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Carbon Sequestration Potential of Hills (Studied) Around Pune City, Pune

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Abstract Pune is situated in close proximity (50kms) on the biodiversity of Sahyadri Hills also known as the Western Ghats. As per the land use distribution of Pune city, the total area covered under hills and hill slopes is 1245 ha i.e., 5.10% of the total land. The Hills environment in the city is subjected to intense pressure due to all types of developmental projects and encroachment. The mounting concrete structures due to these developments have resulted in the loss of green covers on the hills covering parts of Western Ghats which are a resultant of the increasing climate change. We have sampled 10 hills namely ARAI. Baner, Bhopdev Ghat, Chaturshringi, Fergusson College, Kothrud hill, Sutarwadi. University, Vetal- Parvati for biomass, a total of 124 quadrates of size 15 m X 15 m were plotted. Each and every tree in the quadrate is sampled along with GPS and random soil samples were collected for soil carbon analysis. Soil samples were taken from soil profile up to 30 cm depth. Walkley-Black Wet Oxidation method was applied for measuring soil organic carbon. Total amount of above and belowground carbon sequestered was estimated and the values are extrapolated which comes to the value of1336886568 tonnes; litter and deadwood 17509.44 tonnes, and soil organic carbon 792001603.46 tonnes; and the sum of all were 212,89,05,681 tonnes. 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 212,89,05,681 tonnes of CO_2 is worth of US $ 63,867,170,430 or Indian Rs. 4,701,901,087,056.6 /- It will help in mitigating the total carbon emissions and reducing the carbon footprints of the Pune city and thereby decreasing atmospheric carbon dioxide levels.

Keywords: *carbon sinks, carbon pool, carbon footprint, GHG, Soil Organic Carbon, above ground and below ground biomass, GPS, sustainable development*

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1. Introduction

Pune is situated in close proximity (50kms) on the biodiversity of Sahyadri Hills also known as the Western Ghats. The importance of the Hills/ Green spaces surrounded is summarised as Rich biodiversity with local species, play important role in moderating the temperature by acting as heat sinks, in recharging the river as well as groundwater, as coolants, in Carbon Sequestration, Carbon Sinks, Aesthetic Value, provides Ecological services, provide suitable habitat for endemic species, Watershed Value, A cord with Western ghats and Corridor, Role in Weather pattern and Natural Heritage.

The Hills which where once the lungs of Pune are now under threat: Due to excessive concretisation and unscientific plantation drives, lot of construction activity like tiled pathways, gazebo's, statues etc. under the guise of beautification, the construction of roads, access to vehicles, a lot of food stalls , no understanding / awareness about the hills and their natural pristine condition, the unscientific plantation drive, people plant exotic trees instead of native one, increasing concretisation on the hills, over urbanization, Industrialization, construction of highways and various roads, illegal hill cutting, diverting waste and drains, cutting and demolishing the hills to create a plain land for housing project constructions, Gardens, parks and urban forests are rapidly disappearing in the concrete jungle, the rise in the number of private ownership of vehicles, cab numbers, auto and private vehicles, two wheelers, new bikes, haphazard urban growth and environmental pollution, increase in carbon emissions, attempted forest station on such a habitats, no attention is being paid to the human imprint on wild animals and birds, habitat destruction, fragmentation, habitat degradation, new industrial estates, construction of a new ring road, a by-pass and an express highway, leveling and filling up of rainwater pools, road networks passing through the sacred groves, and no botheration from anyone as if there is no need of good quality environment to live in.

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 10 hills surrounding Pune. Also, the study helped in estimating the potentiality of annual carbon sequestration by existing vegetation. The vegetation on these studied hills 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 Methods

2.1. Study Area

The work was carried out on 10 hills (Figure 1). All the trees in the selected quadrates were sampled with respect to their position by using GPS instrument, Tree height and GBH. Soil samples were also collected as per standard protocol and analysed and the data of plant litter and dead wood is also collected. A total of 124 Quadrates of size 15 m x15 m were laid down and the total area sampled was 0.0279 sq. km out of 60.45 sq km.

2.2. Materials Used

Measuring tape, spring weighing balance, thread, polythene bags, sickle, worksheet, marker, Measuring scale and GPS instrument.

