Original Research Article

Assessment of Soil Carbon Stock Potential in a University Campus in Tamil Nadu, India: Insights from Different Soil Layers

ABSTRACT

Mostly soil carbon stock research is done in areas with natural vegetation, ignoring university campuses. This study assesses soil carbon stocks across different layers within the Bharathiar University campus in Tamil Nadu, India. Soil samples were collected from four sections of the campus and analyzed for carbon content across depths of 0-10cm, 10-20cm, and 20-30cm. Results indicate soil carbon stocks ranging from 1.36% to 2.26%, with notable variations observed among campus sections and soil layers. While significant differences were detected in the 20-30cm layer, uniformity was found in the shallower layers. Correlation analysis with soil parameters (pH, conductivity, total dissolved solids) revealed insignificant relationships, except for a positive correlation between soil carbon stocks and pH in the South section and total dissolved solids in the East section. These findings underscore the complexity of soil carbon dynamics in diverse ecosystems like university campuses and emphasize the potential for localized assessments to inform sustainable land management strategies. This study contributes valuable insights into enhancing carbon sequestration efforts within managed ecosystems, necessary for global climate change mitigation. Integrating such localized findings into broader environmental policies can optimize carbon management strategies across similar ecosystems globally.

Keywords: Soil carbon stock, Carbon sequestration, Sustainable land management, Soil layers, University campus ecosystem

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1. INTRODUCTION

Converting natural ecosystems to managed ecosystems increases susceptibility to soil degradation processes, leading to a depletion of soil carbon stocks and the release of carbon dioxide and other greenhouse gases into the atmosphere [1]. Effective soil management practices can mitigate carbon emissions, leveraging soil's substantial carbon fixation potential. Assessing soil carbon stock across various land covers is crucial for formulating sustainable land management strategies. These strategies are pivotal in carbon sequestration efforts and mitigating greenhouse gas emissions, particularly in addressing climate change concerns [1].

Globally, soils store approximately 2135 Gt of soil carbon stock [2], making them the largest terrestrial reservoir of carbon [3]. However, factors such as land use and management practices, exacerbated by rising temperatures from climate change, may potentially shift soils from being a carbon storage to a significant source of atmospheric carbon dioxide (CO_2) [4]. Given the vast size of this terrestrial carbon pool, even slight changes in soil carbon stocks, on the order of a few percentage points, could profoundly impact atmospheric CO_2 concentrations and the global carbon balance [5, 6].

Addressing changing climatic conditions and escalating land-use conflicts necessitates the establishment of sustainable land-use systems that harmonize agricultural production with the provision of diverse ecosystem services [7]. Global estimates indicate that interventions in land use contribute significantly, potentially reducing emissions by approximately 30% through carbon sequestration. These efforts are critical for achieving the carbon reduction targets established during the COP-25 meeting [8].

Over recent decades, scientific research has prioritized strategies to enhance soil carbon levels to mitigate climate change [9] and enhance soil health [10]. Conversion of forests to alternative land uses [11] and unsustainable soil management practices, such as conventional tillage, removal of crop residues, in-field burning, excessive use of agrochemicals, and reduced application of external organic matter [12], have been shown to reduce soil carbon stocks [13].

The predominant factor driving the observed increase in global average temperatures is the steady rise in atmospheric CO_2 levels, as reported by IPCC [14].
Since the beginning of the industrial revolution in 1850, atmospheric CO2 concentrations have risen from 280 parts per million (ppm) to 426 ppm in 2024 [15]. Predictions indicate that the mean global temperature could increase by 1.1°C to 6.4°C by 2100 [16,17].

There are several studies available on soil carbon stocks worldwide, however, they are focused mostly on the natural forest [18,19,20]. Soil carbon stock research on university campuses is completely neglected in understanding their carbon sequestration potential. Hence, the present study aims to fill the knowledge gap. The main objective of this study is to estimate the soil carbon stock by different soil layers in the Bharathiar University campus located in Coimbatore, India.

