



Assessment of biodiversity and biomass carbon stock from an urban forest: A case study of Sambalpur university campus forest

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Abstract

The role of a natural forest patch in providing ecological services such as biodiversity conservation and climate regulation through biomass carbon accumulation was analyzed in the forest area within Sambalpur University campus. The biodiversity assessment of tree species revealed, this forest harbors a total of 36 different species of trees belonging to 20 families and 34 genera. *Anogeissus latifolia* was the dominant tree species followed by co-dominant *Boswellia serrata* and *Chloroxylon swietenia*. The tree density and basal areas were found to be within the reported range for tropical forests. The population structure also suggests this forest is regenerating but there is a threat associated with the conservation of larger trees. The biomass was estimated following nondestructive method and was found to be 116.08 Mg/ha. This biomass value corresponds to the carbon stock of 58.04 MgC/ha in this site. These values indicate the importance of this forest in conserving biodiversity and regulating local climate through carbon sequestration. As this forest is in risk because of increasing demand of new academic buildings, parking places and other developmental works, this study will emphasize the importance of this forest and will help in making appropriate management strategies for the conservation of this forest.

Keywords: urban forest, biodiversity conservation, population structure, biomass carbon stock, ecosystem services.

Introduction

Global climate change and biodiversity loss is the most challenging environmental issue now days^[1, 2]. Recently urban forests received much attention in combating climate change and reducing biodiversity loss^[3, 4, 5, 6]. Yet rapid urban expansion because of urban development and population growth imposes serious risk to the urban green areas^[7]. This leads to a decrease in urban green forests in recent decades. The diminishing urban forest has a negative impact on ecosystem services provisioning^[8]. Such ecosystem services includes reduction of greenhouse gas (GHG) emissions, thermal comfort, improved air quality, energy-use reduction, recreational and psychological benefits^[9,10,11,12]. These benefits can create awareness toward climate change mitigation^[13,14]. But limited studies available on the role of urban forests in mitigating climate change in the form of CO₂ sequestration in India^[15, 16, 17].

Forests play an important role in CO₂ reduction through photosynthesis and fixing the carbon in its biomass^[18, 19]. Urban forests as a potential contributor in CO₂ reduction, recently gained popularity^[20, 21, 22, 23]. The reduction of CO₂ and other greenhouse gases has identified as an extra benefit. Forests within academic institutions within cities are part of the urban forests. Such forest can play an important role in supporting ecological conditions in an era of climate change and biodiversity loss^[24]. Most of the university is losing its green spaces for the need of spaces for new buildings, parking and off campus housing areas^[25, 26]. In such case monitoring and management of forests within these landscapes became very important.

Sambalpur University, in Burla town of Sambalpur district, is an important educational hub in the state of Odisha. The campus has

a natural forest patch (Dehuri dungri) of approximately 30 hectare in size. The forest endowed with rich vegetation under the category of Tropical dry deciduous forest^[27]. This forest provides a suitable environment and a peaceful atmosphere, which is good for learning. Most of the universities around the world now focusing towards the establishment of a green infrastructure as an option of sustainable development^[28]. In this context the forest within the Sambalpur University must be recognized and conserved. Thus Sambalpur University can contribute towards sustainable development goals related to quality education (SDG4), climate actions through regulating services provided by the forest (SDG 13) and prevention of terrestrial life forms through conservation of biodiversity within it (SDG 15). In this context the present investigation deals with assessment of tree diversity and biomass carbon stock in the university campus forest. This work will help in build up the baseline information about biodiversity within the urban university forest and the role of this forest in regulating the local climate through carbon sequestration.

Methodology

Study Area

The study was conducted in the Sambalpur University, in the Burla town, 2 km away from NH 6 and 15 km away from Sambalpur, in the Indian state of Odisha. The campus of this university was established in 1973 and is considered as the knowledge hub of Western Odisha. The university was spread over an area of 270 hectare around a natural forest patch known as Dehuri dungri. The map of the campus is shown in Figure 1.