2.3. Sampling Design

The methods suggested by Ravindranath and Ostwald [14] 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 [1]. As the study area was studied by quadrate method, so, each and every tree was sampled for various parameters. 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. [10]

Data recording formats as per Rabindranath and Ostwald [14] 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).

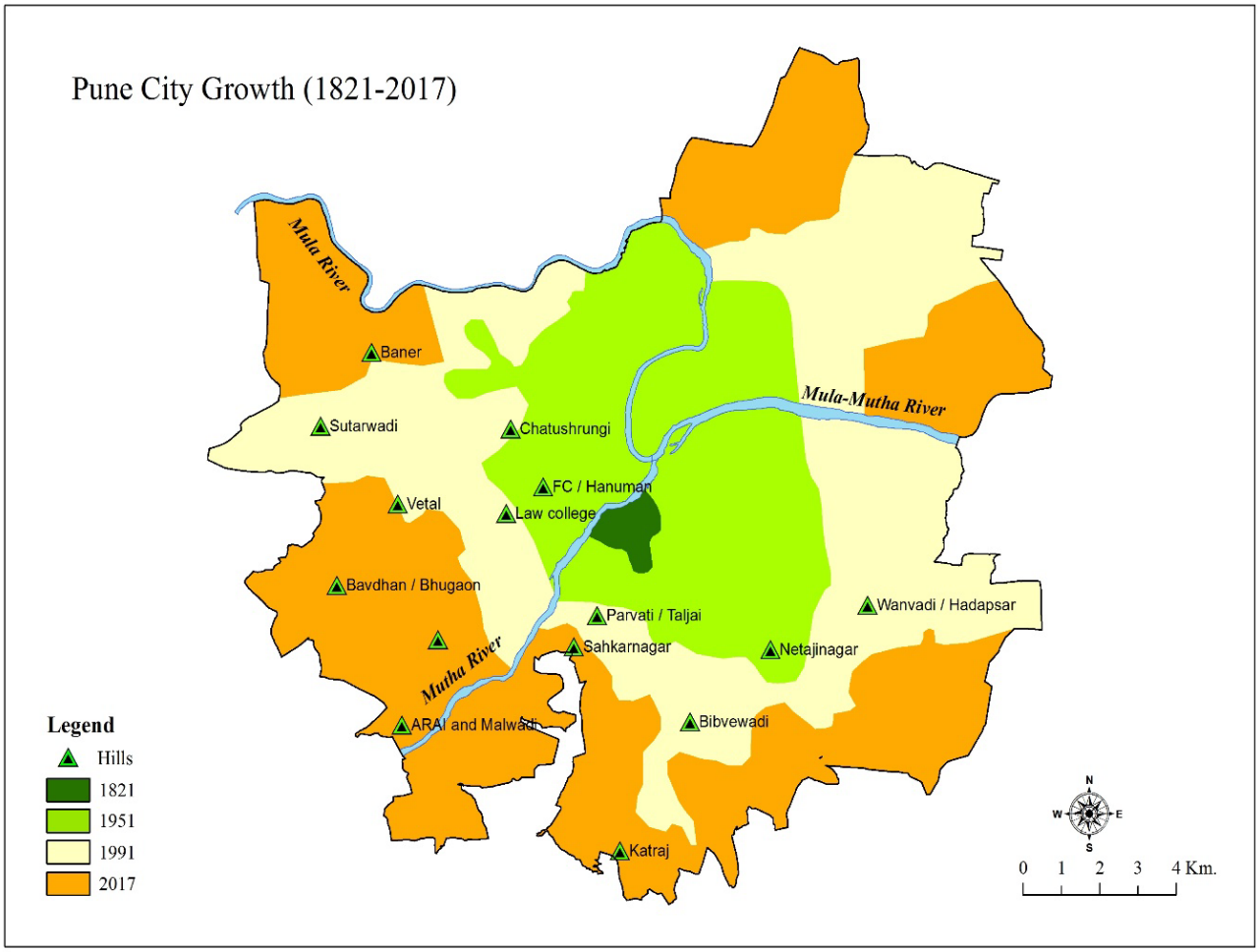

Figure 1. Pune map showing location of Hills

Table 1. Contribution of Native Species in Carbon Pool

Botanical Name	Total no. of individuals	AGB (Tonnes)	BGB (Tonnes)	Total Biomass (Tonnes)	Total Carbon (Tonnes)
Acacia catechu	97	1799.21	467.80	2267.01	1133.50
Acacia chundra	22	173.08	45.00	218.08	109.04
Acacia feruginea	19	706.70	183.74	890.44	445.22
Acasia leucophloea	39	346.89	90.19	437.09	218.54
Acasia nelotica	11	362.65	94.29	456.94	228.47
Aegle marmelos	5	16.77	4.36	21.13	10.57
Albizia amara	7	79.20	20.59	99.79	49.89
Albizia lebbeck	8	67.55	17.56	85.12	42.56
Anogeissus latifolia	22	334.79	87.04	421.83	210.92
Azadirachta indica	91	1947.41	506.33	2453.74	1226.87
Bamboo spp.	130	12523.50	3256.11	15779.61	7889.81
Bauhinia perpuria	1	1.80	0.47	2.26	1.13
Bauhinia recemosa	11	55.54	14.44	69.98	34.99
Bauhinia variegata	27	1147.67	298.39	1446.06	723.03
Bombax ceiba	5	10.09	2.62	12.71	6.36
Boswellia serrata	34	389.24	101.20	490.44	245.22
Bridelia retusa	2	2.47	0.64	3.11	1.56
Buchanania lazan	1	4.85	1.26	6.11	3.06
Butea monosperma	9	44.62	11.60	56.22	28.11
Capparis grandis	7	16.63	4.32	20.95	10.48
Carissa congesta	1	0.70	0.18	0.89	0.44
Caryota urens	2	11.22	2.92	14.14	7.07
Cascabella thevetia	1	0.43	0.11	0.54	0.27
Cassia fistula	4	5.43	1.41	6.84	3.42
Cassia / Senna siamea	33	962.35	250.21	1212.56	606.28
Cleistanthus collinus	1	6.47	1.68	8.15	4.07
Cochlospermum religiosum	5	5.82	1.51	7.33	3.67
