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Evaluating the Miyawaki Afforestation Technique in Urban Landscapes: Opportunities and Challenges

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Abstract

Urban landscapes are increasingly dominated by impermeable surfaces, leading to significant ecological degradation, biodiversity loss, and urban heat island effects. The Miyawaki Afforestation Technique has gained attention as a potential solution for restoring urban green spaces by rapidly creating dense, biodiverse forests. This paper evaluates the potential and limitations of the Miyawaki method in the context of urban planning, with a focus on its ecological, social, and economic implications. While the method offers rapid forest establishment, increased biodiversity, and improved air quality, its applicability in varying climatic and urban conditions remains controversial. Issues such as land availability, maintenance intensity, and public perception of untamed green spaces present challenges for widespread adoption.

Additionally, the need for substantial soil preparation raises concerns regarding cost and feasibility in dense urban environments. This study critically examines these factors, proposing a balanced perspective on the Miyawaki method's role in contemporary urban design. The findings suggest that while the technique holds promise for enhancing urban sustainability, its integration into planning policies requires careful consideration of spatial, financial, and social dynamics.

Keywords: *Green spaces, Miyawaki method, Urban research, Urban ecology, SDG11.*

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INTRODUCTION

Urbanization has significantly altered natural ecosystems, resulting in the degradation of biodiversity, fragmentation of green spaces, and the intensification of urban heat islands. As cities expand, the balance between built environments and natural landscapes continues to shift toward impermeable surfaces, reducing the ecological functions of urban green spaces (Breuste et al., 2021). The pressing need for sustainable urban regeneration has led to exploring innovative afforestation techniques to mitigate environmental damage and enhance urban resilience (Schirone & Salis, 2011; Kohout & Kopp, 2020).

Urban green space must be increased in cities by extending current green space areas and creating new green spaces. This is important for two main reasons: increased health benefits for humans and the provision of ecosystem services for the city (Ramyar et al., 2020; Li et al., 2020; Tian et al., 2020). However, the provision of ecosystem services depends upon the scale of urban green space; large continuous green areas provide more ecosystem services as compared to small fragmented green spaces (Sen & Guchhait, 2021; Vega & Küffer, 2021; Puplampu & Boafo, 2021; Liu & Russo, 2021).

Many cities struggle to balance the rapid construction required for urbanization with the need to implement green spaces, which are crucial for environmental health and human well-being (Czaja et al., 2020; Churkina et al., 2020). Unlike rural areas, where natural landscapes and forests are abundant, urban areas are dominated by buildings and concrete. In these cities, green spaces are often limited and can only fulfill a fraction of the ecosystem functions that forests provide, such as air purification, carbon sequestration, and biodiversity support (Kais et al., 2021; O'Brien et al., 2022; Li & Hu, 2022). One of the methods that will expand the green areas squeezed in cities that have become concrete jungles and establish a balance between nature and the city is The Miyawaki method.

In alignment with Sustainable Development Goal 11 (SDG 11: Sustainable Cities and Communities), which emphasizes the need to make cities inclusive, safe, resilient, and sustainable, the Miyawaki Afforestation Technique has emerged as a promising method for rapidly increasing urban green cover. Developed by Japanese botanist Akira Miyawaki, this approach focuses on creating dense, multilayered forests composed of native plant species. These forests are designed to grow quickly, sequester carbon, improve air quality, and support biodiversity. The technique has gained attention worldwide, particularly for its ability to transform degraded urban spaces into thriving ecosystems. However, while its ecological benefits are well-documented, its broader application in diverse urban environments remains controversial.

This paper critically examines the potential and limitations of the Miyawaki technique within urban planning. While many studies highlight its rapid forest establishment and ecological advantages, its

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practical challenges—including climatic adaptability, soil preparation contradictions, land availability, public perception, and economic feasibility—require further analysis. This study evaluates the applicability of the Miyawaki method beyond its original tropical context. It discusses how it can be integrated into contemporary urban landscapes while addressing the objectives of SDG 11 by promoting greener and more sustainable urban environments.

This research aims to bridge the gap between theory and practice, assessing whether the method can be successfully adapted to varying urban contexts. To do so, the paper will explore empirical case studies, discuss financial and policy implications, and examine how public engagement can influence the acceptance of Miyawaki forests in urban settings. Ultimately, this study aims to provide urban planners, policymakers, and researchers with a comprehensive understanding of how the Miyawaki technique can contribute to urban sustainability while addressing the critical challenges associated with its implementation.

The main question of the research is whether the Miyawaki afforestation technique can be a solution in very dense urban areas where it is impossible to create any open and green areas. For this purpose, the importance and success of the application is emphasized and detailed through examples.

MATERIALS & METHODOLOGY

This study comprehensively reviews the Miyawaki afforestation technique, meticulously examining its theoretical foundations and practical applications. Through a synthesis of existing research and empirical field experiences, the study organizes information thematically to systematically analyze the method's principles, benefits, and strategies for implementation.

The materials utilized in this study were sourced from diverse resources. Academic publications, encompassing peer-reviewed articles, theses, and book chapters, provided essential theoretical insights and technical details. Additionally, conference proceedings and field reports documented practical applications and implementation outcomes, offering valuable case studies for analysis. To further enrich the research, application notes and online resources—such as manuals, blogs, and instructional videos—were scrutinized to capture real-world perspectives, community engagement initiatives, and project-based learning. These sources were accessed via academic databases (e.g., Web of Science, Scopus, Google Scholar) and official project websites, selected for their recency, reliability, and relevance to the study's objectives.