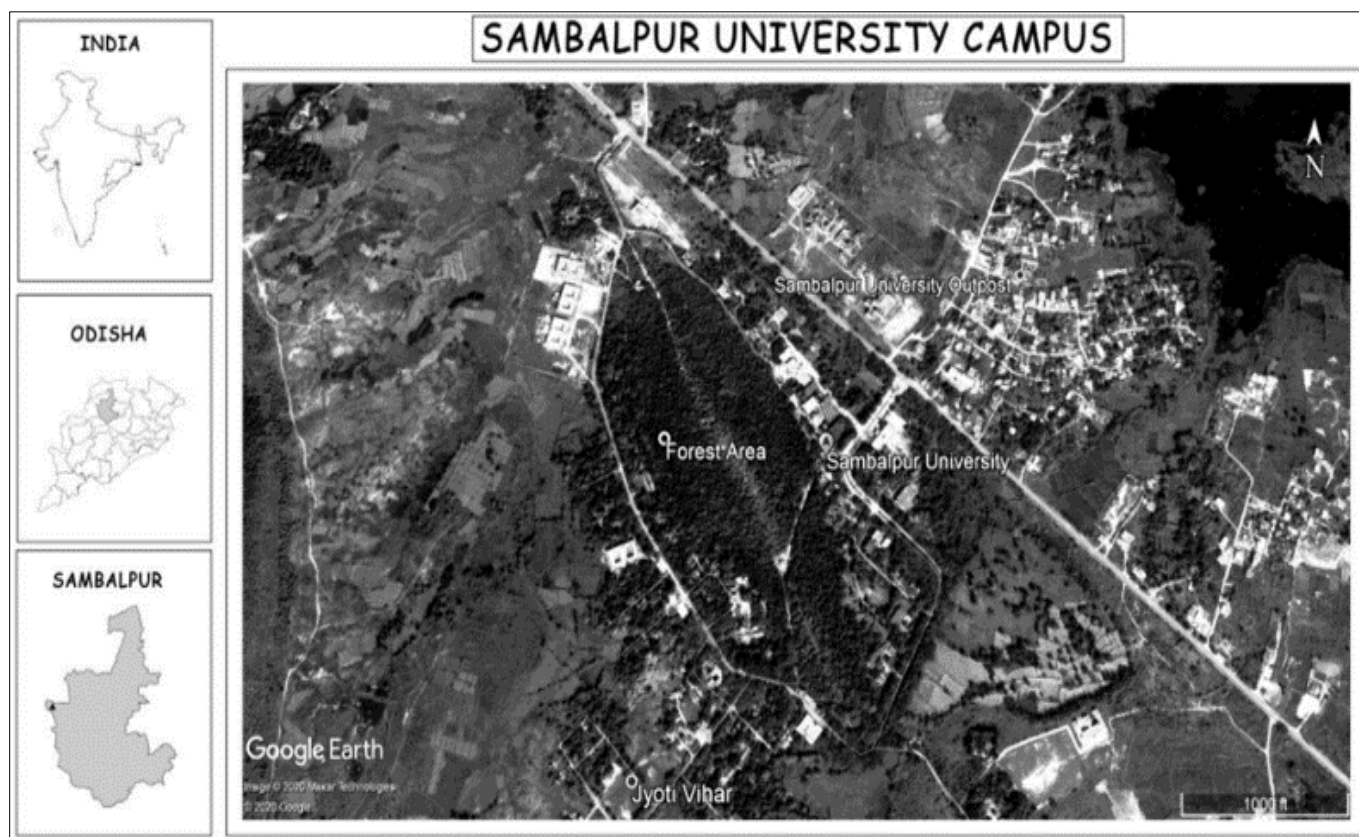


Fig 1: Map of the Sambalpur University Campus.

Vegetation Sampling and Community Analysis

We studied the tree species composition of the university forest by setting 20 random quadrat of size 20×20m. We identified species in the field using standard flora book of Saxena and Brahmam^[29]. We assigned the present accepted names of each species as per the online database, The Plant List. We quantitatively analyzed all tree species with girth at breast height (GBH) ≥ 10cm. We calculate the frequency (F), density (D), basal area (BA) and Importance Value Index (IVI) following the methods of Misra^[30]. The IVI values were further used to compute the diversity indices. We determine species diversity index (H) for each site from the Shannon-Weaver information function^[31]. We measured the Concentration of dominance (Cd), known as Simpson's index, according to Simpson^[32]. We calculated the evenness index according to Pielou^[33]. We analyzed the tree population structure following the method of Pradhan *et al.*^[34] The 6 different classes based on their GBH are 10-31 cm (sapling), 32-66 cm (bole), 67-101 cm (post bole), 102-136 (mature), 137-171 (Over mature) and > 171 (Old). We estimated the number of individuals belonging to each girth class. Then we calculated the percent density of individuals belonging to each girth class using the following formula:

$$\text{Percent density} = \frac{\text{No. of individuals in each girth class}}{\text{Total No. of individuals in all the girth classes}} \times 100$$

