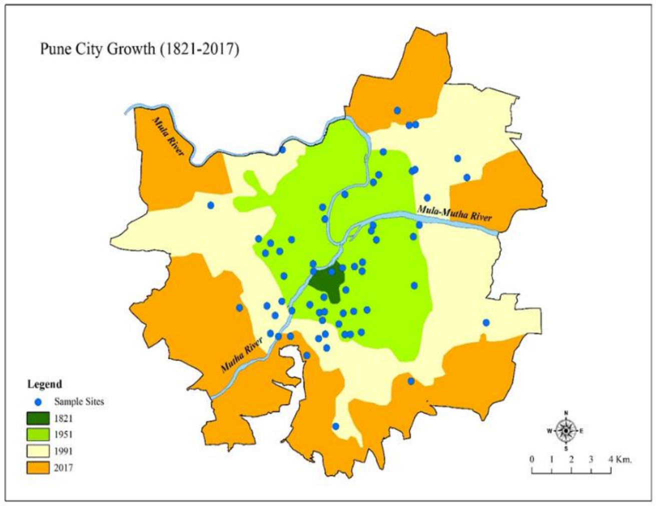


Fig. 2. Sample sites- Selected Gardens (Study areas- blue colour spots)

The work was carried out in the 66 gardens of Pune city (Fig. 1). All the trees in the selected gardens were sampled with respect to their position by using GPS instrument, Tree height and Girth at Brest Height. Soil samples were also collected as per standard protocol and analysed and the data of plant litter and dead wood is also collected. The gardens were selected by considering the criteria of one acre and above. The total area covered is almost 317.25 acres.

2.2 Materials Used

Measuring tape(for measuring the girth of tree), spring weighing balance (to weigh the plant litter and Dead wood material), thread, polythene bags (to keep soil samples), sickle(to dig the soil for collection), worksheet(to record the tree height and girth in cm), marker (to write the soil sampling date, time and sample numbers on the polythene bags), Measuring scale(to check 30 cm depth) and GPS instrument(to record the Latitude and Longitude of a Tree .i.e. position).

2.3 Sampling Design

The methods suggested by Ravindranath and Ostwald [1] were used for measuring the above and belowground biomass and estimation of carbon pool. Random sampling technique was used to collect soil samples in the study areas as it was a cost effective. As the study area was small in size, each and every tree was sampled for parameters like its position, height and Girth at Brest Height. The GPS instrument was used for measuring latitude and longitude of each and every tree.

Soil organic carbon is normally estimated to a depth of 0-30 cm since most of it is present in the top layers and root activity is also concentrated in this horizon. Wet digestion or titrimetric determination method was used to estimate the organic carbon content of soil (Walkley and Black)

Data recording formats as per Rabindranath and Ostwald [1] have been used for trees and shrub species. The carbon pool was estimated based on data taken in sample area for carbon storage pools including live tree aboveground biomass, belowground biomass, litter, dead wood and soil organic carbon. Each and every plant species and individuals above 15 cm GBH were sampled. All tree positions were recorded using a GPS. Each plant was measured for its GBH (cm) and height (m).

2.4 Estimation of Carbon Stocks

Terrestrial vegetation biomass can be divided into above-ground and below-ground carbon stocks/ pools. The analysis and calculation of carbon stocks involve conversion of field and laboratory estimates of various parameters from sample plots, such as diameter at breast height (DBH), height and soil organic carbon content. The carbon pools for which the stocks are to be estimated were: above-ground biomass, below-ground biomass, litter and dead wood biomass and soil organic carbon.

2.5 Soil Organic Carbon at 0.30 M

During the present investigation, 447 soil samples were collected randomly and analyzed for soil organic carbon content.

As a cost-effective method, the random sampling technique was used to collect soil samples in study areas. During this study soil samples were collected from 30 cm depth in all study area and were analysed by Walkley-Black (1934, 1947) method as the most accepted method for Soil Organic Carbon evaluation.

Wet digestion or titrimetric determination method, which is also cost-effective procedure is the most common method used in the field that involved a rapid titration procedure to estimate the organic carbon content of soil [19] Organic matter was oxidized with a mixture of 1N Potassium dichromate ($K_2Cr_2O_7$) and 0.5N Sulphuric acid (H_2SO_4). Unused $K_2Cr_2O_7$ was back titrated with Ferrous Ammonium Sulphate (FAS). Soil organic carbon is oxidised to CO2. The soil organic matter was calculated using the standard formula.