The review process was systematically conducted in three distinct stages. Initially, a literature search utilized relevant keywords, including the Miyawaki method, biodiversity restoration, urban afforestation, and community-based reforestation. The materials collected were subsequently filtered based on their direct relevance to the Miyawaki technique, their coverage of implementation processes, and their scientific credibility.

The data was classified into thematic categories aligned with the study's objectives in the second stage. These categories included (1) the historical background and fundamental principles of the Miyawaki method, (2) its environmental benefits, encompassing biodiversity enhancement, carbon sequestration, and air quality improvement, (3) the implementation process, which details site selection, soil preparation, planting, and maintenance, and (4) the significance of community engagement in afforestation projects.

The final stage involved a thorough analysis and synthesis of the collected data. Theoretical insights were juxtaposed with practical applications, enabling the identification of successes and challenges encountered in real-world implementations. Field reports and application notes proved particularly beneficial in bridging the theoretical and practical domains, highlighting best practices, limitations, and future research directions.

This systematic methodology facilitated a multi-dimensional understanding of the Miyawaki technique while exposing critical gaps in the literature that warrant further scholarly investigation.

UNDERSTANDING THE MIYAWAKI TECHNIQUE

The Miyawaki technique is a widely recognized urban afforestation method developed and refined by Japanese botanist Dr. Akira Miyawaki (Miyawaki, 2004; Meguro et al., 2021). Unlike traditional reforestation methods, which typically use only two or three species, the Miyawaki method incorporates a diverse range of indigenous plants tailored to the specific location of the afforestation project (Lagariya & Kaneria, 2021; Sandeep et al., 2022). The goal is to create a self-sustaining, biodiversity-rich forest in a relatively short period, accelerating natural forest succession. The layered structure of a Miyawaki forest allows for horizontal and vertical coverage, making it highly efficient in urban greening efforts (Lewis, 2022).

A significant advantage of Miyawaki forests is their role in enhancing biodiversity, as they create a rich and stable ecosystem (Anand et al., 2023). Biodiversity refers to the variety of life in a given habitat, and increased plant diversity leads to greater animal diversity, providing food and shelter for various species (Lewis, 2022; Swapna, 2023). Traditional reforestation methods often rely on monoculture plantations, which are far less effective in fostering biodiversity and ecological resilience (Parikh & Nazrana, 2023; Daou et al., 2024).

Miyawaki and his team identified four guiding principles essential to the method (Miyawaki, 2004; Elliott et al., 2023):

- Using only indigenous species,
- Optimizing plant spatial composition,
- Planting multiple layers of vegetation, and

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- Ensuring high-density planting

These principles mimic natural forests, ensuring that a wide range of species, each suited to a different ecological niche, can thrive (Lewis, 2022; Anand et al., 2023). A key feature of Miyawaki forests is the development of a soil seed bank, allowing for long-term ecological stability and self-sustaining plant regeneration (Daou et al., 2024).

One notable feature of Miyawaki forests is their high tree density, with 30 to 40 species planted together in mixed layers, creating diverse habitats for insects, birds, and small mammals (Aarthi et al., 2021; Lewis, 2022). The competition for light among plants encourages rapid vertical growth, leading to a dense undergrowth of shrubs and herbaceous species that support a wide range of organisms (Mandowara, 2022). This structural complexity ensures genetic diversity within species populations, enhancing resilience to environmental changes, such as new diseases, pests, and climate fluctuations (Hara, 2023; Prasad, 2023; Khan et al., 2024).

Miyawaki (1990) emphasized that early forest establishment is knowledge-driven, requiring careful selection of native species, soil enrichment strategies, and pest control methods (Miyawaki et al., 1993; Maurya et al., 2021). The complex interconnections within a mature forest, however, develop over time and cannot be artificially designed by humans (Wang et al., 2023).

The impact of native plant biodiversity extends to insect and bird populations. Ewers and Didham (2006) found that a 2% increase in native plant species could lead to a 50% increase in insect populations, providing essential food sources for many bird species (Staab et al., 2020; Tallamy et al., 2021). Additionally, native plants result in deeper root systems and denser canopy formation, enhancing soil stability and ecosystem resilience (Raven & Wagner, 2021; Tallamy & Shriver, 2021).
The layered vegetation structure of Miyawaki forests—including trees, shrubs, and herbs—is integral to its success, ensuring long-term ecological benefits and urban climate regulation (Postma et al., 2021; Ding et al., 2021; Nakhforoosh et al., 2021; Huber et al., 2021).

