

**EXPLORING BIODIVERSITY IN MIYAWAKI  
AFFORESTED AREAS: A CASE STUDY OF VADODARA  
DISTRICT**

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# **EXPLORING BIODIVERSITY IN MIYAWAKI AFFORESTED AREAS: A CASE STUDY OF VADODARA DISTRICT**

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### Ethical Compliance Certificate 2024-2025

This is to certify Ms. Cheshta Soni study titled; "Exploring Biodiversity and its Ecological Benefits in Miyawaki Afforested Areas: A Case Study of Vadodara District." from Department of Family and Community Resource Management has been approved by the Institutional Ethics Committee for Human Research (IECHR), Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda. The study has been allotted the ethical approval number IECHR/FCSc/M.Sc./10/2024/23.

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## CERTIFICATE

This is to certify that the thesis entitled "EXPLORING BIODIVERSITY IN MIYAWAKI AFFORESTED AREAS: A CASE STUDY OF VADODARA DISTRICT" submitted for partial fulfilment of the requirement for the degree of Masters in the Faculty of Family and Community Sciences (Family and Community Resource Management) to the Maharaja Sayajirao University of Baroda, carried out by **Ms. Cheshta Soni**, is her original bonafide work.

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Vadodara

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# INTRODUCTION

# CHAPTER I

## INTRODUCTION

The world nations have been witnessing rapid urbanization and by 2050, about 66 percent of the global populace is anticipated to reside in cities. India has also witnessed hasty urbanization during the last few decades and currently, the urban dwellers constitute well beyond 32 percent of total population that is likely to continue in the future. (Kumar et al., 2017). The natural world's wild plant and animal species are deteriorating as a result of historical deforestation and resource degradation (Miyawaki, 1999). The primary human-caused global consequences that are devastating natural habitats and raising the risk of desertification include changes in global climate, together with the recent and rapid urbanization and industrialization. Over the past twenty years, researchers have gained fresh perspectives on the theoretical and practical approaches for rebuilding and restoring natural ecosystems. Increasing the amount of vegetation or green patches or urban forests is one of the most effective strategies to mitigate the effects of the urban microclimate (Devadas and Rose, 2009).

### 1.1 Need for Green Space

Global climatic changes, together with recent rapid urbanization and industrialization, have been the main anthropogenic effects worldwide in destroying natural environments and increasing risk of desertification (Miyawaki, 1999). The unexpected natural disasters viz., flood, drought, rise in sea level could affect not only the community and the ecology of the region. The deforestation and degradation of natural resources carried out in the past leads to deterioration of wild plant species and animal kingdom (Kleinschroth and Kowarik 2020; Ugolini et al. 2020; Burnett et al. 2021). For addressing climate variations, restoring forest ecosystems and recreating forests could be better solution. Since the creation of forests could take much more years, the technique of creating green cover in shorter span of time also gains importance across the continents. More coherent initiatives viz., expanding forest cover, restoration for forests and urban forests are imperative and need of the hour. Accessible greenspace is growing in importance in urban areas around the world. For example, many residents sought access to natural reserves or outdoor spaces within

their neighborhood to engage in recreation and to de-stress during the COVID-19 pandemic (Kleinschroth and Kowarik 2020; Ugolini et al. 2020; Burnett et al. 2021), with the number of visits to forests nearby to cities increasing by 40% in some cases (Suda et al. 2021). Yet, forests where people can connect with nature may not be available within many urban landscapes. In response, cities are asking how they can design and implement greenspaces within a city's-built fabric that are accessible to all (Wolch et al. 2014; Bush 2017; Anguelovski et al. 2018; Tozer et al. 2020). Because space is often limited for public urban greenspace creation or transformation, new methods are needed to create or restore forests within urban areas that optimize the space for maximizing vegetation structure and biodiversity (Klaus and Kiehl, 2021). There is a need for performing more environmental conservation activity, as well as using innovative environmental recovery activities. In the last two decades, scientists have developed new insights both in theoretical and in practical actions for restoration and reconstruction of natural ecosystems. Natural restoration is strictly related to increased sustainability and includes rehabilitation of ecosystem functions, enlargement of specific ecosystems, and enhancement of biodiversity restoration. Miyawaki method is a one such potential technique of restoring the forest and ecology as well (Miyawaki, 1999).

## **1.2 Origin of Miyawaki Technique**

The Miyawaki method was developed by Akira Miyawaki, a renowned Japanese botanist and ecologist, in the 1970s. Miyawaki's inspiration came from observing natural forests' resilience and biodiversity. He sought to create forests that could mimic the characteristics of natural ecosystems and accelerate the recovery of native flora and fauna. The method was developed in response to the increasing concerns about deforestation, urbanization, and loss of biodiversity. Unlike traditional reforestation techniques that relied on planting large, spaced-out trees, Miyawaki proposed a denser, more ecologically diverse approach (Miyawaki, 2004). Taking several hundred years to complete the process of forest restoration is too long, because people live in a world where industry and urbanization are developing very rapidly, for instance, 110 cars are manufactured per minute whereas 36 football ground area of forest is being lost so improvement of an alternative reforestation technique that reduces the time could be a useful tool (Miyawaki, 1999). A typical

characteristic of a Miyawaki forest is that trees are planted very close to each-other. In just one square meter, usually three trees are planted. The idea is to create an organic and dense forest with rich biodiversity. (Parikh and Nazrana, 2023)

According to this method, restoring native green environments, multilayer forests and well-developed ecosystems can be quickly established because of the simultaneous use of intermediate and late successional species in plantations through careful ecological engineering and human intervention in an organic and sustainable manner. The Miyawaki technique has been followed in Japan, South American countries, Far East and Malaysia in the environmentally degraded lands as well as urban landscapes. In shorter span of time, more urban forests were developed. The urban forests have multi facet advantages such as reduction in temperature, air quality improvement, CO2 sequestration, improvement of wellbeing indicators and also hike in real estate prices (Kavana, 2023).

### **1.3 Miyawaki Technique and Biodiversity**

Miyawaki method of growing forests has gained much popularity all over the world. In India also, it is touted as one of the most efficient methods to green the urban areas. Traditionally, the forests grown by the Forest Department had the single objective of growing timber and getting money with the plantation. Monoculture was the chief method of afforestation. Even for social forestry, at the most 6-10 species were planted. Unfortunately, that does not give the biodiversity that natural forests bring. When the diversity in the flora is limited, it affects the fauna. Each bird makes a nest in a different kind of tree, each insect species makes home in a different plant. Extinction of species has accelerated over last few centuries. Thus, an afforestation method that encourages many species to take shelter in the new forest can serve an urgent ecological need. If the manmade forest has to mimic the ecosystem of a natural forest, it has to have a large variety of flora. In Miyawaki method, almost 80-90 species of vegetation are planted in one acre of land. The vegetation includes trees, plants, shrubs, grass, canopy and timber. Thus, it tries to introduce rich biodiversity in a small area. It should be mentioned here that the forests created by the Miyawaki method still have much lesser biodiversity compared to a natural forest. Native species that already used to grow in the area without any human intervention are given priority while selecting the species (Parikh and Nazrana, 2023).

Miyawaki forests play a vital role in conserving biodiversity like Habitat creation by replicating natural ecosystems, these forests provide habitats for a wide range of plant and animal species. Attracting native fauna where native plant species attract insects, birds, and other wildlife, fostering a diverse and self-sustaining ecosystem. The use of native plant species in Miyawaki forests helps preserve the genetic diversity of local flora, which is essential for adaptation to changing environmental conditions and Miyawaki forests contribute to the restoration of degraded ecosystems, helping recover native species and their interactions (Niranjan et al., 2023)

#### **1.4 Benefit of Miyawaki Technique**

The Miyawaki technique has been used successfully to restore the forest in many places. The benefits of this method are selecting as many native canopy species as possible based on the potential natural vegetation at each site by the phytosociological method. The Miyawaki technique helps to grow many trees in a limited space in a brief period of time and grow a forest similar to a natural forest (Safvan and Swapna, 2023). The other benefits of Miyawaki forests include, rapid restoration of land, development of an entire ecosystem (instead of just plants), much faster development of greenery as compared to conventional forests, minimal maintenance and care, low-cost, etc (Singh and Saini, 2019). The Miyawaki Forest method represents a paradigm shift in reforestation and biodiversity conservation. Its focus on biodiversity, rapid growth, and adaptability to urban environments makes it a powerful tool in the fight against climate change and ecological degradation. The Miyawaki Forest method offers a sustainable and effective solution to address some of the most pressing environmental issues (Niranjan et al., 2023) Best method to restore the forest and ecology in shorter period of time. Revolutionized the concept of urban afforestation. Increase the green cover by converting the urban backyard into a mini forest. The technique is 100% organic, which provides 10 times faster Plant growth, 20 times increased biodiversity, 30 times denser than usual hence saves the space as well. It encourages the movement of different birds, insects there by maintaining the ecosystem and ecology naturally. This technique creates a forest in 20 to 30 years, while though conventional methods take 200 to 300 years. There is no maintenance after 3 years (Kavana 2023).

The rapid urbanization and industrialization worldwide have led to significant environmental degradation, biodiversity loss, and the exacerbation of urban heat island effects. The Miyawaki method, developed by Akira Miyawaki, offers a compelling solution to combat these challenges by rapidly establishing dense, multi-layered forests that mimic natural ecosystems. This method not only accelerates forest restoration in urban areas but also contributes to mitigating urban heat island effects, improving air quality, and providing habitats for diverse flora and fauna. Moreover, the Miyawaki technique emphasizes biodiversity, rapid growth, and adaptability to urban environments, making it a powerful tool in the fight against climate change and ecological degradation (Singh and Saini, 2019). Benefits of the Miyawaki method are substantial, including rapid restoration of land, development of entire ecosystems, minimal maintenance requirements, and low cost. By promoting the growth of numerous native canopy species, this method offers a sustainable and effective approach to address pressing environmental concerns. It revolutionizes the concept of urban afforestation, fostering increased greenery development in urban spaces, and providing a beacon of hope in the endeavor for a more resilient and sustainable future. In light of the urgent need for environmental conservation and the restoration of degraded ecosystems, widespread adoption of the Miyawaki method holds tremendous promise in addressing the challenges posed by urbanization and climate change. It is crucial to embrace innovative techniques such as the Miyawaki method to create a more sustainable and biodiverse urban environment for future generations (Parikh and Nazrana, 2023)

### **1.5 Miyawaki Technique and Humidity, Temperature and Air Quality**

Miyawaki forests are crucial for raising local humidity, which is particularly beneficial in urban areas since development frequently lowers atmospheric moisture. Improved humidity levels are the result of these forests' increased evapotranspiration, canopy interception, and soil moisture retention. Because of the dense vegetation's ability to efficiently retain moisture, surface temperatures are lowered and severe soil drying is avoided (Niranjan et al., 2023). Urbanization and climate change have significantly contributed to rising temperatures, particularly in cities where the urban heat island (UHI) effect intensifies heat accumulation. The Miyawaki technique afforestation, that promotes

rapid forest growth, has gained attention for its role in mitigating urban heat by enhancing green cover and creating localized microclimates. These processes collectively contribute to cooling effects, reducing surface and ambient temperatures in urban areas (Kurian, 2022). The Miyawaki technique significantly improves air quality by increasing green cover and enhancing natural air filtration processes. The dense vegetation in Miyawaki forests acts as a natural air purifier, capturing airborne pollutants such as particulate matter (PM<sub>2.5</sub> and PM<sub>10</sub>), carbon dioxide (CO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), and sulfur dioxide (SO<sub>2</sub>). Through photosynthesis, trees absorb CO<sub>2</sub> and release oxygen, contributing to cleaner air. The thick foliage and multi-layered structure of these forests help reduce dust, trap pollutants, and mitigate the impact of vehicular and industrial emissions (Parikh and Nazrana, 2023).

### **1.6 Justification of the study**

With the rapid pace of urbanization and industrialization, environmental degradation, biodiversity loss, and increasing urban temperatures have become pressing concerns. The Miyawaki technique is a suitable approach for addressing these issues, as it enables the rapid establishment of dense, biodiverse green spaces. Transforming land into thriving green areas enhances environmental sustainability while improving urban aesthetics and ecological balance. Evaluating biodiversity changes in Miyawaki-developed areas is essential to understanding their ecological benefits. This assessment helps determine the effectiveness of the method in promoting biodiversity conservation and creating habitats for various flora and fauna. Miyawaki-based green spaces contribute significantly to mitigating the Urban Heat Island effect by providing shade, enhancing evaporative cooling, and reducing surface temperatures, thus improving overall urban climate conditions. The content of multimedia resource will later to diverse learning preferences, making information on Miyawaki Technique more accessible and understandable for a wide audience. Raising awareness about biodiversity Conservation, Urban afforestation and climate change mitigation through this resource will foster a culture of environmental responsibility.

Courses such as “Landscaping and Gardening”, “Environment Education”, “Ecology and Environment”, “Landscape and Garden Designs”, “Environment Science” are offered at under-graduate and post graduate level of study in the Department of Family and Community Resources Management. Hence, the findings gathered from the present research would widen the information and will help in strengthening the curriculum.

Several studies undertaken in the department related to topic which were focused around “Japanese Garden” (Shah 2005), “Community Gardens” (Shah 2011), “Outdoor Garden Design” (Doshi 2011), “Designing Terrace Garden” (Chonkar 2013), “Designing Vertical Garden” (Pavasiya 2014). Several researches found during reviewing relevant literature studies focused on “Awareness of Miyawaki technique” (Ullah et.al.,2023), “Biodiversity and Miyawaki Technique” (Niranjan et.al., 2023; Swapna et.al., 2023), “Development of Urban spaces through Miyawaki technique” (Goveanthan et.al.,2019; Manuel 2020; Poddar 2021; Sandip et.al., 2022; Egerer et.al., 2023; Kavana 2023; Parikh et.al., 2023) “Urban Heat Island Mitigation through Miyawaki technique” (Kurian 2020), “Sustainable solution for urban environment through Miyawaki technique” (Singh 2019; Cárdenas 2022; Charkow 2022; Pillath 2023). Hence, it could be concluded that the researches conducted within the department has primarily focused on conventional garden development, and existing studies on the Miyawaki technique mainly explore its concept and implementation. It has highlighted the role of urban forests in promoting a sustainable built environment. However, limited studies have specifically examined the biodiversity and ecological benefits of Miyawaki afforested areas in Indian cities like vadodara. The relationship between Miyawaki forests and their impact on urban ecosystems, temperature regulation, and air quality remains underexplored. Thus, it is critical to assess the effectiveness of these afforested areas.

The findings of the study will be beneficial and helpful to the Landscape designer, Urban space designer and Interior designer as they can incorporate Miyawaki technique and approaches into their design’s projects. It will also be equally helpful and valuable information to the students of “Interior Design” specialization to gain knowledge about the Miyawaki technique, enriching their understanding and expanding their repertoire of design strategies. The multimedia resource developed would foster in raising awareness

about the benefits of the Miyawaki technique, encouraging community participation in urban greening efforts, and inspiring eco-friendly initiatives in residential and public spaces. By advocating for increased green cover in cities, this research will support the broader goal of creating healthier, more sustainable, and livable urban environments for future generations.