2.6 Above and Below Ground Carbon Pool

The random sampling method was used for measuring the above ground biomass of vegetation in period of 2015-2017. All plant species above 15 cm GBH within the Pune city were sampled; and every individual plant diameter or girth at breast height (GBH) and height was measured. Theses parameter represents the volume or height of a tree, which can be converted to biomass per unit area (tonnes/hectare or tonnes/hectare/year). The breast height in DBH was recorded at 130 cm above the ground. Tree height was measured by using instrument 'Abney level'. For quantification of biomass the method suggested by Ravindranath and Ostwald [1] has been used. The total carbon pool including dead wood and litter biomass in the study area were estimated. The GBH was converted to DBH in meters(Diameter at breast Height), then the height was converted from feet to meters, Volume of a tree is calculated by using the formula π*r2*h, the wood density values were obtained for each of the tree species from (http://www.worldagroforestrycentre.org/sea/Products/AFDbases/WD/), or in case density was not available, 0.6 was accepted as wood density [1] Them, Mass is calculated by multiplying Volume and wood density, Above Ground Biomass is calculated by dividing the Mass by 1000 and Below Ground Biomass is always 0.26 of Above ground Biomass. Then total biomass is calculated aby addition of AGB and BGB values.Litter biomass estimation was performed using the quadrats of 1m × 1m size. The quadrats were divided into four parts (1⁄4 each). Herbs were harvested from two corners (Fig. 3.9) of this quadrat to avoid over harvesting in the study area; and it was extrapolated. End of monsoon (rainy season) was selected as the most proper time for sampling. The weight of litter biomass was recorded.

3. RESULTS AND DISCUSSION

The carbon pool of all the 65 gardens covering an area of 317.25 acres were estimated by considering above ground, belowground, litter biomass and dead wood, and soil organic carbon. The entire 66 gardens (having a size of one acre and above) were considered. The study was carried out as per the years mentioned in the abstract (03 years- (from January 2015 to December 2015, January 2016 to December 2016, January 2017 to December 2017).Total number of trees were 5929. The total amount of biomass carbon was 700507.83 tons. Out of total plant species, 3346 were exotic and 2583 native plants (Table 2, and Table 3). The exotic species sequester 269287.4 tonnes and native sequester 80966.55 tonnes of carbon (Table-5). Total amount of above and belowground carbon sequestered was estimated to be 7,00,507.83 tonnes; litter and deadwood 24,904.05, and soil organic carbon 1879.905; and the sum of all were 7,27,291.785 tonnes (Table-4). The exotic species sequester 2,69,287.4 tonnes and native sequester 80,966.55 tonnes of carbon. The rates of carbon in active markets are US$ 30 (Thirty dollars) per tonne. Putting a conservative value of US$ 30 per tonne of CO_2 locked in these sampled gardens, this carbon sink of about 7,27,291.785 tonnes of CO_2 is worth of US $ 2,18,18,753.55 or Indian Rs. 1606733011.422/-. It is also observed that the biomass sequestered more carbon than soil; this is because of the transported soil. It will take some more time to sink more soil organic carbon. The annual increase in carbon will be 73824 t/year. These values were calculated by using the carbon biomass expansion factor 1.17 recommended by IPCC [20] (Fig. 4). The BGB and Total Biomass were observed to be strongly correlated in native plant (correlation coefficient: 0.9) than exotic plant (correlation coefficient: 0.4). AGB and Total carbon is negatively correlated in both exotic and native plants (correlation coefficient: -1).

Table 1. Ward wise number of gardens sampled and their area

Sr. No.	Ward wise list of gardens	Total no. of gardens studied	Area of gardens covered in acres
1	Aundh	3	7
2	Bhavanipeth	4	7.5
3	Bibvewadi	1	4
4	Dhole Patil	8	20.5
5	Ghole road	9	33.5
6	Hadapsar	3	12.5
7	Sahakarnagar_Dhankawadi	10	153.5
8	Sangamwadi	6	14.75
9	Tilak road	3	19.5
10	Vishrambag wada	6	19
11	Warje_Karve	5	11.5
12	Yerwada	8	14
	TOTAL	**66**	**317.25**

Table 2. Contribution of Exotic plant species in carbon pool

Sr. No.	Local name	Botanical name of plant species	Total number of species	Above Ground Biomass	Below Ground Biomass	Total Biomass	Total Carbon
1	Australian babool	*Acacia auriculiformis*	14	50.94	13.24	64.18	32.09
2	Gorakh chinch	*Adansonia digitata*	3	13.52	3.52	17.04	8.52
3	African oil palm	*African oil palm*	3	13.76	3.58	17.34	8.67
4	Rain tree	*Albizia /Samanea saman*	154	1241.73	322.85	1564.58	782.29
5	Sitaphal	*Annona squamosa*	5	5.5	1.43	6.93	3.47
6	Christmas tree	*Araucaria heterophylla*	32	41.87	10.89	52.76	26.38
7	Bougainvillea	*Bougainvillea*	3	9.68	2.52	12.19	6.1
8	Shankeshwar	*Caesalpinia pulcherrima*	4	3.17	0.82	3.99	2
9	Powder puff	*Calliandra haematocephala*	1	4.72	1.23	5.94	2.97
10	Bottle brush	*Callistemon citrinus*	126	230.79	60.01	290.8	145.4
11	Papaya	*Carica papaya*	2	2.94	0.76	3.7	1.85
12	Kashid	*Cassia / Senna siamea*	330	88343.8418	22969.40	111313.26	55656.63

