Investigating above-ground biomass and carbon sequestration potential in the pursuit of carbon neutrality via academic institutions

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ABSTRACT

Climate change, driven primarily by human-induced greenhouse gas emissions, necessitates urgent mitigation strategies at both global and local levels. This study assesses the carbon sequestration potential and emission profile of Mahatma Gandhi University, Kottayam, Kerala, to evaluate its progress toward carbon neutrality. A total of 30 plots (15 within and 15 outside the Jeevaka region) were sampled using 10 × 10 m quadrats to estimate above-ground biomass (AGB) and carbon storage. Data on tree species composition, girth at breast height (GBH), and height were used to compute biomass and carbon content using Forest Survey of India (FSI) volume equations and specific gravity values. The study documented 357 trees from 33 species across 19 families, with *Caryota urens* and *Artocarpus hirsutus* emerging as dominant species in terms of carbon contribution. The total AGB was estimated at 83.55 t/ha, corresponding to 39.49 t/ha of carbon. Carbon distribution was analysed across different DBH (Diameter at Breast Height) classes, with the 20–30 cm class showing the highest carbon storage. Regression analyses revealed strong positive correlations between carbon storage and both tree density ($R^2 = 0.9489$) and basal area ($R^2 = 0.7389$), underscoring the significance of forest structure in carbon sequestration. Carbon emissions from electricity, transportation, LPG, solid waste, and human respiration amounted to 5,479.224 metric tons of CO_2e annually. In contrast, the university's carbon offset initiatives — including green cover, solar energy, biogas, and waste management — accounted for 2,705.34 metric tons of CO_2e, resulting in a net excess of 2,773.88 metric tons. The study highlights the potential of institutional campuses to significantly contribute to climate mitigation through sustainable practices, enhanced green cover, and renewable energy adoption. The findings support the implementation of strategic interventions to achieve full carbon neutrality and promote sustainable campus ecosystems.

1. Introduction

The sustainability of life is ensured by weather and climate, which regulate global temperatures, biodiversity, greenhouse gases, and ocean ecosystems. Nonetheless, human activities such as the burning of fossil fuels, deforestation, and industrial operations have greatly increased the levels of greenhouse gases; from 1951 to 2010, human activities accounted for 78% of emissions (IPCC, 2021) It has resulted in droughts, flooding, sea level rise, and weather extremes, etc. (Sen et al., 2022)

The 2015 Paris Agreement, where 194 nations subscribed, seeks to cap warming at 1.5°C but is contentious in execution (Sen et al., 2022). The G20 nations, which account for 80% of the emissions, will

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have to take the lead in climate mitigation, with India able to balance development and reducing emissions (CARE, 2017). Carbon in plant biomass, soil, and greenhouse gases is expected to increase to 500–1000 ppm by 2100, worsening climate change (Konda Venkata Giri and Mandla, 2017). Forests are carbon sinks, depending on management, and thus conservation is crucial for global carbon balance (Ecological Society of America, 2012).

Complex vegetation structures and high species diversity, contributing to more stored biomass and carbon in forests, indicate that the use of multi-layer forest management may have a positive role in improving biodiversity and climate resilience (Upadhyay, 2025). The national variations in forest cover, carbon stocks, and fire patterns of India; increasing carbon storage; and rising incidences of fires create exigencies for effective forest management, climate mitigation, conservation, and multi-scale carbon accounting. (Gorain et al., 2025). In India, teak has a significant potential to aid in carbon sequestration. Community involvement and support for sustainable forestry practices can be increased by educating people about the environmental benefits of Teak plantations and involving them in conservation and plantation projects, as well as promoting highly carbon-storing tree species for planting (Patel and Naik, 2024).

Aboveground biomass, which represents forest carbon storage and ecosystem stability, is essentially the total mass of living plant material above the soil (Gao et al., 2022). At regional to national levels, aboveground biomass and carbon pools across various vegetation types have been estimated using remote sensing, GIS, and ground truth data (Devagiri et al., 2013). Although there is currently little real-time tracking of forest biomass, high-resolution satellite photos estimate AGB of forests using tree crown, canopy height, and vegetation indexes (Ahmad et al., 2021). For evaluating crop growth and yield, UAV-based RS offers an affordable, non-destructive estimating method to AGB (Liu et al., 2025). In complex forests with varying density and structure, LiDAR, UAV, and deep learning enable precise and scalable AGB estimation (So et al., 2025).