Biomass and Carbon Stock Estimation

We used nondestructive method for the biomass estimation of the trees with GBH of ≥10cm. For the calculation of above ground biomass estimation, we followed the allometric equation of Chambers *et al.*^[35] for mixed species stand.

$$\ln(Y1) = -0.37 + 0.333 \ln D + 0.933 (\ln D)^2 - 0.122 (\ln D)^3$$

Where, Y1 = above ground biomass value (Kg/ tree), D= diameter at breast height (DBH)

For the below ground biomass (BGB) we use the root to shoot ratio and calculate the biomass as 26% of the above ground biomass^[36, 37]

$$\text{Below ground biomass} = 0.26 \times \text{Above ground biomass}$$

We estimated the Carbon content as 50% of the AGB/BGB/total biomass^[38].

Results

The species composition of the university campus forest was diverse, with 36 tree species belonging to 20 families and 34 genera. Leguminosae was the most dominant family (6 species) followed by Combretaceae and Rubiaceae (4 species each). Only single species represented 12 out of 20 families. We recorded total stem density in the site with 1206 individuals/ha. *Anogeissus latifolia* has the highest stem density in the stand with 206 individuals/ha. The lowest stem density in this site was

for *Madhuca indica* and *Terminalia bellirica* (1 individuals/ha each). The total basal area of the tree species was 11.41m²/ha. *Boswellia serrata* has the highest basal area value of 2.62 m²/ha. And we recorded the least basal area for *Madhuca indica* with 0.001 m²/ha. *Anogeissus latifolia* was the most dominant tree species in this forest with an Importance value index (IVI) value of 0.395. The co-dominant species were *Boswellia serrata* with IVI of 0.368 and *Chloroxylon*

swietenia with IVI of 0.312. *Madhuca indica* was the least dominant tree species with an IVI of 0.006. We calculated the Shannon diversity index for the tree species of 2.96, which shows a diverse nature of the forest. The calculated values of concentration of dominance (Cd) and evenness index were 0.07 and 0.83 respectively. We represented the detailed structural attributes of the individual tree species in Table 1.

Table 1: List of tree species recorded from the Sambalpur University forest area along with their structural attributes.