### **1.7 Statement of Problem**

To explore the biodiversity and ecological benefits of Miyawaki afforested areas in Vadodara district, by analyzing flora and fauna diversity, assessing changes in humidity, temperature, and air quality.

### **1.8 Objectives of the study**

1. To analyze the diversity of Flora and Fauna within Miyawaki afforested areas in Vadodara district.
2. To find out the perceived changes in ecological benefits such as humidity, temperature and air quality within Miyawaki afforested areas.
3. To develop a multimedia resource to enhance awareness and understanding of Miyawaki Technique for afforestation.

### **1.9 Delimitations of the study**

1. The study was limited to areas within Vadodara district.
2. The study was limited to 7 selected Miyawaki afforested areas.



# REVIEW OF LITERATURE

## **CHAPTER II**

### **REVIEW OF LITERATURE**

The major areas of related literature, scholarly articles, thesis, research papers, and other sources relevant to the area of research are presented here. For the present study literature was thoroughly reviewed to gain knowledge for the study. To be familiar with the subject matter concerned with the present research problem, a survey of the literature was undertaken. To provide a clear and better understanding of the literature reviewed for the present study, the chapter is presented under the following subheadings:

#### **2.1 Theoretical orientation**

For the presentation, the theoretical literature was divided into following subheads namely:

2.1.1 Need of Miyawaki Technique

2.1.2 Advantages of Miyawaki Technique

2.1.3 Developing Green Spaces using Miyawaki Technique

2.1.4 Impact of Miyawaki Technique on Biodiversity

2.1.5 Ecological Benefits of Miyawaki Technique

2.1.6 Miyawaki in India

#### **2.2 Related researches**

2.2.1 Researches conducted within India

2.2.2 Researches conducted outside India

#### **Conclusion**

## 2.1 Theoretical orientation

### 2.1.1 Need of Miyawaki Technique

The removal of existing green cover in cities to make way for construction and other projects has been a major casualty of India's rapid urbanization. With people demanding that a good quality of life include not only conserving, but also adding to the city's green cover, Vadodara, like other cities, is experimenting with ways to create small green areas in an ever-expanding concrete urban landscape. Planting greater bushes enables to hold wholesome soils and humidity tiers within side the air across the world. Trees take in air and transpire it lower back into the atmosphere, successfully filtering and controlling the ranges of humidity anywhere they are. In the past 5-6 decades, scientists have gained new insights in the theories and practical actions of restoring and rebuilding natural ecosystems (Clewell and Aronson 2007; Falk et al., 2006; Jordan et al., 1981).

Forests have long been recognized as vital components of our planet's ecosystem. They play a crucial role in maintaining biodiversity, regulating climate, and providing essential resources for human survival. However, in recent decades, deforestation, urbanization, and unsustainable land-use practices have led to the rapid degradation of forest ecosystems worldwide. As the world grapples with the challenges of climate change and biodiversity loss, innovative solutions are needed to restore and protect our forests. One such solution is the Miyawaki technique, a term synonymous with ecological rejuvenation and environmental conservation, has gained widespread acclaim and recognition for its remarkable contributions to reforestation efforts worldwide, named after the Japanese botanist Dr. Akira Miyawaki, this unique approach to forest restoration has inspired communities and conservationists alike to combat deforestation and combat the adverse effects of climate change. Miyawaki Forests, also known as Miyawaki Method or Miyawaki Afforestation, involve creating small, dense, and diverse native forests in a relatively short period. These forests are designed to mimic natural ecosystems and promote biodiversity while also providing ecological and environmental benefits. Miyawaki Forests have proven successful in a wide array of landscapes, from urban areas to degraded farmlands. Their adaptability

and rapid growth make them invaluable tools in restoring ecosystems and reclaiming land from desertification. Additionally, they improve soil quality, prevent erosion, and enhance water retention, further contributing to the wellbeing of the environment. Furthermore, the concept of Miyawaki Forests extends beyond environmental benefits. These miniature forests serve as a symbol of community engagement and environmental stewardship. Local communities often take an active role in planting and nurturing these forests, fostering a sense of ownership and responsibility for the natural world (Miyawaki, 2004).

### **2.1.2 Advantages of Miyawaki Technique**

A very successful and sustainable reforestation method that promotes biodiversity, slows down climate change, and speeds up forest growth is the Miyawaki plantation. Dense plantings of native species improve air quality and sequester carbon while establishing self-sustaining ecosystems that support a variety of plants and animals. With trees growing up to ten times quicker than on regular plantations, this technique encourages rapid afforestation, which makes it a perfect way to battle urban heat islands and restore damaged land. Miyawaki forests save water, boost soil fertility, need less upkeep, and offer green areas that promote community involvement and mental health. This method is an effective instrument for sustainable urban development and environmental restoration that is both economical and space-efficient (Kavana, 2023).

The Miyawaki plantation is an innovative and effective reforestation approach that provides several advantages over traditional afforestation methods.

1. One of its key benefits is the restoration of biodiversity in degraded areas. By planting a diverse mix of native species in close proximity, this technique fosters a self-sustaining microclimate that accelerates growth and enhances ecosystem resilience, making the forest more resistant to pests and diseases.
2. Another significant advantage is its role in mitigating climate change. Trees act as natural carbon sinks, absorbing carbon dioxide from the atmosphere. The dense

planting pattern of the Miyawaki method maximizes carbon sequestration, thereby contributing to the reduction of global warming effects.

3. The Miyawaki method is also highly cost-effective. Due to its compact design, a dense forest can be established in a relatively small area, reducing both planting and maintenance costs. Additionally, the rapid growth rate of Miyawaki forests results in quicker ecosystem recovery with minimal intervention.
4. Beyond environmental benefits, Miyawaki forests enhance urban spaces by improving air quality, reducing noise pollution, and creating a green refuge that supports mental well-being and community engagement.

Overall, the Miyawaki plantation is a sustainable, efficient, and eco-friendly solution for restoring degraded land, fostering biodiversity, and combating climate change<sup>(2)</sup>.

### **2.1.3 Developing Green Spaces using Miyawaki Technique**

The Miyawaki technique has been widely adopted in Japan, South America, the Far East, and Malaysia for restoring degraded ecosystems and enhancing urban landscapes. This method has successfully transformed barren and underutilized lands into thriving urban forests within a short period. By promoting high-density plantation using native species, Miyawaki forests accelerate ecological restoration, improve soil health, and foster self-sustaining biodiversity. These urban forests offer multiple environmental and socio-economic benefits. They help mitigate the Urban Heat Island effect by reducing ambient temperatures, enhance air quality by filtering pollutants, and contribute to significant CO<sub>2</sub> sequestration. Additionally, they support psychological well-being by creating natural green spaces in densely populated areas.

Here are the step by step guide develop Green Spaces using Miyawaki Technique:

#### **Step 1: Assessing Soil Quality and Enhancing Biomass**

The first step in the Miyawaki method is to analyze soil texture to determine its fertility, water retention capacity, and percolation ability, all of which influence the forest's growth and sustainability. Additionally, measuring the existing biomass is crucial. To enrich the soil, the following elements are incorporated:

1. **Organic Fertilizers** – Essential for providing nutrients necessary for plant growth. Common organic fertilizers include cow dung, goat manure, and vermicompost.
2. **Perforating Materials** – These aid in root penetration and aeration. Materials such as rice husk, wheat husk, and groundnut shells enhance soil perforation.
3. **Water Retainers** – Maintaining adequate moisture is key for plant survival. Adding coconut coir and peat moss improves the soil's water retention capacity.
4. **Mulch** – A protective layer that prevents excessive soil drying. Decaying leaves, dried bark, and compost serve as effective mulch to safeguard saplings.

### **Step 2: Selection of Native Plant Species**

Choosing the right mix of native species is fundamental. Foresters must consider factors such as deciduous or evergreen classification, plant height, and ecological impact. The plant distribution should follow these guidelines:

1. The most commonly found species in the local environment should be 40-50%.
2. Moderately prevalent species that support biodiversity should be 25-40%.
3. Less common species that contribute to forest diversity should be 10-25%.
4. Saplings should be at least 60-80 cm in height before planting.

### **Step 3: Preparing the Land**

Before plantation, the selected site must be cleared of debris and weeds. The area should receive a minimum of 8-9 hours of sunlight daily. Essential preparations include installing irrigation facilities, creating 100-square-meter mounds, and marking planting zones.

### **Step 4: Execution of Plantation Process**

Developers should dig small holes, carefully remove the root bags from seedlings, and plant them while gently leveling the surrounding soil. Supporting sticks should be chosen based on the saplings' height to provide stability. Plant saplings that are up to 80 cm high, 3 to 5 saplings per square metre, once the soil has been modified to a depth of one metre (Poddar, 2021).

## **Step 5: Maintaining the Forest for Three Years**

The forest itself must be at least 100 square metres in size. After eight months, the forest has grown so dense that sunlight cannot reach the ground. Every drop of rain that falls is saved at this point, and every leaf that falls is transformed into humus. The more the forest expands, the more nutrients it produces for itself, allowing it to expand even faster. Individual trees begin to compete for sunlight as a result of this density, which is another reason why these forests develop so quickly. For the first two or three years, the forest has to be watered and weeded, after which it becomes self-sustaining. After then, it's ideal to leave the forest as undisturbed as possible so that its ecology, including animals, can settle in.

Post-plantation care is critical for the forest's development. This includes:

1. Daily watering, weed removal, and waste management.
2. Maintaining mulch levels for at least one year, ensuring it does not smother the saplings.
3. Avoiding trimming, chemical pesticides, and artificial fertilizers.
4. Allowing natural decomposition of fallen leaves to enrich the soil.

Using the Miyawaki method, forests can become self-sustaining within 2-3 years, compared to the traditional method, which takes nearly a century. Nonetheless, the Miyawaki method remains a promising approach for rapid afforestation and urban greening<sup>(1)</sup>

### **2.1.4 Impact of Miyawaki technique on Biodiversity**

Forests are vital for biodiversity, climate regulation, and human survival, yet they face rapid degradation. Miyawaki Forests, named after Japanese botanist Dr. Akira Miyawaki, is a pioneering approach to reforestation and environmental conservation. These small, dense, and diverse native forests mimic natural ecosystems, promoting biodiversity and providing ecological benefits. Developed in response to deforestation concerns, the Miyawaki Method involves densely planting native species in layers to create self-sustaining ecosystems. These forests sequester carbon rapidly, enhance soil

quality, and attract wildlife. Community engagement is integral to Miyawaki projects, fostering a sense of responsibility. Particularly valuable in urban areas, they improve air quality and quality of life. This method represents a transformative solution to global environmental challenges, emphasizing nature-based solutions for a sustainable future (Niranjan et.al, 2023).

Biodiversity conservation stands as a paramount objective in today's ecological discussions, supporting the preservation of ecosystem functions and services that are vital for human well-being (Cardinale et al., 2012). Forest ecosystems are important because they contain a wide variety of species and play a key role in climate regulation and adaptation (Oliver et al., 2015, Chazdon et al., 2016). However, the conservation of forest biodiversity is facing growing threats from human activities and environmental disturbances, highlighting the need for immediate intervention to minimise negative consequences (Brondizio et al., 2019, Sarre 2020). Forest management significantly impacts biodiversity dynamics, as management strategies have direct and indirect effects on species composition, habitat quality and ecosystem resilience (Lindenmayer and Franklin, 2002, Kroll et al., 2017, Jung et al., 2022, Konczal et al., 2023). In addition to management activities, climate change also affects biodiversity by altering temperature and rainfall patterns, which can change where species occur, their phenology or reproduction (Parmesan 2006).

The plant diversity enriches the soil with different nutrients. It also retains a lot of water because there is a great density of flora on the ground holding both the soil and water. A traditional manmade forest does not retain so much water. The dense forest makes the temperature fall. It also provides more forage that encourages pollinators and birds. More canopy cover discourages the growth of weeds and creates an amicable environment for the insects. Increased leaf litter protects the soil fertility. (Poddar, 2021) highlights carbon sequestration and soil health as the other benefits of Miyawaki forests. (Koziupa, 2021 and Kurian & Vinodan, 2022) add disaster resilience to the benefit list. It was pointed out several examples of such forests acting against ash, air pollution, and noise. When trees are planted so close to each other, they do not have space to grow in girth. They grow tall, to reach the sunlight. It is said that because of the small girth, there is little incentive to cut down the forest; it is not

possible to get much timber from it. Thus, the Miyawaki forest is grown only to help nature thrive; it does not satisfy the human greed for money. As the forests grow, in the middle of the places that had no wildlife to speak of, fauna start appearing. In small areas that are afforested, various types of snakes and lizards; rabbits and fox, tortoise and fish and a large variety of birds and insects can be found. These are not brought in by anyone, they just appear. Ecosystem seems to regenerate itself in enabling conditions. The intervention of humans is not needed in that (Parikh and Nazrana., 2023)

### **2.1.5 Ecological Benefits of Miyawaki Technique**

The Miyawaki method, developed by Japanese botanist Akira Miyawaki, is an afforestation technique that emphasizes the planting of native species in a dense, multilayered configuration to rapidly establish self-sustaining forests (Mongabay-India, 2019). This approach has been increasingly adopted in urban areas to mitigate environmental challenges, including air pollution and the urban heat island effect. Urban areas often grapple with poor air quality due to vehicular emissions, industrial activities, and other pollutants. Implementing the Miyawaki method in such settings has shown promise in enhancing air quality. For instance, a project at the Government School in Gulabi Bagh, Delhi, utilized this method to create a dense forest aimed at acting as a natural air filter. The diverse array of native species planted in close proximity works collectively to trap pollutants and release oxygen, thereby contributing to cleaner air (Rise Foundation, 2023). The urban heat island effect, characterized by elevated temperatures in urban areas compared to their rural surroundings, is exacerbated by the prevalence of concrete and asphalt surfaces that absorb and retain heat. Miyawaki forests can play a significant role in mitigating this phenomenon. The dense canopy provides shade, reducing surface temperatures and contributing to a cooler microclimate. Additionally, the process of transpiration from the multitude of trees increases atmospheric moisture, thereby enhancing humidity levels and further aiding in temperature regulation (Mongabay-India, 2019).

### **2.1.6 Miyawaki in India**

This strategy is steadily gaining traction in India. Afforest, a social company, collaborated with a variety of businesses and people to establish these forests. They recently collaborated with the Government of India's Department of Biotechnology (DBT) to transform a sewage-infested plot of land near the Barapullah drain. The drain was cleaned as part of a larger initiative called Local Treatment of Urban Sewage Streams for Healthy Reuse (LOTUS HR). DBT, the Ministry of Science and Technology, and the Government of India collaborated to build a demonstration facility to clean up the Barapullah drain. The foundation of the forest was set in July 2018 after early site inspections in January 2018 (Poddar, 2021).