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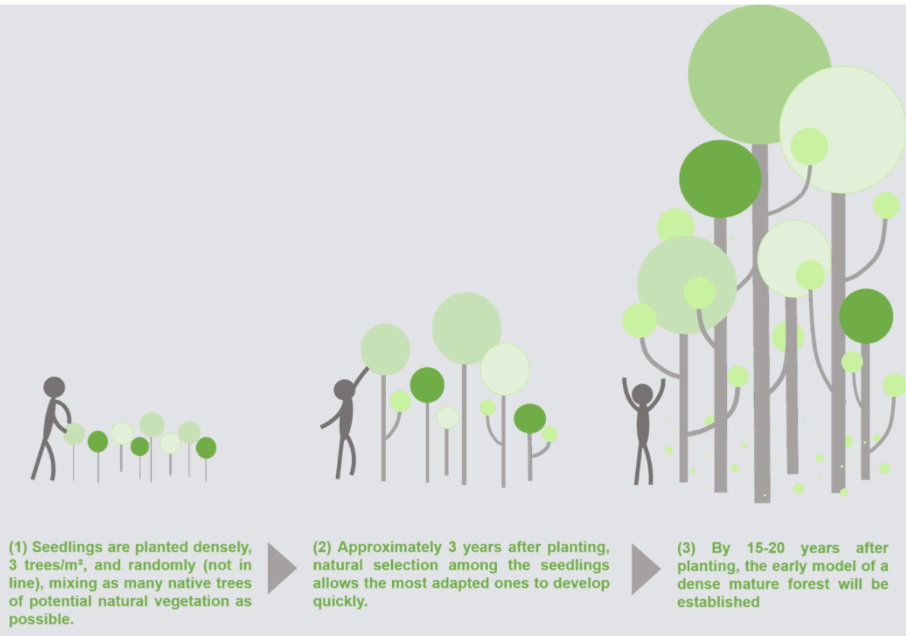

Figure 1. Phases of Miyawaki Forests (Anonymous, 2024).

Native plant species have adapted to their local climate, soil, and microorganisms over hundreds or even thousands of years, making them more resilient to environmental conditions and less susceptible to invasive species (Miyawaki, 1990; Anderson & Song, 2020; Hulme, 2020). The Miyawaki method prioritizes these native species, requiring that at least 50% of the plants used in a plot be indigenous to the region (Miyawaki, 2004; Kurian, 2020; Meguro et al., 2021). This distinguishes it from traditional afforestation techniques, which often incorporate non-native species that may not support local biodiversity as effectively (Lewis, 2022; Sandeep et al., 2022).

Historical research highlights the role of Miyawaki forests in post-war restoration efforts. In Fukutsu, Japan, intentional forest planting efforts aimed to counteract deforestation and resist urban expansion (Xiaoqin et al., 2021). Following World War II, large-scale residential development and road construction led to significant forest loss, with many sites not showing signs of afforestation until the 1950s (Zsolnai & Bajor, 2021). Studies indicate that 80% of Miyawaki forests recorded in the 1960s and 1970s were in early-stage growth. In contrast, by the 1990s and 2000s, these numbers declined to 20% for soil-based forests and 10% for field-based forests, reflecting the growing challenges of urbanization and changing land-use policies (Lewis, 2022; Fratini, 2023; Dhanorkar et al., 2023).

In high-density urban areas like London and New York, where green spaces are scarce, Miyawaki forests effectively restore lost ecosystems and create new green infrastructure (Agnihotri, 2022). However, given limited available land, alternative approaches such as green rooftops and urban micro-forests may be necessary (Meguro et al., 2021; Hanpattanakit et al., 2022). The reintroduction of dense vegetation in urban settings enhances biodiversity and improves human connections to nature, an aspect that has diminished with modern city living (Zsolnai

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& Bajor, 2021; Swapna, 2023). In a time when urbanization has led to ecological detachment, expanding Miyawaki forests can help mitigate environmental degradation and restore urban ecosystems (Lewis, 2022; Dhanorkar et al., 2023; Fratini, 2023).

ADVANTAGES OF THE MIYAWAKI TECHNIQUE

The Miyawaki forest technique offers numerous environmental and societal benefits, particularly in accelerating forest growth and enhancing ecological resilience. Known for its rapid forest development, this method requires irrigation only during the initial growth phase, after which the ecosystem becomes self-sustaining (Miyawaki, 1990; Miyawaki et al., 1993). During this stage, water regulation and protection from overgrazing are essential, and they can be managed through controlled grazing schedules after the initial irrigation process (Miyawaki, 2004).

A key advantage of Miyawaki forests is their role in soil and water quality improvement. Many planted species include medicinal plants, whose root systems facilitate groundwater infiltration and aid in pollutant breakdown through biological processes (Hanpattanakit et al., 2022). Additionally, these forests are highly effective in filtering environmental pollutants, significantly reducing urban temperatures and mitigating the urban heat island effect.

The dense forest canopy fosters rapid ecological succession, creating a resilient ecosystem that actively contributes to global warming mitigation. By sequestering significant amounts of carbon dioxide and filtering vehicular pollutants, Miyawaki forests play a crucial role in reducing greenhouse gas emissions and stabilizing urban microclimates, including lowering temperature and wind speed (Miyawaki, 2004; Hanpattanakit et al., 2022).

Rapid Growth and Development

The dense and layered structure of Miyawaki forests restricts light and space availability, preventing dominant species from outcompeting others and promoting more extraordinary biodiversity (Miyawaki, 2004; Meguro et al., 2021). This method leverages the concept of potential natural vegetation, recognizing that each region has an idealized plant community that would exist without human interference (Poddar, 2021). By identifying and planting species that naturally thrive in a given environment, Miyawaki forests are tailored to local ecosystems, ensuring their resilience and adaptability (Lewis, 2022).

This approach facilitates a process known as ecological facilitation, where pioneer species initiate environmental changes that pave the way for more complex genetic, taxonomic, and structural diversity to develop over time (Miyawaki, 2004). As the forest matures, this succession process leads to the establishment of a stable climax community—a highly diverse, self-sustaining ecosystem composed of mutually supporting species designed to maintain ecological balance (Meguro et al., 2021; Poddar, 2021; Lewis, 2022).

