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Achieving Urban Forest Restoration Using The Miyawaki Method: A Case Study Of Sabarmati Oxygen Park, Ahmedabad.

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Abstract

Objective: This research paper aims to explore the implementation and effectiveness of the Miyawaki method for urban forest restoration in Ahmedabad, focusing on its adaptability, resilience, and impact on local biodiversity.

Methodology/Approach: Through a detailed case study approach, the Sabarmati Oxygen Park in Ahmedabad was evaluated for its Miyawaki forest implementation. The research utilized both qualitative and quantitative methodologies, leveraging site-specific data, vegetation assessments, and temperature measurements to deduce outcomes.

Findings: The Miyawaki method, when applied in Ahmedabad's unique conditions, exhibited notable efficacy in increasing biodiversity, improving ecological functions, and enhancing carbon capture. Moreover, the method demonstrated significant potential in mitigating urban heat island effects.

Implications: The success of the Miyawaki method in Ahmedabad provides a scalable blueprint for cities globally, offering a viable solution to urban environmental challenges. However, it underscores the need for the method's adaptation based on local ecological conditions.

Originality/Value: This paper provides a comprehensive exploration of the Miyawaki method's application in an urban Indian setting, contributing to the existing literature on urban forest restoration and filling a research gap concerning the method's adaptability to different urban environments.

Keywords: *Miyawaki Method, Urban Forest Restoration, Biodiversity, Sabarmati Oxygen Park, India*

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I. Introduction

The greenhouse effect is a natural phenomenon that warms the Earth's surface. It arises because certain gases in the atmosphere (such as water vapor, carbon dioxide, and methane) trap energy from the Sun. However, human activities have led to an exponential increase in these greenhouse gases, intensifying the natural greenhouse effect and leading to more heat being trapped in the atmosphere. Consequently, this results in the widespread phenomenon known as global warming. Recent figures suggest that since the pre-industrial era, the global temperature has risen by approximately 1.0°C, mainly due to anthropogenic causes (UN Environment and International Energy Agency, 2017). The built environment, which includes our buildings and infrastructure, contributes almost 40% of global CO_2 emissions (International Energy Agency, 2016). Between 1850 and 2005, land-use changes contributed to a significant amount of carbon flux to the atmosphere (Houghton, 2008).

Human-induced climate change, fundamentally rooted in the greenhouse effect, continues to pose grave environmental and socio-economic concerns. At its most rudimentary understanding, the greenhouse effect refers to the process by which specific gases, primarily carbon dioxide (CO_2), methane, and water vapor, trap heat in the Earth's atmosphere, consequently elevating global temperatures (Kweku et al., 2018; Lashof &

Ahuja, 1990). Current statistics portray a dire image of this phenomenon, with buildings and constructions significantly contributing to global CO_2 emissions, thereby intensifying the greenhouse effect (UN Environment and International Energy Agency, 2017).

Efforts towards mitigating the repercussions of the greenhouse effect have spotlighted afforestation as a pivotal strategy. Afforestation, the process of establishing forests or tree stands in areas devoid of forest cover, sequesters carbon, making it a vital tool for curbing atmospheric carbon levels (Houghton R.A., 2008). In this context, the Miyawaki method of afforestation emerges as a trailblazing technique. Pioneered by Dr. Akira Miyawaki, this approach facilitates the growth of dense, native forests in a notably short span, which can be up to ten times faster than conventional afforestation methods (Miyawaki, 2011; Miyawaki, 1998).

The global adoption of the Miyawaki method is indicative of its efficacy. Several regions worldwide have successfully harnessed its potential to bolster biodiversity and substantially counter carbon emissions (Thornton, 2020). Yet, despite its myriad benefits and growing international recognition, India remains comparatively nascent in its adoption. Given India's vast landmass, diverse ecological zones, and pressing environmental challenges, a closer inspection of the Miyawaki technique within the Indian context is imperative.