Gujarat has embraced the Miyawaki technique to develop several urban forests, transforming degraded and underutilized areas into thriving green spaces. The Smritivan Earthquake Memorial and Museum, located on Bhujjiyo Hill, features the world's largest Miyawaki forest with over 500,000 trees. Developed in memory of the 2001 Gujarat earthquake victims, this forest serves as a living monument and contributes significantly to the ecological balance of the area. The memorial also includes 50 check dams adorned with plaques bearing the names of 12,932 earthquake victims (The Times of India 2024). In Gandhinagar's Kolvada region, a 10-hectare dumping site was rehabilitated into a dense forest using this method (Gujarat Samachar, 2022). Ahmedabad has also seen significant initiatives; the Gujarat Rajya Gram Vikas Samiti, in collaboration with the Ahmedabad Municipal Corporation, aims to plant 30,000 trees in Vastrapur (Gujarat Rajya Gram Vikas Samiti, 2023). Similarly, the Sabarmati Riverfront Development Corporation has implemented the Miyawaki method to enhance greenery along the riverbanks (IABCD, 2023). Additionally, at Ekta Nagar near the Statue of Unity, a Miyawaki forest has been developed adjacent to the SSNNL Circuit House hill, further promoting biodiversity and ecological balance in the region (Statue of Unity Package, 2023).

In Vadodara, an urban forest comprising 3,000 trees was established along Chhani Lake as part of the CapaCITIES project (ICLEI South Asia, 2023). These projects

collectively contribute to environmental sustainability and offer residents natural spaces for recreation and well-being. The Society for Clean Environment (SOCLEEN) developed the city's first Miyawaki forest and medicinal plant garden in Tandalja (The Times of India 2020).

## 2.2 Related researches

### 2.2.1 Researches conducted within India

**Ranjan et al. (2016)** conducted a study on “Reclamation and rehabilitation of waste dump by eco-restoration techniques at Thakurani iron ore mines in Odisha. The study aimed to evaluate the effectiveness of eco-restoration techniques, specifically the Miyawaki method, in reclaiming and rehabilitating waste dump areas at Thakurani Iron Ore Mines in Odisha, India. Twenty-five native species from the recommended list were planted across the degraded land. The findings revealed that the Miyawaki method resulted in an 87% survival rate after three years, compared to 72% using traditional plantation methods. Additionally, there was a more rapid development of trees, particularly early successional species, leading to increased plant biodiversity. The study concluded that eco-restoration using the Miyawaki technique is a more effective approach for waste dump rehabilitation, promoting faster vegetation growth and improved ecological recovery compared to conventional methods.

An experimental research was conducted by **Goveanthan et al., (2019)** on “Performance of various tree species in Miyawaki plantation in Anna university campus, Coimbatore”. The study aimed to assess the performance of tree species under the Miyawaki method of afforestation by evaluating their growth, productivity, and eco-physiological traits in Anna University Regional Zone, Coimbatore. The plantation comprised sixteen fast-growing tree species, including *Pongamia pinnata*, *Thespesia populnea*, *Terminalia catappa*, *Albizia saman*, *Holoptelea integrifolia*, *Azadirachta indica*, *Melia azedarach*, *Peltophorum pterocarpum*, *Limonia acidissima*, *Albizia lebbeck*, *Spathodea campanulata*, *Cassia siamea*, *Adenantha pavonina*, *Swietenia macrophylla*, *Ficus religiosa*, and *Mimusops hexandra*. The findings revealed that *Spathodea campanulata* exhibited the highest growth rate, productivity,

and eco-physiological performance, making it highly suitable for Miyawaki afforestation. *Cassia siamea* followed closely, performing well in terms of biometric and eco-physiological parameters. Conversely, *Holoptelea integrifolia*, *Swietenia macrophylla*, and *Limonia acidissima* recorded the lowest values. The results suggest that *Spathodea campanulata* and *Cassia siamea* are particularly effective for afforestation in wastelands and urban Miyawaki forests, highlighting their potential for rapid forest development and ecological restoration.

An experimental research was conducted by **Lagariya and Kaneria (2021)** on “Ethnobotanical Profiling and Floristic Diversity of the Miyawaki Plantation in Saurashtra University Campus, Rajkot”. The study aimed to document the ethnobotanical profiling and floristic diversity of the Miyawaki plantation at Saurashtra University campus, Rajkot. The research was conducted using a field survey method, continuously carried out during the year 2020-2021. The findings revealed that 71 plant species belonging to 32 families were recorded. The trees were the dominant plant form, followed by shrubs and herbs. The most dominant families were Caesalpiniaceae and Apocynaceae, while *Ficus* and *Terminalia* were the most common genera. The study highlighted the presence of medicinally important plant species, which contribute to environmental enrichment and provide therapeutic benefits. Additionally, the Miyawaki plantation was found to enhance urban biodiversity, aid in air and water purification, and create a healthier and more pleasant environment. The research suggested that further studies on the phytochemical and pharmacological properties of the recorded species could lead to the discovery of new herbal medicines.

A research was carried out by **Sivabalan et al. (2021)** on “NIRAM - Modified Miyawaki Technique for Forest Creation”. The study aimed to evaluate the effectiveness of the modified Miyawaki technique, known as the Naveen Integrated Rapid Afforestation Method (NIRAM), in establishing dense plantations within a short time while allowing space for post-cultural operations and recreational utilities. The research was conducted in Thuraiyur, Trichy district, Tamil Nadu, India. The study used a purposive sampling technique, selecting a one-hectare site for

afforestation. In one hectare of land, around 1250 pits were excavated, each with four tree saplings, totaling around 5,000 trees. The results demonstrated an 80% survival rate, with trees reaching an average height of 5 meters per year. A green canopy covered 90% of the area, supporting biodiversity with 26 bird species, 16 butterfly species, and six snake species. The study concluded that NIRAM effectively enhances afforestation efforts by improving biodiversity, reducing temperature, and creating sustainable urban forests with economic benefits. The findings highlight the potential of NIRAM to contribute to climate change mitigation and promote green urban spaces, warranting further support from public and private agencies.

**Sandip et al., (2022)** conducted a research on “Development of Tree Plantation Through Miyawaki Method at Sabarmati Riverfront Development Corporation limited - A research”. The study assessed the effectiveness of the Miyawaki method at Sabarmati Riverfront, focusing on biodiversity enhancement, environmental benefits, and stakeholder perceptions. Conducted in Ahmedabad, a total of 50 plants belonging to 24 families, 38 genera were documented from the study area. It was found that Miyawaki forests grew 15% faster than conventional methods, significantly increased native flora and fauna, improved air quality, and reduced temperatures. After two years, the forests became self-sustaining with minimal maintenance. Public perception was largely positive, with over 80% supporting the initiative. The study also explored the feasibility of implementing Miyawaki forests near Sabarmati River, showing promising results.

**Safvan and Swapna, (2023)** conducted research on “Assessment of Biodiversity and Growth Parameters of Miyawaki Forest of Selected Sites in Thiruvananthapuram District of Kerala”. The study aimed to assess the growth performance of selected plant species grown using the Miyawaki afforestation method in three sites within the Thiruvananthapuram district of Kerala. The study site includes Miyawaki forest in Kanakakunnu (site 1), Government High School Chala (site 2), and Dept. of Botany, Kariavattom (site 3). The growth parameters of the selected plants in the sites were recorded. The findings indicated that plant species in the Miyawaki forests at all three sites exhibited a higher growth rate than naturally occurring vegetation. The study

emphasized that Miyawaki afforestation could significantly reduce the time required for environmental restoration, facilitate native species conservation, and provide ecological services such as pollinator protection and biodiversity enhancement. The results suggest that the Miyawaki method can be an effective afforestation strategy for developing dense, multilayered forests, even in urban settings.

**Arora (2024)** conducted a research on “Financing of Biodiversity & Ecosystem Conservation”. The study aimed to analyze the financial mechanisms for biodiversity and ecosystem conservation in India, emphasizing budgetary allocations, public funding, and corporate sector contributions. The research utilized a qualitative approach, reviewing policy documents, financial reports, and conservation initiatives, with a sample size comprising various government institutions, corporate entities, and conservation organizations involved in biodiversity financing. A purposive sampling technique was used to select relevant stakeholders and data sources. The findings highlighted that while multiple institutions contribute to biodiversity financing, overlapping ideologies and uncoordinated efforts lead to inefficiencies. Market fluctuations, policy gaps, and a focus on profit maximization over sustainable wealth creation further exacerbate biodiversity loss. The study suggested that structured financing mechanisms, including designated funds from corporate sectors and well-regulated budgetary allocations, are necessary for effective biodiversity and ecosystem conservation. The results emphasized the need for stronger policy frameworks and self-regulation to minimize biodiversity loss while leveraging economic growth for environmental sustainability.

An experimental research was conducted by **Das et al., (2024)** on “Investigating Surface Urban Heat Island (SUHI) Effect for a Hill City”. The study aimed to examine the Urban Heat Island (UHI) effect in Ranchi, Jharkhand, using Land Surface Temperature (LST) analysis through satellite imagery and Geographic Information System (GIS) applications. The research utilized a quantitative approach, analyzing satellite-derived temperature data from various urban and peri-urban regions within Ranchi. The sample included multiple wards of the Ranchi Municipal Corporation, with a stratified sampling technique used to categorize urban, peri-urban, and rural

areas based on land use and vegetation cover. The findings indicated that Ranchi experiences an average UHI intensity of approximately 1.6°C, with the western and southern urban regions exhibiting higher temperatures than peri-urban and rural counterparts. Green areas and water bodies were observed to mitigate UHI effects in certain wards. Comparisons with earlier studies revealed a shift in thermal patterns, where the city core, once a cooler zone due to blue-green infrastructure and rocky terrain, now exhibits increased temperatures. The study highlighted the growing need for sustainable urban planning and green infrastructure development to counteract rising urban temperatures in Ranchi.

An experimental research was conducted by **Mohapatra (2024)** on “Biodiversity in the Direction of Conservation: A Declared Biodiversity Heritage Site of Odisha”. The study aimed to assess the biodiversity of the newly declared Biodiversity Heritage Site (BHS) in Gupteswar forest, Koraput district, Odisha, and to document rare and threatened faunal species. The study was conducted over an area of 350 hectares from January 2020 to September 2022. The sampling was carried out randomly in open, closed, and dense forest areas, including rocky paths. The findings revealed the presence of several vulnerable species, such as the Mugger Crocodile (*Crocodylus palustris*), Indian Flapshell Turtle (*Lissemys punctata*), and Leopard (*Panthera pardus*), along with the endangered Kanger Valley Rock Gecko (*Hemidactylus kangerensis*). The presence of these species emphasizes the need for continuous biodiversity assessments and conservation measures. Additionally, the limestone caves within the site, protected by local communities due to their cultural and mythological significance, serve as habitats for various bat species, further adding to the ecological value of the site. The study supports the declaration of Gupteswar forest as a BHS and highlights the importance of community participation in biodiversity conservation efforts.

**Parag (2024)** conducted a research on “Greening Urban Landscapes: the Miyawaki Method for Enhanced Biodiversity and Carbon Sequestration in Pune, India”. The study aimed to evaluate the effectiveness of the Miyawaki method in urban afforestation by assessing biodiversity enhancement, soil health improvement, and

carbon sequestration potential in Pune, Maharashtra, India. The project was conducted in Induri Village, where 6000 native tree species were planted using the Miyawaki technique. The findings indicated significant improvements in soil health, as pre- and post-intervention soil analysis showed increased organic carbon content and nutrient levels. The afforestation project also demonstrated a substantial rise in local biodiversity, with increased flora and fauna presence. Additionally, the dense forest contributed to carbon sequestration, aiding in climate change mitigation. The involvement of the Pruthvi Molachi Foundation and local villagers played a crucial role in the project's success, highlighting the impact of community participation in environmental conservation. This study underscores the potential of the Miyawaki method as a scalable urban afforestation strategy, offering ecological and climate-related benefits while fostering community engagement.

### **2.2.2 Researches conducted outside India**

An experimental research was conducted by **Guo (2018)** on “Effects of Different Forest Reconstruction Methods on Characteristics of Understory Vegetation and Soil Quality”. The study aimed to evaluate the effects of different afforestation methods, including four Miyawaki techniques and one traditional method, on forest soil quality and understory vegetation in Nanhai District, Foshan City, China. It assessed soil fertility, microbial diversity, and biomass production to determine the most effective method for restoring degraded forestland. The sample consisted of multiple experimental plots, with three 10×10 m plots for each Miyawaki method and three 20×20 m plots for the traditional and control areas. The study employed a comparative experimental design, using transformed plots as experimental sites and untransformed woodlands as control plots. Findings indicated that Miyawaki Method 3 (MM3) significantly improved soil fertility, microbial diversity, and vegetation biomass, outperforming other afforestation methods. MM3 had the highest microbial count, total nitrogen, and available nitrogen, while the traditional method showed the highest phosphorus levels. Additionally, MM3 had the best capillary water holding capacity and soil porosity, making it the most effective in improving soil health. These results

highlight the potential of the Miyawaki method, particularly MM3, in ecological restoration, supporting its wider application in afforestation initiatives globally.

An experimental research was conducted by **Kabisch et al., (2023)** on “The Urban Heat Island under extreme heat conditions: A case study of Hannover, Germany”. The study aimed to analyze the intensity of the Urban Heat Island (UHI) effect under extreme summer heat conditions in Hannover, Germany, during the years 2018, 2019, and 2020, compared to a non-heat year (2017). Various inner-city urban locations and an urban park were selected, each representing distinct land use and land cover characteristics. The study involved a comparative temperature analysis across these locations using meteorological data. The findings confirmed the presence of the UHI effect across all years studied, with a significant intensification observed during extreme heat years, particularly in night-time temperature minima. However, the effect was less pronounced when analyzing maximum daily temperatures. The lowest UHI intensity was recorded in the urban park, emphasizing the importance of increasing urban greenery, such as tree-covered and open green spaces, to enhance cooling services for urban residents. These results highlight the critical need for city-wide greening strategies to mitigate the impacts of rising temperatures and climate change.

**Afsar et al., (2024)** conducted a research on “Prototype Biodiversity Digital Twin: Forest Biodiversity Dynamics”. The study aimed to develop a Forest Biodiversity Dynamics Prototype Digital Twin (pDT) to integrate forest and biodiversity models, enabling the prediction of management strategies' effects on forest ecosystems. The study included Finnish forests and bird species, with plans for future expansion to other European countries and diverse species. The study incorporated ecological modeling and simulation to evaluate different forest management scenarios under varying climate conditions. The findings suggest that the pDT can help identify optimal strategies for biodiversity conservation and adaptation. The study emphasizes the importance of digital tools in forest management, offering a scalable approach for conservation planning in response to climate change.

