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Carbon Sequestration Through Miyawaki Plantation

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ABSTRACT

Background: Deforestation is a worldwide issue, accounting to the annual forest loss estimate of about 9.4 million hectares. Land degradation and global warming have brought drastic environmental conditions affecting agriculture and human life. Therefore, finding solutions to mitigate climate change has become increasingly important. Turning the carbon clock to normal and protecting the environment is the need of the hour. Thus, the study aimed to mitigate the microclimate through the Modified Miyawaki plantation at SRM CAS with native plants.

Methods: Soil amelioration, Modified Miyawaki Plantation (micro-rainwater harvesting pond), organic inputs and Mycorrhiza biofertilizer enhanced the growth of native plants *Syzygium cumini*, *Madhuca longifolia* and *Millettia pinnata* planted in a square pattern with four plants per square metre. The height, girth at the base of each native tree and soil carbon are measured every 3rd month from May 2022 till October 2024. The carbon sequestration by the native species was estimated by measuring the above and below-ground biomass.

Result: The micro-rain water harvesting ponds in each experimental plot stored 32M3 water and supported the growth of the trees. During the study period of 29 months, the organic amendments such as paddy straw mulching, vermicompost and panchagavya enhanced the carbon from 0.154 to 0.601 in the experimental plots compared to 0.025 in the control plots. The average biomass recorded and estimated at the end of the study period recorded a maximum carbon by *Madhuca longifolia* (250532.71 Kg) and a minimum of 10649.2 Kg by *Syzygium cumini*. The trees are interconnected through mycorrhizal network.

Key words: Modified miyawaki plantation, Paddy straw, Panchagavya, Soil-amelioration, Vermicompost.

INTRODUCTION

Forests are nature's creation in 4.03 billion hectares of arable land worldwide, accounting for about 75% of gross primary production (GDP) and 80% of Earth's total plant biomass, provides a wide range of ecosystem services (FAO). Deforestation is a worldwide issue, accounting for the annual forest loss estimate of about 9.4 million hectares (FAO, 2001). Land degradation and global warming have brought drastic environmental conditions affecting agriculture and human life. Therefore, finding solutions to mitigate climate change has become increasingly important. Carbon dioxide sequestration to trap and store carbon dioxide in the above and below-ground parts of trees can reduce the amount of CO_2 released into the atmosphere. One of the innovative solutions to this problem is the Miyawaki plantation, a massive tree plantation - Afforestation programs executed worldwide did not meet the need, because of rapid deforestation and overlapping statistics. Climatic aberrations are an alarming global concern and it is high time we protect and conserve our natural resources, especially by throwing more light on Afforestation. Land degradation (Chazdon, 2008) and deforestation pose serious threats and obstacles to poverty elimination and hunger. The current need of the hour is to find alternate resources to reduce carbon content in the environment and get back the lost glory of nature. Thus, this study aimed to increase Carbon-di oxide sequestration by raising quick-growing native plantations through Modified Miyawaki plantation.

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MATERIALS AND METHODS

Study area

The study area is at SRM College of Agriculture, Maduranthakam Taluk of Chengalpattu District in the State of Tamil Nadu in India. It is 99 kilometres away from Chennai, India, at the geographical location 12.38534, 79.73638.

Rainfall data

The precipitation data recorded at the SRM College of Agricultural Sciences, meteorological observatory for the study period from May 2022 to October 2024 was analysed. Study Period: May 2022 to December 2024.

Experimental design

The 20-cent area was divided into 4 equal plots 20 × 10 square metres each. Three plots were research plots R1, R2 and R3. The last quarter served as control. In the centre of each experimental and control plot, 4m × 4m size micro rainwater harvesting structures were dug with a depth of 2 metres.

Soil amelioration

The soil was excavated to a depth of 2 meters, the unearthed soil was mixed with a composted mixture of coco-peat, paddy husk and farmyard manure in a ratio of 1:1:1.

Curing

The soil mixed with the organic amendments was left in the field for the decomposition of organic materials. After three months, the soil with the organic mixture was turned three times at one-week intervals.

Modified Miyawaki method of planting

Micro rain-water harvesting structures excavated in the centre of the experimental plots can store 32 M3 of water.

Mycorrhiza

In the excavated pits, 5 grams of Mycorrhiza fertiliser produced at SRM CAS experiential learning Unit was applied to each plant in the experimental plots, not the control plot.

The organic fertiliser Panchagavya produced at SRM CAS experiential learning Unit was applied at one-month intervals by diluting it with water at a ratio of 1:15.