Dalbergia lanceolaria	41	1049.67	272.91	1322.58	661.29
Dalbergia latifolia	1	4.59	1.19	5.78	2.89
Dalbergia melanoxylon	266	59674.22	15515.30	75189.53	37594.76
Dalbergia sisso	18	164.43	42.75	207.18	103.59
Diospyros melanoxylon	19	114.14	29.68	143.82	71.91
Dolichandrone falcata	6	14.06	3.65	17.71	8.85
Ehretia aspara	4	2.36	0.61	2.98	1.49
Eleodendron glaucum	2	4.64	1.21	5.84	2.92
Erythrina suberosa	1	0.14	0.04	0.18	0.09
Erythrina variegata	1	9.45	2.46	11.91	5.96
Ficus benghalensis	6	262.67	68.29	330.96	165.48
Ficus benjamina	1	15.15	3.94	19.09	9.55
Flacourtia indica	8	31.02	8.07	39.09	19.54
Flacourtia montana	6	19.15	4.98	24.13	12.06
Gmelia arborea	13	270.60	70.36	340.96	170.48
Grewia asiatica	7	9.43	2.45	11.88	5.94
Gymnosporia montana	1	0.25	0.06	0.31	0.16
Hardwickia binata	1	2.74	0.71	3.45	1.72
Heterophragma quadriloculare	1	2.85	0.74	3.59	1.80
Holoptelia intigrifolia	12	94.42	24.55	118.97	59.48
Ixora brachiata	1	0.43	0.11	0.54	0.27
Lannea coromandelica	50	960.45	249.72	1210.17	605.09
Madhuca latifolia	3	9.86	2.56	12.43	6.21
Mangifera indica	1	0.27	0.07	0.34	0.17
Morinda pubescens	60	1068.24	277.74	1345.99	672.99
Phoenix sylvestis	2	5.94	1.54	7.49	3.74
Phyllanthus emblica	3	2.17	0.56	2.73	1.37
Podocarpus neriifolius	1	3.31	0.86	4.17	2.09
Polyalthia longifolia	1	2.72	0.71	3.43	1.72
Pongamia pinnata	33	1223.48	318.10	1541.58	770.79
Prosopis juliflora	2	1.55	0.40	1.96	0.98
Putranjiva roxburghii	2	2.51	0.65	3.17	1.58
Rhus mysorensis	3	3.57	0.93	4.50	2.25
Santalum album	28	247.47	64.34	311.82	155.91
Semecarpus anacardium	1	1.09	0.28	1.38	0.69
Sterculia foetida	1	10.78	2.80	13.58	6.79
Syzygium cumini	3	3.21	0.84	4.05	2.02
Tamarindus indica	10	82.66	21.49	104.15	52.07
Terminalia temontosa	6	23.82	6.19	30.01	15.01
Vitex negundo	1	1.76	0.46	2.21	1.11
Ziziphus mauritiana	5	17.88	4.65	22.53	11.27
Total species= 68	1227	86442.24	22474.98	108917.22	54458.61