**Bellamy et al., (2024)** conducted a research on “The forest biodiversity index (FOBI): monitoring forest biodiversity potential over space and time”. The study aimed to develop and implement the Forest Biodiversity Index (FOBI) to quantitatively assess the biodiversity potential of publicly owned forests in the United Kingdom over space and time. The sample size included public forests in England and Scotland, with biodiversity data collected across four annual timestamps between 2014 and 2021. The sampling technique involved spatially comprehensive forest survey data and environmental datasets, integrating multiple biodiversity indicators through a hierarchical aggregation process. The findings indicated an improvement in the biodiversity potential of public forests, with increased diversity, extent, condition, and connectivity over time. The study highlights the effectiveness of FOBI in supporting data-driven decision-making and long-term biodiversity monitoring, with potential applicability to private forests and other geographic regions.

An experimental research was conducted by **Dahlin et al., (2024)** on “Comparisons of biodiversity metrics reveal dissimilarities in biodiversity hotspot identification”. The study aimed to compare biodiversity hotspots identified by 17 diversity indices, including species richness, phylogenetic diversity, functional diversity, and traditional ecological knowledge (TEK)-based diversity, to assess their effectiveness in conservation planning. The dataset included information from 318 plant species found in the Pacific Northwest, USA. The study involved analyzing simulated plant communities to assess whether different indices identified the same biodiversity hotspots. The findings revealed that biodiversity metrics formed two groups based on shared hotspot identification, indicating that relying on a single metric may overlook other forms of biodiversity. Additionally, TEK-based metrics clustered with some traditional indices, such as species richness, suggesting their potential integration into conservation planning. The study provides insights into combining biodiversity measures for identifying regional biodiversity hotspots and setting conservation priorities effectively.

**Duflot and Vähätalo (2024)** conducted a research on “Identifying sites with high biodiversity value using filtered species records from a biodiversity information

facility”. The study aimed to develop scalable and robust methods to identify high-priority conservation areas using biodiversity indicators derived from species records. The dataset comprised over 3 million species records of 878 native Lepidoptera species collected in Finland from 2001 to 2020. The data underwent filtering to include municipal districts with more than 5,000 records, followed by species accumulation curves to estimate overall and endangered species richness. Additionally, local contribution to beta diversity (LCBD) analyses were conducted to assess community uniqueness. The study found that species richness was highest along the southern coast and decreased towards the north, following established Lepidoptera distribution patterns in Finland. The estimated number of endangered species correlated with overall species richness, except in northernmost districts, where the proportion of endangered species was unusually high. Unique species communities were primarily found in the southwest and northern regions of Finland. The findings demonstrate that biodiversity indicators based on accumulation curves and LCBD analyses can effectively guide conservation priorities and site selection using large-scale species records.

**Ford et al., (2024)** conducted a research on “A technological biodiversity monitoring toolkit for biocredits”. The study aimed to assess biodiversity monitoring technologies in the context of biodiversity credit markets, evaluating their ability to meet the SAGED criteria (Scalable, Accessible, Granular, Evidenceable, and Directly measured). The sample included various biodiversity monitoring methods, such as environmental DNA (eDNA) metabarcoding, passive acoustic monitoring, and remote sensing techniques. The study employed a review-based sampling technique, analyzing existing literature and methodologies related to biodiversity credit assessments. The research was conducted globally, with a focus on technological applications for biodiversity finance. The findings indicate that while current biodiversity monitoring technologies enhance large-scale biodiversity assessment, they are not yet sufficient as standalone solutions. Integrating these technologies with ground validation and human-collected ecological data is necessary for verifiable

biodiversity credits. Advances in automation and machine learning are expected to improve the accessibility and efficiency of biodiversity monitoring in the future.

An experimental research was conducted by **Giuliani et al., (2024)** on “Acoustic indices fail to represent different facets of biodiversity”. The study aimed to evaluate the effectiveness of acoustic indices as proxies for biodiversity, specifically assessing their ability to capture species richness, phylogenetic diversity, and functional diversity among acoustically active avian species. The sample consisted of bird recordings collected at dawn across three habitat types in Italy: urban, riparian forest, and deciduous woodland. A trained ornithologist used field observations and secondary recording analysis to identify species. The study employed a purposive sampling technique, for selecting sites that represented different habitat types. The findings revealed that species richness and phylogenetic diversity correlated with at least one acoustic index in each habitat, while functional diversity was only correlated with an index in the urban habitat. However, the relationships observed were often inconsistent with theoretical expectations, and interrelations among indices varied across sites. The results suggest that acoustic indices may not be reliable biodiversity proxies for broad-scale monitoring or geographic comparisons, though they may be useful for temporal monitoring with local validation.

An experimental research was conducted by **Jian She (2024)** on “Mitigating Urban Heat Islands in Wuhan: The Role of Urban Parks Over the Past Five Years”. The study aimed to analyze the impact of urban parks on the Urban Heat Island effect in Wuhan over the past five years, exploring the relationship between park characteristics and surface temperature reduction. The sample included urban parks across Wuhan, with data collected on park area, perimeter, vegetation coverage, and surface temperature. A systematic approach was used to select parks of varying sizes and shapes. The findings indicate that as the total area of urban parks increases, their cooling effect becomes more pronounced. Park area, perimeter, and vegetation coverage showed a negative correlation with surface temperature, while the perimeter-area ratio was positively correlated, suggesting that parks with more regular shapes have better cooling effects. The cooling effect was most significant within a 100-meter radius

from park perimeters. Over time, the cooling effects and coverage of parks have expanded, highlighting their role in urban heat island mitigation.

**Mikkonen and Raatikainen (2024)** conducted a research on “Aesthetics in Biodiversity Conservation”. The study aimed to evaluate whether aesthetic values provide strong justification for biodiversity conservation by analyzing species diversity, ecosystem diversity, and genetic diversity. These included various biodiversity components, assessed through philosophical and ecological perspectives. A qualitative analysis approach was employed to explore the relationship between biodiversity and aesthetics. The findings suggested that there was often a mismatch between perceived and actual biodiversity, indicating that aesthetic appeal does not always align with ecological importance. While aesthetics may offer some support for conservation efforts, its role is limited, as conservation should be based on ecological, functional, and ethical considerations rather than visual appeal alone.

An experimental research was conducted by **Shaltout and El-Khalafy (2024)** on “Biodiversity in Egypt contributing to world biodiversity”. The study aimed to compile and analyze available publications on Egyptian biodiversity from 2000 to 2018, categorizing species and assessing their global contribution. The research collected data from various sources, including university libraries, research centers, and biodiversity specialists. A total of 20,521 species were recorded in Egypt, with insects contributing the highest percentage (48.7%), followed by fungi (12.1%) and vascular plants (11.5%). Minor contributions were observed for amphibians, viruses, reptiles, mammals, cyanobacteria, bryophytes, and bacteria. Egyptian biodiversity represents 1.3% of global biota despite the country's land area accounting for only 0.7% of the world's total area. Globally, Egypt's most represented groups are algae (12.22%), cyanobacteria (6.08%), and birds (4.70%), while amphibians (0.14%), flora (0.84%), and insects (1.00%) were the least represented. The study recommends preparing a phytoplankton checklist, conducting further research on lichen biodiversity, and publishing a book on Egyptian paleo-biology to enhance biodiversity documentation.

## Conclusion

The review of literature collected, based on the objectives of the study, provided insights into the effectiveness of the Miyawaki technique in developing green spaces and its impact on biodiversity. The concept of afforestation and urban green space development was also explored. The review highlighted various ecological benefits of the Miyawaki method, such as rapid forest growth, enhanced biodiversity, improved air quality, and temperature regulation. Additionally, studies examined the role of stakeholder perceptions in the success of urban forest initiatives. The challenges and limitations associated with implementing the Miyawaki technique, including land availability, maintenance, and public awareness, were also discussed. Research findings also highlighted that these forests became self-sustaining within a short period, requiring minimal maintenance while continuing to provide ecological benefits.

Based on the empirical literature reviewed, it was evident that researches conducted outside India mostly focused on "Biodiversity Enhancement," "Urban Afforestation Strategies," "Eco-Restoration of Degraded Lands," "Climate Change Mitigation," "Green Urban Landscapes," and "Stakeholder Perceptions of Green Spaces." However, research in India largely explored the Miyawaki method in urban contexts, emphasizing "Developing land through Miyawaki Technique," "Impact on Air Quality and Temperature Reduction," "Assessment of Biodiversity and Growth Parameters," and "Public Perception of Green Spaces." There remained a gap in comprehensive long-term studies assessing the ecological succession and sustained impact of Miyawaki forests. Hence, there was dearth of research focusing on the combined assessment of biodiversity changes and its ecological benefits within Miyawaki afforested areas. While studies have explored urban greenery, few have directly analyzed the specific contributions of Miyawaki forests to local biodiversity, soil quality, and microclimatic regulation. Despite the evident ecological and environmental significance of the Miyawaki method, there is a scarcity of research in India on its role in long-term biodiversity enhancement, microclimate improvement, and its adoption in urban planning policies. Therefore, the researcher was interested in carrying out present research on the topic undertaken.



# METHODOLOGY

## **CHAPTER III**

### **METHODOLOGY**

The present study required a detailed and systematic research plan to achieve its objectives effectively. The primary goal was to explore the biodiversity and ecological benefits of Miyawaki afforested areas in Vadodara District. Specifically, the research focused on analyzing the diversity of flora and fauna in these areas and assessing the perceived changes in ecological factors such as temperature, humidity, and air quality. To ensure a clear and organized presentation, this chapter describes the various methodological procedures adopted for the study and is divided into the following sections.

3.1 Research Design

3.2 Operational Definitions

3.3 Locale of the study

3.4 Unit of Inquiry

3.5 Selection of sites

3.6 Selection and Development of the tool

3.7 Description of the tool

3.8 Establishment of content validity

3.9 Data Collection

3.10 Development of Multimedia resource on Miyawaki Technique

### 3.1 Research Design

The present study had descriptive research design. The main purpose of descriptive research is explanation of the set of circumstances. Descriptive research design was thought to be most appropriate method to carry out the present research as case study method was used to collect on the needed information for analyzing the diversity of flora and fauna in these areas and assessing the perceived changes in ecological factors such as temperature, humidity, and air quality of the selected sites.

#### Case study method

The case study method was thought to be most appropriate for the present research as the detailed information was needed to be sought on various aspects related to biodiversity and ecological benefits of Miyawaki afforested areas developed in and around Vadodara District. It was thought to be most appropriate method to carry out the present research because it gathered the data on the selected Miyawaki afforested areas where data regarding their general information, planning and implementation, flora diversity, fauna diversity, humidity, temperature, air quality, and maintenance and growth practices.

### 3.2 Operational Definitions

The present operational definitions thus constituted for the present research study are discussed as below:

**3.2.1 Miyawaki Afforestation:** For the present research, it was operationally defined as a method of green space creation that involves planting a variety of native species closely together to encourage rapid growth and ecological restoration in the selected areas in Vadodara district.

**3.2.2 Biodiversity:** For the present research, it was operationally defined as the variety of plant and animal species found within the Miyawaki afforested areas developed in Vadodara district.

**3.2.2.1 Flora:** For the present research, it was operationally defined as the diverse plant species, including trees, shrubs, herbs, and grasses, found within Miyawaki afforested areas in Vadodara district, contributing to biodiversity enhancement, ecological balance, and environmental sustainability.

**3.2.2.2 Fauna:** For the present research, it was operationally defined as the variety of animal species, including insects, birds, mammals, reptiles, that inhabit with in Miyawaki afforested areas in Vadodara district, playing a crucial role in maintaining ecological balance and supporting biodiversity.

**3.2.3 Ecological Benefits:** For the present research, it was operationally defined as change in environmental factors such as air quality, temperature regulation, and humidity in the areas developed using Miyawaki technique.

**3.2.3.1 Air Quality:** For the present research, it was operationally defined as the perceived condition of the air within Miyawaki afforested areas in Vadodara district, based on information provided by the owners and developers regarding clean and pollutant free air.

**3.2.3.2 Humidity:** For the present research, it was operationally defined as the perceived moisture level in the air within Miyawaki afforested areas in Vadodara district, based on information provided by the owners and developers regarding changes in atmospheric moisture.

**3.2.3.3 Temperature:** For the present research, it was operationally defined as the perceived variation in atmospheric heat within Miyawaki afforested areas in Vadodara district, based on information provided by the owners and developers regarding changes in ambient temperature.

### **3.3 Locale of the study**

The research was conducted in Vadodara district of Gujarat state where afforestation was done using Miyawaki technique.

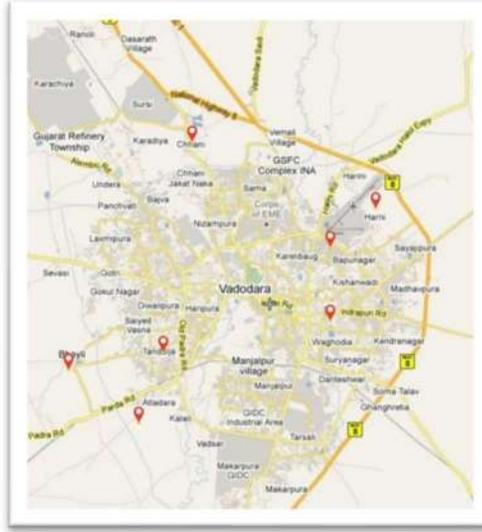


Figure 1: Miyawaki Afforested Areas of Vadodara District [3]

### 3.4 Unit of Inquiry

The unity of inquiry were owners of the land or site where afforestation was done focusing on Miyawaki technique. In case where owners were not able to provide information regarding the site, developers of the afforested area were contacted.

### 3.5 Selection of sites

An enquiry was made through VMC (Vadodara Municipal Corporation) and SOCLEEN to find out the sites within Gujarat that were developed through Miyawaki technique. A list of such sites that were developed through Miyawaki technique in Gujarat was prepared. Out of the twenty-one sites, seven were selected purposively for the present study with a criteria that they were functional at the time of data collection were established minimum two years back and who willingly gave their consent in sharing the information.

### Inclusion Criteria and Exclusion Criteria

#### Inclusion Criteria

- Miyawaki afforested areas located within Vadodara city and district limits.
- Sites which were developed minimum 2 years back from the time of data collection to allow for establishment of flora and fauna.
- Sites with diverse tree species and native vegetation.

- Areas with accessible and reliable data on pre-afforestation ecological conditions.
- Developer and Owners willing to participate in the interviews.

### **Exclusion Criteria**

- Areas outside Vadodara district limits.
- Newly planted sites developed after 2022
- Areas with incomplete or unreliable pre-afforestation data.
- Areas developed through Non-Miyawaki afforestation methods (e.g., traditional plantation).
- Sites with restricted access or safety concerns.