The international NGO Sugi Project creates small forests using the Miyawaki technique. They follow each of their projects from beginning to end, from soil analysis, local and endemic species survey, soil improvement, intensive planting, mulching, maintenance, and monitoring. Since its establishment in 2019, the NGO has created 232 forests in 52 cities, improved 140 school gardens, restored a total area of 203,108 square meters, and stated that a total of 428,508 plants were used in their projects, and 87.4% of these plants survived. It is possible to examine the data on the projects implemented by the NGO, which uses the Miyawaki technique itself, on their website (Sugi Project, 2024a). The project depicted in Figure 2 demonstrates the rapid growth implemented in the garden of ICHK Hong Lok Yuen Forest School in Hong Kong, which has an area of 100 square meters. 352 trees and shrubs were planted by students between 9 and 12. The project, which used 53 different local species, was established in August 2021. Some tree species, which were a few spans tall when planted, reached 5.2 meters in height in August 2023. Stating that there were problems at the beginning of the project due to the soil not being prepared well, the Sugi Project reported that 75% of the plants planted as of 2023 healthily continued their lives (Sugi Project, 2024b).

Figure 2. ICHKHong Lok Yuen Forest School implementation, example for rapid growth (Sugi Project, 2024b).

Enhancing Ait Quality and Reducing Pollution

The dense vegetation of Miyawaki forests serves as a natural barrier against air pollution, particularly in urban areas with high pollution levels. Research on urban green infrastructure indicates that the landscape configuration and quality of green spaces influence airflow, determining their effectiveness in mitigating pollution (Meguro et al., 2021; Zsolnai & Bajor, 2021). The high density and plant diversity in Miyawaki forests create a self-sustaining ecological system capable of generating localized airflow that reduces the transportation of airborne pollutants into populated areas. This function fosters microclimate formation and enhances biodiversity while protecting urban populations from harmful air contaminants (Poddar, 2021; Sandeep et al., 2022; Lewis, 2022).

Studies have demonstrated that Miyawaki forests significantly lower PM2.5 levels, reducing these harmful airborne particles by three times compared to general urban air quality and by 17 times compared to air quality around isolated trees (Aarthi et al., 2021; Lewis, 2022; Sandeep

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et al., 2022). The diverse plant species composition, including tall trees, shrubs, grasses, and flowers, fosters complex ecological interactions, enhancing the forest's ability to absorb and filter pollutants hazardous to human health and urban ecosystems.

Beyond air purification, the Miyawaki method excels in carbon sequestration, oxygen production, and soil pollutant removal, positioning it as an environmentally sustainable solution for urban greening. Unlike traditional afforestation methods, Miyawaki forests feature a high-density planting approach, incorporating a wider variety of species with distinct growth patterns and life cycles. This structural complexity enhances the long-term filtration of airborne toxins, including heavy metals and chemical pollutants, further improving urban environmental quality (Poddar, 2021; Zsolnai & Bajor, 2021; Lewis, 2022; Hanpattanakit et al., 2022).

Mitigating Urban Heat Island Effect

By mitigating the urban heat island (UHI) effect, the Miyawaki forest technique provides a valuable strategy for urban areas with elevated land surface temperatures, playing a key role in retrofitting and re-naturalization efforts aimed at developing sustainable and climate-resilient cities (Lewis, 2022; Sandeep et al., 2022). In contrast, conventionally landscaped urban areas, such as roads and artificial surfaces, typically rely on widely spaced, individual large trees, which remain exposed to direct solar radiation throughout the day. These trees lack dense vegetative support for transpiration, resulting in limited cooling capacity at night and ultimately exacerbating the UHI effect (Sharma et al., 2024).

The Miyawaki method employs systematic, high-density planting of native species to create a multi-layered and complex forest ecosystem in a short period (Poddar, 2021). During the day, dense canopy cover provides extensive shade, intercepting and absorbing solar radiation before it reaches urban surfaces, which reduces land heat absorption and lowers air temperatures through transpiration. This process significantly diminishes heat retention in built environments, making Miyawaki forests a key nature-based solution for urban climate adaptation and resilience (Lewis, 2022).

Another example is the Southbank Centre application from London. In the project, implemented with the motto "giving nature a chance to thrive within the brutalist architecture of London's Southbank Centre", 390 plants were planted in 120 square meters. The project's development in one year, where 12 different species were used, is given in Figure 3. In this urban landscape with no green space, measurements were also made on the urban heat island effect of the Miyawaki application. The measurements determined that a difference of 25.5°C was created with the application compared to the hottest surface of the space (Sugi Project, 2024c).

Figure 3. Southbank Centre Miyawaki Forest from London (Sugi Project, 2024c).

Creating Habitats for Urban Fauna

The Miyawaki method has demonstrated seasonal benefits for urban fauna, supporting biodiversity restoration even in dense urban environments. In Hama-rikyu Garden, Tokyo, a butterfly species migrating from Honshu to Kyushu was observed in the forest just six months after initial planting, suggesting the technique's potential for establishing migratory pathways and reconnecting fragmented species populations (Poddar, 2021; Aarthi et al., 2021; Lewis, 2022; Sharma et al., 2024). This rapid ecological response highlights the method's effectiveness over conventional landscaping in promoting urban biodiversity.