3. 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, into tonnes of carbon per hectare. 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.

4. Soil Organic Carbon at 0.30 M

During the present investigation, 125 soil samples were collected randomly and analyzed for soil organic carbon content. [11,15]

5. Above and Below Ground Carbon Pool

The random sampling method was used for measuring the above ground biomass of vegetation in period of 2017-2018. All plant species above 15 cm GBH within the selected quadrate were sampled; and every individual plant diameter or girth at breast height (GBH) and height was measured. These 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'. Belowground biomass was estimated by the Root: Shoot ratio relationship. For quantification of biomass the method suggested by Ravindranath and Ostwald [14] has been used. The total carbon pool including dead wood and litter biomass in the study area were estimated.

Table 2. Contribution of Exotic Species in Carbon Pool

Botanical Name	Total no. of individuals	AGB (Tonnes)	BGB (Tonnes)	Total Biomass (Tonnes)	Total Carbon (Tonnes)
Acacia auriculiformis	5	29.30	7.62	36.92	18.46
Afrocarpus gracilior	1	4.35	1.13	5.48	2.74
Agathis robusta	2	3.00	0.78	3.78	1.89
Albizia /Samania saman	9	376.24	97.82	474.06	237.03
Araucaria bidwillii	2	30.53	7.94	38.47	19.23
Bamboo	2	3.19	0.83	4.02	2.01
Cissus woodroii	1	0.25	0.06	0.31	0.16
Cryptomeria japonica	2	23.40	6.09	29.49	14.75
Delonix regia	11	269.95	70.19	340.14	170.07
Eucalyptus globulus	10	77.52	20.16	97.68	48.84
Glyricidia sepium	866	382025.91	99326.74	481352.64	240676.32
Guazuma ulmifolia	1	0.52	0.13	0.65	0.33
Khaya selegenesis	3	7.99	2.08	10.06	5.03
Leucaena leucocephala	139	20104.14	5227.08	25331.22	12665.61
Limonia acidissima	1	2.61	0.68	3.29	1.64
Peltophorum pterocarpum	8	238.38	61.98	300.36	150.18
Phyllanthus acidus	1	0.29	0.07	0.36	0.18
Psidium guajava	1	0.79	0.20	0.99	0.50
Samanea saman	1	3.99	1.04	5.03	2.51
Tabebuia aregentiana	4	16.80	4.37	21.17	10.58
Taxodium distichum	1	4.83	1.26	6.09	3.04
Tecoma stans	10	9.56	2.49	12.04	6.02
Tectona grandis	9	26.27	6.83	33.1	16.55
Total species =23	1090	403259.80	104847.55	508107.34	254053.67

Table 3. Comparative table showing Contribution of Native and Exotic Plants Species in Carbon Pool (0.0279 sq.km.)