### **3.6 Selection and Development of the tool**

The interview schedule as a tool for data collection was selected to gather the information to construct questions for the selected afforested Miyawaki areas in Vadodara district because of the following reasons:

- It gave oral-verbal response.
- It provided an in-depth information.
- It made the understanding of the respondent much clear and simplified.
- It was a speedy data collection effort on the part of the investigator.
- It avoided any unanswered question, ensuring complete information in the tool.
- It guaranteed information seeking in an informal and relaxed environment.

The tool was constructed in compliance with the objectives of the study. A number of sources such as books, journals, newspaper, magazines in printed media; electronic media as well as personal meetings with the experts in the related field were utilized to construct the tools.

### 3.7 Description of the tools

The Interview Schedule comprised of six sections which are described as below:

**Section I General information:** This section collected essential details about the sites, including its name, location, establishment date, and the year of evaluation. It also notes proximity to urban infrastructure, canopy density, afforestation area and density, along with the primary objectives behind its creation, such as enhancing biodiversity or mitigating urban heat. Additionally, it addresses how these objectives were communicated with the community or stakeholders, ensuring engagement and awareness. These details provide a comprehensive overview of the forest's context, purpose, and potential environmental impact.

**Section II Planning and Implementation:** This section covered the planning and implementation of the Miyawaki Technique, including site selection, key considerations like environmental conditions and community impact, and the main steps taken, such as site preparation and planting. It also addresses challenges faced during the process, providing insight into the practical aspects of establishing the forest and management of obstacles.

**Section III Flora Diversity:** This section focused on the diversity of flora in the Miyawaki forest. Here list of each species' botanical and local names, average growth rate, survival rate, and advantages, such as medicinal, timber, fruit, or flower benefits was prepared. It also categorizes plants by type (evergreen, deciduous, perennial) and layer (trees, canopy, sub-trees, shrubs, herbs). Growth rate was calculated using measurements over time, and survival rate measures plant success. Additionally, it details the criteria for species selection, including considerations like native species and fast-growing plants, highlighting their ecological and practical benefits.

**Section IV Fauna Diversity:** This section evaluated the diversity of fauna within the site, starting with an initial assessment of species (insects, birds, mammals) present before the forest's establishment by the respondent. Then examining current faunal diversity, noting increases in insect, bird, and mammal species, with population estimates and observations on new species and behaviors. Additionally, it explores interactions between fauna and

flora, such as mutualistic relationships like pollination or seed dispersal, and predator-prey dynamics, highlighting their significance and impact on the ecosystem's balance.

**Section V Humidity, Temperature and Air Quality:** This section assessed the environmental impact of the Miyawaki forest on local humidity, temperature, and air quality. It evaluates changes in humidity levels, temperature differences between the forest and surrounding urban areas. Here questions related to the type of surfaces present before the forest was established (e.g., concrete, asphalt) was asked. It also examined the forest's effect on air quality, noting reductions in CO<sub>2</sub> or other pollutants, with any measurements taken before and after its establishment. Additionally, it gathered feedback from local residents on perceived heat reduction and their overall perception by the respondent.

**Section VI Maintenance and Growth:** This section outlined the maintenance and growth practices for the site, detailing key maintenance strategies adopted to ensure its health and sustainability. It described the monitoring of forest's growth and development over time, including any specific metrics or observations recorded. Challenges faced during maintenance were addressed, along with the strategies employed to overcome them. Additionally, the use of fertilizers post-plantation was discussed, as well as the flowering and fruiting patterns of the species, providing insight into the forest's ecological dynamics and productivity.

### **3.8 Establishment of content validity**

The scale prepared by the researcher for the present study was given to the panel of total 7 judges, who were from Department of Family and Community Resources Management, Faculty of Family and Community Science, The Maharaja Sayajirao University of Baroda, Vadodara and 2 experts from the SOCLEEN (a voluntary, non-profit and non-political organization). They were requested to check the clarity and relevance of the content. They were also requested to state whether each question falls in category under which it was listed. A consensus of 80% among the judges was taken as yardstick for the final tool. Minor modifications were required to be made in the final tool.

### 3.9 Data Collection

The data were collected through interview schedule. The data were collected by the personal visits made by the researcher to the selected Miyawaki afforested sites within Vadodara district with prior permission and appointment with them based on their convenience. On an average the interview with the respondent of sites selected lasted for 2-3 hours. The data were collected in the month of October, November and December, 2024.

The primary objective was to gather first-hand data on the ecological transformation of these sites. Prior to the site visits, permissions were obtained from the owners and developers, and appointments were scheduled to ensure uninterrupted access. A series of site visits were conducted as part of the data collection process to assess the biodiversity and ecological benefits of the selected sites in Vadodara District. These visits allowed for direct observation of the flora and fauna diversity, environmental conditions, and the overall impact of the Miyawaki technique on the afforested areas. During the visits, plant species and animal presence were observed, the information related to environmental data such as temperature, humidity, and air quality were collected, and interviews were conducted with site owners and developers. Changes in the local environment due to afforestation efforts were documented through photographs and videos, capturing the canopy density, species diversity, and overall growth of the forests as reported by the respondent.

Site orientations were provided by the owners or developers, detailing the site establishment, the species planted, and the objectives behind the project, followed by a guided tour of the site. A thorough survey of plant species was conducted, identifying each species by its botanical and local names, measuring growth rates and canopy density, and noting survival rates. The presence of various animal species, including insects, birds, and small mammals, was recorded, with special attention to new species observed since the forest's establishment as reported by the respondent. These efforts provided valuable insights into the biodiversity and ecological impact of the Miyawaki afforested areas.

### **3.10 Development of Multimedia resource on Miyawaki Technique**

One of the objectives of the study was to develop multimedia resource for creating awareness among stakeholders about Miyawaki technique. Two approaches were utilized to develop multimedia resources aimed at raising awareness among stakeholders about Miyawaki technique. One approach involved developing an informative booklet, while the other utilized audio-visual media. The content of booklet included information regarding awareness about the Miyawaki method, its principles, benefits, challenges, and real-world applications, particularly in Vadodara District, plays a crucial role in promoting sustainable urban development. It serves as a valuable resource for urban designers, landscape architects, policymakers, and environmentalists dedicated to ecological restoration. Additionally, it beneficial for the public by providing knowledge about the Miyawaki technique and raising awareness of its importance. It also inspired eco-friendly initiatives in residential and public spaces, encouraging greener and healthier environments.

The audio-visual media showcased key information related to the importance of urban forests, highlighting the growing need for green spaces in cities. It explored the origins of the Miyawaki method, explained its step-by-step plantation process, and showcased its positive impact on biodiversity and climate. Real-world applications were featured, particularly in Vadodara District, where the technique has been successfully implemented at sites such as Channi Lake, Moti Bapod, and Ashray Green, Bhayli. These projects contribute to sustainable urban development by restoring ecosystems, improving environmental quality, and enhancing urban resilience. The audio-visual media recorded during the site visits with due permissions from the authorities. The final editing and voice over were done by the experts.



# FINDINDS AND DISCUSSION

## **CHAPTER IV**

### **FINDINGS AND DISCUSSION**

The findings of the study obtained through the analysis of the data supported by relevant discussions and interpretations are presented in this chapter. It covered detailed information on selected Miyawaki afforested areas developed in and around Vadodara district. This chapter deals with presenting, interpreting and discussion of the findings obtained through analysis of the data collected through interview and site visits. The results are presented under the following sub-heading:

#### **4.1: Case studies on the selected Miyawaki afforested areas of Vadodara city**

4.1.1 Case study 1: Site A

4.1.2 Case study 2: Site B

4.1.3 Case study 3: Site C

4.1.4 Case study 4: Site D

4.1.5 Case study 5: Site E

4.1.6 Case study 6: Site F

4.1.7 Case study 7: Site G

#### **4.2: Development of Multimedia resource on Miyawaki Technique**

#### 4.1: Case studies on the selected Miyawaki afforested areas

The data highlights seven case studies of areas developed using the Miyawaki technique in and around Vadodara city. It provides detailed information about the general characteristics of each site, including location, area, and surrounding land use. The planning and implementation process was documented, covering aspects such as site preparation, soil enhancement, species selection, and planting techniques. The dataset also presents insights into the diversity of flora and fauna observed within these afforested areas, showcasing species richness and ecological variety. Additionally, it includes information on environmental parameters such as humidity, temperature, and air quality, highlighting changes observed by the respondent within the Miyawaki plantations sites.

To gather this data, structured interviews were conducted with the developers and owners of the afforested sites. These interviews, lasted approximately two to three hours, provided in-depth information regarding site development, funding sources, and long-term maintenance strategies. The interviewees detailed the financial support available for afforestation projects, which played a crucial role in the successful establishment of the green spaces. To monitor the progress and ecological impact of the planted species, their growth and survival rates were calculated. The average growth rate was determined using the formula  $(S_2 - S_1) / T$ , where  $S_1$  was the initial measurement,  $S_2$  was the final measurement, and  $T$  was the number of days between measurements. The survival rate was assessed using the formula  $(\text{Total number of plants surviving} / \text{Total number of plants originally planted}) \times 100$ , ensuring an organized evaluation of plant establishment and resilience. This structured approach ensured consistency and accuracy in evaluating plant survival rates, growth patterns, and the overall impact of Miyawaki site on the urban ecosystem. The findings emphasized the effectiveness of the Miyawaki technique in enhancing urban biodiversity and improving microclimatic conditions.

The interaction with the owners and developers revealed that prior to the site's development, no systematic assessment of fauna diversity was conducted. Additionally, no scientific assessment of data on Humidity, Temperature, and Air Quality was carried out. Hence, the information presented here is solely based on the insights and perceptions of

the site's developers and owners. A direct observation of the sites by the workers gave the insights into current faunal diversity. It was based on the direct observation where they spent time at different times of the day in different season to observe their presence. Information gathered from site workers or gardeners who frequently visit the area was used. The footprints, droppings, burrows, nests, scratch marks or feathers as evidence of their presence was marked.

#### **4.1.1 Case study 1: Site A**

##### **4.1.1.1 Profile of the site**

The Miyawaki site project in Vadodara, located in the Tandalja area near CH Cancer Hospital, was created in October 2020 with a strong commitment to promoting urban greenery and ecological sustainability. At present in its fourth year of evaluation, the site comprises an afforestation area of 2000 m<sup>2</sup>, with a canopy density including approximately 50% of the total area. The project is located within a residential area and developed using the Miyawaki afforestation technique, which is known to generate dense rapidly growing site by planting trees at a high density of 2.6 inches apart. This close planting pattern has served develop a thriving, multi-layered ecosystem which promotes biodiversity and ecological balance. The primary objective for developing this Miyawaki Technique was to create a sustainable urban green space that enhances local biodiversity, mitigates pollution, and combats the urban heat island effect.



Plate 1: Site A located in Tandalja area of Vadodara District

#### 4.1.1.2 Planning and implementation

For the purpose to develop a sustainable green space that improves biodiversity and environmental quality, the Miyawaki Technique was proposed on a vacant urban space in the Tandalja area of Vadodara. The goal of the project was to create a thriving urban space that would benefit the local community on an ecological, social, and aesthetic level.

During the planning and implementation phase, extensive efforts were made to prepare the land for afforestation. To make sure the soil was prepared for planting, the area was carefully cleansed to get rid of any waste and obstacles. To make space for new seedlings and maintain the natural environment, some dead and rotting trees were also carefully removed. Assessments of the soil's quality were carried out, and then enhancements like mulching and organic composting were made to increase the soil's quality and hold onto moisture, which promoted the growth of healthy plants.



Plate 2: Banana and Papaya plant at Site A

The project's effortless and efficient execution was one of its main features. Fortunately, there were no major hurdles to overcome, allowing the transformation from an underdeveloped urban area to a healthy Miyawaki site possible. Careful planning is all responsible for this success. Rapid growth and the creation of a self-sustaining ecosystem were made possible by the Miyawaki approach, which emphasizes dense planting with native species.

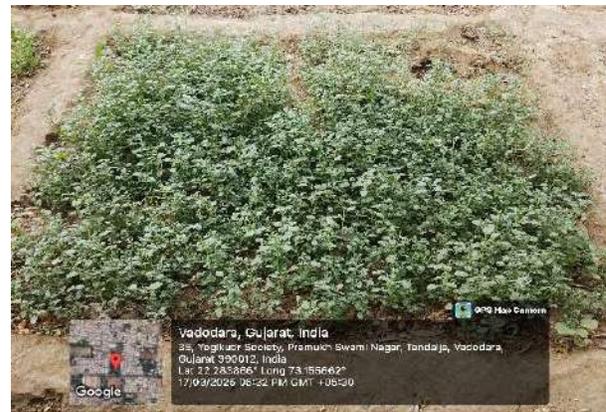
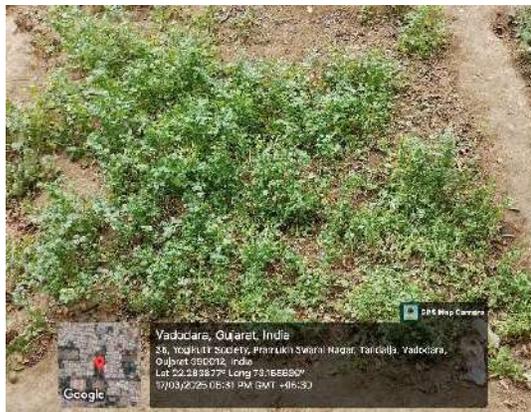




Plate 3: Vegetable plantation inside site A

#### 4.1.1.3 Flora Diversity

This comprised a diverse selection of 30 plant species, primarily consisting of native species with varying heights and ecological roles. These species were carefully chosen to create a self-sustaining, multi-layered ecosystem that mimics natural forests. The selection includes a mix of evergreen, deciduous, and perennial plants, ensuring year-round greenery and ecological benefits. A total of 1,000 plants were planted, contributing to the rapid development of a dense and resilient green space.