Mulching

The experimental plots were mulched with paddy straw at a six-month interval. Carbon sequestration (Kilawe, 2001) Determination of CO_2 absorbed by trees. Two essential measurements are taken directly from the tree: its diameter, measured in cm and height, measured in meters to calculate the Above-Ground Biomass (AGB) and Below-Ground Biomass (BGB).

$$AGB = 0.25 \times D2 \times H$$

Where:

- AGB: Above-Ground Biomass (Kilograms).
- D: Tree diameter measured at 1.37 meters from the ground (inches).

H: The tree height (feet).

The overall weight of the biomass is estimated to be 120% of the AGB value, based on the assumption that the BGB, which comprises the tree's root system accounts for approximately 20% of the AGB.

Therefore, Below Ground Biomass can be calculated as follows.

$$\text{Below ground biomass - BGB} = 0.2 \times \text{Above Ground Biomass - AGB}$$

$$\text{Total biomass of a tree (TB)} = AGB + BGB = AGB + 0.2 \times AGB = 1.2 \times AGB$$

Soil analysis

The soil samples collected in the Miyawaki plantation were analysed in the SRM CAS soil science laboratory.

Soil carbon

Chromic acid digestion method – SRM CAS – Soil Science Laboratory.

RESULTS AND DISCUSSION

Policies to use natural ecosystems to sequester and store carbon should be accompanied by technological solutions (Abdul, 2013). Miyawaki, (1992), a Japanese botanist developed a reforestation method called Miyawaki forest to create a dense forest with diverse and rapidly growing native trees. This technique involves planting a mix of native plant species nearby, mimicking the structure of natural forests. The closed spacing helps the plantation to mature faster and become more resilient. The data published by various authors on afforestation programs indicate that the process couldn't prevent the rise in Global temperature, which implies that deforestation is faster than the afforestation process.

Restoration

Miyawaki plantation has been used to restore degraded soil and lands throughout the World, A similar attempt was made at SRM College of Agricultural Sciences (Fig 1) to ameliorate the bulky soil by Miyawaki plantation with native trees. Across the world, many ecologists and scientists have proposed, tried and implemented various concepts of restoration of natural agro-ecosystem achieving a balance between human needs and biodiversity. Miyawaki plantation can also be deûned as 'an intentional activity that initiates or accelerates recovery of an ecosystem concerning its health, integrity and sustainability' (Aronson *et al*. 2010). One reliable forest restoration method is "native forests by native trees" based on knowledge of the area's potential vegetation and the methods of germination and growth (Miyawaki, Frank and Golley 1993). This research confirmed that the poor soil can be regenerated with Modified Miyawaki plantation and sustained in two years (Fig 2).

Soil amelioration

The organic mixture (Fig 3) included in this study; paddy husk, coco-peat and Farm yard manure reduced the bulkiness and increased the secondary growth and biodiversity of the Miyawaki plantation.

Species selection

Akira Miyawaki's method of Afforestation was introduced as an ecological method of Afforestation to focus on "native forests by native trees" (Miyawaki, 2004) the most effective way to restore the natural environment locally and globally, fight climate change, buffer natural disasters and build a resilient and sustainable future. Choosing the right species combination is the most important component of the Miyawaki way of Afforestation. The selection was made based on an extensive survey of the ecology and natural environment of the local area for the restoration activity. The selected species (Table 1) generally have a straight and deep tap root and are planted with a large selection of companion species. (Miyawaki, 1989). In the current study, three species *Syzygium cumini*, *Madhuca longifolia* and *Pongammia pinnata* native to the geographical location of the study area were planted to evaluate carbon absorption. The mixing of species reflects their natural patterns of associations in the forests (Padilla and Pugnaire 2006). Four plants per square metre, a square pattern produced a dense plantation in this research. Soil amelioration activity in ecosystem restoration and environmental conservation is needed, as healthy soils contribute to biodiversity and water quality. This study agrees that the survival percentage of three native plant species *Syzygium cumini*, *Madhuca longifolia* and *Pongammia pinnata* in the Miyawaki plantation was analysed after three months and found that the survival of native plants under the experimental plot was 100 per cent and that of the control plot with 86.07 per cent.

Rainwater harvesting system

The excavated ponds (Fig 4) stored 32 M3 water in the experimental plots and the control. This attracted cattle and browsing caused fluctuation in the physical growth of *Madhuca longifolia*. The experimental and control plots were watered initially through flood irrigation. The plots absorbed more water and supported the plant growth. The Modified Miyawaki plantation aimed to create a self-sustaining

Fig 1: Study area: SRM College of Agricultural Sciences.