Sr. No.	Local name	Botanical name of plant species	Total number of species	Above Ground Biomass	Below Ground Biomass	Total Biomass	Total Carbon
13	Horse cassia	*Cassia grandis*	12	40.1	10.43	50.53	25.26
14	Jawa cassia	*Cassia javanica*	1	2.07	0.54	2.61	1.3
15	Motha tarwad	*Cassia surattensis*	1	3.11	0.81	3.92	1.96
16	Suru	*Casuarina equisetifolia*	391	13181.64	3427.23	16608.87	8304.43
17	Pandhari sawar	*Ceiba petandra*	18	219.925	57.18	277.11	138.55
18	Kailaspati	*Courupita guanensis*	49	132.99	34.58	167.57	83.78
19	Cocoplum	*Chrysobalanus icaco*	2	2.07	0.54	2.61	1.31
20	Star apple	*Chrysophyllum cainito*	1	0.24	0.06	0.3	0.15
21	Scarlet cordia	*Cordia sebestena*	4	2.69	0.7	3.39	1.69
22	Cycus	*Cycus circinalis*	4	20.57	5.35	25.92	12.96
23	Gulmohar	*Delonix regia*	311	99511.0648	25872.88	125383.94	62691.97
24	Dracaena	*Dracaena fragrans*	6	1.76	0.46	2.22	1.12
25	Areca palm	*Dypsis lutescens*	18	136.14	35.4	171.54	85.77
26	Oil palm	*Elaeis guineensis*	1	5.52	1.44	6.96	3.48
27	Nilgiri	*Eucalyptus globulus*	52	4431.2168	1152.12	5583.33	2791.67
28	Snow bush	*Euphorbia leucocephala*	9	23.94	6.22	30.16	15.08
29	Anjeer	*Ficus carica*	1	4.56	1.19	5.75	2.87
30	Triangle leaf fig	*Ficus natalensis*	2	2.57	0.67	3.24	1.62
31	Fern tree	*Filicium decipiens*	10	2215.87	576.13	2792	1396
32	Giripushpa	*Glyricidia sepium*	74	15388.0516	4000.89	19388.94	9694.48
33	Silver oak	*Gravillea robusta*	353	983.59	255.73	1239.32	619.66
34	Rudraksh	*Guazuma ulmifolia*	2	7.18	1.87	9.05	4.52
35	Neelmohar	*Jacaranda mimosifolia*	25	2021.79	525.67	2547.46	1273.73
36	Common juniper	*Juneper gymnosperm*	1	0.97	0.25	1.22	0.61
37	Khaya	*Khaya senegalensis*	35	252.0432	65.53	317.57	158.78
38	Brahmdand	*Kigelia africana*	6	30.03	7.81	37.83	18.92
39	Tantani	*Lantana camera*	1	643.74	167.37	811.11	405.56
40	Subabhul	*Leucaena leucocephala*	79	16532.054	4298.34	20830.39	10415.19
41	Foot stool palm	*Livistona chinensis*	4	15.53	4.04	19.57	9.78
42	Markhamia	*Markhamiya platycalyx*	7	4.89	1.27	6.16	3.08
43	Booch	*Millingtona hortensis*	98	28485.95	7406.35	35892.3	17946.15
44	Tuti	*Morus alba*	1	0.8901	0.23	1.12	0.56