Urbanization in India has, in return, increased CO_2 emissions; the limited carbon-storage capacity of cities makes campus-level biomass and sequestration assessments crucial in achieving carbon balance and sustainability (Baste and Thakare, 2023). Car-

bon budgeting, which caps emissions to limit warming to 2°C, offers a scientific foundation for climate policy (IPCC, 2021). It is possible to reach carbon neutrality by reducing emissions, using sequestration techniques, and endorsing sustainable development through reforestation and renewable energy (Baede et al., 2001). Climate change requires a worldwide, collaborative effort to combat and ensure long-term sustainability (CARE, 2017).

2. Study area

The current investigation was carried out at Mahatma Gandhi University, at Kottayam, in Kerala state of India, which was established on 2nd October, 1983, and is one of the major Universities in Kerala. The University spans across the expansive 110-acre Priyadarsini Hills Campus located at Athirampuzha, approximately 12 km from Kottayam. It is surrounded by eastern highlands, midlands, and wetlands, thereby providing immense opportunities for agriculture, tourism, and development (Fig. 1). The University has a well-maintained green campus with energy, water, waste, and biodiversity management systems.

Ecologically significant zones with rich plant and faunal diversity have been formally designated as the 'Jeevaka Live Laboratory' under the Department of School of Environmental Sciences. The canopy covers 87.13% of the 106.49 acres which form the campus. Jeevaka vegetation constitutes 23% of the canopy cover, while the remaining is sparse vegetation. The Jeevaka region represents a protected, minimally disturbed area within the campus. Comprehensive documentation of biodiversity has been carried out in this zone. It functions as a natural medicinal garden of Mahatma Gandhi University and supports 303 plant species, comprising 124 herbs, 95 shrubs, 68 trees, and 16 climbers. Faunal diversity is also high, with 268 species, including mammals, reptiles, amphibians, birds, butterflies, dragonflies, damselflies, and fish. The university encompasses an extensive area of 110 acres, with the total land area, excluding Jeevaka, amounting to 82 acres (33.18 hectares). The area features a range of trees, including coconut palms, mango trees, jackfruit trees, teak trees, and various flowering plants. They are essential for keeping the ecological balance on campus, helping to reduce air pollution, producing oxygen, and offering homes for birds and small animals.
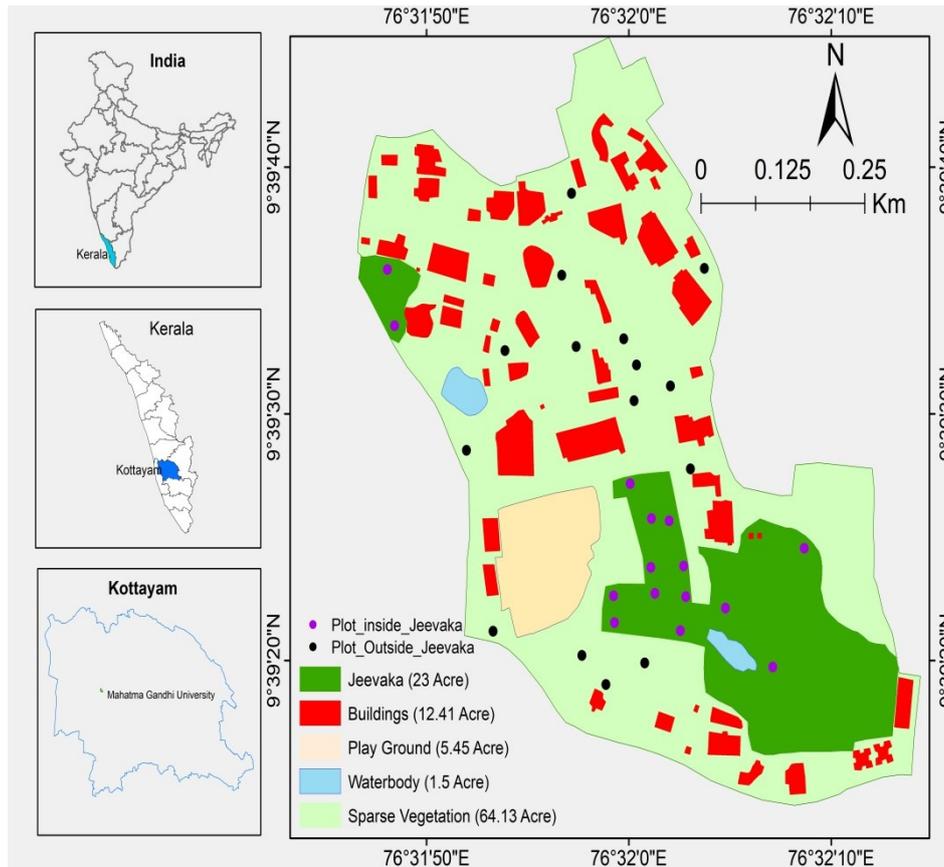
Fig. 1. Study area along with land use/land cover (LULC) distribution.

