Biological Forum – An International Journal 16(11): 163-167(2024)

ISSN No. (Print): 0975-1130
ISSN No. (Online): 2249-3239

Estimation of Carbon Sequestration Potential of various Tree Species under Miyawaki Planting Method at Veterinary College Campus, Orathanadu, Thanjavur, Tamil Nadu

D. Senthilkumar[1]* and A. Bharathidhasan[2]

[1]Assistant Professor, Livestock Farm Complex, Veterinary College and Research Institute, Orathanadu, Thanjavur, Tamil Nadu Veterinary and Animal Sciences University (Tamil Nadu), India.

[2]Professor, Livestock Farm Complex, Veterinary College and Research Institute, Orathanadu, Thanjavur, Tamil Nadu Veterinary and Animal Sciences University (Tamil Nadu), India.

(Corresponding author: D. Senthilkumar)*

(Received: 19 August 2024; Revised: 23 September 2024; Accepted: 21 October 2024; Published: 14 November 2024)
(Published by Research Trend)

ABSTRACT: The escalating levels of greenhouse gases (GHGs) in the atmosphere, particularly carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), are widely acknowledged as the primary forces behind global warming and climate change. This has resulted in a global surface temperature increase of 1.07°C from the period 1850-1900 to 2010-2019, with global net anthropogenic GHG emissions reaching an estimated 59 ± 6.6 $GtCO_2$-eq in 2019. These shifts are evident in changing precipitation patterns, rising sea levels, and the heightened frequency and severity of extreme weather events, posing significant threats to ecosystems worldwide. In response to these challenges, tree planting and afforestation initiatives are vital strategies for reducing atmospheric GHG concentrations. This study investigates the Miyawaki method of afforestation, an innovative technique developed by Japanese botanist Akira Miyawaki, which allows for the creation of dense, biodiverse forests in compact areas. This method is gaining attention for its potential in rapid ecological restoration and increased carbon sequestration. However, comprehensive data on carbon pools in both above-ground and below-ground biomass, as well as soil carbon in young eco-forests established using the Miyawaki method, remain scarce. This research aimed to estimate the carbon stock in biomass and soil carbon sequestration, thereby enhancing predictions of the climate impacts and carbon cycling dynamics of Miyawaki-planted eco-forests at the Veterinary College Campus in Orathanadu, Thanjavur, Tamil Nadu. A diverse selection of 16 plant species, including both fruit-bearing trees and ornamental plants, was introduced to the area. This selection comprised a variety of herbs, shrubs, and trees, with a total of 1,600 saplings planted. Trees significantly increase their carbon capture capacity from the first to the second year of growth. In the initial year, trees sequester between 0.02 and 0.15 kg of carbon per tree due to their small size and developing root system. By the second year, this capacity increases to 0.15-0.70 kg per tree. The findings highlight significant carbon sequestration potential across various tree species, emphasizing the Miyawaki method as a crucial tool for ecological enhancement and climate change mitigation.

Keywords: Miyawaki, Dense plantation, carbon sequestration, stem girth.

INTRODUCTION

The scientific evidence warns that global warming is primarily caused by increased atmospheric concentrations of greenhouse gases (GHG), such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The anthropogenic rise in global surface temperature from 1850 to 1900 to 2010–2019 ranged from 0.8°C to 1.3°C, with a best estimate of 1.07°C. In 2019, global net anthropogenic GHG emissions were estimated at 59 ± 6.6 $GtCO_2$-eq, marking an increase of approximately 12% (6.5 $GtCO_2$-eq) since 2010 and 54% (21 $GtCO_2$-eq) since 1990. The most substantial share and growth in gross GHG emissions were observed in CO_2 from fossil fuel combustion and industrial processes (CO_2-FFI), followed by methane, while the highest relative growth was noted in fluorinated gases (F-gases), which began from low levels in 1990 (IPCC, 2023). These changes have detrimental effects on global environments, including alterations in precipitation patterns, sea level rise, and an increased frequency and intensity of extreme weather events.

