JOURNAL OF AGRICULTURE AND APPLIED BIOLOGY
2024, Vol. 5, No. 2, 194 - 202
http://dx.doi.org/10.11594/jaab.05.02.05
E-ISSN: 2723-5106

Research Article

Dynamic interplay of soil parameters and CO_2 sequestration in Solankuruni Freshwater Pond Wetland, Tamil Nadu, India

Packiaraj. P[1]*, S. Gayathrippriya[2], M. Chinnakaruppan[3], M. Premkumar[4], S. Gopala Krishnan[5], U. Muthuvel[1], K. Suresh[1]

[1]PG and Research Centre, Department of Botany, Saraswathi Narayanan College (Autonomous), Madurai – 625 022, Tamil Nadu, India
[2]Department of Botany, University of Calicut, Kerala - 673635, India
[3]CSIR - National Botanical Research Institute, Lucknow, Uttar Pradesh, India
[4]Botanical Survey of India, SRC, Coimbatore, Tamil Nadu, India
[5]CSIR – CSMCRI - Marine Algal Research Station, Mandapam camp, Tamil Nadu, India

Article history:

Received 17 May 2024
Revised 12 July 2024
Accepted 19 July 2024
Published 03 September 2024

Keywords:

Anthropogenic activities
Global Climate change
Microclimate
Soil carbon sequestration
Solankuruni freshwater Pond

***Corresponding author:**

E-mail:
pkrajtaxon@gmail.com

Abstract

This study investigates the dynamic interplay between soil temperature, pH levels, and CO_2 sequestration across ten sample sites over a four-month periods from January to April 2018 in Solankuruni freshwater pond wetland in Madurai District, Tamil Nadu, India. The soil temperature fluctuations, ranging from 31°C to 44°C, reveal distinct site-specific patterns, with sample site six consistently exhibiting the highest temperatures. Soil temperature exhibited notable variations, influenced by factors such as soil composition, and microclimate variations. Regarding pH level, the range between 6.23 to 8.1 display variability influenced by factors like soil composition and anthropogenic influences, study site five consistently leading in pH levels. Soil CO_2 sequestration varying from 1517.857 g/m^2 to 3357.143 g/m^2, highlight the influence of soil microbial activity, vegetation cover, and soil moisture content, ninth site consistently showing the highest sequestration rates. The findings reveal substantial variations in factors such as soil composition, vegetation type, microclimate, and anthropogenic activities, prominence the intricate nature of soil dynamics. These results stress the importance of understanding the interconnections among soil properties to create effective climate change mitigation strategies. Moreover, the research provides valuable understanding of the intricate connections between soil properties, emphasizing the necessity for region-specific studies to inform comprehensive environmental policies. Understanding these dynamic soil processes is crucial for advancing sustainable land management practices and boosting soil carbon sequestration in wetland ecosystems.

How to cite:
Packiaraj. P, S. Gayathrippriya, M. Chinnakaruppan, M. Premkumar, S. Gopala, Krishnan, U. Muthuvel, & K. Suresh (2024). Dynamic interplay of soil parameters and CO_2 sequestration in Solankuruni Freshwater Pond Wetland, Tamil Nadu, India. *Journal of Agriculture and Applied Biology, 5*(2): 194 - 202. doi: 10.11594/jaab.05.02.05

1. Introduction

Wetlands offer a plethora of ecosystem services crucial for human well-being, range from flood control to biodiversity preservation (Zedler & Kercher, 2005). Notably, wetlands are crucial in efforts to mitigate climate change because of their ability to capture and store carbon. This is especially important in light of alarming global warming projections. Although wetlands cover only 5–8% of the Earth's land surface, their soils hold a significant portion of global soil carbon, accounting for 20–25% (William et al. 2015). This carbon storage ability, with carbon pools comprising 30–40% of wetland soil mass, highlights the critical role of wetlands in the worldwide carbon cycle. Anthropogenic disturbances and ecological changes significantly impact wetlands carbon sequestration potential, factors that impact includes soil properties and types of vegetation (Bridgham et al. 2006). Despite their critical role, inland wetlands have faced degradation, diminishing their carbon storage capacity over recent decades (Fennessy et al. 2018; William et al. 2015).