University has implemented a Miyawaki afforestation plot in collaboration with the Directorate of Environment and Climate Change, Government of Kerala, promotes dense and fast-growing forests using native species. The Miyawaki site comprises 12 tree species from 9 families, 9 shrub species, 4 herb species, 12 saplings, one climber, one tree fern, and one deadwood, and requires minimal maintenance while offering high carbon sequestration and biodiversity benefits. The canopy covers 87.13% of the 106.49 acres which form the campus. Jeevaka vegetation constitutes 23% of the canopy cover, while the remaining is sparse vegetation.

3. Materials and methods

In the present study, above ground biomass and carbon were calculated in 30 plots, comprising 15 within and 15 outside the Jeevaka region, utilizing 10×10 m quadrat sampling. A 10×10 m plot size was adopted as it is commonly used in ecological studies and provides reliable estimates of tree density, basal area, and biomass in upland environments (Robiansyah, 2011). The same size of the quadrat was applicable in tropical forest studies with great results, where 10 x 10m plots within transects have been used to conduct rapid assessments on plant diversity (Replan and Malaki, 2017). The use of small quadrats ensures information is collected in a field with less confusion and measurement error than when using larger plots (Lang et al., 1971). Hence, thirty 10×10 m quadrats (15 within and 15 outside the Jeevaka region) were laid out to ensure adequate representation and to enable comparison between managed and less-managed areas of the campus while maintaining a feasible field sampling effort. Data were collected on species composition, girth at breast height (GBH), tree height, etc. Based on the field-based data, the tree volume was calculated using tree volume equations generated by the Forest Survey of India (FSI, 1996), and, in accordance with the study of Nayar (1996), specific gravity data from the Forest Research Institute (ICFRE, 1996–2002) was used to estimate above-ground biomass. Trees >10 cm DBH were included in the estimation of carbon. An average of 47% carbon in the tree biomass was considered for regional level carbon pool estimation. Biomass values were converted to carbon by multiplying with a

factor of 0.47. An average value of 47% of carbon in the tree biomass is considered for regional-level estimation of the carbon pool (Padmakumar et al., 2021). The campus-level carbon source inventory was established using a bottom-up approach, consistent with the methodological frameworks adopted by Gopika et al. (2024) and Jayakumar et al. (2018), total emissions were determined using the equation: Total emissions $= \sum$ (Activity Data $\times$ Emission Factor). Major emission sources considered in the assessment included human factor, electricity, LPG, transportation, and solid waste. Emissions from human respiration were calculated by determining the average daily population entering the campus, applying a standard emission factor of 0.9 kg CO_2 per person per day, and converting the values into annual totals. Electricity-related emissions were estimated using monthly consumption values obtained from electricity bills, which were aggregated to derive annual electricity use. LPG consumption data were collected from the academic, cafeteria, and residential areas, with a total of 948 cylinders utilized during the study period. Biodegradable solid waste emissions were estimated from residential areas, cafeterias, and canteens. Daily waste quantities were measured at collection points, averaged to obtain representative daily values, and then extrapolated to annual totals to reflect yearly waste generation. Transportation-related emissions were calculated considering both the campus vehicle fleet and the average daily use of other vehicles, along with the average daily distance travelled for each vehicle category. Daily usage values were estimated from weekly operational schedules and extrapolated to monthly and annual mileage, enabling the application of fuel-specific emission factors prescribed by IPCC (2006). All emissions from electricity, LPG, and biodegradable solid waste were calculated using appropriate emission factors, outlined by Jayakumar et al. (2018). An estimation of the total carbon offset from sectors such as biogas, solar panels, waste sorting, and vegetation cover (trees) was made. Afterwards, the overall carbon offset is summed up with the observed carbon from 30 plots and the Miyawaki forest to get the total managed carbon. Finally, the total carbon emissions were subtracted from the total managed carbon to derive the net carbon balance.