A variety of animal species benefit from Miyawaki forests. For instance, Hibiya Park Forest in central Tokyo has recorded over 100 species of beetles and multiple spider species, likely due to the multi-layered vegetation that creates diverse micro-habitats and ecological niches (Zsolnai & Bajor, 2021; Aarthi et al., 2021). Additionally, Miyawaki forests provide ideal conditions for urban birds, as their closed canopy and dense undergrowth offer prime nesting sites and sufficient prey populations, supporting species such as sparrowhawks and kestrels. Amphibians, including frogs and newts, also thrive in the artificial wetlands integrated into Miyawaki forests, further expanding their ecological impact (Lewis, 2022; Sandeep et al., 2022).

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IMPLEMENTING THE MIYAWAKI TECHNIQUE

Before initiating planting, the Miyawaki team conducts a comprehensive site analysis, assessing factors such as land history, topography, soil conditions, hydrology, and nutrient flow to ensure suitability for afforestation (Schirone & Salis, 2011; Poddar, 2021). Public consultation is often included for restoration projects, while research sites may feature varied land histories to evaluate the technique's effectiveness compared to conventional reforestation (Zsolnai & Bajor, 2021). Once site selection and assessments are complete, initial preparation begins under the guidance of experts with extensive plant ecology experience (Sandeep et al., 2022). Unwanted vegetation is cleared to eliminate competition for nutrients, sunlight, and water, expediting ecosystem establishment (Lewis, 2022). The extent of clearing depends on land history; for example, at the Kelana Jaya project, significant removal of woody vegetation and invasive species was necessary to support native pioneer species (Ullah et al., 2023). After clearing, mounding creates undulating terrain, accelerating ecological succession (Sharma et al., 2024). Planting typically occurs post-monsoon when soil moisture supports growth, aiming for forest maturity within three years. Weeding and monitoring are conducted throughout this period to minimize competition from invasive species and ensure forest establishment (Schirone & Salis, 2011; Ullah et al., 2023).

Site Selection and Preparation

The lack of green space in many cities, driven by dense urban development, necessitates a critical reassessment of landscape planning and the integration of open spaces into green infrastructure wherever possible. While urban peripheries may offer more prominent areas for afforestation, securing sizable plots in city centers remains a challenge. However, Miyawaki's afforestation technique has demonstrated effectiveness even in compact areas as small as 100 square meters, significantly enhancing ecosystem services in constrained urban environments (Poddar, 2021). Given the limited afforestation options available in cities, optimizing every possible planting space is crucial.

Public participation was central to Miyawaki's approach, ensuring community engagement in every project. Initially, awareness campaigns and sapling planting events should involve the public to foster local ownership of the initiative. Site preparation begins with clearing existing vegetation and managing invasive species (Poddar, 2021). Underground utilities such as cables and pipelines must be assessed in the urban context before further interventions. Soil quality plays a critical role in afforestation success; therefore, comprehensive soil analysis should be conducted to ensure adequate nutrient levels. In cases where invasive herbaceous species are present, Miyawaki recommended herbicide application followed by a six-month observation period before further soil assessment (Lewis, 2022). The land should be leveled; if necessary, organic-rich soil should be supplemented to optimize growth conditions. A thorough examination of the region's climatic conditions, soil pH, nutrient composition, and texture is essential, alongside in-depth research into endemic and native plant species to ensure long-term ecological stability (Zsolnai & Bajor, 2021; Sharma et al., 2024; Panchabhai, 2024).

Bruns et al. (2019) highlight that the soil is the foundation upon which a tiny forest is established. During soil preparation, a loose and airy structure is created to a depth of one meter, incorporating sufficient organic material to facilitate the development of a dense fungal network within a year. The prepared soil consists of a subsoil layer, a mixed layer enriched with humus, a humus layer, and a top layer of litter cover. Humus, formed through the partial decomposition of plant and animal matter, provides essential nutrients for the growth of trees (Figure 4). They also advise how to heal soil structures depending on their types, such as sand, clay, or peat, as shown in Table 1.

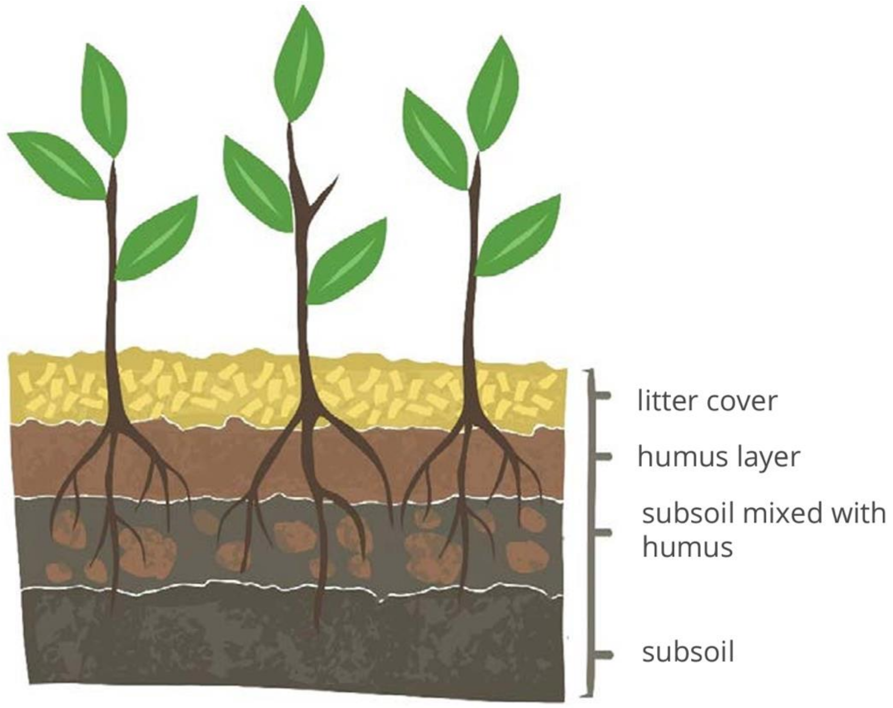

Figure 4. Tiny forest soil structure (Bruns et al. 2019).