S.N.	Species	Family	F (%)	BA (m ² /ha)	Density (Nos./ha)	IVI
1	<i>Acacia catechu</i> (L.f.) Willd.	Leguminosae	15	0.006	4	0.018
2	<i>Anogeissus latifolia</i> (Roxb. ex DC.) Wall. ex Guillem. and Perr.	Combretaceae	75	1.723	206	0.395
3	<i>Azadirachta indica</i> A. Juss.	Meliaceae	25	0.098	15	0.045
4	<i>Boswellia serrata</i> Roxb. ex Colebr.	Burseraceae	50	2.615	109	0.368
5	<i>Bridelia retusa</i> (L.) A.Juss.	Phyllanthaceae	15	0.015	5	0.020
6	<i>Buchanania cochinchinensis</i> (Lour.) M.R.Almeida	Anacardiaceae	60	0.577	75	0.171
7	<i>Butea monosperma</i> (Lam.) Taub.	Leguminosae	15	0.080	8	0.028
8	<i>Caesalpinia pulcherrima</i> (L.) Sw.	Leguminosae	5	0.085	3	0.014
9	<i>Casearia tomentosa</i> Roxb.	Salicaceae	10	0.056	11	0.024
10	<i>Careya arborea</i> Roxb.	Lecythidaceae	10	0.045	5	0.018
11	<i>Cassia fistula</i> L.	Leguminosae	25	0.046	9	0.036
12	<i>Chloroxylon swietenia</i> DC.	Rutaceae	75	1.677	111	0.312
13	<i>Cleistanthus collinus</i> (Roxb.) Benth. ex Hook.f.	Phyllanthaceae	60	0.628	116	0.210
14	<i>Dalbergia sissoo</i> DC.	Leguminosae	10	0.156	3	0.025
15	<i>Diospyros melanoxylon</i> Roxb.	Ebenaceae	90	1.160	146	0.310
16	<i>Corymbia citriodora</i> (Hook.) K.D.Hill and L.A.S.Johnson	Myrtaceae	5	0.043	3	0.011
17	<i>Gardenia latifolia</i> Aiton	Rubiaceae	25	0.049	24	0.048
18	<i>Gmelina arborea</i> Roxb.	Lamiaceae	10	0.016	3	0.013
19	<i>Haldina cordifolia</i> (Roxb.) Ridsdale	Rubiaceae	5	0.017	4	0.009
20	<i>Helicteres isora</i> L.	Malvaceae	20	0.014	11	0.030
21	<i>Holarrhena pubescens</i> Wall. ex G. Don	Apocynaceae	35	0.081	39	0.073
22	<i>Ixora parviflora</i> Lam.	Rubiaceae	45	0.025	24	0.066
23	<i>Lagerstroemia parviflora</i> Roxb.	Lythraceae	65	0.795	89	0.206
24	<i>Lannea coromandelica</i> (Houtt.) Merr.	Anacardiaceae	40	0.347	31	0.095
25	<i>Madhuca indica</i> J.F.Gmel.	Sapotaceae	5	0.001	1	0.006
26	<i>Morinda tinctoria</i> Roxb.	Rubiaceae	55	0.050	14	0.069
27	<i>Nyctanthes arbor-tristis</i> L.	Oleaceae	25	0.050	15	0.041
28	<i>Pongamia pinnata</i> (L.) Pierre	Leguminosae	10	0.030	5	0.016
29	<i>Shorea robusta</i> Gaertn.	Dipterocarpaceae	5	0.017	3	0.008
30	<i>Firmiana simplex</i> (L.) W.Wight	Malvaceae	10	0.029	4	0.015
31	<i>Syzygium cumini</i> (L.) Skeels	Myrtaceae	15	0.024	8	0.023
32	<i>Terminalia bellirica</i> (Gaertn.) Roxb.	Combretaceae	5	0.064	1	0.011
33	<i>Terminalia chebula</i> Retz.	Combretaceae	15	0.319	11	0.052
34	<i>Terminalia tomentosa</i> Wight and Arn.	Combretaceae	15	0.078	8	0.028
35	<i>Woodfordia fruticosa</i> (L.) Kurz	Lythraceae	30	0.123	61	0.091
36	<i>Ziziphus xylopyrus</i> (Retz.) Willd.	Rhamnaceae	50	0.279	25	0.094

(F = Frequency, BA = Basal Area, IVI = Importance Value Index)

We studied the population structure of tree species among different girth classes. The results show the existence of only four girth classes. The larger-sized trees with higher than 136 cm GBH were absent in the site (Figure 2). Larger proportion of the density was from the sapling class (10-31cm GBH) and the density

gradually decreases as increases in the girth class. The higher stand density in lower girth class and lower density in higher girth classes shows this forest is a secondary forest with a good regeneration potential. However, the absence of larger-sized tree shows disturbance or threats to large sized tree in this forest.

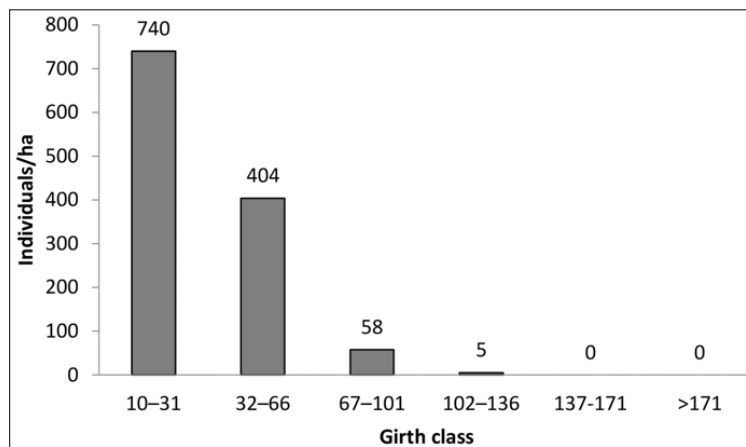


Fig 2: Tree density across different girth classes.