4. Results

4.1. Phytosociological Analysis

Phytosociology examines plant community distribution and classification (Salisu et al., 2021). The study documented 357 trees from 33 species belonging to 19 families from the selected 30 plots. In the case of relative frequency, the results were found that relative frequency ranged from 0.68 trees/ha to 14.48 trees/ha. *Artocarpus hirsutus* and *Caryota urens* species have the highest relative frequency. Regarding relative density, the results found that *Caryota urens* (28.29 trees/ha) has the highest relative density, and the most dominant is *Ailanthus excelsa* (27.06 trees/ha). *Caryota urens* was ranked top by the Importance Value Index (IVI) (67.46 trees/ha). The need for conservation efforts is demonstrated by two endemic species, *Cinnamomum malabatrum* and *Artocarpus hirsutus*.

4.2. Biomass and Carbon Storage

The total biomass from all plots is 83.55 t/ha, having 39.49 t/ha of total carbon. The total above-ground biomass (AGB) of the Jeevaka ranges from 0.93 t/ha to 6.97 t/ha, whereas carbon storage ranges from 0.44 to 3.31 t/ha. The total biomass of the plot Jeevaka is 43.83 t/ha, whereas total carbon storage is 20.62 t/ha. In the case of the Outside Jeevaka plot, above-ground biomass ranged from 1.13 t/ha to 9.73 t/ha, while carbon storage ranged from 0.53 t/ha to 4.62 t/ha. The total biomass of the outside jeevaka plot is 39.72 t/ha, whereas the total carbon storage is 18.86 t/ha. In the Jeevaka plot, plot 6 has the highest biomass, 6.97 t/ha, and 3.31 t/ha total carbon. Plot 5 outside Jeevaka has the highest biomass, 9.73 t/ha and 4.62 t/ha.

4.3. Species-wise Contribution

Out of 29 species with DBH (Diameter at Breast Height) ≥ 10 cm, *Caryota urens* held maximum carbon (37%), primarily because it is the dominant species in the study area. This was followed by *Artocarpus hirsutus* (18%), *Hevea brasiliensis* (11%), and *Ailanthus excelsa* (11%), amounting to 77% of biomass. Basal area maximum was held by *Ailanthus excelsa* (4.858 cm^2) and minimum by *Hevea brasiliensis* (1.360 cm^2).
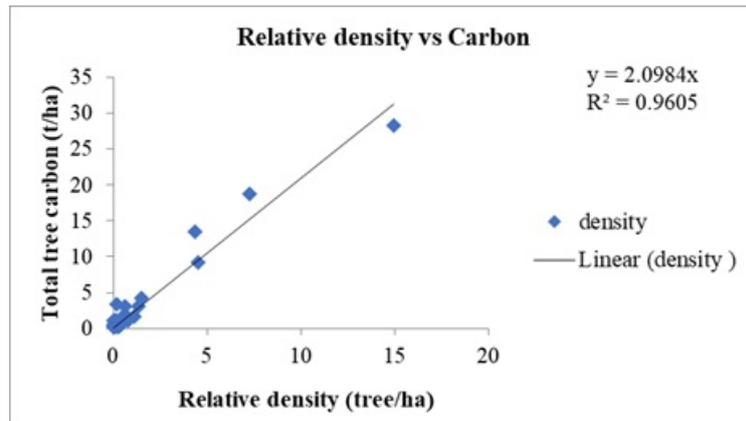
Fig. 2. Relationship between carbon vs. relative density.