2. MATERIAL AND METHODS

2.1 Study area

The present study was conducted at Bharathiar University campus, situated at the foothills of Maruthamalai, a mountain forest within the Western Ghats, in the Coimbatore district of Tamil Nadu state, India (Fig. 1). Covering a vast area of 1000 acres, the campus is located 15 km west of Coimbatore city, along Maruthamalai road. Vegetation

The Bharathiar University campus holds different types of vegetation, including natural forests, grasslands, and mono-species and multi-species plantations. The mono-species plantations such as Coconut and Eucalyptus are common in the study area [21]. The predominant species of the multi-species plantations are *Acacia farnesiana*, *Cassia montana*, *Prosopis juliflora*, and *Acacia nilotica*. The campus is situated adjacent to the Marudamalai hills, and its terrain is almost plain, and the elevation gradually varies from 482-512 m asl [22]. The study area mainly consists of red soil rich in organic matter, with granite bedrock covered by shallow sandy loam.

2.2 Climate

Based on climate data covering from 1991 to 2021, the study area at Bharathiar University received an average annual rainfall of 952 mm. Significantly, 77% of this rainfall occurred between June and November. The average monthly temperature throughout this period was 25°C. The lowest monthly temperature, 18°C, was recorded in January, while the highest, 35°C, was observed in April [23].

2.3 Field survey

For the field survey, the Bharathiar University campus was divided into four sections: East, West, North, and South. A total of 60 soil samples were collected systematically. Within each section, five representative sampling spots were identified. From each spot, soil samples were collected from three layers: 0-10cm, 10-20cm, and 20-30cm depths.

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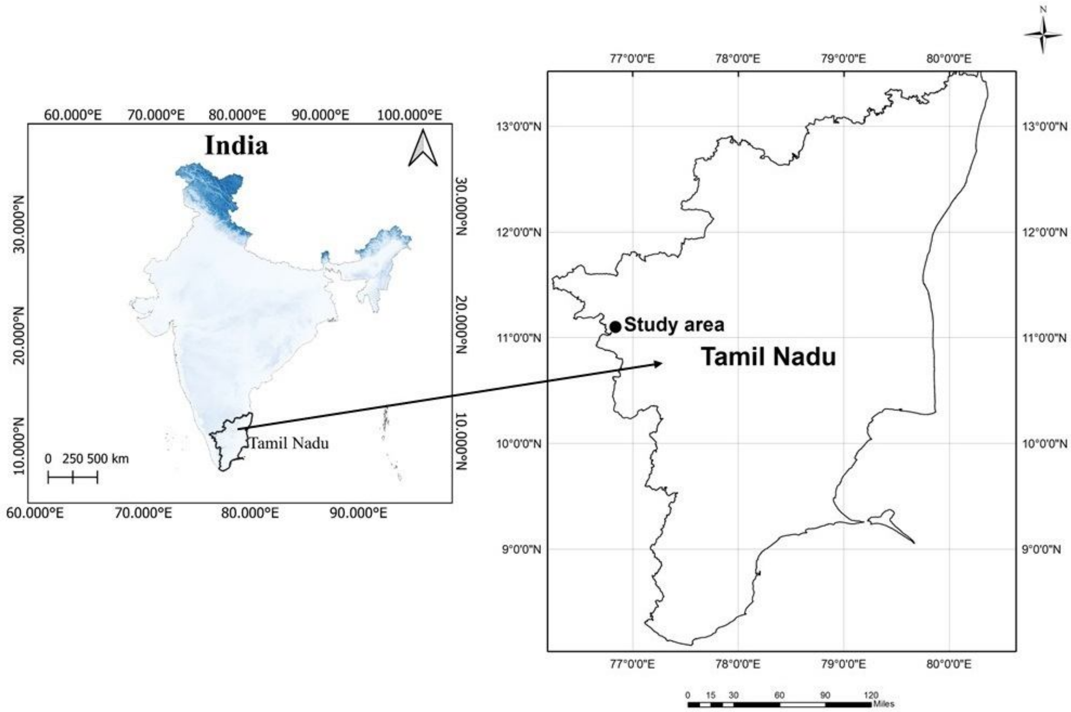

Fig. 1. Map showing the location of the study area

2.4 Laboratory analysis

The collected soil samples were used for determining the soil carbon stock across the campus. Also, soil parameters including pH, conductivity, and total dissolved solids were analyzed.