Comprehending the complex processes that govern carbon storage across wetland ecological gradients remains a challenging task. Human activities, such as deforestation and changes in land use, contribute to a 30% reduction in carbon supply. Key threats to biodiversity encompass increased inhabitants pressure, expansion and intensification of farming, and expansion of infrastructure (Manral et al. 2022; Bargali et al. 2022; Bisht et al. 2023). Human activities with natural hydrological events like drought have contributed significantly to the destabilization and destruction of inland wetlands. As a consequence, their once considerable capacity for carbon sequestration has diminished in recent decades. In some instances, inland wetlands have transformed into carbon sources rather than sinks due to heightened methane emissions. This transition highlights the susceptibility of wetland ecosystems to ecological pressures and emphasizes the pressing necessity for improved conservation measures and sustainable management strategies. Tackling these challenges necessitates a comprehensive strategy that combines ecological studies, policy measures, and community involvement to protect the essential function of wetlands in universal carbon cycling and environment directive (Turetsky et al. 2014; Panneer Selvam et al. 2014; Kolka et al. 2018; Saunois et al. 2016).

Due to this, many studies on the cost-effective assessment of inland wetlands have frequently left out the assessment of carbon storage and sequestration services. Nonetheless, it is crucial to measure and analyze the carbon balance of these wetlands to comprehend the natural benefits they offer to humans. The processes that influence variations in carbon stocks along different ecological conditions remain poorly understood. This study aims to explore the interactions between soil characteristics and CO_2 sequestration within the Solankuruni freshwater pond wetland in the Madurai District.

2. Materials and methods

2.1. Study area description – Solankuruni Freshwater Pond Wetland:

This research was conducted at Solankuruni freshwater pond (Lat: 9.807363, long: 78.10753), a temporary body of water situated in the Solankuruni Village of Madurai District (Figure 1), Tamil Nadu, India, spanning from January 2018 to April 2018. This ephemeral pond, primarily replenished by rainwater and the Mullai Periyar channel, exhibits irregular depth and typically holds water for 4 to 7 months under normal rainfall conditions. Excess water is discharged towards Solankuruni village through a sluice gate located approximately 0.5 km away from the inlet aqueduct. Vegetation, predominantly comprising *Acacia nilotica* and *Prosopis juliflora*, as well as extensive grasslands, characterizes the pond area. Additionally, the pond water serves the dual purposes of agricultural performance and fulfilling domestic needs for the communities residing along its embankments. Throughout the study periods, the temperature remains relatively stable, with average monthly minimum and maximum temperatures ranging from 22ºC to 40ºC. The annual rainfall varies between 535 and 800 mm (Figure 2).

2.2. Methods

2.2.1. Soil analysis

Soil quality investigation involved monthly collection of soil samples using soil cores from experimental pond surfaces of 10 sampling sites. Various parameters were measured: Soil temperature: Determined on-site using a field thermometer at sampling points. Soil pH: Soil solution made by mixing 10 g soil with 50 ml distilled water, the level of pH measured using a pH meter.

2.2.2. Soil CO_2 emission

Two to three weeks before the study commenced, freshly fallen litter was cleared from each site, including the herbaceous layer. A protocol involving the placement of 0.1N KOH in a covered beaker, positioned 10 cm deep and the lower parts of the cylinders were embedded in the soil, while the top sections were securely covered with a metal lid and a polyethylene sheet for duration of 24 hours. After incubation, 5 ml of 10% $BaCl_2$ solution was added. The quantity of CO_2 taken up by the remaining alkali was then determined through a standardized titration process with 0.1 N HCl, using phenolphthalein as the indicator. The CO_2 emissions within the boxes were calculated using the subsequent method: Soil CO_2 Emission= Titration value ×N×1000 /Area of Cylinder Where 'N' is the normality of the HCl solution used in the titration (Anderson & Ingram, 1993).