4.4. DBH carbon distribution

The total carbon of trees having >10 cm is classified according to DBH classes (Kerala Forest Department, 1971). The difference between DBH classes is 10 cm. DBH class 20–30 has the highest carbon content (10.79 t/ha) and has 88 tree species. However, the highest number of species occupied in DBH class 10–20 (118 species) had 6.071 t/ha total carbon. The least carbon content plot is 80–90 (0.49 t/ha), having one tree species. The average DBH of Miyawaki forest is 9.31cm.

4.5. DBH-wise tree biomass distribution

The total tree biomass (>10 DBH) was distributed according to DBH-wise classification. Total tree biomass is 83.36 t/ha. The highest biomass of 22.76 t/ha falls under the DBH class of 20–30. The lowest tree biomass, 1.04 t/ha, falls in the 80–90 DBH class.

4.6. DBH-wise species biomass distribution

Each species' biomass was distributed according to DBH-wise classification. The total species biomass is 87.39 t/ha. *Caryota urens* has the highest biomass (31.44 t/ha). Gmelina arborea has the lowest biomass (0.03 t/ha). DBH class 20–30 has the highest number of species biomass (25.76 t/ha), and DBH class 80–90 has the lowest number of species biomass (1.04 t/ha).

4.7. Species-wise contribution (dominant species) of basal area in different diametric classes

The most common species in all the plots were sorted according to their basal area under various diameter classes. *Artocarpus hirsutus* had the maximum basal area in the 0–10 cm DBH class (0.1119

cm^2). In other diameter classes, the species with the highest basal area were *Caryota urens* (0.7155 cm^2) at 10–20 cm, *Caryota urens* (1.6278 cm^2) at 20–30 cm, *Ailanthus excelsa* (1.9442 cm^2) at 30–40 cm, *Artocarpus hirsutus* (0.6249 cm^2) at 40–50 cm, *Ailanthus excelsa* (0.6972 cm^2), 60–70 cm (0.6229), and 80–90 cm (0.5382 cm^2). The 70–80 cm DBH class was vacant by any species. Among the leading species, *Ailanthus excelsa* had the highest total basal area (4.8580 cm^2) in all diameter classes. The least number of species occupied basal area in diametric classes are 0–10 *Ailanthus excelsa* (0.003184713 cm^2), 10–20 *Ailanthus excelsa* (0.16226911 cm^2), 20–30 *Hevea brasiliensis* (0.284410828 cm^2), 30–40 *Hevea brasiliensis* (0.10166401 cm^2), 40–50 *Hevea brasiliensis* (0.1912818 cm^2), 50–60 *Caryota urens* (0.203821656 cm^2), 60–70 *Caryota urens* and *Hevea brasiliensis* (0.318471338 cm^2). *Hevea brasiliensis* has the lowest basal area (1.360184 cm^2) among the dominant species.

4.8. Carbon vs. tree relative density

The graph (Fig. 2) indicates a positive linear trend between the relative density of trees and the total carbon, indicating that increased relative density of trees leads to increased total carbon storage. The R^2 is 0.9489, meaning that 94.89% of total carbon variation is explained by the data given here: critical data in the understanding of dynamics in the forest with far-reaching implications for climate change mitigation

4.9. Carbon vs. basal area

The regression equation indicates a 0.3463 unit increase in carbon per unit basal area, $R^2 = 0.7389$,
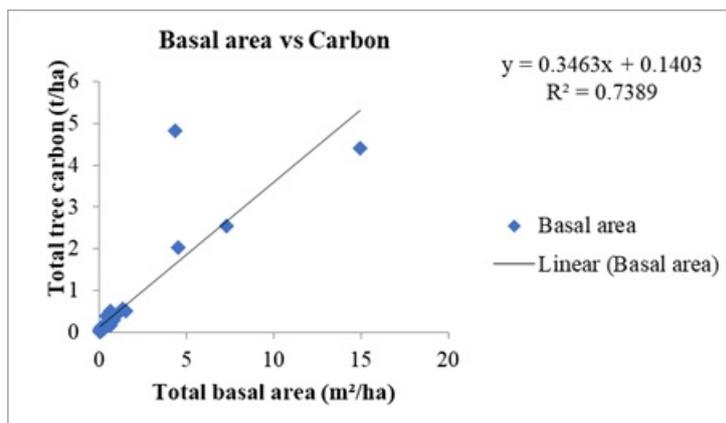
Fig. 3. Relationship between carbon vs. basal area.

accounting for 73.89% variation (Fig. 3). The findings point to tree density and basal area as important for sequestration of carbon, highlighting their importance in forest management to mitigate climate.