Tree plantations are considered a strategy to reduce atmospheric greenhouse gas concentrations. In 2023, forests covered 713,789 sq km in India, accounting for 21% of the country's total geographical area, with a 19% loss of forest cover over the past 23 years (Geography Host, 2023). The reduction in forest cover in India has significant implications for biodiversity and ecosystem services (Veldkamp *et al.,* 2020). To address this issue, the Indian government has implemented various afforestation and reforestation programs. However, the effectiveness of these initiatives in mitigating climate change and restoring ecological balance remains a topic of debate among environmental experts (Pérez-Silos *et al.,* 2021). In recent years, the Miyawaki method of afforestation has gained recognition as a transformative strategy for establishing dense, biodiverse forests in limited spaces, thereby facilitating rapid ecological restoration and carbon sequestration. Developed by Akira Miyawaki, a Japanese botanist, since 1980, this technique is inspired by natural ecosystems and involves the dense planting of 15-30 different species in a relatively small area to enhance biodiversity. The Miyawaki method is characterized by its ability to create dense, multi-layered forests that mimic natural ecosystems. This approach entails the close planting of a diverse array of native species, typically 3-5 trees per square meter, promoting rapid growth and competition for light. The resulting forests are notable for their high biodiversity, improved soil quality, and enhanced ecosystem services, including carbon sequestration, air purification, and wildlife habitat provision (Briske *et al.,* 2024; Nan *et al.,* 2024).

The method's success is attributed to its emphasis on site-specific soil preparation, the careful selection of native plant species, and intensive management during the initial years of growth (Farooqi *et al.,* 2020; Moomaw *et al.,* 2019; Wang & Huang 2020; Singh *et al*., 2023). The Miyawaki method holds significant promise for climate change mitigation. Forests established using this method can grow up to ten times faster and achieve densities thirty times greater than conventional plantations, thereby potentially sequestering carbon at a significantly higher rate (Wang & Huang 2020). Furthermore, the method's adaptability to diverse climatic conditions and its capacity to thrive in urban environments render it a versatile tool for ecological restoration and carbon offsetting across various contexts. As global initiatives to address climate change intensify, the Miyawaki method presents a promising approach for rapid reforestation and carbon sequestration, complementing broader strategies aimed at reducing greenhouse gas emissions and mitigating the impacts of global warming. However, there is a paucity of data regarding carbon pools in the above-ground and below-ground biomass and soil of young eco-forests established using the Miyawaki method. Further research is required to quantify the carbon sequestration potential of Miyawaki forests across different climatic zones and soil types. Long-term studies comparing the carbon storage capacity of Miyawaki forests with traditional reforestation methods could yield valuable insights for climate change mitigation strategies. Additionally, exploring the potential of Miyawaki forests to enhance biodiversity and ecosystem services alongside carbon sequestration could provide a more comprehensive understanding of their environmental benefits.

Objective. The primary aim of this study was to estimate the carbon stock accumulated within the biomass of various tree species and the extent of soil carbon sequestration in an eco-forest established using the Miyawaki planting method. By quantifying these carbon pools, this study seeks to enhance the prediction of climate impacts and improve our understanding of carbon cycling dynamics within rapidly growing and densely planted eco-forest systems. The Miyawaki method, renowned for its capacity to create dense, diverse forests in a short period, presents a promising approach to urban greening and carbon sequestration. The findings of this study could offer valuable insights into the potential of such eco-forests as nature-based solutions for climate change mitigation in urban areas. Furthermore, the results may inform urban planning and policy decisions regarding the implementation of Miyawaki forests as an effective strategy for enhancing carbon sinks in cities.

MATERIALS AND METHODS

The site study, conducted from 2022 to 2024 at the Veterinary College and Research Institute in Orathanadu, Tamil Nadu, India, aimed to restore multi-layer natural communities and iv=ncreasing carbon sequestration potential using native tree species. The site's precise geographical coordinates (10°37'0.12″ N latitude, 79°16'0.12″ E longitude) locate it in the eastern region of the Tamil Nadu District. In 2022, a diverse selection of 16 plant species, including both fruit-bearing trees and ornamental plants, was introduced to the area. This selection comprised a variety of herbs, shrubs, and trees, with a total of 1,600 saplings planted. The chosen species included popular fruit trees such as *Psidium guajava* (guava), *Syzygium cumini* (jamun), *Citrus limon* (lemon), *Annona squamosa* (custard apple), *Punica granatum* (pomegranate), *Phyllanthus emblica* (Indian gooseberry), *Artocarpus heterophyllus* (jackfruit), and *Mangifera indica* (mango). Additionally, ornamental plants like *Jasminum* (jasmine), *Hibiscus*, *Artabotrys hexapetalus* (climbing ylang-ylang), and *Nyctanthes arbortristis* (night-flowering jasmine) were incorporated. To assess the carbon sequestration potential of these planted species, a carbon storage calculator was employed, utilizing measurements of tree circumference and dry weight, as recommended by Jones (2018). This methodology enables the quantification of carbon sequestered in the newly established vegetation, thereby providing essential data on the project's contribution to carbon sequestration and climate change mitigation. The planting initiative aimed to enhance biodiversity and establish a sustainable ecosystem within the campus grounds. Regular monitoring and maintenance were conducted to ensure the survival and growth of the newly introduced species. This restoration project not only serves as a valuable educational resource for veterinary students but also contributes to local conservation efforts and climate change mitigation.