Plate 4: Flowering plants inside site A

**Table 1: Flora Diversity at site A**

Sr. No.	Botanical Name	Local Name	Average growth rate (cm)	Survival rate (%)	Advantage (Medicinal/Timber/Fruit/Flower)	Type (Evergreen/deciduous/perennial)	Layer (Trees/Canopy/ Sub Trees/ Shrubs Herbs)
1	Moringa oleifera	Drum stick	400	20-30	Vegetable, Medicinal	Deciduous	Tree canopy
2	Anacardium occidentale	Cashew nut	250	60-70	Fruit, Timber	Evergreen	Tree, Sub Trees
3	Mangifera indica	Mango	300	70-80	Fruit, Timber	Evergreen	Tree, Canopy
4	Bambusa vulgaris	Bamboo	1000	75-85	Timber, Soil Protection	Perennial	Tree, Canopy
5	Artocarpus heterophyllus	Jack fruit	250	65-75	Fruit, Timber	Evergreen	Tree, Canopy
6	Syzygium cumini	Jamun	300	70-80	Fruit, Medicinal	Evergreen	Tree, Canopy
7	Psidium guajava	Guava	350	75-85	Fruit, Medicinal	Evergreen	Sub Trees
8	Annona squamosa	Sitafal	250	60-70	Fruit, Medicinal	Deciduous	Sub Trees
9	Casuarina equisetifolia	Casuarina	500	80-90	Timber, Windbreaker	Evergreen	Tree, Canopy
10	Terminalia arjuna	Arjuna	300	70-80	Medicinal	Deciduous	Tree, Canopy
11	Terminalia elliptica	Sadad	200	65-75	Timber, Medicinal	Deciduous	Tree, Canopy
12	Bixa orellana	Sindoori	150	60-70	Medicinal, Dye (Sindoor)	Evergreen	Shrubs
13	Tectona grandis	Saag	250	70-80	Timber	Deciduous	Tree, Canopy
14	Gmelina arborea	gmelina	300	75-85	Timber, Medicinal	Deciduous	Tree, Canopy
15	Kigelia africana	Sausage	150	65-75	Medicinal, Ornamental	Deciduous	Tree, Sub Trees
16	Pithecellobium dulce	Goras amla	200	65-75	Fruit, Medicinal	Evergreen	Tree, Sub Trees
17	Sterculia foetida	Rangali badam	250	60-70	Timber, Ornamental	Deciduous	Tree, Canopy
18	Azadirachta indica	Neem	300	75-85	Medicinal, Timber	Evergreen	Tree, Canopy
19	Eucalyptus globulus	Eucalyptus	400	70-80	Timber, Medicinal	Evergreen	Tree, Canopy
20	Vachellia nilotica	Babul	250	65-75	Timber, Medicinal	Deciduous	Tree, Sub Trees
21	Acacia auriculiformis	Australian acacia	350	70-80	Timber, Windbreaker	Evergreen	Tree, Canopy
22	Neolamarckia cadamba	Kadamba	300	65-75	Timber, Flowering	Deciduous	Tree, Canopy
23	Ziziphus mauritiana	Ber	250	60-70	Fruit, Medicinal	Deciduous	Sub Trees
24	Pongamia pinnata	Karanj	250	65-75	Medicinal, Oil (Biofuel)	Deciduous	Tree, Sub Trees

Table 1contd.

Table 1contd.

Sr. No.	Botanical Name	Local Name	Average growth rate (cm)	Survival rate (%)	Advantage (Medicinal/Timber/Fruit/Flower)	Type (Evergreen/deciduous/perennial)	Layer (Trees/Canopy/ Sub Trees/ Shrubs Herbs)
25	Ficus religiosa	Peepal	200	70-80	Medicinal, Religious	Evergreen	Tree, Canopy
26	Ficus benghalensis	Vad	250	70-80	Medicinal, Religious	Evergreen	Tree, Canopy
27	Ficus virens	Pakar	250	65-75	Medicinal, Ornamental	Evergreen	Tree, Canopy
28	Hevea brasiliensis	Rubber plant	300	70-80	Latex, Timber	Evergreen	Tree, Canopy
29	Nyctanthes arbor-tristis	Parijat	150	65-75	Medicinal, Flowering	Deciduous	Shrubs
30	Nerium oleander	Nerium	100	60-70	Medicinal, Ornamental	Evergreen	Shrubs

The data regarding survival rate indicated that 30 % of the plant species had survival rate of 70-80% and 65-75% (Jackfruit, Mango, Jamun, Eucalyptus, Peepal, and Rubber plant). It was also found that 20 % of the plant species had survival rate of 60-70% (Cashew nut, Sitafal, Sindoori, and Nerium). The least survival rate of 20-30% was found among 3.33 % of plant species. These species were Drum stick and Casuarina, respectively. The average growth rate across all species was 320 cm. The minimum recorded growth rate was 100 cm (Nerium oleander), while the maximum was 1000 cm (Bambusa vulgaris).

The species were categorized based on their advantages, with 17 species serving medicinal purposes, 14 species used for timber, 9 species being fruit-bearing, and 4 species known for their flowers. Additionally, some species provided ecological benefits such as biofuel production, soil protection, and windbreaking. In terms of plant type, 15 species were evergreen, 13 were deciduous, and 2 were perennial. These species occupied different layers within the Miyawaki site, with 22 species belonging to the trees and canopy layer, 6 species classified as sub-trees, and 2 species identified as shrubs.



Plate 5: Measuring plants height at site A

#### **4.1.1.4 Fauna Diversity**

In order to gather this data, respondents were asked if any initial assessment of the fauna which includes number of insects, birds, and mammals had been carried out before the development of the Miyawaki site. They were asked to describe the observed species and provide population estimates if such an assessment was done. Respondents were also asked if they had observed an increase in insect and bird species, and if yes, to list the species and their estimated populations in order to assess changes in biodiversity. They were also asked if any new mammal species had appeared since the establishing, along with information on their habits and population patterns. Respondents were also asked if they had witnessed any mutualistic relationships such as birds spreading seeds or insects pollinating plants and to explain their relevance in order to gain a better understanding of the

interaction between fauna and flora. Additionally, they were asked if there were any predator-prey relationships in the environment and how these relationships affected ecological balance.

#### **4.1.1.4.1 Initial Faunal Presence**

A preliminary survey conducted by the respondent prior to the creation of the Miyawaki site revealed a low level of wildlife. Only common species of insects were seen, and the only species of birds were the House Crow and the House Sparrow. Due to a lack of foliage and food sources, small mammals like squirrels were also present, but in small numbers. According to the feedback, there was little faunal activity in the area because there were no suitable habitats.

#### **4.1.1.4.2 Current Faunal Diversity**

The respondent revealed that, the number of insect species has increased noticeably. In the Miyawaki site, the development of lush vegetation and flowering plants has improved the ecosystem and drawn a wider range of insects. Because of this, there were more insects in the region, which enhances biodiversity and pollination. The details of the species observed and estimated population is mentioned in table 2.

**Table 2: Faunal Diversity (Insects Species) at site A**

<b>Sr. No.</b>	<b>Name of the species observed</b>	<b>Estimated population</b>
1.	Common Immigrant Butterfly	25
2.	Plain Tiger Butterfly	30
3.	Common Crow Butterfly	20

The data on faunal diversity revealed a significant increase in species within the Miyawaki site, with approximately 30 Plain Tiger Butterflies, 25 Common Immigrant Butterflies, and 20 Common Crow Butterflies as reported by the Developer.

**Table 3: Faunal Diversity (Birds Species) at site A**

Sr. No.	Name of the species observed	Estimated population
1.	White-browed Fantail Flycatcher	5
2.	Purple Sunbird	10
3.	House Sparrow	15
4.	House Crow	8
5.	Red-vented Bulbul	12
6.	Jungle Babbler	7

The data on faunal diversity showed in Table 3 revealed a notable increase in species within the Miyawaki site, with approximately 15 House Sparrows, 12 Red-vented Bubluls, 10 Purple Sunbirds, 8 House Crows, 7 Jungle Babbler, and 5 White-browed Fantail Flycatchers were reported by the Developer.

**Table 4: Faunal Diversity (New mammal species) at site A**

Sr. No.	Name of the species observed	Notable behaviors/characteristics	Population trends
1.	Indian Palm Squirrel	Nesting in tree cavities, active in mornings	Stable
2.	Rodents (various species)	Burrowing in soil, foraging for food	Increasing

Since the establishment of the Miyawaki site, new mammal species has been observed, as shown in table 4. The Indian Palm Squirrel has been frequently sighted, actively nesting in tree cavities and remaining stable in population. Additionally, an increase in rodent populations has been noted, by the respondent with various species burrowing in the soil and foraging for food. This rise in mammal diversity suggests improved habitat conditions, supporting ecosystem stability and biodiversity.

#### 4.1.1.4.3 Faunal Interaction with Flora

Mutualistic relationships between fauna and flora have been observed within the Miyawaki site. Purple Sunbirds contribute to pollination by feeding on nectar, while butterflies such as the Common Crow and Plain Tiger aid in pollinating flowering plants. Additionally, fruit-eating birds like the Red-vented Bulbul and House Sparrow assist in seed dispersal by consuming fruits. As food availability increased, both insect-eating and fruit-eating birds were observed in greater numbers, indicating improved ecological interactions and biodiversity. However, no predator-prey dynamics have been observed within the ecosystem.



Plate 6: Faunal Diversity at site A

#### 4.1.1.5 Humidity, Temperature and Air quality

Since the establishment of the Miyawaki site in the Tandalja area of Vadodara city, significant improvements in the local microclimate have been observed, underscoring the positive environmental impact. One of the most notable changes, as reported by the respondent, is the rise in local humidity levels, creating a cooler and more humid microenvironment compared to the surrounding urban areas. The dense vegetation retains moisture and facilitates transpiration, resulting in a more refreshing atmosphere.

A considerable reduction in temperature has also been recorded, with daytime temperatures within the area notably lower than those in nearby urban spaces. The thick tree canopy provides extensive shade and minimizes heat absorption by the ground, effectively mitigating the urban heat island effect. Before afforestation, the land was barren and primarily composed of soil, with surface temperatures ranging between 25–35°C approximately, as reported by the respondent. The introduction of dense greenery now serves as a natural coolant, significantly lowering heat levels in the area.

Furthermore, the Miyawaki site has contributed to improved air quality. While no formal air quality measurements were taken, the respondent reported a fresher and cleaner atmosphere. The plantation of indigenous species plays a crucial role in filtering dust, absorbing pollutants, and increase in oxygen levels, further enhancing environmental conditions.



Plate 7: Dense plantation at site A

#### 4.1.1.6 Maintenance and Growth

In order to maintain the ecosystem's healthy growth and development, significant maintenance processes were put in place for the Site A of Vadodara as reported by the respondent, a regular watering schedule was strictly observed during the first year to aid in the establishment of the plants and promote the development of deep roots. For the saplings to flourish in the dense planting conditions typical of the Miyawaki technique and to adjust to their new surroundings, this first stage of rigorous care was crucial. Mulching was also done to improve soil fertility through natural decomposition, keeping the soil moist, and prevent weed growth.

This scientific approach, which is a defining feature of the Miyawaki technique, helped to track the rapid growth of the vegetation and offered insightful data about the site's progress. Unexpectedly there were no notable difficulties reported during the maintenance phase, because the Miyawaki technique stresses the natural enrichment of soil through organic sources, the space flourished without the use of chemical fertilizers. No further fertilizers were used after the first plantation, allowing the ecosystem to grow organically and continue to be self-sufficient. The site durability and quick growth were further enhanced by the planting of native plant species, which were well adapted to the local climate and soil conditions.

In terms of flowering and fruiting patterns, minimal flowering was observed during the early stages of development. This was primarily due to the plants channeling their energy into structural growth, including the development of stronger trunks, roots, and branches. The focus on vertical growth and canopy formation during the initial years was the common characteristic of dense plantations like the Miyawaki Technique. It is anticipated that as the matures and the plants stabilize, more flowering and fruiting will occur, enhancing biodiversity and supporting pollinators and other wildlife.

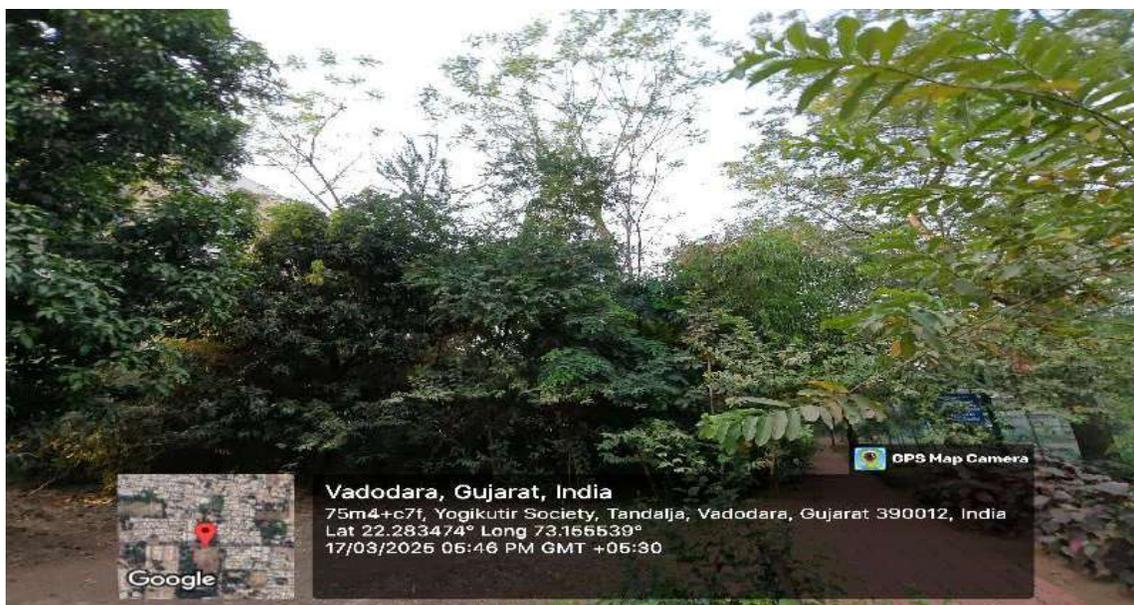


Plate 8: Mature trees at site A

## 4.1.2 Case study 2: Site B

### 4.1.2.1 Profile of the site

The Miyawaki Urban site, which was built in December 2021 and covers 4000 square meters, has a high plant density of three plants per square meter and is located close to Ashram Bill. The chosen urban site has quickly turned it into a dense green area, greatly increasing biodiversity in the area. The canopy has grown throughout the last three years, farm-like setting that reduces pollutants, controls temperature, and offers the nearby built-up region much-needed ecological balance, as reported by the respondent. The National High-Speed Railway provided financial support to the Vadodara Municipal Corporation (VMC), for this project.



Plate 9: Site B located in Ashram Bill area of Vadodara District

#### 4.1.2.2 Planning and implementation

The Miyawaki Urban site developed on Vadodara Municipal Corporation (VMC) property was carefully chosen for urban greening. To guarantee successful afforestation, the site's biological potential, accessibility, and soil quality were evaluated. The National High-Speed Rail Corporation provided funding for the project, which sought to improve biodiversity and environmental sustainability by converting an unused area into a flourishing green habitat.



Plate 10: Different types of species planted at site B

The implementation focused on high-density planting with native species, supported by proper soil preparation and irrigation systems. Due to meticulous planning and strong stakeholder collaboration, the project progressed smoothly without major challenges. Today, the site stands as a model for ecological restoration and urban biodiversity enhancement.

#### **4.1.2.3 Flora Diversity**

A dense and self-sustaining green zone, the Miyawaki site in Ashram Bill, Vadodara, is made up of 7,000 native species. This afforestation technique helps reduce the urban heatwave effect, boosts air quality, and increases biodiversity. The plantation promotes ecological balance and sustainability by containing a wide mix of fruit-bearing, floral, wood, and medicinal plants. This project attempted to restore green cover, assist local species, and offer major environmental benefits to the urban ecology.