4.10. Carbon emission

4.10.1. Human Factor

Human respiration emits 463,129 kg CO_2/year based on an emission factor of 0.9 kg CO_2 person per day (GLOBE, 2008). While we exhale almost three billion tons of carbon dioxide yearly, that carbon was once in the air; much of it was absorbed by the plants we and our farm animals eat (NASA Earth Observatory, 2011).

4.10.2. Electricity

Electricity usage emits 1,398,518.46 kg CO_2/year. If the consumption amount of electricity is 1 kWh, then about 10 kg of CO_2 is released into the atmosphere, the emission factor given by Jayakumar et al. (2018) (0.81 kg/kWh). Carbon offsetting of carbon footprint is estimated by conservation method like Non-conventional source of energy Solar panels. Currently institution has installed 1258 rooftop solar panels, produces 420 units (kWh) of energy per day. 50 grams of CO_2 is emitted from 1 unit of solar power. Annual energy production of solar panels from university is 940.24 metric tons.

4.10.3. LPG

LPG-related emissions are estimated at 47,891.76 kg CO_2e per year, based on the LPG emission factor provided in Jayakumar et al. (2018) (2.90 t/MWh). CO_2 replaced by Biogas plant. The biogas plant has been recognized as a suitable technology for improving energy access, waste management, and sanitation.

Biogas plants also provide a residue of organic waste after anaerobic digestion, which has superior nutrient qualities and considerable environmental benefits by reducing GHG emissions like CO_2, methane, and nitrous oxide. Approximately 20 kg of food waste is fed into the plant daily, resulting in biogas harvesting that consumes nearly 2–4 hours. The School of Environmental Sciences has also installed a biogas plant with a capacity of 0.73 m^3. The annual CO_2 released by the biogas plant is 1.57 metric tons.

4.10.4. Transportation

Transportation-related emissions are estimated at 2,031,333 kg CO_2 per year. Of this total, 190,557.9 kg CO_2 is from diesel consumption and 1,840,775.1 kg CO_2 is from petrol consumption. These values were calculated using the IPCC (2006) Tier 1 emission factors of 2.7 kg CO_2 per litre of diesel and 2.3 kg CO_2 per litre of petrol, respectively. Fossil fuels remain the dominant source of transport energy, and the amount of CO_2 emitted depends on fuel type, fuel consumption, engine efficiency, and distance travelled. Expanding the use of electric vehicles (EVs) and shared transport modes can substantially reduce total transportation-related emissions and help transition the campus toward low-carbon mobility.

4.10.5. Waste

Waste emissions are 70,543.38 kg CO_2/year based on the emission factor of 0.541 tCO_2e per tonne recommended by Jayakumar et al. (2018). The campus, including the academic, administrative, residential, canteen, and other sectors, generates an average of approximately 130.39 metric tons of solid waste each year, with food waste comprising 76.5% or 99.73 metric tons. In the 'Nirmalam MGU' scheme, the waste

Table 1. Total CO_2 emission from the Human factor, energy, transportation, and waste sector.

Sector	Resource	Consumption	Emission Factor	CO_2 EMISSION (kg/year)
Human factor	Academic, Administrative, Residential, Cafeteria/Canteen sector, and floating population	5875 (Total population)	0.9 kg per person per day	1930937.5
Energy	Electricity	1726566 kWh/year	0.81 kg/kWh	1398518.46
Energy	LPG	16514.4 Kg/year	2.90 t/MWh	47891.76
Transportation	Diesel	70577 litres/year	2.7 kg/L	190557.9
	Petrol	800337 litres/year	2.3kg/L	1840775.1
Waste	Biodegradable waste generated	130394.42 kg/year	0.541tCO$_2$e/tonne	70543.38

is handled by the University through aerobic compost units, food, paper, and plastic waste bins, the Material Collection Facility for the disposal of non-biodegradable waste, and using compost for plant pots and growing bags. This is in line with the Green Protocol campaign initiated by the University in the year 2018. Carbon offsets in this study amounted to IVI$_2$ (Table 2).

Table 2. The overall carbon offset achieved by the campus.