The Sabarmati Oxygen Park in Ahmedabad, Gujarat, India, offers a relevant case study in this regard. Representing a pioneering effort in India, the park epitomizes the successful execution of the Miyawaki method. While select studies, such as those by Kurian (2020), have delved into aspects like the Urban Heat Island mitigation potential of Miyawaki forests, comprehensive research encapsulating the holistic implementation and outcomes of this method in India is conspicuously lacking.

Given the alarming global figures on greenhouse gas emissions (International Energy Agency, 2016; Baumert et al., 2005) and the urgent call for sustainable measures (Khan et al., 2020; Lee & Min, 2015; Bhattacharya et al., 2016), it is paramount to study the Miyawaki method's viability as a remedy. This research, therefore, seeks to bridge the existing knowledge gap by comprehensively evaluating the Sabarmati Oxygen Park. Through this lens, the study aims to shed light on the method's practicality, advantages, challenges, and potential replication across India's diverse terrains.

In a world grappling with climate change's catastrophic effects, understanding and capitalizing on innovative afforestation methods can play an instrumental role in charting a sustainable future. The Miyawaki method, with its promising potential, necessitates deeper exploration, especially in regions like India where its widespread adoption could be transformative. This research, therefore, stands as both a scientific inquiry and a clarion call for environmental rejuvenation.

The study attempts to answer the following research question:

"How effective is the implementation of the Miyawaki method in promoting afforestation and combating the greenhouse effect in urban areas, with a case study focus on Sabarmati Oxygen Park, Ahmedabad, Gujarat, India?"

The structure of the paper is as follows. The following section provides a literature review on the greenhouse effect, the Miyawaki method, and its application in India and around the world. Next, the research methodology is described, which is then followed by the main findings. The discussion section establishes connections between the results and prior studies, explains the practical implications of the study, recognises its limitations, and proposes avenues for further research in this field.

II. Literature Review

Greenhouse Effect

The greenhouse effect can be understood as a warming of Earth’s surface and the layer of the atmosphere directly above it, resulting from the trapping of solar energy (Hoornweg, et al., 2020). Solar radiation passes through the Earth's atmosphere. A portion of it is reflected back into space and the remainder is absorbed by the planet's surface. As the Earth warms, it releases this energy back into space in the form of infrared radiation. However, some gases, known as greenhouse gases (GHGs), absorb and re-radiate some of this energy, thereby warming the planet (Kweku et al., 2018).

The primary consequence of the enhanced greenhouse effect is global warming, with Earth's average surface temperature increasing by approximately 1.2°C since the late 19th century (Lashof & Ahuja, 1990). This rise in temperature has had a cascading effect on our environment. Polar ice caps and glaciers, for instance, have experienced rapid melting due to the heightened temperatures, contributing to rising sea levels that threaten coastal habitats (Hoornweg, et al., 2020). Alongside these shifts, there's been a noticeable uptick in the frequency and intensity of extreme weather events, such as hurricanes, droughts, and heavy rainfall. These events not only affect human societies but also have profound impacts on natural ecosystems. As climates change, natural habitats for many species get altered, leading to shifts in migration patterns, early flowering, and fruiting in plants, increasing the risk of extinction for numerous species. Additionally, our oceans bear the brunt of these changes too. As more carbon dioxide gets absorbed by the oceans, it results in ocean acidification, adversely impacting marine life, especially coral reefs and shelled organisms (UN Environment and International Energy Agency, 2017).

Afforestation is one of the primary means to combat the greenhouse effect. Planting trees absorbs $CO2$, which helps in reducing the concentration of this dominant greenhouse gas in the atmosphere. Techniques like the Miyawaki method have been effective in afforestation, particularly in urban areas Kurian (2020). Transitioning from fossil fuels to renewable sources of energy such as wind, solar, and hydroelectric power can significantly reduce GHG emissions. Carbon Capture and Storage (CCS) technology involves capturing $CO2$ emissions at their source (like power plants) and storing them underground or using them in a beneficial manner to reduce the amount released into the atmosphere. Enhancing energy efficiency in transportation, industrial processes, and buildings can lead to substantial reductions in GHG emissions. Furthermore, educating the public and implementing strong policy measures at national and international levels are crucial for a coordinated and comprehensive approach to combating the enhanced greenhouse effect (UN Environment and International Energy Agency, 2017).