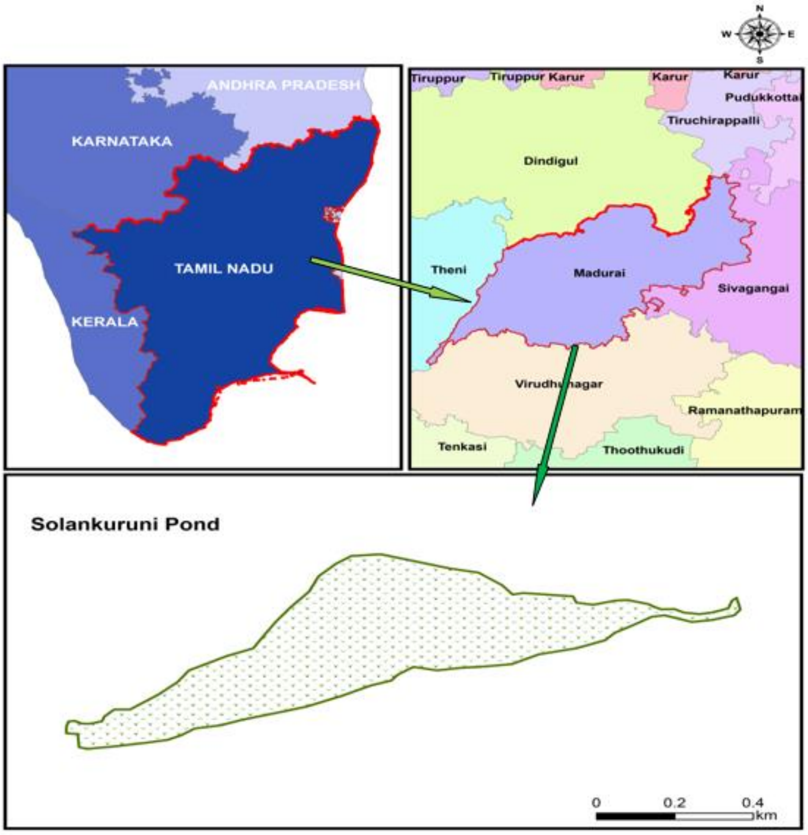

Figure 1. Depicts a panoramic view of the Solankuruni freshwater pond wetland situated in Madurai District, Tamil Nadu

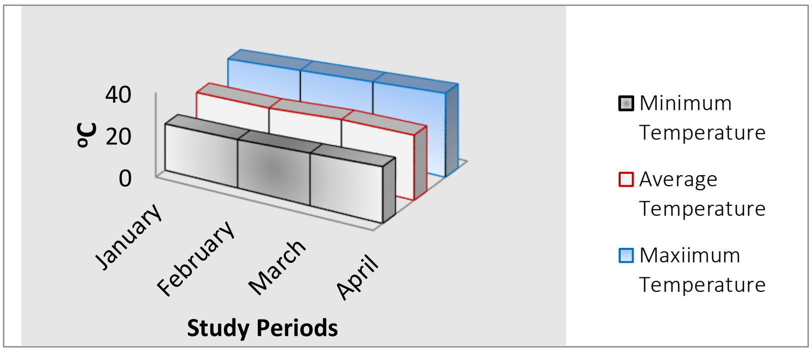

Figure 2. Temperature range in the study area from January to April 2018

3. Result and discussion

Wetlands play a vital role as global carbon reservoirs. However, uncertainties persist regarding whether these areas consistently act as carbon sinks within specific climatic zones, and how restoration and management techniques affect carbon sequestration. Variability in wetland carbon dynamics is heavily influenced by climate, making cross-regional comparisons difficult. Enhanced understanding of site-specific conditions and their evolution over time is essential to optimize restoration efforts and manage carbon storage effectively. Figure 4 shows that the soil temperature across the ten sample sites (Figure 3) exhibited variations over the monitored months. In January, temperatures ranged from 31°C to 37°C (Table 1), with site 6 showing the highest value. February saw a slight increase in temperatures, from 33°C to 40°C, in site 10 recording the highest value. In the March, temperatures fluctuated between 36°C to 42°C, site 6 consistently showing the highest values. Considerable variations of temperatures in April from 39°C to 44°C, the sixth sampling site maintaining the highest temperature throughout the monitoring periods.