Total offsets	
Carbon offsets	Total (metric tons)
Biogas	1.576
Solar panel	940.24
Solding of waste	53.286
Green cover (trees)	2705.3395

The green canopy cover of the campus offsets carbon emissions. The total tree biomass of the campus is 3600.5 t/ha, which sequesters 1710.2375 t/ha of carbon.

4.11. Total observed carbon

The total observed carbon in the 30 plots and Miyawaki forest is 39.6562227 t/ha.

Table 3. Total CO_2 emission from MG University campus.

Emission Inventory	Total (metric tons)
Human factor	1,930.938
Electricity	1,398.518
LPG	47.892
Transportation	2,031.333
Waste	70.543
Total	5,479.224
Carbon offset	2705.3395

4.12. Carbon balance

The carbon balance assessment for the institution shows total CO_2 emissions of 5479.22 metric tons, with transportation being the most significant contributor at 2031.33 metric tons, followed by human factor at 1930.94 metric tons. In contrast, the institution's carbon offset initiatives sequester 2705.34 metric tons of CO_2, the emissions exceeding offsets by 2773.88 metric tons.

5. Discussion

Phytosociology studies the distribution and classification of plant communities (Salisu et al., 2021). The present study documented 357 trees from 33 species across 30 selected plots on the university campus. In contrast, the study by Padmakumar et al. (2021) analyzed 992 trees from 66 species and 31 families in four home gardens, each with an area of one hectare (ha). The dominant species identified were *Tectona grandis*, with its dominance attributed to large biomass and high wood density, which significantly contribute to carbon sequestration. *Caryota urens* and *Artocarpus hirsutus* are emerging as dominant species in terms of carbon contribution in the present study. Similarly, Kumar and Nair (2006) recorded 839 homegardens across the 28 Panchayaths in Thrissur, Palakkad, and Malappuram districts with a total of 463 species, which includes 208 tree species, whereas *Cocos nucifera* was ubiquitous in household gardens. Estimating stand-level carbon stocks per unit area of forests or woodlands is of great importance for forestry-related mitigation options in response to future climate change (Khan et al., 2020). The species with the highest IVI were considered the leading dominants of the community and were best adapted to the environmental conditions in the area (Jahantigh and Efe, 2010). Here, *Caryota urens* was ranked top by the Importance Value Index (IVI) (67.46 trees/ha). Two endemic species (*Artocarpus*

hirsutus and *Cinnamomum malabatrum*) are pointers to conservation requirements, while 28 exotic species reflect non-native presence (Kumar and Nair, 2006). A university-level assessment of biomass and carbon stocks was conducted by Kumari et al. (2023) using allometric equations. The study evaluated 1,260 trees representing 20 species and 14 families. *Ficus racemosa* had the highest carbon stock, and *Azadirachta indica* was the most dominant species of the study area.

Diameter classes play a crucial role in defining structural complexity, dynamics, and function of forest ecosystems with a significant impact on carbon storage (Lutz et al., 2013). The 20–30 cm DBH class possessed the highest amount of carbon (10.79 t/ha) as well as biomass (22.76 t/ha) among 88 tree species, representing the extensive dominance of trees in an intermediate size class in carbon sequestration. On the other hand, the carbon content (0.49 t/ha) and biomass (1.04 t/ha) values were the lowest for the 80–90 cm DBH class, with a single tree species, proving that the contribution of larger diameter classes is in a downward trend in this scenario. It aligns well with Padmakumar et al. (2021), where carbon stocks peaked in the 20–29 cm DBH class and declined in subsequent classes, specifically 70–79 cm. Similarly, Baishya et al. (2009) reported that AGB accumulation in plantations peaked at 40–60 cm DBH, whereas natural forests peaked at 60–80 cm DBH, which indicates differences between forest types. The distribution of carbon stocks by diameter classes is considered the most important feature in the study of tree carbon storage in a given location. Large-diameter trees in forests play a crucial role in carbon storage (Raha et al., 2020). Such findings highlight the importance of understanding the distribution of diameter classes in optimizing carbon management in forest ecosystems.