Though the greenhouse effect is a completely natural phenomenon, its effects have been magnified by human activities, posing significant challenges to the environment and human societies. A multifaceted approach, including both technological solutions and behavioral changes, is required to mitigate these impacts and ensure a sustainable future.

The Miyawaki Method

The Miyawaki method, named after its creator, Japanese botanist Akira Miyawaki, has gained significant attention in the 21st century as a unique and effective approach to forestation (Thornton, 2020). Developed over 40 years ago, this method offers a solution to several ecological and environmental challenges posed by rapid urbanization and climate change. The method has witnessed widespread adoption and accolades, especially in the 21st century. Its evolution and effectiveness have been the subjects of myriad research studies and applications in various regions across the world. The method is renowned for its ability to regenerate native forests rapidly, while simultaneously serving other multifaceted purposes.

The method was initiated by Akira Miyawaki with a foundational idea of restoring urban green environments, with a focus on native vegetation (Miyawaki, 1998). The method emphasizes the use of locally native species, meticulously chosen based on ecological field surveys, ensuring the forests regenerated are adapted to local conditions and can thrive (Lieth and Lohmann, 1991). Since its inception, the method has been meticulously refined through practical applications and research endeavors, evolving over time to become more efficient and adaptable.

Since 1973, various organizations, regional government agencies, and ministries have worked towards forest restoration using this approach (Lieth & Lohmann, 1991). Surveys from regions as diverse as Japan, Kalimantan in Indonesia, Sarawak in Malaysia, mangrove forests in Thailand, and dipterocarpus forests at Doi Internon highlight the global reach of this method (Miyawaki, 1982; Miyawaki, 1985; Miyawaki, 1992).

The Miyawaki method allows for the creation of miniature urban forests, which can be cultivated in strips as narrow as one meter (Miyawaki, 2008). This has been particularly advantageous in urban and industrialized areas, where space is limited but the need for greenery and carbon sequestration is paramount. The method prioritizes the use of locally native species, serving purposes that range from aesthetic to practical, including disaster prevention (Miyawaki, 2006). Moreover, the forests resulting from this method play a crucial role in disaster prevention. With their deep, axial roots, the primary trees are resistant to falling, thereby minimizing damage from natural catastrophes such as tsunamis (Miyawaki, 2006).

The effectiveness of the Miyawaki method is evident from its results. It enables the creation of multi-stratal quasi-natural forests with a remarkable success rate. In contrast to the two centuries that conventional forest regeneration can take, Miyawaki forests can develop into fully developed ecosystems in a mere two decades (Torkington, 2023). For instance, in Japan, forests matured within 15-20 years, while in Southeast Asia, it took a more extended period of 40-50 years (Kurian, 2020). The rapid growth rate of the trees, about 1 meter per year initially, and their eventual height of up to 18 meters within two decades, indicates the method's efficacy (Lieth & Lohmann, 1991). Moreover, these forests have shown a profound ability for carbon sequestration, addressing the urgent need for climate change mitigation (Miyawaki, 1998).

Another testament to its success is the increasing global prevalence of Miyawaki forests. Species such as local pollinators and amphibians flourish in environments with a larger variety of food and shelter (Torkington, 2023). Their contributions to biodiversity and human wellbeing have been recognized and lauded, making them an integral part of global reforestation efforts (Kurian, 2020).