Type of plant species	AGB (Tonnes)	BGB (Tonnes)	Total Biomass (Tonnes)	Total Carbon (Tonnes)
Native	86442.24	22474.98	108917.22	54458.61
Exotic	403259.80	104847.55	508107.34	254053.67
Total =	489702.04	127322.53	617024.56	308512.28
Extrapolated value for 60.45 sq.km.	1061021086.66	275865481.66	1336886568.32	668443284.16

Table 4.Total Area of all Hills and Sampled Area

Name of the Hill	Area in Sq. Km.	Area sampled in Sq. km
Baner and Sutarwadi hill	5.75	0.0279
Chaturshringi Law College Vetal hill Bavdhhan / Bhugaon Kothrud Depo	20.10 (Continuous)	
ARAI and Malwadi	0.35	
Taljai / Sahkarnagar_Parvati Katraj Bibvewadi Neatjinagar Wanvadi	34.25 (Continuous)	
Total	60.45	0.0279 0.046 %

Table 5. Total amount of carbon sequestered

Carbon pool	Estimated quantity (tonnes)
AGB carbon	1061021087
BGB carbon	275865481.7
Litter and deadwood carbon	17509.44
Soil organic carbon	792001603.5
Total	212,89,05,681

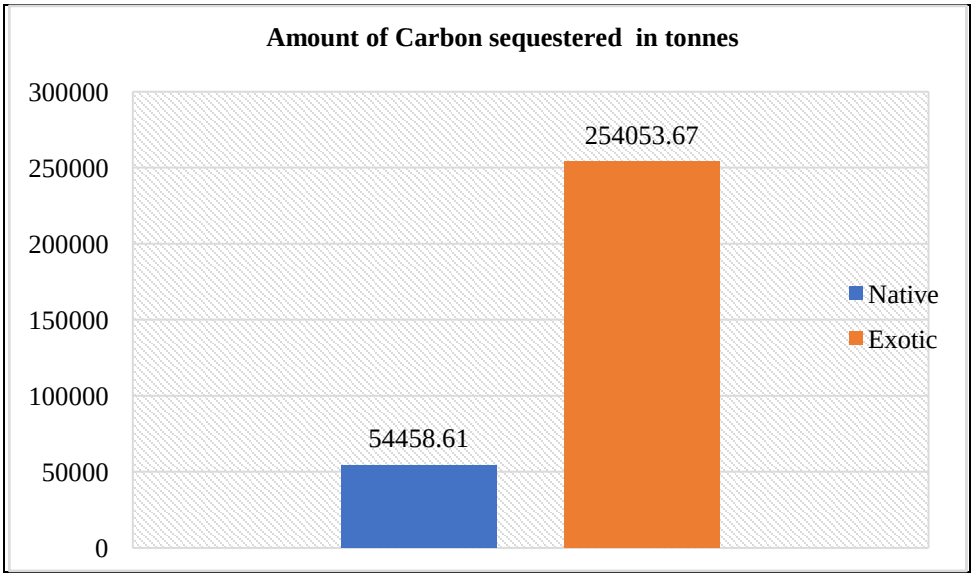

Figure 2. Percentage of Carbon Sequestration by Native and Exotic plant species

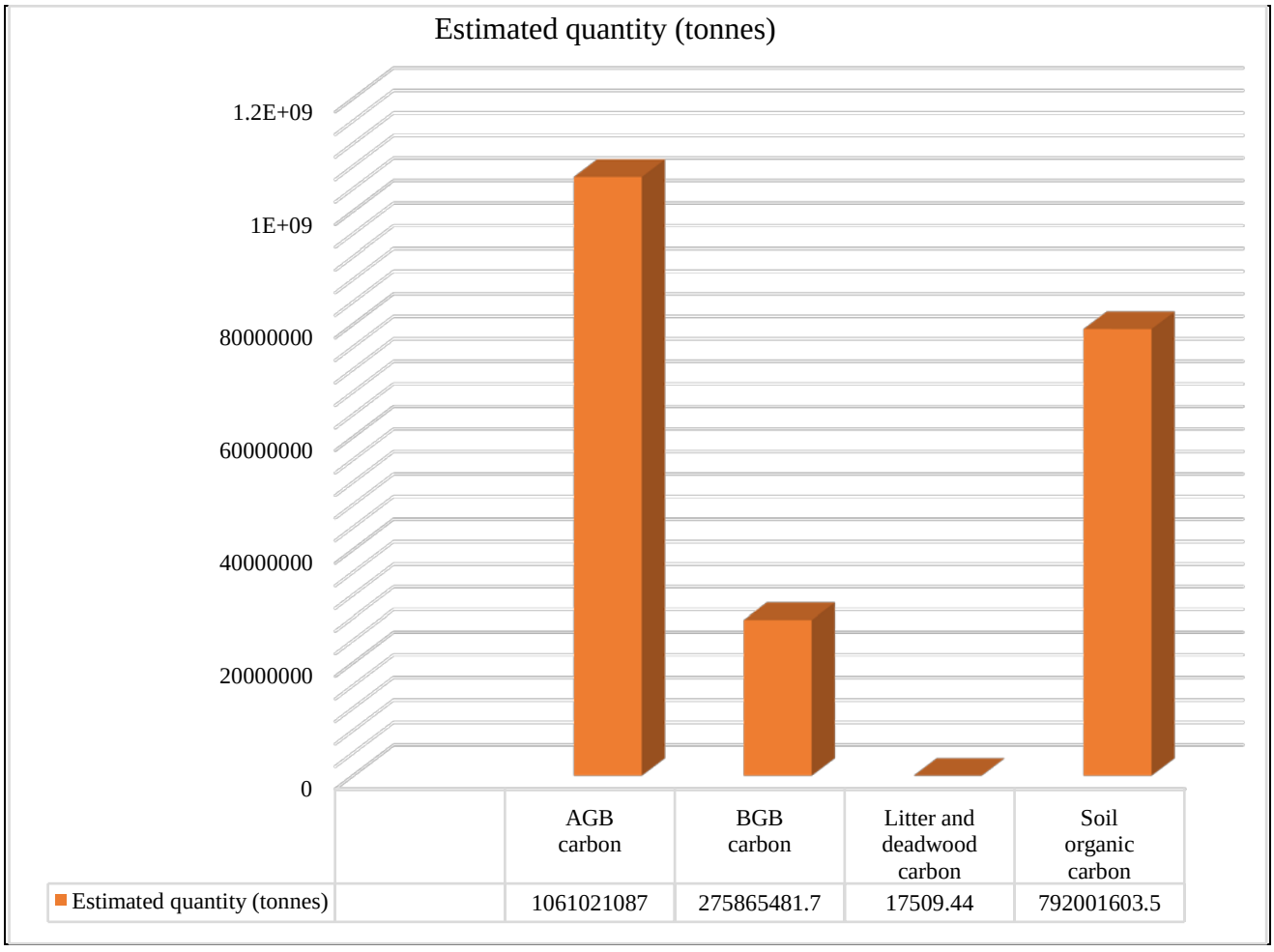

Figure 3. Amount of Carbon Sequestered in Tonnes

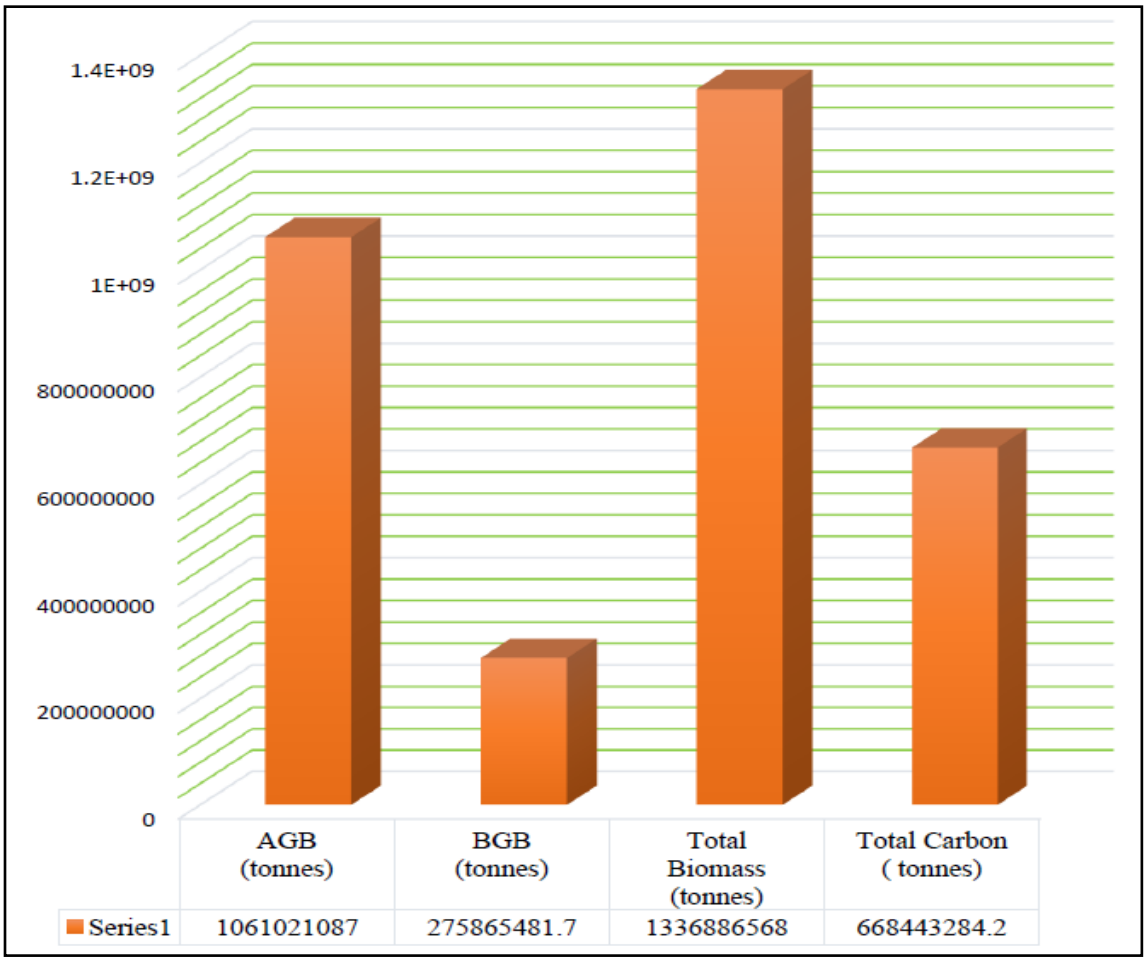