Fig 2: Selected native plants.

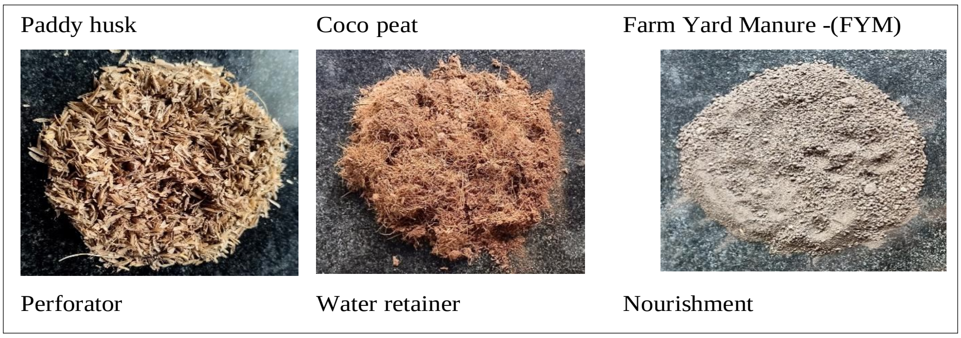

Fig 3: Agricultural waste.

ecosystem that could thrive without human intervention (Miyawaki, 2004). In this research, the potential of native plants in carbon sequestration was investigated with in-built rainwater harvesting structures. An ancient practice rainwater harvesting is still used for flood and drought risk mitigation with environmental and social benefits which links them to the Sustainable Development Goals (Raimondi, 2023). These structures prevented surface runoff, soil loss and increased groundwater storage levels. The distributed rainfall significantly improved soil water content and plant morphology, similar to the result obtained by Tadros, (2021).

Fig 4: Rain water harvesting pond.

Fig 5: Panchagavya application.

Fig 6: Paddy straw mulching.

Soil amelioration

Chikkaraju *et al.* (2020) described the soil of SRM CAS as having limitations such as poor drainage, gravel, calcareousness and heavy clay content. The authors suggested that the use of organic fertilisers can improve the organic matter content as well as carbon. The practice of soil amelioration is common across all Miyawaki plantations and decomposition and composted coco-peat and paddy husk provide Nitrogen, phosphorous, potassium, micronutrients and fibre that increase the water-holding capacity and porosity. The high survival percentage of the native trees planted confirmed the quick adaptability (Miyawaki 1992). Soil regeneration: In the case of damaged topsoil, soil amelioration was achieved by mixing the top 20 to 30 centimetres of the soil with local organic matter such as leaf litter, mowed grass etc. (Miyawaki, 1989).

Traditional bio-fertiliser-panchagavya

The Bio-fertiliser (Fig 5) had qualitative microbial activities in the soil. In forest modelling, the inclusion of eco-accommodating items like panchagavya effectively acts on the soil as well as plants and biodegradable (Ponmanickam, 2023). Bacillus sp. and growth-promoting properties like P, Zn, K solubilisation, IAA and siderophore production showed bio-control action against potential plant pathogens (Ram, 2022). The panchagavya bio fertiliser plant growth-enhancing fermented liquid (Ponmanickam, 2023) applied enhanced microflora and stimulated the plant's growth.

Mulching

Mulching with paddy straw (Fig 6) enhanced moisture conservation, weed control, improved organic matter content and enhanced earthworm multiplication.

Progression of Native trees planted in SRM Miyawaki plantation

The growth of Native plants (Fig 7) in the experimental plots with close spacing resulted in higher growth in 29 months than the control plots with normal spacing (Table 1). Biometric evaluation (Goveanthan *et al.,* 2019) height and girth of Afforested Plantation was evaluvated every three months from the date of planting.

The average height and girth of native tree species were measured every 3rd month of the study period

The average height (Fig 8) of *Syzygium cumini* reached 5.4 meters over 29 months which was comparatively higher than *Milletia pinnata* and *Madhuca longifolia* and three native plants in control. Due to cattle browsing, the height of the *Milletia pinnata* decreased intermittently and recovered.

The average height of all three species in the control plots was relatively less than in the experimental plots.