RESULTS AND DISCUSSION

The carbon sequestration capacity of trees exhibits a significant trajectory of growth and variation over time. In the initial year, individual trees demonstrate a modest capacity, sequestering between 0.02 and 0.15 kg of carbon. However, this capacity expands considerably in the second year, ranging from 0.15 to 0.70 kg, with an average of 0.36 kg per tree. As trees mature, their carbon sequestration potential continues to increase exponentially. By the fifth year, individual trees can sequester between 1.5 and 3.5 kg of carbon annually, contingent upon species and environmental conditions. This rapid growth in sequestration capacity underscores the importance of long-term forest management strategies in maximizing the carbon mitigation potential of tree planting initiatives. A study by Stephenson *et al.* (2014) found that for 97% of 403 tropical and temperate tree species, mass growth rate increases continuously with tree size, contradicting the assumption that tree carbon accumulation peaks early in life.

When converted to CO_2 equivalent, the sequestration potential shows an even more dramatic increase, rising from 0.07 kg per tree in the first year to 2.60 kg in the second year. This substantial growth in carbon capture ability underscores the accelerating efficiency of trees as carbon sinks as they mature (Dold *et al.*, 2019; Kathiresan *et al.*, 2013). The total carbon sequestration potential in CO_2 equivalent by the end of the second year ranged from 63 kg to over 1695 kg, depending on the number and types of trees involved. This extensive range underscores the substantial influence that strategic tree planting and forest management initiatives can exert on carbon capture efforts. Furthermore, the data indicates that as trees continue to mature beyond the second year, their carbon sequestration capacity is likely to further increase. This highlights the long-term advantages of afforestation and reforestation initiatives in mitigating climate change, underscoring the critical role that mature forests play in global carbon cycles and climate regulation (Domke *et al.*, 2020; Li *et al.*, 2023). The exponential growth in sequestration capacity from the first to the second year also underscores the importance of protecting young forests and ensuring their survival to maximize their potential as effective carbon sinks in the fight against climate change (Sun *et al.*, 2024).

Table 1: Calculations of Carbon Sequestration potential of various trees and shrubs.

Tree Species	Avg Tree Height (m)	Diameter at Breast Height (DBH) (cm)	Estimated Biomass (kg)	Carbon Cont ent (%)	Carbon Sequestered (kg) per tree	Carbon Sequestered (kg) (CO_2 Equiv.) per tree	Number of trees	Total Carbon Sequestered (kg) (CO_2 Equiv.)
Psidium guajava	1.9	12.8	1.4	0.5	0.7	2.6	250	650
Syzygium cumini	0.8	4.3	0.15	0.5	0.42	0.42	150	63
Phyllanthus emblica	1.8	11.2	0.15	0.5	0.7	2.6	150	390
Mangifera indica,	1.6	8.3	0.35	0.5	0.7	2.5	100	250
Hibiscus	1.1	5.6	0.6	0.5	0.42	0.42	200	84
Artabotrys hexapetalus	0.8	6.2	0.15	0.5	0.42	0.42	150	63
Annona squamosa	1.3	7	0.5	0.5	0.7	1.3	150	195