Figure 4. Summary of Results

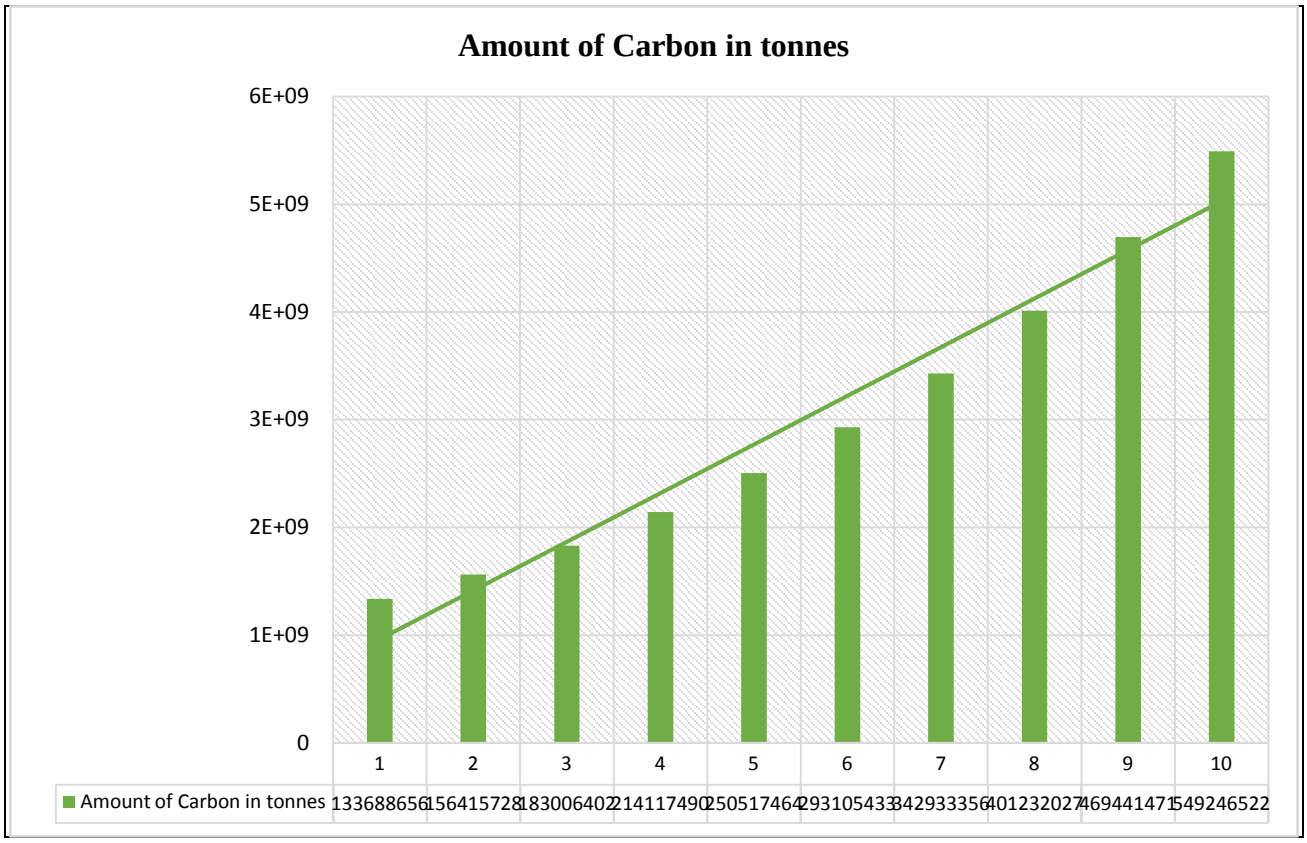

Figure 5. Annual Increase in Biomass Carbon Pool

6. Results and Discussion

We have sampled 10 hills namely ARAI. Baner, Bhopdev Ghat, Chaturshringi, Fergusson College, Kothrud hill, Sutarwadi. University, Vetal- Parvati for biomass, a total of 124 quadrates of size 15 m X 15 m were plotted. Each and every tree in the quadrate is sampled along with GPS and random soil samples were collected for soil carbon analysis. Soil samples were taken from soil profile up to 30 cm depth. Walkley - Black Wet Oxidation method was applied for measuring soil organic carbon. Total amount of above and belowground carbon sequestered was estimated and the values are extrapolated which comes to the value of1336886568 tonnes; litter and deadwood 17509.44 tonnes, and soil organic carbon 792001603.46 tonnes; and the sum of all were 212,89,05,681 tonnes. 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 212,89,05,681 tonnes of CO_2 is worth of US $ 63,867,170,430 or Indian Rs. 4,701,901,087,056.6 /-

The annual increase in carbon will be 10132013.5 t/year. These values were calculated by using the carbon biomass expansion factor 1.17 recommended by IPCC [8].