The fluctuation in temperatures across the study sites can be attributed to various factors. The Microclimate variations further influence soil temperature dynamics at the local scale. Factors such as aspect, vegetation cover, and proximity to water bodies can create microclimates within the study area, leading to spatial heterogeneity in soil temperature (Jackson et al. 2017). For instance, areas with dense vegetation cover may experience lower soil temperatures due to shading effects and increased moisture retention, whereas open, exposed areas may exhibit higher temperatures due to greater solar radiation absorption (Geiger, 1965). The fluctuations in soil temperature across the sample sites underscore the complex interactions between soil properties, topographical features, and microclimatic conditions (Smith et al. 2020). Understanding these dynamics is crucial for accurate environmental monitoring and management.

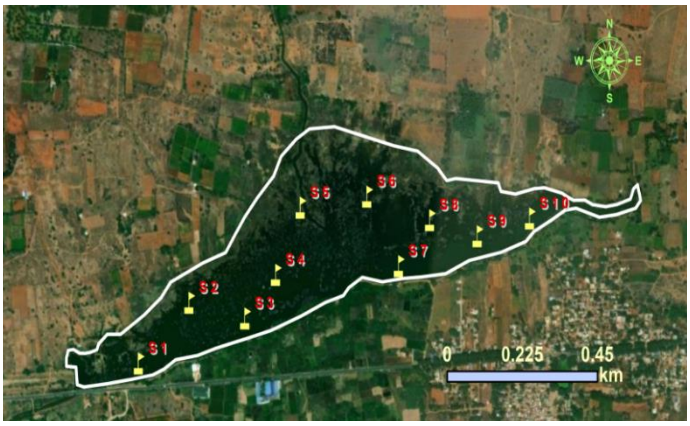

Figure 3. Different sampled sites within the experimental Pond

Similarly, the soil pH levels from different sample sites also exhibited variability throughout the experimental time (Figure 5). In January, pH values ranged from 6.23 to 7.65, it specifies that the study site one had the highest recorded value. In the February showed a similar pattern of 6.57 to 7.78 (Table 2), again site one had the highest pH level. The March month witnessed fluctuations between 6.59 and 7.7 in the study site five showing the highest range. In April, displayed values ranged from 7.35 to 8.1 throughout the research times, with the fifth site consistently leading in higher levels. The changes in pH levels can be linked to elements like soil makeup, types of plant community, and human activities, including land use practices such as agricultural expansion and nearby construction projects. The findings of the current study are consistent with the research conducted by Smith et al. (2018) and Jackson et al. (2017), which examined the impact of land use changes on soil pH variations in rural area. The study revealed that transforming natural habitats into agricultural areas led to a notable drop in soil pH, which was attributed to higher nutrient inputs and alterations in soil management techniques. Another study examined the impacts of urbanization on soil pH in urban parks across different cities. The researchers observed a gradual increase in soil pH levels with increasing urbanization intensity; contributing factors include the expansion of pavement areas, the deposition of alkaline dust from the atmosphere, and a decrease in the amount of organic matter being added.

Sequestering CO_2 in soil is essential for addressing climate change, maintaining biodiversity, securing food supplies, and promoting sustainable development. Efforts to enhance soil carbon storage should be prioritized as part of broader strategies to address climate change and promote environmental sustainability (Smith et al. 2020). The current research data indicates varying levels of CO_2 sequestration in each location throughout the study periods (Figure 6). In January, CO_2 sequestration ranged from 1803.571 g/m^2 to 2875 g/m^2, with study site 9 exhibiting the highest value. In the month of February showed a similar pattern, with 1875 g/m^2 to 3035.714 g/m^2 (Table 3), again the same site 9 once again recording the highest value. In March, witnessed fluctuations between 2053.571 g/m^2 and 2785.714 g/m^2, the same site 9 maintaining dominance in CO_2 sequestration. April displayed rates ranged from 1517.857 g/m^2 to 3357.143 g/m^2, with study site 9 consistently leading in sequestration.