The scatter plot validates basal area as a reliable predictor of carbon, with the same findings as Slik et al. (2013) and Padmakumar et al. (2021), establishing a positive correlation in the case of ≥ 3 cm DBH trees. The analysis of this study presents a very positive linear relationship between tree relative density and the total carbon, with an R^2 value of 0.9489, explaining 94.89% of the variance in carbon content. Such findings emphasise the importance of tree density in forest dynamics and its potential for mitigating climate change. In the same line, Padmakumar et al. (2021) reported a strong positive re-

lationship between tree carbon and tree density (R^2 = 0.85, p < 0.001). Moreover, at the current study, it was found that when the basal area is increased by one unit, then total carbon increases by 0.3463 units with an adjusted R^2 value of 0.7389, thereby accounting for 73.89% variability. This outcome is also in consonance with Padmakumar et al. (2021), which showed a positive relationship between basal area and tree carbon at the plot level, combining all the trees with a DBH of ≥ 3 cm.

Several studies have also been conducted to estimate carbon stock at the university level. These provide background information on the importance and relevance of the current study. Patel and Naik (2024) tried to calculate the biomass, carbon stock, and sequestered CO_2 on an 18-year-old teak plantation at Pt. The Ravishankar Shukla University campus at Raipur, Chhattisgarh, indicated a biomass value of approximately 79.31 t/ha, 37.28 t/ha for carbon stock, and sequestered CO_2 at 136.66 t/ha. Although Singh and Tiwari (2024) estimated the carbon content in forests around industrial regions, their findings indicated lower values due to disturbances and the presence of a thermal power plant. Similar campus-based carbon inventory studies, such as the work by Lee et al. (2025), provide insight into tree distribution mapping, carbon storage estimates, and methodological frameworks used globally. Taken together with these current findings, these results demonstrate that environmental and management factors, as well as methodological procedures, impact Carbon stock considerably, and there is a role for standardization in these procedures on a campus scale.

6. Conclusion

This study confirms the effectiveness of the role that academic institutions can and should play in reducing climate change impacts through the implementation of ecosystem-based carbon sequestration and sustainable energy and resource utilization strategies. From the above-ground biomass and carbon assessment carried out in the 30 sample sites within the Mahatma Gandhi University, the total biomass measured at 83.55 t/ha and the stored carbon at 39.49 t/ha demonstrate the great potential within the ecosystem to act as a major carbon sink, and this is highly affected by the stand and composition of the vegetation established in the ecosystem. Dominant native species such as *Caryota urens* and

Artocarpus hirsutus contribute substantially to the carbon pool, particularly in the 20–30 cm DBH class, is significant and promotes the preservation and effective utilization of the indigenous flora to increase carbon sequestration in the ecosystem.

The pattern of biomass and carbon distribution by diameter classes highlights the importance of stands of high structural diversity for augmenting carbon sequestration in ecosystems. The positive correlations between carbon sequestration and forest stand density as well as basal area traits suggest that these structural features of forests have been established as important factors that determine sequestration capabilities and are consistent with similar research conducted on tropical forests, as well as existing research on campus settings.

The campus-level emission inventory further reinforces the sequestration potential by indicating transportation and human factor as the major source of emissions, accounting for a cumulative annual emission of 5,479.22 tons of CO_2e. The existing mitigation efforts of solar energy systems, biogas plants, waste management systems, and the tree canopy further result in the reduction of 2,705.34 tons of CO_2e, are creating a carbon gap of 2,773.88 tons. Although this carbon gap shows the target of complete carbon neutrality is still unattained, it is, nonetheless, a target that could be easily achieved by deploying more renewables, increasing the green cover, electrifying the campus transport systems, and improving the respective waste management systems.

The findings confirm that Mahatma Gandhi University is making progress toward achieving carbon neutrality and can serve as a model for other educational institutions seeking to integrate climate action with biodiversity conservation and sustainable development. Continued investment in ecological restoration, green energy, and sustainable campus practices will not only bridge the remaining carbon deficit but also fortify the university's commitment to environmental leadership.

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CRediT statement

Akshaya Vinod T: Investigation, Formal Analysis, Writing Original draft. Amalu Shaju: Conceptualization, Methodology, Validation, Formal Analysis, Editing. Baiju K R: Supervision, Editing. Dr Abin Varghese: Conceptualization, Supervision.

Declaration of competing interest

The authors had no potential conflict of interest reported.

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