As trees grow older, their ability to capture carbon increases considerably. In their initial year, trees have a limited capacity for carbon capture, with rates between 0.02 and 0.15 kg per tree. This low rate is attributed to the tree's small size and the development of its root system during early growth stages. However, by the second year, trees significantly enhance their carbon capture potential. At this stage, individual trees can sequester between 0.15 and 0.70 kg of carbon, a notable improvement from their first year. This marked increase in carbon capture capacity is due to several factors: 1. Expanded leaf area: As trees grow taller and develop more branches, they produce more leaves, increasing their photosynthetic capacity. 2. Strengthened root system: In the second year, trees establish more extensive root networks, allowing them to absorb more nutrients and water, which supports greater carbon uptake. 3. Enhanced efficiency: With a year of growth, trees become more efficient in physiological processes like photosynthesis and carbon fixation. 4. Accelerated growth: Many tree species experience a growth spurt in their second year, leading to a rapid increase in biomass and, consequently, carbon storage. This significant rise in carbon capture from the first to the second year highlights the importance of tree survival and proper care during early growth stages (Lázaro-Lobo *et al.*, 2023). As trees continue to mature beyond their second year, their carbon capture potential generally continues to grow, although at varying rates depending on species, environmental conditions, and management practices (Ameray *et al.*, 2021).

CONCLUSIONS

Miyawaki forests offer more than just an increase in green spaces; each tree within these forests can absorb between 0.15 to 0.70 kg of carbon, showing a notable improvement from their first year of growth. These forests are crucial in alleviating urban heat islands, improving air quality, and diminishing noise pollution in cities. By the end of the second year, the total potential for carbon sequestration, expressed in CO_2 equivalent, varies from 63 kg to over 1695 kg, depending on the number and types of trees planted. This impressive ability to capture carbon makes Miyawaki forests a powerful nature-based solution for combating climate change. Beyond carbon absorption, Miyawaki forests provide numerous ecosystem services in urban areas. Their dense structure and variety of species enhance habitat availability for local plants and animals, potentially acting as ecological corridors in fragmented landscapes. The rapid growth rates typical of Miyawaki forests further boost these advantages, offering swift and effective improvements to urban ecosystems. Ongoing research continues to explore the long-term ecological effects and scalability of this approach. Miyawaki forests may increasingly play a role in sustainable urban planning and ecosystem restoration strategies, presenting a comprehensive approach to tackling environmental challenges in urban settings.

FUTURE SCOPE

The research identifies several areas for future investigation and application:

- **Further Quantification:** More research is needed to quantify the carbon sequestration potential of Miyawaki forests across diverse climatic zones and soil types.
- **Long-term Studies:** Conducting long-term studies to compare the carbon storage capacity of Miyawaki forests with traditional reforestation methods will provide valuable insights for climate change mitigation strategies.
- **Comprehensive Environmental Benefits:** Exploring the full potential of Miyawaki forests to enhance biodiversity and a broader range of ecosystem services, alongside carbon sequestration, will lead to a more comprehensive understanding of their environmental benefits.
- **Climate Change Mitigation:** The research contributes to a better prediction of climate impacts and an improved understanding of carbon cycling dynamics within rapidly growing and densely planted eco-forest systems, underscoring the Miyawaki method's role as a vital tool for ecological enhancement and climate change mitigation.
- **Soil Carbon Dynamics:** Deeper analysis into the below-ground biomass and soil carbon sequestration within Miyawaki eco-forests, as comprehensive data in this area remains limited.

Acknowledgement. The authors would like to thank the staff of the Livestock Farm Complex, Veterinary College and Research Institute, Orathanadu, for their technical support and assistance during the research period.

Conflict of Interest. None.

REFERENCES

Ameray, A., Bergeron, Y., Valeria, O., Montoro Girona, M. and Cavard, X. (2021). Forest carbon management: A review of silvicultural practices and management strategies across boreal, temperate and tropical forests. *Current Forestry Reports*, *7*(4), 245–266.

Briske, D. D., Vetter, S., Coetsee, C. and Turner, M. D. (2024). Rangeland afforestation is not a natural climate solution. *Frontiers in Ecology and the Environment*, *22*(5).

Dold, C., Thomas, A. L., Philipp, D., Ashworth, A. J., Sauer, T. J. and Brauer, D. K. (2019). Carbon sequestration and nitrogen uptake in a temperate silvopasture system. *Nutrient Cycling in Agroecosystems*, *114*(1), 85–98.

Domke, G. M., Oswalt, S. N., Walters, B. F. and Morin, R. S. (2020). Tree planting has the potential to increase carbon sequestration capacity of forests in the United States. *Proceedings of the National Academy of Sciences*, *117*(40), 24649–24651.