Table 1. Variation in soil temperature across different sampling locations during the study periods

Sampling sites	Soil Temperature (^{0}C)			
	January	February	March	April
1	31.00	33.00	42.00	43.00
2	32.00	33.80	40.00	44.00
3	31.50	33.80	40.00	42.40
4	36.00	40.00	36.00	39.00
5	35.00	38.00	39.00	41.00
6	37.00	38.00	38.00	42.00
7	32.50	35.00	39.00	43.00
8	31.00	34.00	38.00	40.00
9	34.00	39.00	39.00	41.00
10	37.00	40.00	40.00	42.00

Table 2. Differences in soil pH observed at different sampling locations throughout the study periods

Sampling sites	Soil pH			
	January	February	March	April
1	7.65	7.78	7.30	7.57
2	7.40	7.64	7.34	7.98
3	7.10	7.58	7.00	7.65
4	7.00	7.21	6.59	7.35
5	7.28	7.34	7.70	8.10
6	6.57	7.47	7.22	7.86
7	6.23	6.88	7.50	7.90
8	6.84	7.21	7.11	7.60
9	7.18	7.49	7.14	7.43
10	6.93	7.36	7.22	7.58

Table 3. Seasonal changes in soil CO_2 sequestration rate at various sampling periods

Sampling sites	Soil CO_2 Sequestration (G/m^2)			
	January	February	March	April
1	2401.79	2267.86	2553.57	1517.86
2	1910.71	1875.00	2589.29	2633.93
3	2464.29	2080.36	2366.07	3044.64
4	2107.14	1964.29	2312.50	3258.93
5	1803.57	2598.21	2714.29	2633.93
6	2133.93	2232.14	2151.79	3008.93
7	2339.29	2321.43	2508.93	2928.57
8	2821.43	2410.71	2544.64	2910.71
9	2875.00	3035.71	2785.71	3357.14
10	2607.14	2821.43	2053.57	2723.21

The observed variations in CO_2 sequestration rates indicate that factors including soil microbial activity, vegetation cover, and soil moisture content exert significant influence. These findings imply a multifactorial specifically; soil microbial activity, vegetation cover, and soil moisture content emerge as notable influencers. Furthermore, soil microbial communities are pivotal in organic matter decomposition and carbon turnover, thereby affecting both CO_2 emissions and sequestration (Davidson & Janssens, 2006). The vegetation cover influences carbon input through litter fall and root turnover, while also affecting soil moisture levels and microbial activity. Soil moisture content directly affects microbial activity and decomposition rates, thereby influencing CO_2 fluxes. These observations align with existing literature on soil carbon dynamics and highlight the intricate interplay among biotic and abiotic factors in regulating CO_2 sequestration in terrestrial ecosystems (Manral et al. 2022). Despite this, there is limited evidence connecting plant diversity to soil carbon sequestration processes on a large scale throughout the extended period of natural plant diversity recovery (Chen et al. 2020; Duffy et al. 2017). Vegetation restoration is frequently employed to boost the storage and sequestration of soil organic carbon (SOC), aiming to lower CO_2 emissions and revive ecosystem functions. This type of restoration enhances the buildup of SOC, making it the largest element within the terrestrial SOC reservoir. As a result, SOC is typically 2 to 3 times more substantial than the carbon stored in vegetation and is vital in moderating global warming (Pandey et al. 2023; Shahi et al. 2023).