2.4.1 Determination of soil carbon stock

In the laboratory, the collected soil samples were dried in an oven at 105°C for 2 hours to obtain their dried weights. Subsequently, two grams of the oven-dried and ground soil samples were transferred into pre-weighed crucibles. These crucibles were then placed in a furnace and heated to 550°C for 1 hour. After heating, the crucibles were allowed to cool slowly inside the furnace. After cooling, the crucibles containing the ash samples were weighed to determine the percentage of carbon stock, following the methodology described by Allen et al. [24].

Estimation of carbon stock (C):

$C\ (\%) = (100 - \text{ash}\ \%) \times 0.58$
Calculation of ash (%) for estimation of carbon stock
$\text{Ash}\ (\%) = (W3 - W1)/\ (W2 - W1) \times 100$
Where, W1 is the weight of crucible
W2 is the weight of oven-dried grind sample + Crucible
W3 is the weight of ash + Crucible

2.4.2 Estimation of other soil parameters

pH indicates acidity or alkalinity on a scale of 0 to 14, with 7 being neutral. Each pH unit represents a tenfold change in acidity or alkalinity. Soil pH was measured using a pH meter in this study to compare samples accurately. Soil conductivity was measured using a conductivity meter.Total Dissolved Solids (TDS), analyzed per APHA [25] standard methods, involved filtering a 50 mL sample through filter paper. The filtrate was transferred to a pre-weighed silica crucible and evaporated in a hot air oven at 105°C until dry. The final weight (W2) of the crucible was recorded after cooling in a desiccator.

Calculation of TDS:

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TDS (mg/L) = ((W2-W1) × F)/V
Where, W1 = Weight of the empty crucible
W2 = Weight of the crucible with dried residue after evaporation
F = Factor to convert weight to TDS
V = Volume of the sample filtered

2.5 Statistical analysis

One-way analysis of variance (ANOVA) was performed to check for significant variation in soil carbon stock value for the different soil layers between the four sections (East, West, North, and South) in the Bharathiar University campus. Further, Pearson's Correlation analysis was performed to understand the relationship between the carbon stock values and the soil parameters such as pH, conductivity, and total dissolved solids.

3. RESULTS AND DISCUSSION

3.1 Soil carbon stock and other soil parameters

Soil carbon stock (%) and other soil parameters such as pH, Conductivity, and TDS varied among the four sections studied at the Bharathiar University campus. The highest carbon stock value was found in the South section (2.26%, 22.64 gC/kg of soil), followed by North (1.67%, 16.68 gC/kg of soil), West (1.39%, 13.91 gC/kg of soil), and East (1.36%, 13.65 gC/kg of soil) (Table 1). The pH values varied with the highest recorded in the West section (8.49), followed by East, South, and North (Table 1). Conductivity was highest in the East section (0.24 S/m), followed by West, North, and South (Table 1). Total Dissolved Solids (TDS) were also highest in the East section (0.15 mg/L), followed by West, North, and South sections (Table 1).

Table 1. Soil carbon stock (%)in the four sections studied at the Bharathiar University campus with other soil parameters.

Section	Parameter	n	Average	±SD
East	Carbon stock (%)	15	1.36	0.54
	pH	15	8.15	0.26
	Conductivity (S/m)	15	0.24	0.02
	TDS (mg/L)	15	0.15	0.01
West	Carbon stock (%)	15	1.39	0.43
	pH	15	8.49	0.36
	Conductivity (S/m)	15	0.16	0.04
	TDS (mg/L)	15	0.10	0.02
North	Carbon content (%)	15	1.67	0.81
	pH	15	7.39	0.79
	Conductivity (S/m)	15	0.10	0.05
	TDS (mg/L)	15	0.05	0.02
South	Carbon content (%)	15	2.26	0.31
	pH	15	7.94	0.49
	Conductivity (S/m)	15	0.09	0.02
	TDS (mg/L)	15	0.05	0.01

3.2 Carbon stock in the soil layer 0-10cm

The carbon stock in the 0-10cm soil layer at Bharathiar University campus averaged 16.80 gC/kg of soil, with values ranging from 13.60 gC/kg to 21.85 gC/kg across the four sections studied (Fig. 2). The South section exhibited the highest carbon stock, followed by North, West, and East sections (Fig. 2). However, single-factor ANOVA indicated that the carbon stock in the 0-10cm soil layer did not differ significantly among the sections at the Bharathiar University campus

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(Table 2). This suggests overall uniformity in carbon content across the different sections despite observed variations in absolute values.