We estimated the above-ground biomass, belowground biomass and total biomass in the campus forest with 92.13 Mg/ha, 23.95Mg/ha and 116.08 Mg/ha respectively. The highest total biomass was for *Boswellia serrata* (31.71 Mg/ha), followed by *Chloroxylon swietenia* (18.22 Mg/ha) and *Anogeissus latifolia* (15.10Mg/ha). We calculated the lowest biomass for *Madhuca indica* with a value of 0.005 Mg/ha. We presented the distribution of biomass across different girth classes in Figure 3. The results showed highest biomass in the 32-66 cm GBH class, contributing 51% of the total tree biomass. We recorded the lowest biomass

for 102-136cm GBH class having 5.25% of the total tree biomass. The lowest biomass in the highest girth class is because of the presence of least number of individuals in this category. The total biomass carbon content considering the 50% of the total biomass was 58.04 MgC/ha. The trend for the distribution of biomass carbon stock across different girth class was like the total biomass distribution. We presented the detailed information about total biomass value and biomass carbon stock for individual species in Table 2.

Table 2: List of tree species recorded from the Sambalpur University forest area along with their density, biomass and biomass carbon stock values.

S.N.	Species	Density (Nos./ha)	TB (Mg/ha)	TBC (MgC/ha)
1	<i>Acacia catechu</i> (L.f.) Willd.	4	0.027	0.014
2	<i>Anogeissus latifolia</i> (Roxb. ex DC.) Wall. exGuillem. andPerr.	206	15.104	7.552
3	<i>Azadirachta indica</i> A. Juss.	15	0.869	0.434
4	<i>Boswellia serrata</i> Roxb. exColebr.	109	31.712	15.856
5	<i>Bridelia retusa</i> (L.) A.Juss.	5	0.100	0.050
6	<i>Buchanania cochinchinensis</i> (Lour.) M.R.Almeida	75	5.461	2.731
7	<i>Butea monosperma</i> (Lam.) Taub.	8	0.930	0.465
8	<i>Caesalpinia pulcherrima</i> (L.) Sw.	3	1.062	0.531
9	<i>Casearia tomentosa</i> Roxb.	11	0.383	0.192
10	<i>Careya arborea</i> Roxb.	5	0.365	0.183
11	<i>Cassia fistula</i> L.	9	0.370	0.185
12	<i>Chloroxylon swietenia</i> DC.	111	18.218	9.109
13	<i>Cleistanthus collinus</i> (Roxb.) Benth. exHook.f.	116	4.560	2.280
14	<i>Dalbergia sissoo</i> DC.	3	2.627	1.314
15	<i>Diospyros melanoxylon</i> Roxb.	146	11.883	5.942
16	<i>Corymbia citriodora</i> (Hook.) K.D.Hill and L.A.S.Johnson	3	0.429	0.214
17	<i>Gardenia latifolia</i> Aiton	24	0.252	0.126
18	<i>Gmelina arborea</i> Roxb.	3	0.127	0.063
19	<i>Haldina cordifolia</i> (Roxb.) Ridsdale	4	0.115	0.058
20	<i>Helicteres isora</i> L.	11	0.065	0.032
21	<i>Holarrhena pubescens</i> Wall. ex G.Don	39	0.489	0.245
22	<i>Ixora parviflora</i> Lam.	24	0.117	0.058
23	<i>Lagerstroemia parviflora</i> Roxb.	89	7.632	3.816
24	<i>Lannea coromandelica</i> (Houtt.) Merr.	31	3.266	1.633
25	<i>Madhuca indica</i> J.F.Gmel.	1	0.005	0.002
26	<i>Morinda tinctoria</i> Roxb.	14	0.360	0.180
27	<i>Nyctanthes arbor-tristis</i> L.	15	0.300	0.150
28	<i>Pongamia pinnata</i> (L.) Pierre	5	0.242	0.121
29	<i>Shorea robusta</i> Gaertn.	3	0.125	0.063
30	<i>Firmiana simplex</i> (L.) W.Wight	4	0.246	0.123
31	<i>Syzygium cumini</i> (L.) Skeels	8	0.146	0.073
32	<i>Terminalia bellirica</i> (Gaertn.) Roxb.	1	0.898	0.449

33	<i>Terminalia chebula</i> Retz.	11	3.768	1.884
34	<i>Terminalia tomentosa</i> Wight and Arn.	8	0.662	0.331
35	<i>Woodfordia fruticosa</i> (L.) Kurz	61	0.656	0.328
36	<i>Ziziphus xylopyrus</i> (Retz.) Willd.	25	2.509	1.255

(TB = Total Biomass, TBC = Total Biomass Carbon)