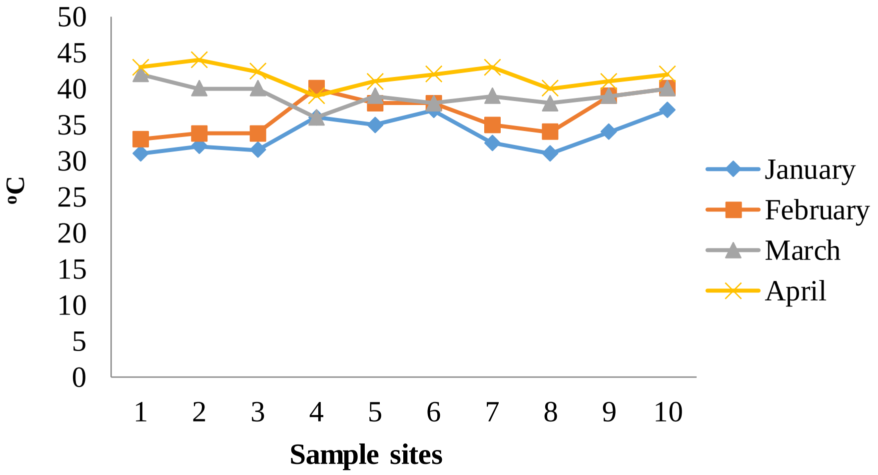

Figure 4. Seasonal fluctuations in soil temperature

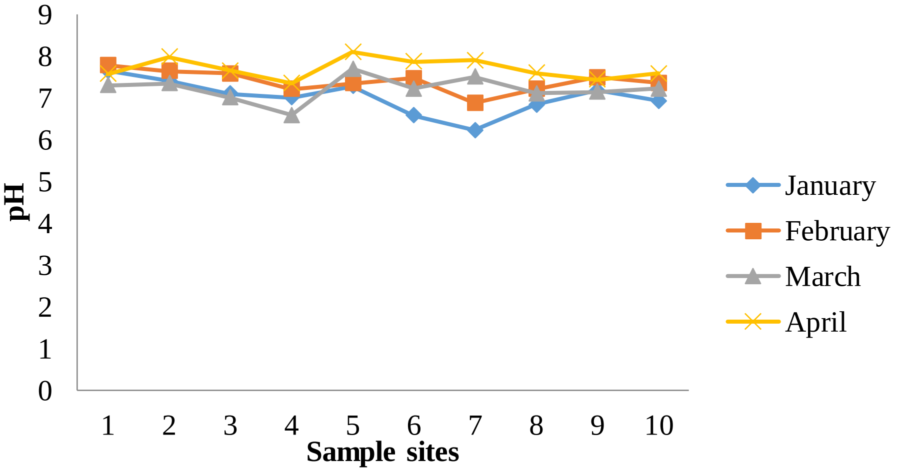

Figure 5. Variability in soil pH across different study seasons

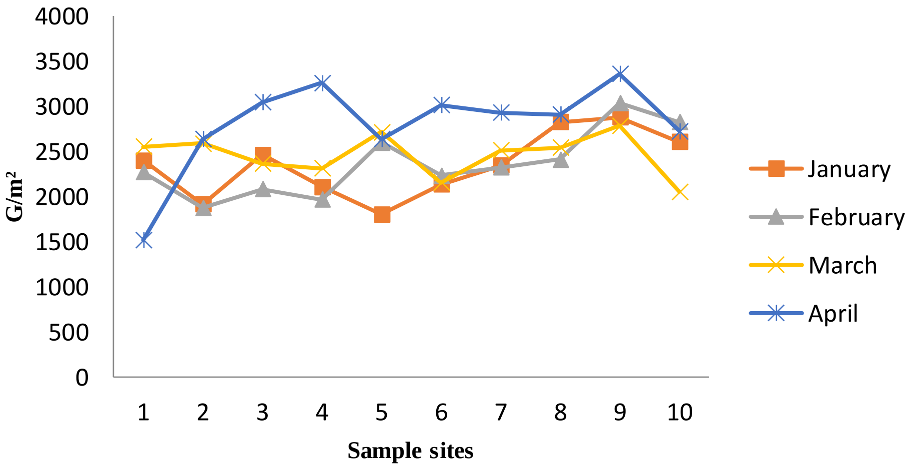

Figure 6. Seasonal variations in CO_2 sequestration in the study area

Correlation analysis among the variables (Soil temperature, pH and CO_2 sequestration) may provide insights into the complex interactions within the ecosystem. For instance, higher temperatures may accelerate microbial activity, affecting both CO_2 sequestration rates and soil pH. Additionally, the vegetation cover and soil moisture, influenced by temperature variations, can further impact these relationships. Understanding these interconnections is crucial for effective ecosystem management and climate change mitigation strategies. This research offers valuable perspectives on the factors influencing plant diversity and soil carbon sequestration, as well as their relevance to tackling global climate impacts. To accurately determine the role of various mechanisms in soil carbon sequestration, future studies should integrate additional biotic and abiotic elements. This approach will help clarify the relationships between aboveground and belowground vegetation components. Future investigations should also focus on evaluating the multiple sources of variability and uncertainty related to ecosystem restoration efforts aimed at mitigating atmospheric greenhouse gases.

4. Conclusion

The current investigation across various sites unveils dynamic variations influenced by diverse environmental factors in the Solankuruni freshwater pond wetland. The fluctuating soil temperatures reflect the interplay of soil composition and microclimate variations. Variability in pH levels underscores influences of soil, vegetation type, and human activities. Significant variability in CO_2 sequestration rates highlights the relationship between soil microbial activity, vegetation cover, and soil moisture of study region. Notably, study site nine consistently exhibits the highest rates of CO_2 sequestration, indicating that local environmental conditions and soil characteristics are essential factors. These results highlight the importance of thorough monitoring and comprehension of soil dynamics amid global climate change. Tackling these challenges is essential for crafting effective strategies to reduce the impacts of climate change and boost the potential for carbon sequestration in soil systems. To effectively address climate change and promote sustainable land management practices, it is crucial to integrate the expertise of various scientific fields and stakeholders.