Sr. No.	Local name	Botanical name of plant species	Total number of species	Above Ground Biomass	Below Ground Biomass	Total Biomass	Total Carbon
45	Singapore cherry	*Muntingia calabura*	12	4.45	1.16	5.61	2.81
46	Olive	*Olea europaea*	1	3.21	0.84	4.05	2.02
47	Chenduphali	*Parkia biglandulosa*	7	84.13	21.87	106	53
48	Pegu gulmohar	*Pegu gulmohar*	1	674.83	175.46	850.29	425.14
49	Copper pod	*Peltophorum pterocarpum*	154	69903.373	18174.87	88078.26	44039.13
50	Ray awala	*Phyllanthus acidus*	17	13778.79	3582.49	17361.28	8680.64
51	Vilayti chinch	*Pithecellobium dulce*	33	15023	3905.98	18928.98	9464.50
52	Chinar	*Platanus orientalis*	1	0.84	0.22	1.06	0.53
53	Laal Chafa	*Plumeria obtusa*	28	366.09	95.18	461.28	230.64
54	Poplar tree	*Populus deltoides*	7	29.69	7.72	37.41	18.71
55	Fiji fan Palm	*Pritchardia pacifica*	16	61.6	16.01	77.61	38.81
56	Shami	*Prosopis juliflora*	3	16.146	4.20	20.34	10.17
57	Peru	*Psidium guajava*	3	1.66	0.43	2.1	1.05
58	Dalimb	*Punica granatum*	1	1.79	0.47	2.26	1.13
59	Travellers palm	*Ravenala madagascariensis*	18	33.82	8.79	42.61	21.31
60	Royal palm	*Roystonia regia*	463	2256.98	586.82	2843.8	1421.9
61	Pichkari	*Spathodea companulata*	111	46662.46	12132.24	58794.71	29397.36
62	Umbrella tree	*Schefflera actinophylla*	1	0.91	0.24	1.15	0.58
63	Spectacular cassia	*Senna spectabilis*	2	7.2	1.87	9.07	4.53
64	Laxmi taru	*Simaruba glauca*	6	11.23	2.92	14.15	7.08
65	Mahogani	*Sweitenia mahogani*	27	60.0044	15.60	75.60	37.80
66	Pink trumpet	*Tabebuia rosea*	37	115.35	29.99	145.35	72.67
67	Golden trumpet	*Tabebuia argentea*	23	47.38	12.32	59.7	29.85
68	Ticoma	*Tecoma castanifolia*	8	6	1.56	7.56	3.78
69	Saag	*Tectona grandis*	1	0.836	0.22	1.05	0.53
70	Bitti	*Thevetia peruviana*	1	0.7	0.18	0.88	0.44
71	Khota Badam	*Terminalia catappa*	93	3990.119	1037.43	5027.55	2513.78
72	Madagascar almond	*Terminalia mantaly*	7	11.4	2.96	14.36	7.18
73	Foxtail palm	*Wodyetia bifurcata*	8	19	4.94	23.94	11.97
			3346	**427440.20**	**111134.51**	**538574.73**	**269287.4**

(The values of AGB, BGB, Total Biomass and total carbon are expressed in tonnes)

Table 3. Contribution of Native plant species in carbon pool

Sr. No.	Local name	Botanical name of plant species	Total number of species	Above Ground Biomass	Below Ground Biomass	Total Biomass	Total Carbon
1	Supari	*Arecha catechu*	19	88.4288	22.993088	111.421888	55.715944
2	Pandhara khair	*Acacia feruginea*	4	17.6	4.5788	22.1788	11.0894
3	Khair	*Acacia chundra*	1	0.2816	0.073216	0.354816	0.177408
4	Hivar	*Acacia leucophloea*	7	42.864	11.14464	54.00864	27.00432
5	Babul	*Acasia nelotica*	20	149.502	38.87392	188.37592	94.18296
6	Bel	*Aegle marmelos*	2	7.85	2.04	9.89	4.94
7	Shirish	*Albizia lebbeck*	4	4440.42	1154.51	5594.93	2797.46
8	Chinchwa	*Albizia odoratissima*	1	3.79	0.99	4.78	2.39
9	Satveen	*Alstonia scholaris*	169	373.46	97.1	470.56	235.28
10	Roktarohida	*Aphanamixis polystachya*	3	6.2	1.61	7.81	3.91
11	Phanas	*Artocarpus heterophyllus*	16	69.67	18.11	87.78	43.89
12	Neem	*Azadirachta indica*	179	5700.53	1482.1422	7182.674624	3591.337312
13	Bamboo	*Bambusa vulgaris*	9	7.33	1.91	9.24	4.62
14	Newar	*Barringtonia acutangula*	6	17.73	4.61	22.34	11.17
15	Kanchan	*Bauhinia perpuria*	1	1.74	0.45	2.19	1.1
16	Apta	*Bauhinia recemosa*	2	2.57	0.67	3.24	1.62
17	Kanchan	*Bauhinia variegata*	128	2701.37	702.36178	3403.73478	1701.86239
18	Kate savar	*Bombax ceiba*	9	13.2008	3.434208	16.635008	8.317504
19	Tad	*Borassus flabellifer*	1	0.92	0.24	1.16	0.58
20	Salai	*Boswellia serrata roxb*	4	13.53	3.5228	17.0528	8.5214
21	Charoli	*Buchania lazaan*	1	0.54	0.1404	0.6804	0.3402
22	Palas	*Butea monosperma*	4	7.108	1.85168	8.95968	4.47984
23	Panchunda	*Capparis grandis*	2	5.52	1.4352	6.9552	3.4776
24	Bherli maad	*Caryota urens*	153	643.45	167.3	810.75	405.37
25	Bitti	*Cascabella thevetia*	21	13.28	3.45	16.73	8.37
26	Bahava	*Cassia fistula*	19	34.9504	9.089304	44.039704	22.014852
27	Red cassia	*Cassia roxburghii*	3	8.95	2.33	11.28	5.64
28	Bhutya	*Cassine glauca*	6	5680.62	1476.96	7157.58	3578.79
29	Savar	*Ceiba petandra*	16	17.5	4.55	22.05	11.025
30	Behru	*Chloroxylon swietenia*	2	9.29	2.42	11.71	5.85