7. Conclusion

The carbon pool of all 10 sampled hills was estimated by considering above ground, belowground, litter biomass and dead wood, and soil organic carbon. Total number of trees were 2317 in 124 plots. Total amount of above and belowground carbon sequestered was estimated and the values are extrapolated which comes to the value of1336886568 tonnes; litter and deadwood 17509.44 tonnes, and soil organic carbon 792001603.46 tonnes; and the sum of all were 212,89,05,681 tonnes. 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 212,89,05,681 tonnes of CO_2 is worth of US $ 63,867,170,430 or Indian Rs. 4,701,901,087,056.6 /-

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? However, long-term measurement of biomass is necessary for more accurate and precise results. While selecting the species for plantation on hills, one can emphasize on considering the native species as the hills enjoy tropical wet and dry climate. 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. It is therefore essential to conserve the remaining hills mentioned above that harbour large and rich bio-diversity bearing habitats not only for the future but for their own sake.

It is therefore essential that not only the bio-diversity, but also the geo-climatic environment of these hilly habitats should be kept status-quo with no interference of any kind. Any alterations such as road and other constructions, quarrying, tunnelling, rope-ways, wind-mills or other similar interference should not be allowed to safeguard the life that exists in these hilly habitats, more so because these life forms do not have their say.

In contrast, several concerned citizens with the cooperation of the forest department have planted and nurtured trees here to create conducive habitats for the existing bio-diversity. Documentation of the existing base-line bio-diversity of this region will assist conservation prioritization, both for planners and protectors. So also, such data creates public awareness and sensitizes citizens, leading to the protection of the precious local bio-diversity. Identification of endemic and threatened species and recognition of immediate and possible future risks shall effectively protect this bio-diversity.

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