Acknowledgements

The authors express their deep gratitude to Dr. D. Kannan, Associate Professor of and Head of Botany at Thiagarajar College, Madurai, Tamil Nadu, for his unwavering support, inspiration, and wise counsel. Additionally, special thanks go to B. H. Sree Pragathi for providing the energy, support, and inspiration needed to strive for excellence. The authors also acknowledge the DST-FIST facility of the Department of Botany at Saraswathi Narayanan College (Autonomous), Madurai.

Author's declaration and contribution

The authors certify that they have no conflicts of interest. Additionally, all contributors to the work have made equal contributions, and the entire author team unanimously agreed to and provided consent for the final version of the work.

References

Anderson, J. M & Ingram, J. S. L. (1993). *Tropical soil biology and fertility: A handbook of methods*. C A B International.

Bargali, S. S., Shahi, C., Bargali, K., Negi, B & Khatri, K. (2022). Energy and monetary efficiencies at the different altitudinal agroecosystems in Central Himalaya, India. *Heliyon*, *8*(11),e11500. CrossRef

Bisht, S., Rawat, G. S., Bargali, S. S., Rawat, Y. S & Mehta, A. (2023). Forest vegetation response to anthropogenic pressures: A case study from askot wildlife sanctuary, Western Himalaya. *Environment Development and Sustainability*, 1–25. CrossRef

Bridgham, S., Megonigal, P., Keller, J. K, Bliss N. B & Trettin, C. (2006). The carbon balance of north american wetlands. *Wetlands*, *26*(4), 889–916. CrossRef

Chen, X., Chen, H. Y., Chen, C., Ma, Z., Searle, E. B., Yu, Z., et al. (2020). Effects of plant diversity on soil carbon in diverse ecosystems: A global meta-analysis. *Biological Review*, *95*(1), 167–183. CrossRef

Davidson, E. A & Janssens, I. A. (2006). Temperature sensitivity of soil carbon decomposition and feedbacks to climate change. *Nature, 440*, 165–173. CrossRef

Duffy, J. E., Godwin, C. M., & Cardinale, B. J. (2017). Biodiversity effects in the wild are common and as strong as key drivers of productivity. *Nature*, *549*(7671), 261–264. CrossRef

Fennessy, M. S., Wardrop, D. H., Moon, J. B., Wilson, S & Craft, C. (2018). Soil carbon sequestration in freshwater wetlands varies across a gradient of ecological condition and by ecoregion. *Ecological Engineering, 114*, 129–136. CrossRef

Geiger, R. (1965). *The Climates near the ground* (4thed.). Harvard University Press.