Miyawaki forests are becoming increasingly well-known as a result of initiatives in Europe, India, the Amazon, and the United States. The pocket forest company SUGi, a partner in the World Economic Forum's Uplink initiative, has planted 160 tiny forests in 28 cities across six continents, including one it is funding at Danehy Park in Cambridge, Massachusetts on the site of a former landfill. Voluntary organisations such as Urban Forests in Belgium and France and Tiny Forest in the Netherlands are collaborating to rehabilitate small areas of wasted land. Another Forum Uplink partner, Earthwatch Europe, has planted more than 200 small forests in the United Kingdom and mainland Europe (Torkington, 2023). Various collaborations, ranging from academic institutions to corporations, have endorsed and adopted this method. Examples include the joint venture between Yokohama National University, Mitsubishi Corporation, and Universiti Putra Malaysia in Sarawak in 1990 and Kenya's reforestation project in 2011 (Miyawaki, 2011).

III. Research Methodology

The case study research approach was utilised to comprehend the implementation of the Miyawaki method in an Indian park. This was due to the fact that it is an appropriate methodology for describing a phenomenon and gaining insight into social processes (Onwuegbuzie and Leech 2010; Yin 2009).

The Ahmedabad Municipal Corporation was the promoter of the park in association with The Serenity Trust and Acacia Eco. Consent was obtained from these organisations to conduct an examination of their implementation processes and the improvements that ensued as a consequence of adopting the Miyawaki method.

As indicated by Meredith (1998), data were gathered via structured interviews with the senior management of Acacia Eco and The Serenity Trust and direct observation during a series of meetings in a natural setting between June 2019 and August 2019.

Several data sources were used: archival data, which included websites of various developmental agencies and information provided by the management, interviews with company leaders and workers and visual information observed during the visits. The data was collected in the following phases:

i. Prior to the visit, archival data was analysed, and it was supplemented throughout the visit which provided general information about the geographical layout, the technique and the objectives behind the use of Miyawaki method.

ii. A 90-minute interview was undertaken with the project manager in order to gather pertinent information pertaining to the determination concerning the application and execution of the Miyawaki method.

IV. Findings

Case Study: Sabarmati Oxygen Park, Ahmedabad, Gujarat, India

Location: Ahmedabad, the largest city in Gujarat, India, experiences a semi-arid climate. It is characterized by moderate green cover, with average temperatures ranging from 20°C in winter to 41°C in summer. The average annual rainfall is about 800 mm. The city is located at a latitude of 23.0225° N and longitude of 72.5714° E with an elevation of around 53 meters above sea level.

Description of Site: The location of the chosen plot was on size Science City Road right next to Ugati Lake. This location is situated near the Sabarmati river. The size of the plot was 11,000 sq. mt., out of which 5,700 sq. mt. was allocated to the Miyawaki plantation. The topography of the site was flat. It was located adjacent to the Sabarmati River. Two types of soil are generally found in this region:

Type 079: Calcareous fine loamy soils that are extremely deep, moderately well-drained, and situated on a gently undulating flood plain. These soils exhibit minimal erosion and salinity. They are also associated with calcareous fine soils that are also quite deep and moderately well-drained, with minimal erosion and salinity.

Type 100: Loamy soils that are fine, well-drained, and situated on a gently sloping alluvial plain with minimal salinity and erosion; accompanied by calcareous, fine soils that are deep and moderately well-drained and situated on gently sloping lands with modest erosion (Kamdar, 2009).

Description of Natural Environment on Site: The site, due to its proximity to the Sabarmati River, had a slightly cooler microclimate compared to the inner parts of the city. Natural flora included indigenous riverine species.

Steps in the Implementation of Miyawaki Method

The steps followed in the implementation of the Miyawaki method at this location were as under (Sharma, 2019).