Table 1. Choosing soil supplements to heal the structure (Bruns et al. 2019).

Soil Type	Which supplement should be added?	Supplement function	How much?
Sand	Ripe compost from organic waste or peat	Ensures that the soil can hold more water and makes the soil more nutrient-rich.	5 – 10 kg/m^2
	Add dried manure from goats, horses, or cattle.	Nutrients for young saplings.	5 – 10 kg/m^2
Clay	Straw cut into small pieces.	Straw helps loosen clay soils, which makes it easier for trees to take root.	5 – 10 kg/m^2
	Ripe compost from organic waste.	Nutrients for young saplings.	5 kg/m^2
Peat	Straw cut into small pieces.	Straw helps loosen peat soils, which makes it easier for trees to take root.	5 kg/m^2

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Once the necessary soil supplements have been selected and procured, soil preparation at the planting site can commence. This process typically involves using heavy machinery, including excavators, dump trucks, and graders. Ottburg et al. (2018) cataloged the phases of soil preparation for a tiny forest facilitated in Zaanstad, Netherlands, within their case study application notes (Figure 5).

Figure 5. Preparing the soil for planting and maintenance process (Ottoburg et al. 2018; Bruns et al. 2019).

Ottburg et al. (2018) explain the seven steps in their case. In the first phase, soil supplements are delivered to the planting location. In the second phase, the length and width of the Tiny Forest down to 1 meter deep were excavated, and the excavated dirt was placed next to the trench. Half of the dirt was poured back into the trench in the third phase. Half of the soil supplements were poured into the trench in the fourth phase and spread evenly over the planting surface. In the fifth phase, the soil supplements were mixed through the dirt using the excavator. In the sixth phase, the rest of the excavated dirt was poured back into the trench and mixed in the other half of the soil supplements. Lastly, the soil was ready for planting.

Planting and Maintenance Process

While soil preparation is about to be completed, research on the supply of plants can be started. Miyawaki gave importance to the youngness of the plants when choosing them. He did not prefer saplings with thick and tall trunks (Aarthi et al., 2021; Poddar, 2021; Meguro et al., 2021). After planting pits are opened in the field, primary or secondary school students generally plant the saplings together (Figure 6). Because children's weight is less than that of adults, it prevents the root area from being seriously crushed. At this stage, the sociological aspect of the project also comes to the fore. While ground cover, herbaceous, and shrub species are preferred on the edges of the land, tree species that will grow in height are planted towards the center. A dense planting of up to three plants per square meter is preferred. When the soil is optimal regarding plant nutrients and water retention capacity, plants begin to proliferate by competing to receive more sunlight (Daou et al., 2024). Communities around the world have widely embraced the innovative Miyawaki method. It has been proven effective in restoring and conserving degraded areas. Using the latest ecological and biodiversity census done on the Miyawaki forest in Sumatra, the increased progression in species recolonization from the initial to the final stage of the forest has been successfully documented. Such evidence caters to the continuous eligibility for such projects for carbon offset funding (Zsolnai & Bajor, 2021; Lewis, 2022; Mandowara, 2022; Sandeep et al., 2022; Sharma et al., 2024).

Figure 6. Planting phase with children (UNESCO, 2024; Morino Project, 2024).

Community Engagement and Involvement

As a flourishing forest will need to be enjoyed by all for generations to come, community engagement is a crucial part of any Miyawaki forest project. Of course, by regenerating native forests, the environment and wildlife will benefit. However, the human community must agree that a forest is desirable in the chosen area, and a sense of local ownership and stewardship needs to be generated. Also finally, the education and

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personal development created by the involvement of all community sections in this kind of project is incalculable. While the inclusion of children in sapling planting activities is especially important as it provides better results for the root health of plants, it also increases children's awareness of issues such as environmental problems, biodiversity, and urban ecosystem at an early age (Zsolnai & Bajor, 2021; Xiaoqin et al., 2021; Mandowara, 2022; Charkow, 2022).

Monitoring and Evaluation

Monitoring and evaluation are essential components of the Miyawaki method, ensuring the long-term success of afforestation projects. Miyawaki emphasized these processes as a response to the ineffective 'gardenification' of large conservation areas, advocating for a scientifically driven approach to urban forestry (Kurian, 2020; Zsolnai & Bajor, 2021).

Before planting, the site undergoes detailed mapping and soil fertility assessments, including nitrogen, phosphate, and soil moisture tests, to determine optimal conditions for tree growth (Xiaoqin et al., 2021). Unlike landscapes dominated by grasses and wildflowers in early ecological succession, shrubs dominate in mid-succession, forming the foundation for forest development. In tropical mixed forests, full maturity typically takes 30 to 50 years. However, a reasonable ten-year goal is to reach an open canopy stage, fostering biodiversity accumulation and increasing the presence of plant and animal species (Lewis, 2022).

The Miyawaki afforestation process is highly site-specific, accounting for land size, location, and natural resources. Public participation is integral, with communities selecting tree species best suited to local soil conditions and project objectives. Tree shelters and canes are used, particularly in the early months, to protect young saplings and prevent damage from wildlife. Unlike traditional planting methods, where one person digs and plants each tree, the Miyawaki technique promotes collective participation in afforestation efforts (Kurian, 2020; Zsolnai & Bajor, 2021; Xiaoqin et al., 2021; Lewis, 2022).