**Table 5: Flora Diversity at site B**

Sr. No.	Botanical Name	Local Name	Average Growth Rate (cm)	Survival rate (%)	Advantage (Medicinal/Timber/Fruit/Flower)	Type (Evergreen/deciduous/perennial)	Layer (Canopy/Trees/Herbs)	(Trees/Sub Shrubs)
1	Lagerstroemia speciosa	Jarul	50	80-90	Medicinal, Ornamental	Deciduous	Canopy	
2	Morus alba	Mulberry	40	75-85	Fruit, Medicinal, Fodder	Deciduous	Sub Trees	
3	Punica granatum	Pomegranate	30	85-95	Fruit, Medicinal	Deciduous	Shrubs	
4	Annona squamosa	Custard Apple	35	80-90	Fruit, Medicinal	Deciduous	Sub Trees	
5	Mimusops elengi	Bakul	40	85-90	Medicinal, Timber, Ornamental	Evergreen	Trees	
6	Cordia dichotoma	Lasora	45	75-85	Fruit, Medicinal, Timber	Deciduous	Sub Trees	
7	Psidium guajava	Guava	55	85-95	Fruit, Medicinal	Evergreen	Sub Trees	
8	Cassia fistula	Amaltas	45	80-90	Medicinal, Ornamental	Deciduous	Canopy	
9	Annona reticulata	Ramphal	40	75-85	Fruit, Medicinal	Deciduous	Sub Trees	
10	Swietenia mahagoni	Mahogany	65	80-90	Timber	Deciduous	Trees	
11	Melia dubia	Black Neem	75	70-80	Timber, Medicinal	Deciduous	Trees	
12	Polyalthia longifolia	Ashoka	45	85-95	Ornamental, Medicinal	Evergreen	Trees	
13	Tectona grandis	Teak	65	75-85	Timber	Deciduous	Trees	
14	Butea monosperma	Flame of Forest	30	70-80	Medicinal, Flowering	Deciduous	Canopy	
15	Madhuca longifolia	Mahua	40	85-95	Medicinal, Oil, Timber	Evergreen	Trees	
16	Peltophorum pterocarpum	Copperpod	50	75-85	Ornamental, Shade	Deciduous	Canopy	
17	Azadirachta indica	Neem	75	85-95	Medicinal, Timber	Evergreen	Trees	
18	Pongamia pinnata	Karanj	55	80-90	Medicinal, Oil, Timber	Evergreen	Trees	

The analysis of plant survival rates revealed that 27.7% of the plant species had survival rates ranging from 75% to 95%, including plants such as Jarul, Mulberry, Pomegranate, and Guava. Additionally, 11.1% of the plant species, namely Black Neem and Flame of the Forest, exhibited a survival rate between 70% and 80%. The

lowest survival rate, recorded at 85% to 95%, was observed in 5.5% of the plant species, specifically Bakul. The average growth rate across all species was 49 cm. The minimum recorded growth rate was 30 cm for *Punica granatum* and *Butea monosperma*, while the maximum was 75 cm for *Melia dubia* and *Azadirachta indica*.

The Miyawaki site in Ashram Bill, Vadodara, was developed with a total of 7,000 plants, comprising 18 different species carefully selected for their ecological benefits. These species were categorized based on their advantages, with many serving medicinal 11 species, timber 6 species, fruit-bearing 7 species, and ornamental or shade purposes 6 species. Additionally, two species contributing to oil production. In terms of plant type, the site included a mix of evergreen 7 species, deciduous 10 species, and perennial 1 species tree. The distribution of plants across different layers ensured a multi-tiered, self-sustaining ecosystem, with trees and canopy species 10, sub-trees 5, and shrubs 3 playing crucial roles in enhancing biodiversity.

As reported by the respondent, the careful selection and arrangement of these species have helped in creating a thriving urban site, significantly improving air quality, reducing local temperatures, and supporting local wildlife. The Miyawaki afforestation model implemented in Ashram Bill demonstrates a successful approach to restoring green spaces and fostering urban biodiversity.



Plate 11: Measuring the plant height at Site B

#### **4.1.2.4 Fauna Diversity**

To collect the necessary biodiversity data, respondents were first asked whether any initial surveys of insects, birds, and mammals had been conducted before the Miyawaki site was established. Those who confirmed prior assessments were requested to describe the originally observed species and provide population estimates where available. Developer were then asked to report any increases in insect and bird species diversity after the development, including specific species names and their estimated population trends. Regarding mammals, respondents were questioned about any new species observed since the creation, along with details about their behavioral patterns and population changes. Additionally, they were asked to describe any observed mutualistic relationships, such as birds aiding seed dispersal or insects facilitating plant pollination, and to explain their ecological importance. Finally, respondents were questioned about potential predator-prey interactions within the ecosystem and how such dynamics might influence ecological balance. This comprehensive line of questioning allowed for a thorough evaluation of biodiversity changes and ecological interactions resulting from the Miyawaki afforestation project.

##### **4.1.2.4.1 Initial Faunal Presence**

Before the Miyawaki site was established, a preliminary assessment conducted by the respondent revealed little biodiversity. Bird variety was restricted to the House Crow and House Sparrow, and only common pester species were seen. Because there was little greenery and food, there were few small mammals, including squirrels. Furthermore, snakes were known to exist in the area prior to afforestation. The lack of appropriate habitats was the reason for the low levels of faunal activity.

##### **4.1.2.4.2 Current Faunal Diversity**

The respondent indicated that the number of insect species has increased significantly. In the Miyawaki site, the growth of dense vegetation and

flowering plants has enhanced the ecosystem, attracting a greater variety of insects. As a result, the region now supports a larger insect population, which contributes to increased biodiversity and improved pollination. For detailed data on observed and estimated species populations, shown in Table 6.

**Table 6: Faunal Diversity (Insects Species) at site B**

Sr. No.	Name of the species observed	Estimate population
1.	Common Immigrant Butterfly	20
2.	Plain Tiger Butterfly	25
3.	Common Crow Butterfly	15
4.	Honey bee	200

The Miyawaki site has seen a notable rise in species, according to data on faunal diversity. About 200 honey bees, 25 Plain Tiger Butterflies, 20 Common Immigrant Butterflies, and 15 Common Crow Butterflies was recorded by the respondent.

**Table 7: Faunal Diversity (Birds Species) at site B**

Sr. No.	Name of the species observed	Estimate population
1.	White-browed Fantail Flycatcher	4
2.	Oriental Magpie Robin	10
3.	House Sparrow	10
4.	House Crow	6
5.	Red-vented Bulbul	10
6.	Jungle Babbler	5

There was a noticeable increase in species in the Miyawaki site, according to the faunal diversity data in Table 7, with about 10 House Sparrows, 10 Oriental Magpie Robin, 10 Red-vented Bulbuls, 6 House Crows, 5 Jungle Babbler, and 4 White-browed Fantail Flycatchers were seen by the Developer.

**Table 8: Faunal Diversity (New mammal species) at site B**

Sr. No.	Name of the species observed	Notable behaviors/characteristics	Population trends
1.	Indian Palm Squirrel	Nesting in tree cavities, active in mornings	Stable
2.	Rodents (various species)	Burrowing in soil, foraging for food	Increasing
3.	Indian Hare	Seen foraging at dusk, cautious behavior	Stable

Field observations indicate varying population trends and behavioral patterns among mammalian species in the Miyawaki site. The Indian Palm Squirrel, frequently observed nesting in tree cavities, maintains a stable population and is most active during morning hours. Certain rodent species, recognized for their burrowing and feeding behaviors, exhibit a growing population trend. Meanwhile, the Indian Hare, displaying cautious behavior while foraging at dusk, also demonstrates a stable population. These trends suggest that the afforested area provides suitable resources and habitats that support the survival and adaptation of these species shown in Table 8 for detailed data.



Plate 12: Faunal diversity at Site B

#### **4.1.2.4.3 Faunal Interaction with Flora**

The Miyawaki site has significantly strengthened ecological relationships between fauna and flora, promoting biodiversity and ecosystem stability. The increase of flowering plants has attracted diverse pollinators including butterflies and honey bees, enhancing plant reproduction. Bird species such as the Oriental Magpie Robin and Red-vented Bulbul have benefited from increased insect and fruit availability, contributing to natural pest control and seed dispersal. Mammals including the Indian Palm Squirrel and various rodents utilize the for shelter and food sources while facilitating seed distribution and soil aeration. Notably, the ecosystem currently shows no observable predator-prey interactions. These findings demonstrate how afforestation initiatives can effectively support species adaptation and maintain balanced ecological functions.

#### **4.1.2.5 Humidity, Temperature and Air Quality**

The establishment of the Miyawaki Urban site has significantly improved the local microclimate, particularly by enhancing humidity levels and regulating temperature. The dense canopy had reduced direct sunlight exposure, helping retain soil moisture and creating a more comfortable environment, especially during dry seasons. This increase in humidity has contributed to a noticeable cooling effect, making the space more pleasant compared to the surrounding urban areas as reported by the respondents. Additionally, during summer afternoons, temperatures within the site remain lower due to shade and evapotranspiration, offering relief from the heat and mitigating the urban heat island effect. Previously, the site was barren soil exposed to extreme temperatures, but it has now transformed into a thriving green lung for the city.

The site has also positively influenced air quality, with local residents reporting fresher, cleaner air despite the lack of formal measurements. As reported by the respondents, the dense vegetation helps absorb pollutants, filter carbon dioxide, and

release oxygen, contributing to a healthier atmosphere. Residents and stakeholders have also noted a perceived reduction in daytime heat, which led to lower energy consumption in nearby buildings. Overall, the Miyawaki Urban site has become a model of urban sustainability, demonstrating how strategic afforestation can enhance biodiversity, regulate microclimates, and improve the quality of life in cities.



Plate 13: Dense plantation at site B

#### **4.1.2.6 Maintenance and Growth**

Over the past three years, diligent maintenance practices have ensured the sustainable growth of the Miyawaki Urban site. Regular monitoring during the initial phase helped identify and address potential challenges, allowing the plants to establish a strong foundation. Water scarcity was a significant challenge, particularly during dry periods, but strategic watering schedules and conservation measures helped sustain the young saplings. Conservation measures such as mulching, the use of drought-resistant native species, and water supply through tanks played a crucial role in maintaining soil moisture and reducing water dependency. Despite these hurdles, the resilience of the Miyawaki technique was evident, as native species adapted well to local conditions, demonstrating rapid growth and canopy formation.

Following the initial planting phase, no fertilizers were used, allowing the space to develop naturally and maintain its ecological balance. The plants have shown normal flowering and fruiting patterns, indicating successful adaptation to their environment. As the matures, biodiversity continues to expand, reinforcing its role as a self-sustaining urban green space. The ongoing success of this afforestation initiative highlights the long-term environmental benefits of dense urban space, making it a model for sustainable urban greening.



Plate 14: Mature trees at site B

### 4.1.3 Case study 3: Site C

#### 4.1.3.1 Profile of the site

The Miyawaki project at Channi Lake area was established in November 2022, spans 1,000 square meters and is strategically positioned near the lake to enhance both the ecological and urban landscape. With a high planting density of three plants per square meter, the project maximizes greenery while contributing to pollution reduction, biodiversity enhancement, and urban heat mitigation. Designed as a sustainable green initiative, it aims to improve air quality, regulate temperature, and promote ecological balance in the area.

Developer played a crucial role in the project's success, fostering a sense of ownership among local residents and stakeholders. The Site C stands as a model for urban afforestation, demonstrating how underutilized spaces can be transformed into thriving green environments, offering long-term environmental and social advantages.



Plate 15: Different types of species planted at site C

#### 4.1.3.2 Planning and implementation

The Site C area was strategically chosen to enhance both the local ecosystem and urban environment. The site selection process involved thorough research, to evaluate factors such as soil quality, proximity to water sources, and accessibility. These considerations ensured the land was suitable for afforestation and long-term sustainability.

The planning and implementation of the project were carried out in collaboration with an experienced Landscape designer working in VMC, focusing on optimal planting density, native species selection, and site-specific ecological needs. The respondents reported that due to careful preparation and coordinated execution, the project faced no major challenges, allowing the site to be established smoothly and efficiently.

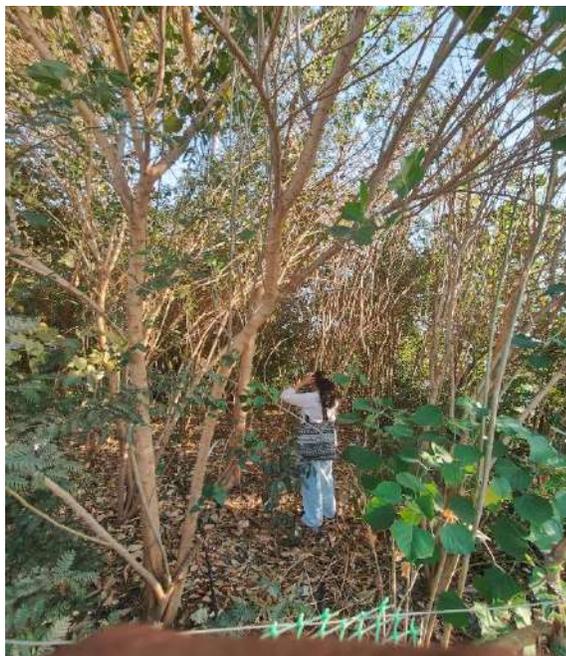


Plate 16: Mature plants at site C

#### 4.1.3.3 Flora Diversity

The Miyawaki technique was used to plant 3,000 plants at Site C as part of an afforestation project. Rapid development of green space, biodiversity enhancement, and ecological restoration in urban settings are the main goals of this technique. With

a variety of trees, shrubs, and herbs that support soil enrichment, carbon sequestration, and the establishment of habitat for a wide range of wildlife, the chosen plant species have a variety of ecological functions.