1) Analyzing the Biomass and Soil Texture

It was crucial to examine the soil texture since it influences factors such as fertility, water retention, percolation, etc. All of these factors have an impact on the growth and lifespan of the forest. The remaining biomass in the soil was then be measured. In order to improve the soil, the following biomasses were added:

- Organic fertilizers such as cowpat, goat muck, and vermicompost to provide nutrients for plant growth.
- Perforating materials (materials with holes in them) such as groundnut shells, wheat husks, or rice husks to help plants' roots sink farther into the soil.
- Water retainers such as peat moss and coconut oil to increase the soil's capacity to retain water as the ground needs to possess sufficient capacity to retain water for a forest to grow.
- Mulch such as compost, dried bark, or decomposing leaves to shield the earth from the harsh sun and protect young trees whose growth could be hampered by dried-out soil.

2) Selecting Native Species for Plantation

While planting trees, it was important to choose native species and acknowledge their genus (evergreen or deciduous), height, and impact on the environment. Considering the conditions of the site, the layering of the plants was decided. As per the guidelines of the Miyawaki method, 40 to 50 percent of the total number of trees were from the most commonly found species in the neighborhood. Five distinct genera were selected to represent the important species in the. 25 to 40 percent of supporting plants were chosen from some moderately found native species will compose 25 to 40 percent of supporting plants. The remainder of the forest consisted of a few other minor species. For all these species, saplings at a minimum height of 60 to 80 cm were collected from local horticultural associations and forest departments. Table 1 shows the list of species used on this site.

Table 1: List of Plant Species Used

Sr. No.	Local Name	Botanical Name
1	Amba	*Mangifera indica*
2	Amla	*Phyllanthus emblica*
3	Amli	*Tamarindus indica*
4	Ardusa	*Ailanthus Excelsa*
5	Arjun	*Terminalia arjuna*
6	Badam	*Terminalia catappa*

7	Baheda	*Terminalia bellerica*
8	Bignonia	*Bignonia metapotomica*
9	Bili	*Aegle marmelos*
10	Kacchnar - purple	*Bauhinia variegata*
11	Kacchnar - mauve	*Bauhinia purpurea*
12	Borsali	*Mimusops elengi*
13	Buch	*Millingtonia hortensis*
14	Desi saag	*Tectona grandis*
15	Garmala	*Cassia fistula*
16	Gulmohar	*Delonix regia*
17	Gultora	*Caesalpinia pulcherrima*
18	Gunda	*Cordia dichotoma*
19	Jambu	*Syzygium cumini*
20	Jamfal	*Psidium guajava*
21	Kadamb	*Anthocephalus cadamba*
22	Kajaliya	*Kajaliya pinnata*
23	Kanji	*Pongamia pinnata*
24	Kapok	*Bombax ceiba*
25	Kashid	*Senna siamea*
26	Khakhra	*Butea Monosperma*
27	Kodiya	*Cordia sebestena*
28	Lagerstroemia	*Lagerstroemia indica*
29	Mahuda	*Madhuca longifolia*
30	Nagod	*Vitex nagundo*
31	Neem	*Azadirachta indica*
32	Paras pipla	*Ficus arnottiana*
33	Peltoform	*Peltophorum pterocarpum*
34	Pink cassia	*Cassia renigera*
35	Putranjiva	*Drypetes roxburghii*
36	Rain tree	*Albizia saman*
37	Saptaparni	*Alstonia scholaris*
38	Saragvo	*Moringa oleifera*
39	Saru	*Casuarina equisetifolia*
40	Setur	*Morinda citrifolia*
41	Singapore cherry	*Muntingia calabura*
42	Sitafal	*Annona squamosa*
43	Spethodia	*Spathodea campanulata*
44	Tebubia	*Tabebuia rosea*
45	Thespesia	*Thespesia populnea*

3) Setting up the Forest Area and Getting the Ground Ready

First of all, the soil was cleared of debris and weeds. Figure 1 shows the site before the clearing process. According to the guidelines of the Miyawaki method (Miyawaki, 1998), the site must receive sunlight for at least 8 to 9 hours per day in order to begin afforestation. Since the climate of Ahmedabad is hot and sunny, this requirement was easily fulfilled. Next, irrigation facilities were installed after which 100 sq m. mounds were created and demarcated before the plantation could begin. Figure 2 shows this step in progress.