The average girth (Fig 9) of three species planted in experimental plots and in control was measured and the results indicated higher girth in the experimental plots than the control. The girth of *Pongammia pinnata* reached the maximum of 49 cm which was the highest compared to the other two species where *Madhuca longifolia* recorded the lowest girth measured. Physical growth parameters of native trees: Goveanthan *et al*. (2019) found that *Pongamia pinnata* recorded 2.97 and 35.68 mm girth in 30 months whereas in the current research, the height of the tree reached 5.31 meters and 119 cm girth. This enlightened effect might be due to the trees benefiting from each other through, the mycorrhizal network, root exudates, plant growth-promoting rhizobacteria enriched by leaf litter and the micro rain-water harvesting system of this modified Miyawaki system. *Madhuca longifolia* is a fast-growing tree and reached 4.52 meters in 29 months. The same was confirmed by Shams *et al.* (2024) that the higher doses of organic inputs correlates positively with the physiological parameters of the crop.

Distribution of rainfall

The high rainfall recorded was due to the cyclonic storms that occurred during the study period from 2022 to 2024. Soil moisture and the optimum temperature were maintained throughout the project period (Fig 10). The rainwater stored in the micro rainwater harvesting ponds increased the seepage of water and maintained the optimum moisture of the soil, enhancing plant growth and carbon content of the soil. In addition, the bulk density of the soil was reduced.

Despite the bulky soil with poor drainage at the SRM CAS farm, the native plants in close spacing, *i.e.*, four plants in one square metre, soil amendment resulted in 84% higher growth parameters such as height and girth compared to the plants in the control plot. Khoirunnisak *et al.* (2024) suggests that the utilization of organic matter can improve soil aggregation, thus increasing porosity and available water capacity.

The carbon content of the soil

The carbon content of the soil in the study area was estimated every three months and the results indicated that the carbon content increased positively (Fig 11).

Fig 7: The progression of the Miyawaki plantation at SRM CAS from May 2022 to October 2024.

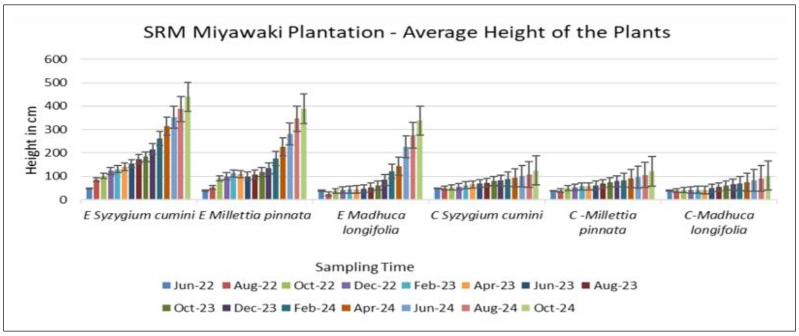

Fig 8: Analysis of height of plants E- Experimental Plots R1, R2 and R3 C-Control.

Table 1: Native plants chosen.

Species	Family	Height	Type	Normal spacing	Economic value
Syzygium cumini	Myrtaceae	30-40 M	Ever green	10×10 M	Fruit, Fodder
Madhuca longifolia	Sapotaceae	15-20 M	Ever green	04×04 M	Oil, Floers (Medicine)
Millettia pinnata	Fabaceae	20-25 M	Semi Ever green	03×03 M	Oil, Nitrogen fixation

Mycorrhiza network

The microscopic analysis of the root samples of *Syzygium cumini*, *Madhuca longifolia* and *Pongammia pinnata* showed the presence of mycorrhiza (Fig 12). Similar to the natural forest the mycorrhiza connected all three species planted in the experimental plots R1, R2 and R3. Mycorrhizal fungi (AMF) are productive and establish comprehensive symbiotic connections with plants and are a *via*ble option for sustainable agroforestry (Boyno *et al*., 2024). The presence of a mycorrhizal network has connected all three native species and exchanged nutrients and water similar to the forests. In addition, the mycorrhiza increased the phosphorous content in the soil. Mycorrhizal fungi (AMF) are productive and established comprehensive symbiotic connections with plants are a *via*ble option for sustainable agroforestry (Boyno *et al*., 2024). The mycorrhiza is a potential contributor to soil organic matter (Matos *et al*., 2022). The native plants chosen for this study were known to form symbiotic relationships with ecto and endo mycorrhizae (Fig 11). The results of this research was similar to Balasubramanian (2024) in terms of organic inputs and Arbuscular mycorrhiza application. There are significant difference in soil bulkiness, soil carbon and pH when treated with farm yard manure and vermicompost (Singh *et al.,* 2024).