CHALLENGES AND LIMITATIONS

While the Miyawaki Afforestation Technique has demonstrated significant ecological benefits, its broader application faces several challenges that must be carefully considered. These challenges include climatic adaptability, soil preparation contradictions, land availability, public perception, and economic feasibility.

Climate Adaptability

The Miyawaki method, conceptualized by Akira Miyawaki, represents a reforestation technique focusing on the rapid establishment of native forests within constrained areas. Despite its growing acclaim for promoting ecological diversity, several critiques underscore its limitations and potential pitfalls. A notable concern regarding the Miyawaki method is its effectiveness across varying ecological contexts.

Schiavone et al. contend that, although the method is grounded in self-organized criticality and cooperation theories, its application within Mediterranean forest restoration initiatives has not consistently demonstrated favorable outcomes. They postulate that the biocoenotic relationships promoted by the Miyawaki method may not invariably culminate in a dynamic equilibrium, a critical component for sustainable forest ecosystems (Schiavone et al., 2010). This raises the possibility that the method lacks universal applicability and could engender ecological imbalances in particular environments.

Furthermore, the method's dependence on elevated planting densities may foster interspecies competition, inhibiting growth, and diminishing biodiversity. Nayak and Solanki assert that while the method aspires to restore natural vegetation, introducing a multitude of species nearby can inflict stress on individual plants, thereby impeding their maturation and the establishment of a balanced ecosystem (Nayak & Solanki, 2022). This perspective suggests that the Miyawaki method may unintentionally disrupt the natural processes it aims to enhance.

Additionally, the methodology's necessity for intensive initial care and maintenance prompts inquiries regarding its practicality and sustainability. The substantial initial investment in labor and resources may prove unfeasible for specific communities or regions, particularly those grappling with economic constraints. The imperative for continued management to secure the survival of planted species could further detract from the method's appeal as a swift solution for reforestation. However, it is important to note that specific references to substantiate this claim were not found in the provided literature, leaving this point largely unverified.

Moreover, the Miyawaki method has faced criticism for potentially disregarding local ecological knowledge's significance. In certain instances, the method's standardized approach may inadequately account for the idiosyncrasies of local ecosystems, resulting in the introduction of non-native species or neglecting crucial ecological interactions. Such oversights can undermine the long-term viability of reforestation endeavors, as the method may fail to adequately address the unique requirements of the local environment (Kiboi et al., 2014).

In summary, while the Miyawaki method offers a novel approach to reforestation, it is imperative to evaluate its applicability and efficacy across diverse ecological contexts critically. The aforementioned concerns regarding ecological sustainability, practicality, and the necessity for localized knowledge underscore the importance of fostering a more nuanced understanding of reforestation strategies that can effectively navigate the complexities inherent in various environments.

Soil Preparation and Contradictions

The soil preparation phase is the technique's most critical and expensive phase. Unfortunately, soils in urban areas are often problematic. According to the analysis results of soil samples taken from

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the field, deficient and excess plant nutrients and chemical or biological pollution elements in the soil are determined. If there is a level of pollution that cannot be cleaned, it may be necessary to dig up and dispose of the soil in the field to a large extent and replace it with a healthy soil layer, which is a very laborious and long phase. The main goal in soil preparation is to have dense organic matter on the upper part of the soil, to be deep and fluffy, and to be processed, just like in a forest, quickly.

The soil in the area to be applied is excavated about one meter. An excavator is required for this phase. According to the analysis and structure result, the excavated soil is mixed with different preparations and filled back into the excavated area. This stage is critical for improvement if there is a problem in the soil structure (such as dense clay layers or hard, impermeable zones). The new mixture filled into the planting area is not compacted. Leveling work is done with rakes, and the seedling planting stage has started. The soil is compacted due to the use of heavy vehicles during the excavation stage. However, the point is that these vehicles do not go above the ground where the soil is processed. It is important that the soil is not compacted and does not harm the young roots of the newly developing plants. This is why Miyawaki generally preferred to have children plant the young saplings.

However, the impact of afforestation on soil health has been a contentious topic. Studies by Kong et al. and Qi et al. reveal that afforestation can decrease microbial diversity and functionality in soil, which is essential for maintaining healthy ecosystems (Kong et al., 2022; Qi et al., 2022). This reduction in soil health can undermine the ecological benefits afforestation techniques like Miyawaki aims to provide, further complicating public perception of their efficacy. Additionally, Guo's research indicates that different afforestation methods, including Miyawaki, can adversely affect understory vegetation and soil quality. This suggests that the outcomes may vary significantly based on local conditions and implementation practices (Guo, 2018).

Land Availability and Urban Constraints

One of the primary advantages of the Miyawaki method is its ability to create forests in small, degraded urban spaces. However, its effectiveness is often maximized in larger, contiguous areas where species interactions can thrive. In densely populated cities with scarce and expensive land, allocating sufficient space for Miyawaki forests may not always be feasible. Additionally, there is a paradox in the literature. While some sources promote Miyawaki as suitable for small urban spaces, others suggest that significant land areas are necessary for a self-sustaining forest. Policymakers and urban planners must assess whether the method can be integrated into fragmented green networks or is more suitable for peri-urban and suburban areas.