Jackson, R. B., Lajtha, K., Crow, S. E., Hugelius, G., Kramer, M. G & Pineiro, G. (2017). The ecology of soil carbon: pools, vulnerabilities, and biotic and abiotic controls. *Annual Review of Ecology, Evolution, and Systematics*, *48*(1), 419–445. CrossRef.

Kolka, R., Trettin, C., Tang, W., Krauss, K., Bansal, S., Drexler, J., Chimner, R., Kane, E. S., Scott Bridgham, S & Curtis Richardson, C. (2018). Terrestrial wetlands. *Second state of the carbon cycle report (SOCCR2): A Sustained Assessment Report*, 507–567.

Manral, V., Bargali, K., Bargali, S. S., Jhariya, M. K & Padalia, K. (2022). Relationships between soil and microbial biomass properties and annual flux of nutrients in central himalaya forests, India. *Land Degradation & Development*, *33*(12), 2014–2025. CrossRef

Pandey, R., Bargali, S. S., Bargali, K., Karki, H., Kumar, M & Sahoo, U. K. (2023). Fine root dynamics and associated nutrient flux in Sal dominated forest ecosystems of central himalaya, India. *Frontiers in Forests and Global Change*, *5,* 1064502. CrossRef

Panneer Selvam, B., Natchimuthu, S., Arunachalam, L & Bastviken, D. (2014). Methane and carbon dioxide emissions from inland waters in India–implications for large scale greenhouse gas balances. *Global Change Biology, 20*(11), 3397–3407. CrossRef

Saunois, M., Jackson, R. B., Bousquet, P., Poulter, B & Canadell, J. G. (2016). The growing role of methane in anthropogenic climate change. *Environmental Research Letters, 11*(12), 120207. CrossRef

Shahi, C., Bargali, S. S & Bargali, K. (2023). Dry matter dynamics and CO_2 mitigation in the herb layer of central himalayan agroecosystems along an altitudinal gradient, India. *Tropical Ecology, 64*(1), 180–192. CrossRef

Smith, J. K., Williams, A. B & Davis, C. D. (2018). Effects of land use change on soil pH dynamics in a rural landscape. *Soil Science Society of America Journal, 82*(3), 691–701. CrossRef

Smith, P., Gregory, P. J., Hillier, J., & Macdonald, J. (2020). Climate change, soil processes, and carbon cycling in terrestrial ecosystems. In S. A. Levin (Eds.), *The Princeton guide to ecology* (pp. 248–254). Princeton University Press.

Turetsky, M. R., Kotowska, A., Bubier, J., Dise, N. B., Crill, P., Hornibrook, R. C., Minkkinen, K., Moore, T. R., Myers-Smith, I. H., Nykänen, H., Olefeldt, D., Rinne, J., Saarnio, S., Shurpali, N., Tuittila, E. S., Waddington, J. M., Jeffrey, R., Kimberly, W., Wickland, P & Wilmking, M. (2014). A synthesis of methane emissions from 71 northern, temperate, and subtropical wetlands. *Global Change Biology, 20*(7), 2183–2197. CrossRef

William, J., Mitsch, James, G & Gosselink. (2015). *Wetlands* (5th ed.). John Wiley & sons.

Zedler, J. B & Kercher, S. (2005). Wetland resources: status, trends, ecosystem services and restorability. *Annual Review of Environment and Resources*, *15*(30), 39–74. CrossRef.