Figure 1: Site Appearance Before Clearing

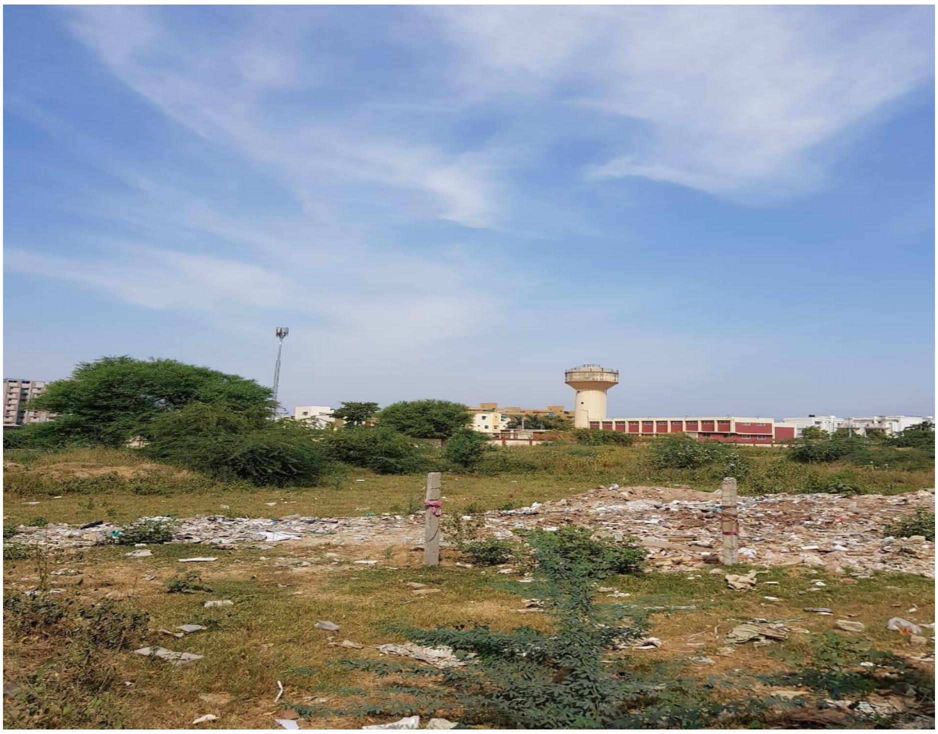
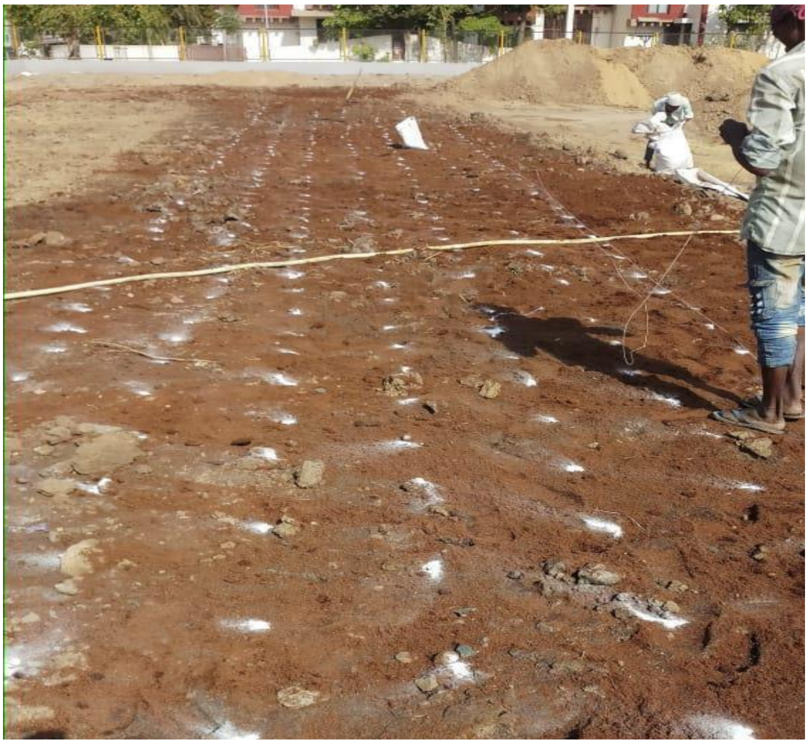