Farooqi, T. J. A., Liu, S., Yu, Z., Sun, O. J. and Li, X. (2020). Reconciliation of research on forest carbon sequestration and water conservation. *Journal of Forestry Research*, *32*(1), 7–14.

Geography Host. (2023). *Forest cover in India (2023) – Important statistics*. https://geographyhost.com/forest-cover-in-indiaimportant-statistics/

Intergovernmental Panel on Climate Change (2023). Summary for policymakers. In H. Lee & J. Romero (Eds.), *Climate change 2023: Synthesis report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 1–34). IPCC.

Jones, A. (2018). *Carbon positive project technical report: Calculating Natural Resources Wales' net carbon status* (NRW Evidence Report No: 303). Natural Resources Wales.

Kathiresan, K., Saravanakumar, K., Anburaj, R. and Gomathi, V. (2013). Carbon sequestration potential of *Rhizophora mucronata* and *Avicennia marina* as influenced by age, season, growth and sediment characteristics in southeast coast of India. *Journal of Coastal Conservation*, *17*(3), 397–408.

Lázaro-Lobo, A., Castro-Díez, P., Ruiz-Benito, P. and Cruz-Alonso, V. (2023). Quantifying carbon storage and sequestration by native and non-native forests under contrasting climate types. *Global Change Biology*, *29*(16), 4530–4542.

Li, Q., Xiao, W., Zhu, J., Kou, X., Wan, F., Xia, X. and Niu, L. (2023). Forest carbon storage and carbon sequestration potential in Shaanxi Province, China. *Forests*, *14*(10), Article 2021.

Moomaw, W. R., Faison, E. K. and Masino, S. A. (2019). Intact forests in the United States: Proforestation mitigates climate change and serves the greatest good. *Frontiers in Forests and Global Change*, *2*, Article 27.

Nan, G., Qin, S., Ma, L., He, X., Han, L. and Xu, S. (2024). Identify a sustainable afforestation pattern for soil carbon sequestration: Considering both soil water-carbon conversion efficiency and their coupling relationship on the Loess Plateau. *Land Degradation & Development*, *35*(6), 2058–2070.

Pérez-Silos, I., Barquín, J. and Álvarez-Martínez, J. M. (2021). Large-scale afforestation for ecosystem service provisioning: Learning from the past to improve the future. *Landscape Ecology*, *36*(11), 3329–3343.

Singh, S. K., Kumar, A. and Singh, K. K. (2023). Carbon Sequestration Potential of Different Land Use Pattern in Calcareous Soils of Muzaffarpur District, Bihar. *Biological Forum – An International Journal, 15*(4), 498-503.

Stephenson, N. L., Das, A. J., Condit, R., Russo, S. E., Baker, P. J., Beckman, N. G., Coomes, D. A., Lines, E. R., Morris, W. K., Rüger, N., Álvarez, E., Blundo, C., Bunyavejchewin, S., Chuyong, G., Davies, S. J., Duque, Á., Ewango, C. N., Flores, O., Franklin, J. F. and Zavala, M. A. (2014). Rate of tree carbon accumulation increases continuously with tree size. *Nature*, *507*(7490), 90–93.

Sun, N., Luo, X., Sarkar, B., Yang, X., Sha, L., Li, S., Gao, Y. and Tian, Y. (2024). Biochar addition increased soil carbon storage but did not exacerbate soil carbon emission in young subtropical plantation forest. *Forests*, *15*(6), Article 917.

Veldkamp, E., Powers, J. S., Corre, M. D. and Schmidt, M. (2020). Deforestation and reforestation impacts on soils in the tropics. *Nature Reviews Earth & Environment*, *1*(11), 590–605.

Wang, S. and Huang, Y. (2020). Determinants of soil organic carbon sequestration and its contribution to ecosystem carbon sinks of planted forests. *Global Change Biology*, *26*(5), 3163–3173.

How to cite this article: D. Senthilkumar and A. Bharathidhasan (2024). Estimation of Carbon Sequestration Potential of various Tree Species under Miyawaki Planting Method at Veterinary College Campus, Orathanadu, Thanjavur, Tamil Nadu. *Biological Forum – An International Journal, 16*(11): 163-167.