Sr. No.	Local name	Botanical name of plant species	Total number of species	Above Ground Biomass	Below Ground Biomass	Total Biomass	Total Carbon
31	Limbu	*Citrus limon*	1	0.45	0.12	0.57	0.28
32	Coconut	*Cocos nucifera*	56	122.92	31.96	154.88	77.44
33	Bhokar	*Cordia dichotoma*	6	8.91	2.32	11.23	5.61
34	Queen sago	*Cycus circinalis*	3	3.36	0.87	4.23	2.12
35	Shisav	*Dalbergia latifolia*	4	19.64	5.11	24.74	12.37
36	Phansi	*Dalbergia lanceolaria*	8	136.898	35.59775	172.49525	86.247625
37	Motha Karmal	*Dillenia indica*	19	44.56	11.59	56.15	28.07
38	Temru	*Diospyros melanoxylon*	1	1.8	0.47	2.27	1.14
39	Medhshingi	*Dolichondrone falcata*	3	7.1484	1.858584	9.006984	4.503492
40	Putranjeev	*Drypetes roxburghii*	1	0.35	0.09	0.44	0.22
41	Aamla	*Emblica officinalis*	18	21.26	5.53	26.79	13.39
42	Pangara	*Erythrina variegata*	9	40.08	10.42	50.5	25.25
43	Umber	*Ficus recemosa*	60	394.54	102.57787	497.11737	248.563685
44	Pipal	*Ficus religiosa*	71	439.51	114.27	553.78	276.89
45	Nandruk	*Ficus benjamina*	64	68.06	17.7	85.76	42.88
46	Vad	*Ficus benghalensis*	37	14866.1	3865.186	18731.283	9365.6415
47	Rubber	*Ficus elastica*	26	87.44	22.73	110.17	55.09
48	Payar	*Ficus virens*	4	18.08	4.7	22.78	11.39
49	Fish tail palm	*Fish tail palm*	1	161.85	42.08	203.93	101.97
50	Shivan	*Gamelia arborea*	1	1.2	0.3	1.47	0.74
51	Phalsa	*Grewia asiatica*	2	1.7385	0.45201	2.19051	1.095255
52	Khatkhati	*Grewia flavescens*	12	13.14	3.42	16.56	8.28
53	Anjan	*Hardwickia binata*	4	10.36	2.69	13.05	6.53
54	Waras	*Heterophragma quadriloculare*	1	2.76	0.7176	3.4776	1.7388
55	Waval	*Holoptelia intigrifolia*	22	96.267	25.02982	121.29682	60.64341
56	Tamhan	*Lagerstroemia reginae*	68	133.5	34.71	168.21	84.105
57	Kavath	*Limonia acidissima*	1	5.35	1.39	6.74	3.37
58	Moi	*Lannea coromandelica*	2	11.247	2.92422	14.17122	7.08561
59	Son chafa	*Michelia champaca*	66	45.12	11.73	56.85	28.43
60	Moh	*Madhuca latifolia*	1	1.02	0.27	1.29	0.64
61	Mango	*Mangifera indica*	94	3941.94	1024.9	4966.85	2483.42
62	Limboni	*Melia azedarach*	7	12.38	3.22	15.6	7.8

Sr. No.	Local name	Botanical name of plant species	Total number of species	Above Ground Biomass	Below Ground Biomass	Total Biomass	Total Carbon
63	Bakul	*Mimuseps elangi*	18	31.61	8.22	39.83	19.92
64	Kalam	*Mitragyna parvifolia*	1	20.16	5.24	25.4	12.7
65	Bartondi	*Morinda pubescense*	1	0.414	0.10764	0.52164	0.26082
66	Shevga	*Moringa oleifera*	2	3.48	0.9	4.38	2.19
67	Kadamb	*Neolamarckia cadamba*	19	83.54	21.72	105.27	52.63
68	Prajakta	*Nyctanthes arbortristis*	9	14.93	3.88	18.81	9.41
69	Tetu	*Oroxylum indicum*	3	4.75	1.24	5.99	2.99
70	Putranjeev	*Patranjiva roxburghii*	71	25450.92	6617.23	32068.15	16034.08
71	Shindi	*Phoenix sylvestris*	23	84.21	21.89	106.1	53.05
72	Ashok	*Polyalthia longifolia*	607	3644.31	947.52	4591.82	2295.91
73	Karanj	*Pongamia pinnata*	34	4244.4	1103.544	5347.940162	2673.975081
74	Padauk	*Pterocarpus indicus*	13	30.34	7.89	38.23	19.11
75	Karnikar	*Pterospermum acerifolium*	1	1.06	0.28	1.34	0.67
76	Muchkund	*Pterospermum canescens*	1	0.9	0.23	1.13	0.57
77	Chandan	*Santalum album*	62	8856.34	2302.65	11158.99	5579.49
78	Ritha	*Sapindus laurifolis*	1	1.09	0.28	1.37	0.69
79	Sita ashok	*Saraca indica*	69	16612.2	4319.17	20931.38	10465.69
80	Jambhul	*Syzygium cumini*	56	9191.5	2389.7971	11581.29912	5790.65456
81	Jungali badam	*Sterculia foetida*	18	48.09	12.5	60.6	30.3
82	Chinch	*Tamarindus indica*	54	19323.68	5024.157	24347.837	12173.9185
83	Teak	*Tectona grandis*	1	1.1	0.29	1.39	0.69
84	Arjun	*Terminalia arjuna*	14	29.86	7.77	37.63	18.82
85	Arjun	*Terminalia eliptica*	1	1.428	0.37128	1.79928	0.89964
86	Paras bhendi	*Thespesia populnea*	8	8.38	2.18	10.56	5.28
87	Gol	*Trema orientalis*	4	5.6	1.46	7.06	3.53
88	Nirgudi	*Vitex negundo*	1	3.92	1.02	4.94	2.47
89	Kala kuda	*Wrightia tinctoria*	3	12.36	3.22	15.58	7.79
90	Ber	*Ziziphus mauritiana*	3	8.5708	2.224608	10.805408	5.397704
			2583	**128518.31**	**33414.80**	**161933.12**	**80966.55**