Total biomass produced in Miyawaki plantation

Biomass accumulation/The Miyawaki forest concept involves creating small, dense, native forests. In Tamil Nadu, India, initiatives have been taken to establish Miyawaki forests to combat deforestation and promote biodiversity. These forests typically consist of native species planted close together to accelerate growth and create a self-

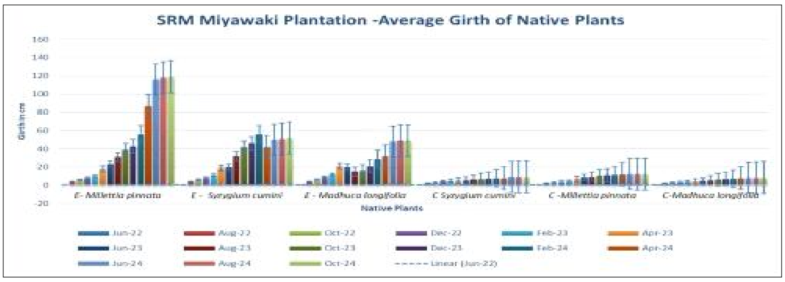

Fig 9: The average Girth of all the three native plants compared with Control E- Experimental Plots R1, R2 and R3. C-Control.

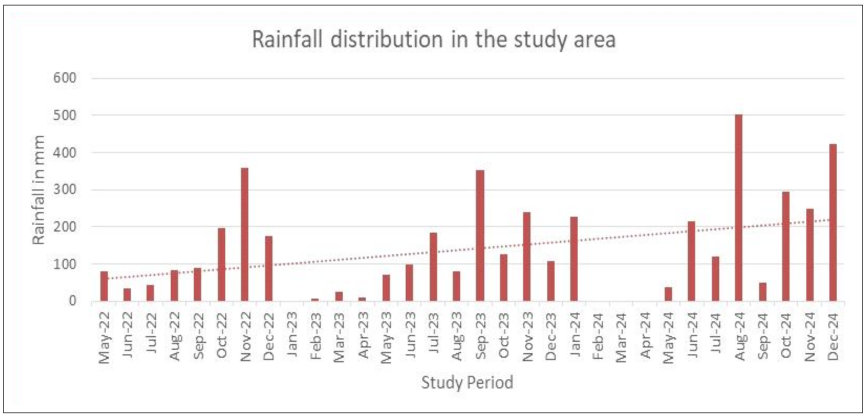

Fig 10: Rainfall recorded during the study period.

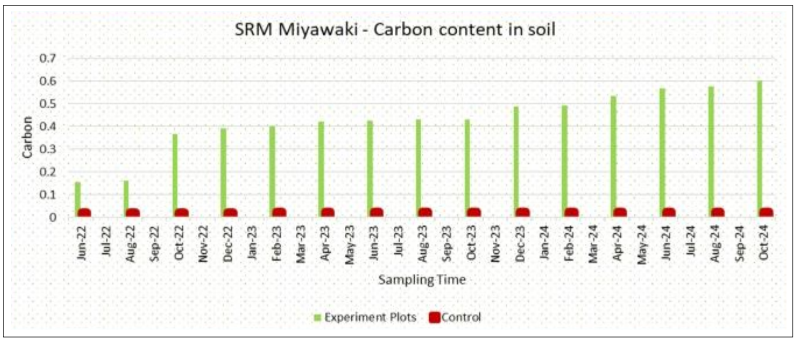

Fig 11: Total carbon absorbed by the native plants in SRM miyawaki plants.

sustaining ecosystem. The CO_2 absorbed from the atmosphere is assimilated into both Above Ground Biomass and Below Ground Biomass (Table 2). The capacity of the tree to sequester carbon increases as it matures, making them more efficient in absorbing CO_2 and store as carbon sinks. Apart from carbon captured by the trees, paddy straw, farm yard manure, tree leaf litter and mycorrhizal network enhanced soil carbon. The decomposition of leaf litter and root exudation favoured the growth of soil microbes. Additionally, these forests can serve as a recreation and oxygen-rich environment for local communities, promoting environmental awareness and contributing to the overall ecological balance.

The average carbon sequestration in the trees was estimated after 29 months. Based on the average height and girth of the native trees, the carbon captured was calculated and the result indicated that the maximum carbon by *Madhuca longifolia* (250532.71 Kg) and the minimum of 10649.2 Kg by *Syzygium cumini* (Table 2). The author suggests that the low carbon content in the soil can be increased with the application of higher organic matter coir pith, FYM and crop wastes coincides with the current research where fermented coco-peat, FYM, paddy straw, vermicompost and panchagavya. These organic manures release organic acids during decompositionand enrich the soil with available nutrients for plant uptake (Sabareeshwari *et al*., 2024).