Figure 2: Getting the Ground Ready



The Plantation Process

Before plantation, a 3-ft layer of top soil was enhanced using coco peat, rice husk and compost. To plant the seedlings, tiny holes were made in the ground and the saplings' root bags were removed. The saplings were planted in the holes after lightly levelling the ground around their stems. The native tree species were planted in clusters in 3 ft by 3 ft grids. The saplings were supported with Jeevamrut, an organic growth enhancer. Supporting sticks were provided for the plants in accordance with their height. They were also covered with rice straw to retain soil moisture

The plantation activities were inaugurated on World Environment Day, June 5, 2019 by Mr. Vijay Nehra, Commissioner, Ahmedabad Municipal Corporation and Mr. Firdos Cambatta, Serenity Trust. The plantation of Miyawaki areas and individual trees and shrubs was completed in August 2019. Thereafter the maintenance team was trained in daily watering and weeding activities. Figure 3 shows the site after completion of plantation.

Figure 3: Site Appearance after Completion of Plantation

Maintaining the Forest for the subsequent three years.

This step was the longest in duration and involved daily watering, weed and trash removal, and drainage maintenance. For the first year, the mulch level was maintained and continually replaced. In order to prevent the mulch from engulfing the plants, close attention was paid to the plants' growth. There was absolutely no trimming of the forest, no use of chemical pesticides and fertilizers. Additionally, the leaves shed on the forest floor were not cleaned.

Figures 4 and 5 show the progress of the forest plantation at six months and one year interval respectively.

Figure 4: Progress of Forest at Six Months after Plantation

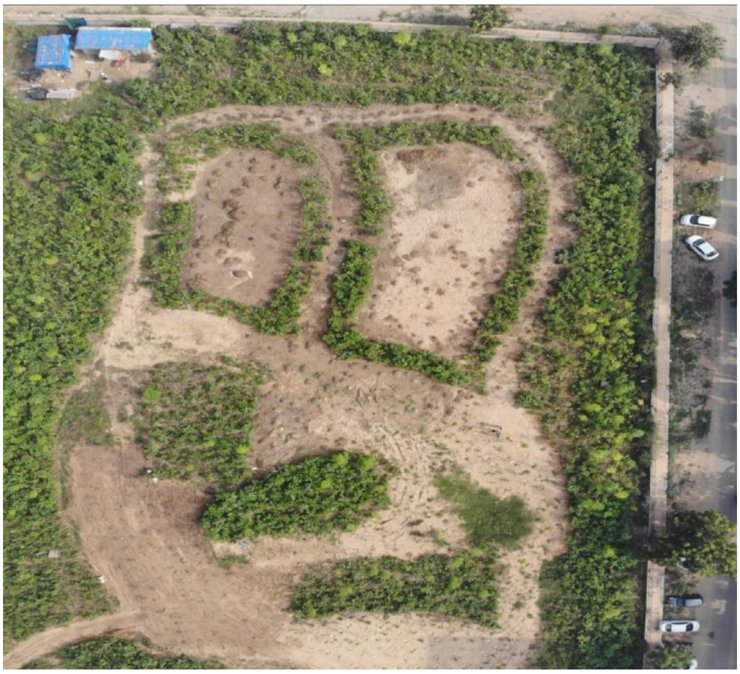


Figure 5: Progress of Forest at One Year after Plantation

V. Discussion

The current global discussion regarding naturalization of degraded forests, and landscape restoration is ongoing as demonstrated by various authors (Perrow & Davy 2002; Walker & del Moral, 2003; Falk et al., 2006; Van Andel & Aronson 2006; de Dios et al., 2007).