(The values of AGB, BGB, Total Biomass and total carbon are expressed in tonnes)

Table 4. Total amount of carbon sequestered

Carbon pool	Estimated quantity (tonnes)
AGB carbon	555958.52
BGB carbon	144549.31
Litter and deadwood carbon	24904.05
Soil organic carbon	1879.905
Total	727291.785

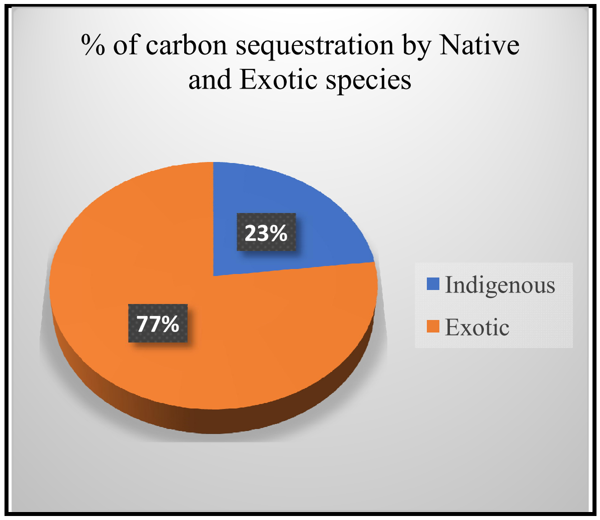


Fig. 3. Percentage of Carbon sequestered by Native and Exotic species

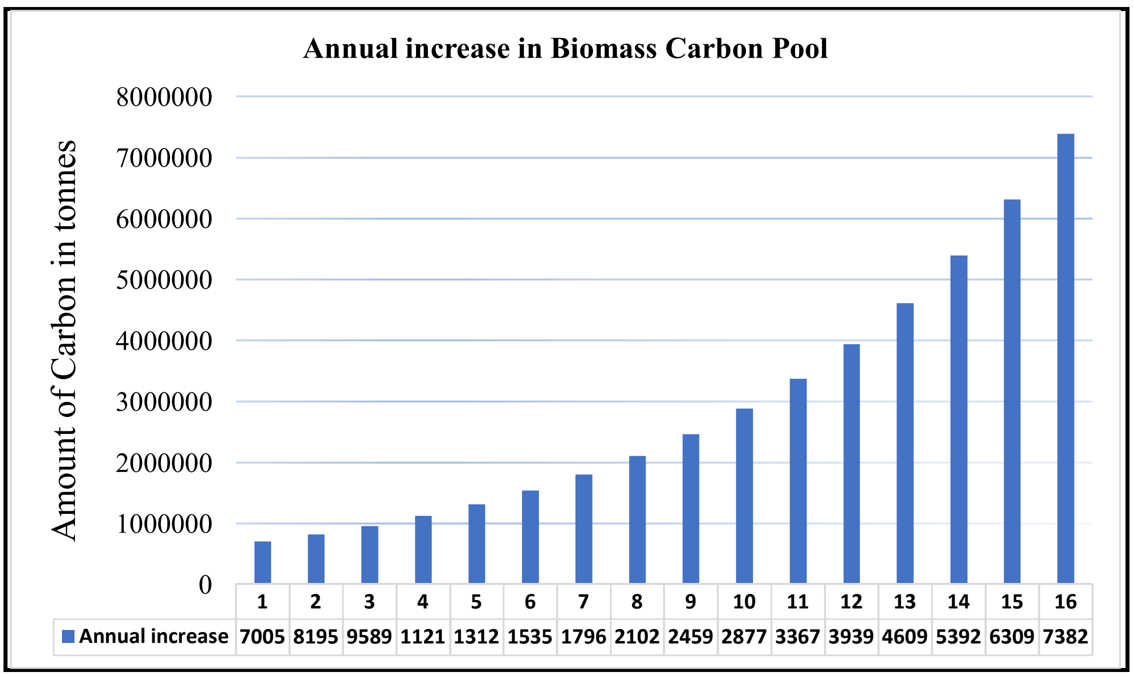


Fig. 4. Annual increase in biomass carbon pool (the numbers from 1 to 16 indicates years)