The pros of miyawaki afforestation

The potential benefits of Miyawaki plantations lie in soil regeneration, soil fertility, biodiversity and mitigating effects of climate change. This inexpensive and quick establishment of degraded land creates green spaces in urban areas, allowing people to relax and enjoy nature. Good management practices boosts soil carbon-storing

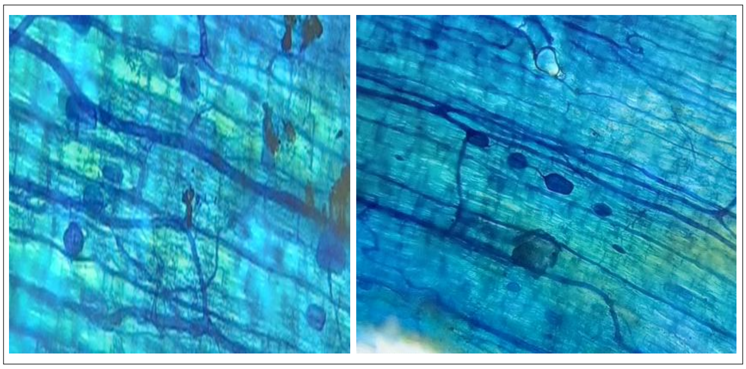

Fig 12: Ecto and endo mycorrhiza colonisation.

Table 2: Carbon sequestration above and below ground biomass in Kg.

Sampling time	AGB - Above ground Bio-mas Kg			BGB - Below ground Bio-mas Kg			Total biomass (TB) Kg
	Millettia pinnata	*Syzygium cumini*	*Madhuca longifolia*	*Millettia pinnata*	*Syzygium cumini*	*Madhuca longifolia*	
Jun-22	0.12	0.0975	3.25	0.144	0.117	3.9	7.6285
Aug-22	3.4	2.16	33.3333	4.08	2.592	40	85.56533
Oct-22	9.8022	9.029475	129.7066	11.76264	10.83537	155.648	326.7844
Dec-22	20	16.4025	276.75	24	19.683	332.1	688.9355
Feb-23	32.5	33.275	504	39	39.93	604.8	1253.505
Apr-23	121.5	99.275	1764	145.8	119.13	2116.8	4366.505
Jun-23	253.92	80	1733.3333	304.704	96	2080	4547.957
Aug-23	569.3925	238.08	1162.5	683.271	285.696	1395	4333.94
Oct-23	943.02	485.1	1600	1131.624	582.12	1920	6661.864
Dec-23	1248.075	608.35	3417.75	1497.69	730.02	4101.3	11603.19
Feb-24	2359.84	1019.2	8480.0833	2831.808	1223.04	10176.1	26090.07
Apr-24	6660.72	846.72	11520	7992.864	1016.064	13824	41860.37
Jun-24	13254.16	1587.5	56640	15904.99	1905	67968	157259.7
Aug-24	15734.12	2568.488	72030	18880.94	3082.185	86436	198731.7
Oct-24	18798.73	3055.52	91238	22558.47	3666.624	109485.6	248802.9
Total	60009.3	10649.2	250532.71	72011.16	12779.04	300639.2	706620.6

The average carbon sequestered: *Syzygium cumini trees, Madhuca longifolia* and *Pongammia pinnata* (50 trees each).

capacity and increase soil fertility by enhancing nutrient availability to plants and microbial populations in the soil (Chahal, 2020).

CONCLUSION

Miyawaki plantations are an innovative way to sequester carbon and mitigate climate change. The trees reduce carbon dioxide in the atmosphere at a rapid speed and store it in the soil, leaves, trunk and roots of plants. The organic carbon storage increased through soil amelioration with farm yard manure, paddy husk and coco-peat. In addition, intermittent application of vermicompost, panchagavya and paddy straw mulching added soil carbon and increased microbial activity. The mycorrhizal network distributed the nutrients and water. This research recommends soil amelioration and organic inputs can restore damaged ecosystems and increase biodiversity. Miyawaki plantation can also create green spaces in urban areas, for people to relax and enjoy nature. Miyawaki plantations are an effective way to combat climate change and create a sustainable future. Self-sustaining high-density native plantations can be designed to suit local conditions. This quick and fast-growing Miyawaki plantation with native species having high carbon absorption capacity could be one of the solutions to sustain global warming.

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Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

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Conflict of interest

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