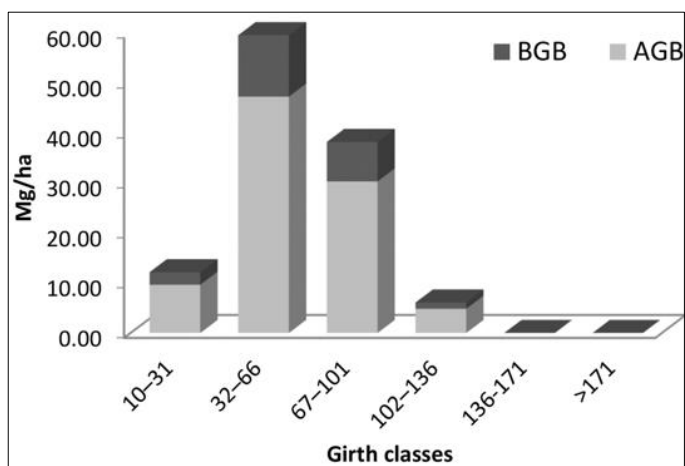


Fig 3: Above ground and below ground biomass of tree species in different girth classes.

Discussion

From the present study it was found that the campus is endowed with a diverse tree species in a naturally regenerating forest patch. While most of the prior report on university campus diversity focuses on the plantation forests or cultivated plant species [16, 17, 20], the current study focuses on the contribution of natural forest within Sambalpur University toward biodiversity conservation and climate regulation. The observed stand density of 1206 individuals/ha was comparatively higher than the values (276–905 trees/ha) reported for the tropical forests of Tamil Nadu, Karnataka and Western Ghats of India [39, 40, 41]. These values were also higher than the reported values (640–986 trees/ha) from the states of Tamil Nadu and Andhra Pradesh in the Eastern Ghats of India [42, 43, 44]. The basal area of 11.41 m²/ha in this forest is relatively lower than the range (17–40 m²/ha) of tropical dry forests globally [45]. However, the value is comparable with the values (7–23 m²/ha) from certain dry forest communities in India [46]. These comparative values of stand density and basal area suggest this forest under urban set up can match up with the natural forests if conserved and maintained effectively. The population structure with higher density of low girth class trees also suggests good regeneration potential of existing tree species. However the absence of larger trees in this forest is a matter of concern and can indicate a disturbed nature of the forest, with a risk to larger sized trees.

Species diversity can be measure through diversity indices and higher values suggests higher diversity in the stand [47]. The Shannon diversity index of 2.96 in this study was found to be within the range of 1.85 to 5.18 reported from various studies of Eastern Ghats [42, 43, 44, 48, 49, 50]. The value for concentration of dominance (Cd) in our study (0.07) was in the lower end as compared to the values recorded from the eastern ghats of Tamil Nadu (0.07–0.19) [42, 43]. However, this value was higher than the value reported for the Eastern Ghats of Odisha (0.03 and 0.015) [48, 51]. The higher dominance value was due to the dominant nature of few tree species with higher IVI values. The evenness

index in this study (0.83) was comparable to the range of 0.86 to 0.98 reported from tropical deciduous forests of Odisha [51]. These comparative values of diversity indices showed comparable values with the natural forest and hence we can assume that the forest within the university campus is as diverse as natural forests within different forest ranges.

The biomass carbon stock stored in the living biomass of tree species within a forest is an essential aspect to understand the carbon cycle [52, 53]. The present recorded biomass value of 116.08 was within the range of 76.77–712.51 Mg/ha recorded for tropical dry deciduous forests of the Eastern Ghats [54]. As most of the university measured their campus vegetation biomass from the planted species or cultivated species as a function of green infrastructure development, the values ranges greatly among the campuses [16, 17, 20]. Hence in present study we only compared our values with natural forests as our recorded values are from a natural forest pocket within the university campus.

Conclusion

From the present study we can conclude that a natural forest patch within the university campus not only contributed towards the green infrastructure of the campus but also contributing towards the promotion of different sustainable development goals such as SDG4, SDG 13 and SDG 15. We also find that this forest harbor a rich diversity of tree species and the density, basal area and diversity indices are comparable with the natural forests of the Eastern Ghats of India. In addition, the biomass carbon stored in the living biomass can contribute towards the climate change mitigation and regulating the regional climate. However, increasing demand of new academic buildings, parking places and other developmental processes within the university are some threats associated with this urban forest patch. Hence the present work can act as baseline information regarding the importance of the biodiversity which can help in making appropriate management strategies for the conservation of this forest.

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