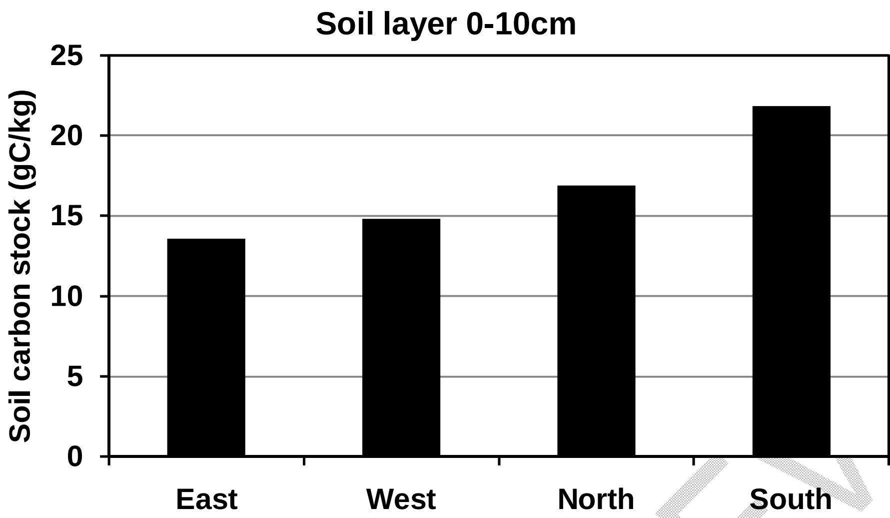

Fig. 2. Carbon stock in the soil layer 0-10cm for the four sections studied at the Bharathiar University campus.

Table 2. Results of single factor ANOVA to check the variation of carbon stock in the soil layer 0-10cm among the four sections studied at Bharathiar University campus.

SUMMARY

Groups	***Count***	***Sum***	***Average***	***Variance***
East	5	6.7976	1.35952	0.244577
West	5	7.4066	1.48132	0.166806
North	5	8.4448	1.68896	1.264934
South	5	10.9272	2.18544	0.146744

ANOVA

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	1.988627	3	0.662876	1.454423	0.264349	3.238872
Within Groups	7.292244	16	0.455765			
Total	9.280871	19				

3.3Carbon stock in the soil layer 10-20cm

The carbon stock in the 10-20cm soil layer at Bharathiar University campus averaged 17.10 gC/kg of soil, with values ranging from 13.50 gC/kg to 23.51 gC/kg across the four sections studied (Fig. 3). The South section exhibited the highest carbon stock, followed by North, West, and East sections (Fig. 3). However, single-factor ANOVA indicated that the carbon stock in the 10-20cm soil layer did not show significant variation among the sections at Bharathiar University campus (Table 3). This suggests consistent carbon stock levels across different sections in absolute values observed within the 10-20cm soil layer.

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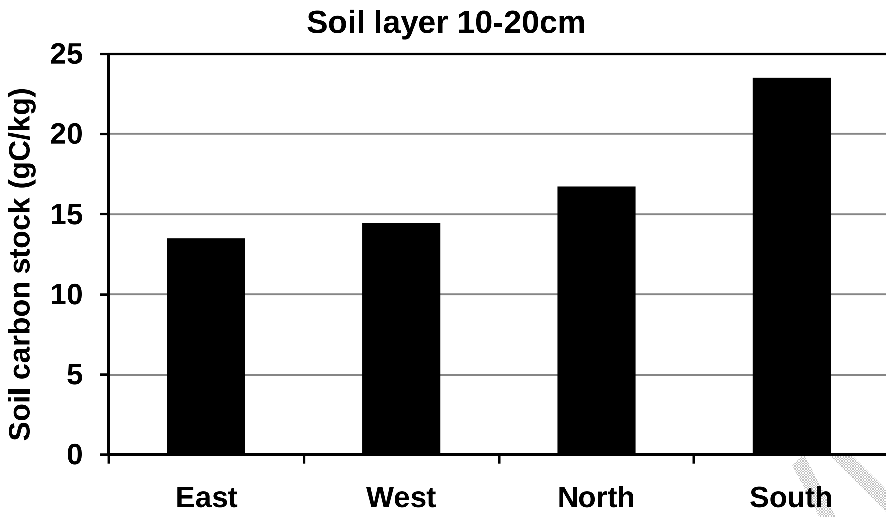