Several Asian nations, including India, have subjected their ecosystems to human exploitation and modification for millennia. Forests have been subject to numerous processes that have resulted in degradation and subsequent soil depletion. Due to these effects, reforestation methods adopted have typically required a long time for a complete environmental restoration.

By implementing new, untested naturalistic theoretical principles, the Miyawaki method may provide a more expedient and efficient approach to reforestation in India. This area is further complicated by its seasonal climate, which is distinguished by arid summers.

While the current case study has been documented for one year post plantation, it has already show progress in terms of rapid development of trees in comparison to other methods. The results are comparable with those obtained by the Miyawaki method in 75 micro forests across the world (Urban Forests, 2020) as seen in Table 2.

Table 2: Results of Miyawaki Method Globally

Benefit	Miyawaki Design Components Leading to Benefit	Impact
Carbon Sequestration	● Individual tree clusters ● Miyawaki forest clusters with 45 tree species in the periphery and clusters ● Selection of tree species	Carbon sequestration by 100 m² Miyawaki forest = 5980 kg of CO2. An Indian city with reasonable emissions (as per current per capita emission) can offset 5 years of carbon emissions per 100 m² lot of planted Miyawaki forest in the long term.
Temperature Regulation	● Individual tree clusters ● Miyawaki forest clusters	Reduction of minimum of 2 ℃ minimum locally.
Stormwater Regulation	● Individual tree clusters ● Miyawaki forest clusters ● Natural contours towards water body	Reduction in annual runoff by 2-7 percent.
Air Purification	● Selection of specific tree species ● Shrubs and grasses that contribute to arresting dust particles	Absorption of 15 percent microparticles, leaves, and bark intercept dust.
Noise Mitigation	● Dense forest plantations in periphery ● Individual tree clusters and dense forest clusters around utility areas	Reduction of 10 dB for a mature Miyawaki forest.
Increase in Biodiversity	● Selection of specific trees and shrubs to attract birds and butterflies	Increase in bird species.

VI. Conclusion

The case study on the implementation of the Miyawaki method in Ahmedabad provides a deep dive into the potential of this technique for creating urban green spaces. From the findings, the Miyawaki method has proved to be an effective approach for the restoration of urban forests, leading to increased biodiversity, improved ecological functions, and enhanced carbon capture, as highlighted by Miyawaki (2011) and Thornton (2020). The unique nature of the Sabarmati Oxygen Park and its underlying conditions showcased both the method's adaptability and resilience. Furthermore, studies by Kurian (2020) and Koziupa (2021) emphasize the significance of the method in mitigating urban heat islands and analyzing its pros and cons in various settings.

However, this research was not without limitations. While the case study provides a comprehensive overview of the implementation in Ahmedabad, it cannot be universally generalized due to the site-specific nature of the Miyawaki method. As highlighted by sources such as Schirone et al. (2011) and Goveanthan et al. (2019), the effectiveness and performance of various tree species within the Miyawaki plantation can differ across regions and climatic conditions.

Practically speaking, the success of the Miyawaki method in Ahmedabad has broad implications. Cities worldwide, especially those grappling with urban heat island effects, reduced green cover, or those looking to boost biodiversity, can use this method as a blueprint. Yet, as Miyawaki (2008) and others suggest, it is essential to tailor the approach based on local environmental and ecological conditions.

In terms of future research, there is vast scope. Comparative studies can be undertaken between Miyawaki forests in various urban environments to draw broader conclusions. Additionally, a deeper exploration into the long-term sustainability of these forests, especially concerning water-use efficiency, as touched upon by González de Andrés et al. (2018), and their role in combating climate change could be invaluable. Lastly, understanding the socio-economic impacts of these green spaces on local communities and urban dwellers would provide a holistic view of the Miyawaki method's real-world benefits.

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