Table 5. Total number of plant species, their total individuals, AGB, BGB, Total Biomass and Total Carbon

Type	Total number of Species	Total number of all plants	AGB (Tonnes)	BGB (Tonnes)	Total Biomass (Tonnes)	Total Carbon (Tonnes)
Native	90	2583	128518.31	33414.80	161933.12	80966.55
Exotic	73	3346	427440.20	111134.51	538574.73	269287.4
Total	163	5929	555958.51	144549.31	700507.85	350253.95

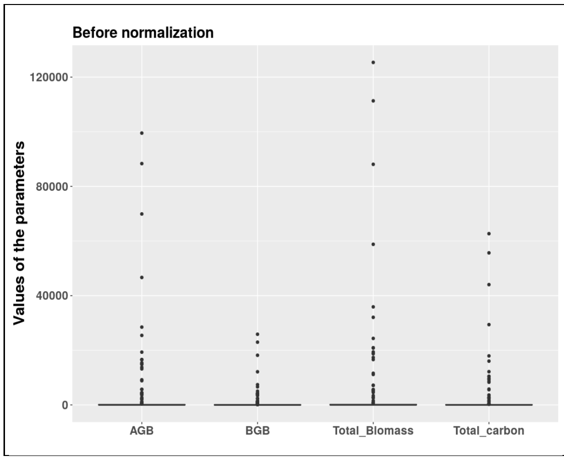
3.1 Data Normalization

Parameters before normalization

3.2 Correlation Analysis

Pair wise correlation of parameters in all plants

BGB and Total Biomass were observed to be strongly correlated in native plant (correlation coefficient: 0.9) than exotic plant (correlation coefficient: 0.4). AGB and Total carbon is negatively correlated in both exotic and native plants (correlation coefficient: -1)



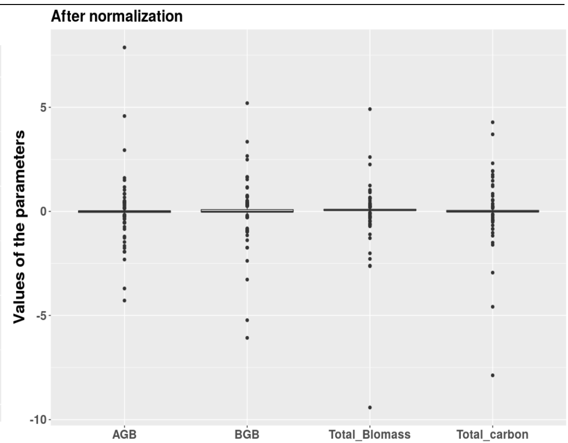


Fig. 5. Data normalisation w.r.t.all the parameter **Fig. 6. Data normalisation w.r.t.all parameters**