Public Perception and Social Functionality

Public acceptance of the Miyawaki method poses another challenge. Conventional urban parks are designed for recreation and accessibility, providing open spaces for walking, exercise, and social gatherings. In contrast, Miyawaki forests prioritize dense vegetation and ecological restoration, often limiting direct human interaction. The aesthetic of a densely packed urban forest may be perceived as unstructured or unkempt, which could lead to resistance from communities accustomed to manicured green spaces. To increase public acceptance, hybrid models that combine Miyawaki forests with recreational green spaces could be explored, ensuring both ecological and social benefits.

Economic Feasibility

Implementing the Miyawaki method often involves significant initial expenses due to intensive ground preparation, dense planting, and the need for ongoing maintenance in the early stages. These requirements can make the method financially demanding, particularly when applied over extensive areas. Dr. Derrick Lai, an associate professor at the Chinese University of Hong Kong, notes that while the method promotes rapid tree growth and high survival rates, it necessitates substantial investments, which may not be practical for large-scale afforestation in developing countries (Lee, 2023).

The method's resource demand—including labor, materials, and energy—can pose logistical and financial challenges. The necessity for soil rejuvenation, dense sapling planting, mulching, and subsequent watering and weeding contributes to the overall costs, potentially limiting its applicability in regions with constrained budgets (Rewilding Academy, 2024).

Urban planners, policymakers, and researchers can develop strategies to optimize the Miyawaki method for diverse urban contexts by addressing these challenges. While the technique holds promise for ecological restoration, its long-term success depends on careful integration with existing urban planning frameworks and continued empirical assessment.

CONCLUSION

The Miyawaki Afforestation Technique constitutes a noteworthy strategy for enhancing urban green infrastructure, characterized by its capacity to facilitate rapid forest development, bolster biodiversity, and mitigate environmental stressors. However, the technique's effectiveness is contingent upon several determinants, including land availability, maintenance requirements, and climate compatibility. While empirical evidence showcases its ecological successes across numerous urban initiatives, the scalability and adaptability of the Miyawaki method necessitate further exploration.

Ecological Benefits

From an ecological perspective, Miyawaki forests are pivotal in bolstering urban resilience. Their functions include carbon

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sequestration, pollutant filtration, and the provision of essential habitats for many species. Furthermore, these forests contribute to soil health enhancement and the urban heat island effect mitigation, positioning them as valuable instruments for climate adaptation. Nevertheless, uncertainties regarding their long-term ecological efficacy in non-tropical climates remain, underscoring the need for additional empirical research.

Social and Economic Considerations

Socially, Miyawaki forests have the potential to cultivate community engagement, promote environmental education, and foster local stewardship, thereby instilling a heightened sense of ecological responsibility among urban residents. Conversely, these forests' dense and self-sustaining characteristics might conflict with public expectations regarding accessible and recreational green spaces. A hybrid approach that merges Miyawaki forests with thoughtfully designed recreational areas may provide a viable solution for balancing ecological integrity and public usability.

Economically, while Miyawaki forests promise long-term cost reductions through diminished maintenance demands and enhanced ecosystem services, the associated initial investment and soil preparation expenses present significant challenges. Innovative financial models, including public-private partnerships and municipal funding incentives, merit further investigation to facilitate broader adoption of this technique.

Addressing Challenges and Future Directions

A fundamental challenge is ensuring that Miyawaki forests are appropriately integrated within urban planning frameworks and land-use policies. Planners must evaluate the compatibility of these forests with existing urban networks and determine whether they should be prioritized in specific locations, such as underutilized or degraded sites. Policymakers should also contemplate the establishment of standardized methodologies to enhance the replication and scalability of the Miyawaki technique across diverse contexts.

Final Thoughts

To comprehensively assess the Miyawaki Afforestation Technique, a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis provides a structured evaluation of its potential and limitations.

- Strengths: Rapid growth, high biodiversity, minimal long-term maintenance, carbon sequestration, and climate resilience make it a valuable afforestation tool.
- Weaknesses: High initial investment, intensive soil preparation, suitability concerns in non-tropical climates, and limited public accessibility challenge its implementation in urban settings.
- Opportunities: Growing global emphasis on sustainability, climate adaptation policies, urban reforestation initiatives, and increasing environmental awareness create a favorable environment for the method's expansion.

- Threats: Urban land scarcity, public resistance to unmanaged green spaces, financial constraints, and the need for long-term monitoring may hinder widespread adoption.

By addressing these strengths and mitigating the weaknesses while capitalizing on emerging opportunities, urban planners and policymakers can integrate the Miyawaki method effectively into sustainable city strategies.

In conclusion, the Miyawaki technique represents a transformative methodology for urban greening, aligning with Sustainable Development Goal 11 (SDG 11) by striving to render cities more sustainable, resilient, and livable. However, the successful implementation of this technique necessitates a comprehensive understanding of the spatial, financial, and societal constraints involved. Future research should prioritize optimizing its application across varied climatic conditions, evaluating its socio-economic impacts, and integrating its principles more seamlessly into urban planning agendas.

Thus, while the Miyawaki technique holds substantial promise, its contribution to urban sustainability must be contextualized within a broader framework considering ecological functionality, public accessibility, and economic viability. By addressing these critical dimensions, urban centers can unlock the full potential of the Miyawaki method as an instrument for sustainable urban regeneration.

Ultimately, the Miyawaki technique offers a promising solution for urban afforestation, but its success depends on its adaptation to local conditions and integration into urban policy frameworks.

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Resume

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