Fig. 3. Carbon stock in the soil layer 10-20cm for the four sections studied at the Bharathiar University campus.

Table 3. Results of single factor ANOVA to check the variation of carbon stock in the soil layer 10-20cm among the four sections studied at Bharathiar University campus.

SUMMARY

Groups	***Count***	***Sum***	***Average***	***Variance***
East	5	6.7483	1.34966	0.313586
West	5	7.2355	1.4471	0.222529
North	5	8.3665	1.6733	0.753919
South	5	11.7566	2.35132	0.063771

ANOVA

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	3.057564	3	1.019188	3.011332	0.060935	3.238872
Within Groups	5.415216	16	0.338451			
Total	8.47278	19				

3.4 Carbon stock in the soil sayer 20-30cm

In the soil layer 20-30cm at Bharathiar University campus, the carbon stock averaged 16.30 gC/kg of soil, with values ranging from 12.45 gC/kg to 22.55 gC/kg across the four sections studied (Fig. 4). The South section exhibited the highest carbon stock, followed by North, East, and West sections (Fig. 4). Further, single-factor ANOVA indicated that the carbon stock in the 20-30cm soil layer varied significantly among the four sections at the Bharathiar University campus (Table 4). These findings suggest consistent variation in carbon stock within the 20-30cm soil layer across the different sections of the Bharathiar University campus.

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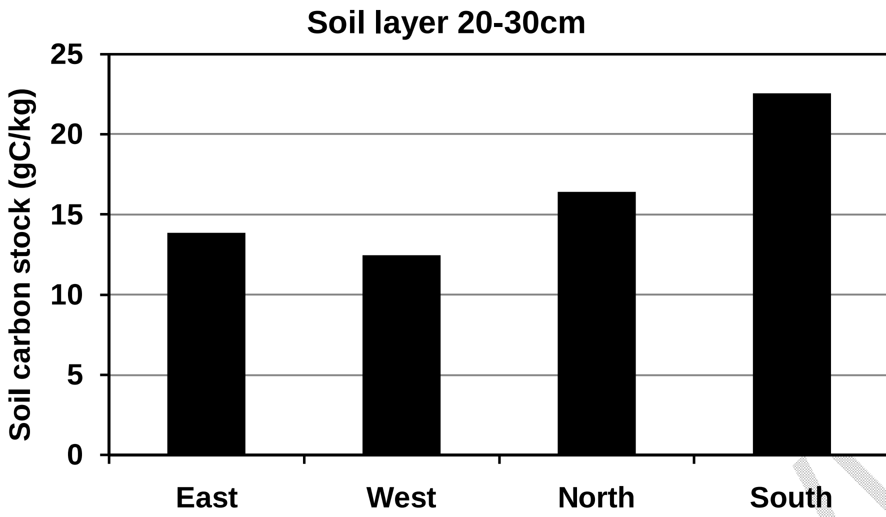

Fig. 4. Carbon stock in the soil layer 20-30cm for the four sections studied at the Bharathiar University campus.

Table 4. Results of single factor ANOVA to check the variation of carbon stock in the soil layer 20-30cm among the four sections studied at Bharathiar University campus.