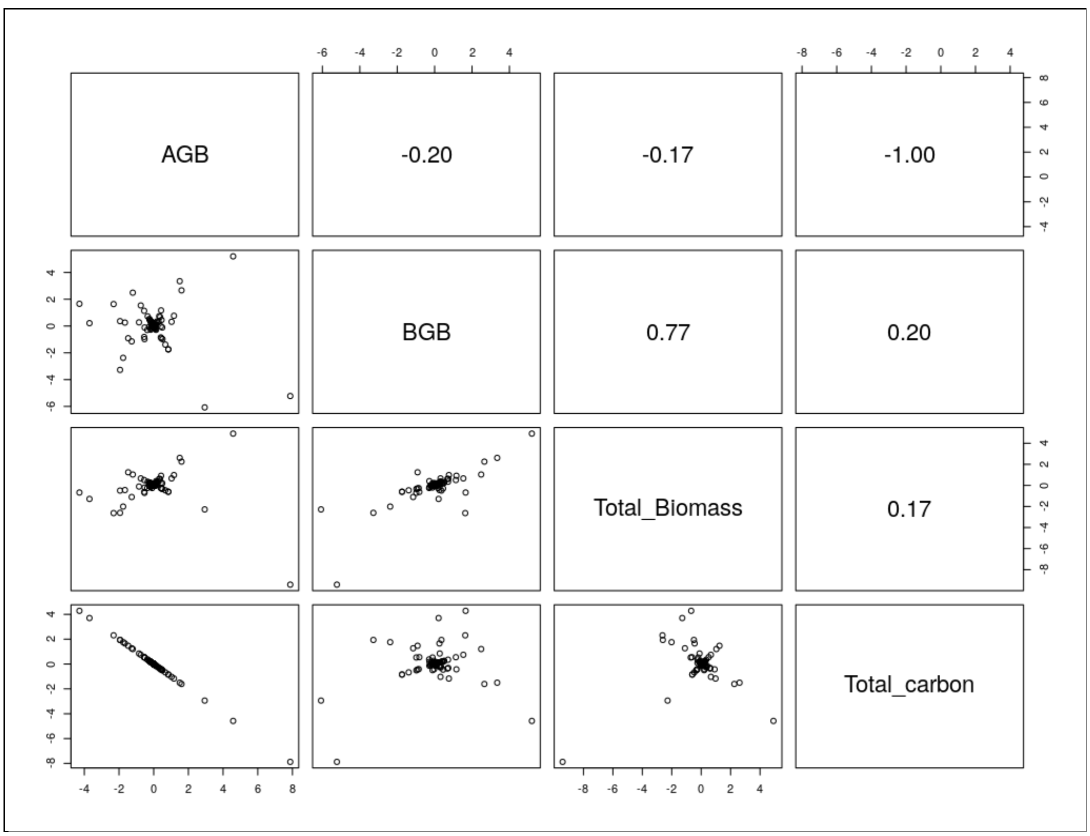


Fig. 7. Pair wise correlation of all parameters in all plants

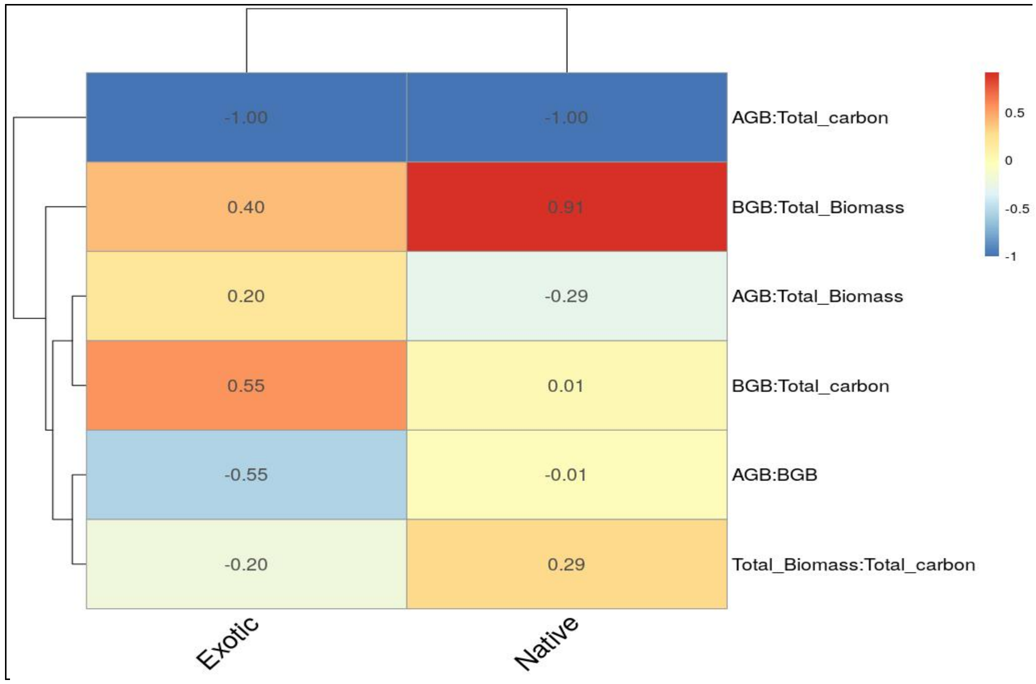


Fig. 8. Correlation Coefficient between native and Exotic plant species
Both Native and Exotic plants are having similar profile w.r.t 4 parameters

4. CONCLUSION

Based on the results it was suggested that the litter and dead wood biomass can be managed carefully from a viewpoint to increase the soil carbon content. It should not be burnt away; instead, it must be used as a source of increasing carbon content in soil. Further study is required to determine precisely, how significant the net carbon sequestration benefit is to the environment? One can estimate the cost-benefit equation of such offsetting factors as fuel expense in maintaining green spaces, fertilizer and pesticide use, energy for water costs, etc. Our results are based on one two-time field measurement. However, long-term measurement of biomass is necessary for more accurate and precise results. While selecting the species for plantation in gardens and other areas, one can emphasize on considering the native species. The most important benefit in selecting the native species is that these species can be long lasting and better suited to the local climate, thereby continue to sequester the carbon for longer duration, whereas, exotics being new to such habitats may not survive for longer duration.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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