SUMMARY

Groups	***Count***	***Sum***	***Average***	***Variance***
East	5	6.9281	1.38562	0.444668
West	5	6.2234	1.24468	0.215815
North	5	8.2099	1.64198	0.273175
South	5	11.2752	2.25504	0.099468

ANOVA

Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	2.994991	3	0.99833	3.865282	0.029631	3.238872
Within Groups	4.132502	16	0.258281			
Total	7.127494	19				

3.5Relationship between soil carbon stock and other soil parameters

Pearson's Correlation analysis revealed that in the East section, soil carbon stock showed a positive correlation with TDS (r=0.563, p<0.05), but no significant correlations with pH (r=0.226, p>0.05) or conductivity (r=0.362, p>0.05) was observed. For the West section, soil carbon stock did not correlate significantly with pH (r=0.0005, p>0.05), conductivity (r=-0.341, p>0.05), or TDS (r=-0.354, p>0.05). In the North section, soil carbon stock did not correlate significantly with pH (r=-0.494, p>0.05), conductivity (r=0.212, p>0.05), or TDS (r=0.257, p>0.05). However, in the South section, soil carbon stock showed a positive correlation with pH (r=0.550, p<0.05), but not with conductivity (r=0.316, p>0.05) or TDS (r=0.327, p>0.05). These findings reveal the variability in soil carbon stock and its relationships with pH, conductivity, and TDS across different sections of the Bharathiar University campus.

We observed that the soil carbon stocks varied from 1.36% to 2.26% in the Bharathiar University campus. While, it was from 1.26% to 1.56% at Tezpur University, India [26], from 0.64% to 1.05% at Pondicherry University, India [27], from 1.4% to 2.33% at the University of Lampung, Malaysia [28], and from 1.03% to 1.37% in Chittagong University, Bangladesh [29]. Here we observe that the soil carbon stocks in universities range from 0.64% to a maximum of 2.33%. However, the ranges can vary widely across the nations.

Statistical analysis revealed that there was no significant correlation between the soil carbon stock and the soil pH, TDS and electrical conductivity in the Bharathiar University campus, except for soil carbon stock with pH for the South section (p<0.05), and with TDS for the East section (p<0.05). It was reported earlier that the correlation between soil carbon stock and electrical conductivity can vary, showing positive and negative relationships [30].

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Worldwide numerous measures have been implemented to mitigate the increasing concentration of atmospheric carbon [31]. Initiatives such as Clean Development Mechanism (CDM) forestry projects, which started in 2006 to achieve carbon offsetting targets, have been complemented by the establishment of frameworks like the Climate Action Reserve (CAR), Verified Carbon Standard (VCS), and the American Carbon Registry (ACR) [32]. The United Nations Framework Convention on Climate Change (UNFCCC) holds regular meetings with nations to combat global warming and climate change. Future agreements are expected to introduce incentives aimed at reducing fossil fuel usage. These negotiations include provisions for Clean Development Mechanisms under the IPCC and facilitate carbon trading in national and international markets. Despite implementing policies such as carbon taxes, subsidies, and the growth of carbon markets, the increase in atmospheric carbon concentration and its consequential impacts remain alarming [17].

Developing countries, particularly vulnerable populations in these regions, are expected to face significant adverse effects from climate change. Despite India not being the top carbon emitter, its increasing emissions from fossil fuel combustion highlight the need for reduction to curb rising atmospheric carbon concentrations. Besides soil, forests and oceans are crucial carbon sinks in mitigating climate impacts.

4. CONCLUSION

From the findings of our study, we conclude that the soil carbon stocks in the Bharathiar University campus ranged from 1.36% to 2.26%, with notable variations observed across the campus's sections and soil layers. While significant differences were found in carbon stocks among sections for the 20-30cm soil layer, uniformity was observed in the 0-10cm and 10-20cm layers. Interestingly, correlations between soil carbon stocks and soil parameters such as pH, electrical conductivity, and total dissolved solids were generally insignificant, except for a positive correlation between carbon stock and pH in the South section, and with total dissolved solids in the East section. The novelty of our study lies in its focused investigation of soil carbon stocks within a university campus environment which is often overlooked in broader soil carbon research.

Our study underscores the importance of localized assessments in understanding soil carbon dynamics within diverse ecosystems like university campuses. They highlight the potential for sustainable land management practices to enhance carbon sequestration efforts, contributing to global climate change mitigation strategies. Further, integrating such findings into broader climate policies and management frameworks can optimize carbon management strategies in similar ecosystems worldwide.

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