**Table 9: Flora Diversity at site C**

Sr. No.	Botanical Name	Local Name	Average Growth Rate (cm)	Survival rate (%)	Advantage (Medicinal/Timber/Fruit/Flower)	Type (Evergreen/deciduous/perennial)	Layer (Trees/Canopy/Trees/Herbs)	(Trees/ Sub Shrubs)
1	<i>Nyctanthes arbor-tristis</i>	Parijat	30	80-90	Medicinal, Flowering	Deciduous	Shrubs	
2	<i>Bauhinia variegata</i>	Bahunia	45	75-85	Medicinal, Ornamental	Deciduous	Sub Trees	
3	<i>Cassia javanica</i>	Pink Karen	50	75-85	Ornamental, Shade	Deciduous	Canopy	
4	<i>Psidium guajava</i>	Guava	55	85-95	Fruit, Medicinal	Evergreen	Sub Trees	
5	<i>Punica granatum</i>	Pomegranate	30	85-95	Fruit, Medicinal	Deciduous	Shrubs	
6	<i>Cestrum nocturnum</i>	Rat Rani	38	80-90	Ornamental, Medicinal	Evergreen	Shrubs	
7	<i>Bixa orellana</i>	Sindoor	40	75-85	Medicinal, Dye Production	Evergreen	Sub Trees	
8	<i>Ziziphus mauritiana</i>	Setur	45	75-85	Fruit, Medicinal	Deciduous	Shrubs	
9	<i>Millettia pinnata</i>	Millettia	55	80-90	Medicinal, Timber	Evergreen	Trees	
10	<i>Cordia myxa</i>	Moto Gundo	40	75-85	Fruit, Medicinal	Deciduous	Sub Trees	
11	<i>Ziziphus nummularia</i>	Borasalli	35	70-80	Medicinal, Fruit	Deciduous	Shrubs	
12	<i>Moringa oleifera</i>	Saragavo	60	85-95	Medicinal, Edible Leaves	Deciduous	Trees	
13	<i>Curcuma amada</i>	Amada	30	75-85	Medicinal, Culinary	Perennial	Herbs	
14	<i>Bauhinia purpurea</i>	Kanchanar	45	75-85	Medicinal, Ornamental	Deciduous	Sub Trees	
15	<i>Butea monospera</i>	Kesudo	30	70-80	Medicinal, Flowering	Deciduous	Canopy	
16	<i>Ficus religiosa</i>	Paras Pipal	55	85-95	Medicinal, Religious Significance	Evergreen	Trees	
17	<i>Putranjiva roxburghii</i>	Putranjiva	40	80-90	Medicinal, Ornamental	Evergreen	Trees	
18	<i>Holoptelea integrifolia</i>	Garamado	45	75-85	Medicinal, Timber	Deciduous	Trees	
19	<i>Acacia nilotica</i>	Acacia	60	80-90	Medicinal, Timber	Evergreen	Trees	
20	<i>Tamarindus indica</i>	Amli	40	85-95	Fruit, Medicinal	Evergreen	Trees	

Table 9 contd.

Table 9 contd.

Sr. No.	Botanical Name	Local Name	Average Growth Rate (cm)	Survival rate (%)	Advantage (Medicinal/Timber/Fruit/Flower)	Type (Evergreen/deciduous/perennial)	Layer (Trees/Canopy/Trees/Herbs)	(Trees/ Sub Shrubs)
21	<i>Syzygium cumini</i>	Jambu	55	85-95	Fruit, Medicinal	Evergreen	Trees	
22	<i>Albizia lebbek</i>	Siras	60	75-85	Timber, Shade	Deciduous	Trees	
23	<i>Dalbergia sissoo</i>	Sisam	65	75-85	Timber, Medicinal	Deciduous	Trees	
24	<i>Cassia grandis</i>	Pink Shower	55	80-90	Ornamental, Shade	Deciduous	Canopy	
25	<i>Holarrhena antidysenterica</i>	Kanaji	30	75-85	Medicinal	Deciduous	Shrubs	
26	<i>Azadirachta indica</i>	Akas Neem	75	85-95	Medicinal, Timber	Evergreen	Trees	
27	<i>Madhuca longifolia</i>	Mahudo	40	85-95	Medicinal, Oil, Timber	Evergreen	Trees	
28	<i>Sapindus mukorossi</i>	Aritha	45	80-90	Medicinal, Soap Production	Deciduous	Trees	
29	<i>Holarrhena pubescens</i>	Kanajo	38	70-80	Medicinal	Deciduous	Shrubs	
30	<i>Gmelina arborea</i>	Kashid	60	80-90	Timber	Deciduous	Trees	
31	<i>Ficus racemosa</i>	Umaro	55	85-95	Medicinal, Religious Significance	Evergreen	Trees	
32	<i>Pithecellobium dulce</i>	Goras Amlu	50	80-90	Fruit, Shade	Evergreen	Sub Trees	
33	<i>Mangifera indica</i>	Ambo	60	85-95	Fruit, Timber	Evergreen	Trees	
34	<i>Sterculia foetida</i>	Jangali Badam	55	80-90	Timber, Oil	Deciduous	Trees	
35	<i>Gmelina asiatica</i>	Sevan	45	75-85	Medicinal, Timber	Deciduous	Trees	
36	<i>Terminalia arjuna</i>	Arjun	55	85-95	Medicinal, Timber	Evergreen	Trees	
37	<i>Terminalia bellirica</i>	Baheda	55	80-90	Medicinal, Timber	Deciduous	Trees	

Based on the analysis of plant survival rates, it was found that 32.43% of the species including setur, bahunia, pink karen, and siras had survival rates between 75% and 85%. Furthermore, 29.7% of the species i.e. *Cassia grandis*, Parijat, and Rat Rani showed a survival rate ranging from 80–90% to 85–95%. The lowest survival rate, range 70 – 80%, was found in 8.1% of the plant species, namely kanajo, kesudo, and borasalli. The average growth rate across all species was 47 cm. The minimum recorded growth rate was 30 cm for multiple species, while the maximum was 75 cm for *Azadirachta indica*.

The Miyawaki site at Channi Lake, Vadodara, consists of 3,000 plants from 37 species, selected for their ecological benefits. These include 21 medicinal, 12 timber, 10 fruit-bearing, and 6 ornamental species, with 3 contributing to oil and dye production. The site C featured 18 evergreen, 18 deciduous, and 1 perennial species, ensuring year-round greenery. Distributed across different layers, it included 18 trees, 4 canopy species, 7 sub-trees, and 7 shrubs, creating a self-sustaining ecosystem that enhances biodiversity, improves air quality, and mitigates the urban heat island effect.



Plate 17: Measuring plants height at site C

#### 4.1.3.4 Fauna Diversity

The biodiversity assessment for the Miyawaki site project followed a structured interview approach with respondents. They were first questioned about pre-site baseline surveys, including whether initial faunal inventories of insects, birds and mammals had been conducted, with requests for species lists and population estimates where available. For post-establishment observations, respondents provided data on: increased insect and bird diversity, including specific species identification and population trends; new mammal species sightings with associated behavioral and demographic information; documented mutualistic interactions like pollination services and seed dispersal activities; and observed predator-prey relationships and their ecosystem impacts.

#### 4.1.3.4.1 Initial Faunal Presence

Prior to the establishment of the Miyawaki site, a preliminary evaluation found minimal biodiversity. Only common pest species were observed, and only the House Crow and House Sparrow were among the variety of birds. There were few squirrels and other tiny creatures because there was little food and foliage. Additionally, according to the participants, snakes were present in the area before it was developed. Feedback indicated the low faunal activity levels were due to a lack of suitable habitats.

#### 4.1.3.4.2 Current Faunal Diversity

It was reported that, the number of insect species has increased noticeably after afforestation. In the Miyawaki site, the development of lush vegetation and flowering plants has improved the ecosystem and drawn a wider range of insects. Because of this, there are now more insects in the region, which enhances biodiversity and pollination. The details of species observed and estimated population is mentioned in Table 10.

**Table 10: Faunal Diversity (Insects Species) at site C**

<b>Sr. No.</b>	<b>Name of the species observed</b>	<b>Estimate population</b>
1.	Common Immigrant Butterfly	25
2.	Plain Tiger Butterfly	35
3.	Common Crow Butterfly	30
4.	Honey bee	250
5.	Dragonflies	40

Data on faunal variety show a significant increase in species in the Miyawaki site. About 250 honey bees, 40 Dragonflies, 35 Plain Tiger Butterflies, 30 Common Crow Butterflies and 25 Common Immigrant Butterflies, and were observed by the gardener.

**Table 11: Faunal Diversity (Birds Species) at site C**

Sr. No.	Name of the species observed	Estimate population
1.	White-browed Fantail Flycatcher	7
2.	House Sparrow	15
3.	House Crow	10
4.	Red-vented Bulbul	15
5.	Jungle Babbler	8

Based on faunal diversity data as shown in Table 11, the Miyawaki site showed a notable increase in species, with approximately 15 pairs of House Sparrows, 15 Red-vented Buleuls, 10 House Crows, 8 Jungle Babblers, and 7 White-browed Fantail Flycatchers were observed by the respondent.

**Table 12: Faunal Diversity (New mammal species) at site C**

Sr. No.	Name of the species observed	Notable behaviors/characteristics	Population trends
1.	Indian Palm Squirrel	Nesting in tree cavities, active in mornings	Stable
2.	Rodents (various species)	Burrowing in soil, foraging for food	Increasing
3.	Indian Hare	Seen foraging at dusk, cautious behavior	Stable

Field observations of the mammalian species in the Miyawaki site revealed in Table 12 shown a variety of population trends and habits. The Indian Palm Squirrel has a consistent population and is most active in the early morning hours. It is frequently observed nesting in tree cavities. Certain rat species, which are well-known for their burrowing and consumption patterns, are seeing an increase in population. The Indian Hare has a stable population and is typically seen foraging at dusk while being cautious. These trends suggest that the afforested area provides habitats and resources that are beneficial for the survival and adaptation of these species.



Plate 18: Faunal diversity at site C

#### **4.1.3.4.3 Faunal Interaction with Flora**

The Miyawaki site has greatly improved the relationships between plants and animals, which supports biodiversity and environmental stability. In order to sustain plant reproduction, the rise in flowering plants has drawn pollinators including dragonflies, butterflies, and honey bees. The availability of fruits and insects' benefits birds, such as the White-browed Fantail Flycatcher and Red-vented Bulbul, which help spread seeds and fight pests. Tree cavities are used by rodents and mammals like the Indian Palm Squirrel for feeding and nesting, which helps spread seeds and aerate the soil. These interactions show how afforestation contributes to the creation of a sustainable and balanced habitat. Nevertheless, no dynamics between predators and prey have been noted in the environment.

#### **4.1.3.5 Humidity, temperature and air quality**

The Developer of the site reported that Miyawaki site at Channi Lake has significantly improved the local microclimate, with increased humidity levels and reduced surface temperatures due to the dense tree canopy. By providing ample shade and moisture retention, the green space has created a cooler, more comfortable environment, particularly during the warmer months. Prior to afforestation, the site was mainly bare soil, exposed to direct sunlight and heat, making the transformation

even more impactful. As reported by the respondents, the noticeable drop in temperature and improved air quality have made the area more pleasant for residents and visitors.

Beyond temperature regulation, the site has contributed to fresher air and improved atmospheric conditions. While formal air quality measurements were not conducted, residents and stakeholders have reported noticeable improvements in air freshness and a perceived reduction in heat levels. This feedback underscores the Miyawaki green space role in mitigating the urban heat island effect, making it a valued green asset in the community.



Plate 19: Dense plantation at Site C

#### **4.1.3.6 Maintenance and Growth**

Over the three years since its establishment, Site C has demonstrated healthy growth and adaptability, with consistent monitoring ensuring its long-term success. The first year's observations showed satisfactory plant growth, confirming the positive impact of the afforestation efforts. Regular assessments helped track the progress, ensuring that trees were thriving in their environment without external interventions.

The use of fertilizers during the initial phase allowed the natural ecosystem to sustain itself, was a crucial component of upkeep. Several species' flowering and fruiting rhythms were noted as typical, demonstrating the site consistent ecological equilibrium. The project's smooth development, free of significant challenges, highlights how well the Miyawaki technique performs to establish an urban space that is sustainable, biodiverse, and improves environmental health in the surrounding region.



Plate 20: Water supply mechanism at site C

#### 4.1.4 Case study 4: Site D

##### 4.1.4.1 Profile of the site

The Miyawaki site at Moti Bapod Lake area, established in March 2021, spans 2,500 square meters with a high planting density of three plants per square meter. Strategically located near a residential area, it enhances biodiversity, improves air quality, and acts as a natural buffer against urban pollutants. The project aimed to promote greenery, reduce pollution, and create an eco-friendly space efficiently. Engaging local residents and stakeholders, the initiative highlighted benefits like temperature regulation and urban heat island mitigation.



Plate 21: Site D located in Moti Bapod lake area of Vadodara District

#### **4.1.4.2 Planning and implementation**

The chairman of Bio Soil South NGO funded the Miyawaki site at Moti Bapod Lake in an effort to turn the area into an explosion green location. In order to ensure that the site was suitable for afforestation, it was carefully chosen based on factors such as the quality of the soil, accessibility to water, and proximity to urban facilities. A competent landscape designer working in VMC created a strategy tailored to the site, maximizing planting density and tree species choices. Because of effective preparation, collaboration, and involvement of stakeholders, the project encountered no significant obstacles. Its flawless implementation emphasizes how crucial cooperation.



Plate 22: Mature trees at site D

#### 4.1.4.3 Flora Diversity

The Miyawaki afforestation technique was implemented in the Moti Bapod area, where 7,000 plants were planted to enhance biodiversity and mitigate urban heat effects. This method promoted rapid vegetation growth and improved ecological resilience by selecting native plant species suited to the local environment.

**Table 13: Flora Diversity at site D**

Sr. No.	Botanical Name	Local Name	Average Growth Rate (cm)	Survival rate (%)	Advantage (Medicinal/Timber/Fruit/Flower)	Type (Evergreen/deciduous/perennial)	Layer Canopy/Trees/Herbs	(Trees/Sub Shrubs)
1	Cestrum nocturnum	Night Queen	40	80–90	Flower (Fragrant, Ornamental)	Evergreen	Shrubs	
2	Buddleia asiatica	Buddleia	50	75–85	Medicinal, Flower (Attracts butterflies)	Deciduous	Shrubs	
3	Holmskioldiasanguinea	Cup and Saucer	40	70–80	Flower (Ornamental)	Evergreen	Shrubs	

Table 13 contd.

Table13 contd.

Sr. No.	Botanical Name	Local Name	Average Growth Rate (cm)	Survival rate (%)	Advantage (Medicinal/Timber/Fruit/Flower)	Type (Evergreen/deciduous/perennial)	Layer Canopy/Trees/Herbs	(Trees/ Sub Shrubs)
4	Thunbergia erecta	Meyenia Erecta	32	75–85	Medicinal, Ornamental Flower	Evergreen	Shrubs	
5	Nicodemia diversifolia	Nicadevia	50	70–80	Ornamental, Erosion Control	Evergreen	Shrubs	
6	Clerodendrum wallichii	Clerodendrum	45	75–85	Medicinal, Ornamental Flower	Deciduous	Shrubs	
7	Jatropha curcas	Jatropha	65	80–90	Medicinal, Biofuel, Ornamental	Deciduous	Trees	
8	Canna indica (Yellow)	Yellow Canna	40	80–90	Flower (Ornamental)	Perennial	Herbs	
9	Canna indica (Red)	Red Canna	40	80–90	Flower (Ornamental)	Perennial	Herbs	
10	Pandanus odoratissimus	Kakada	50	85–95	Flower (Fragrant, Medicinal)	Evergreen	Shrubs	
11	Galphimia glauca	Galphimia	38	75–85	Medicinal, Ornamental	Evergreen	Shrubs	
12	Euryops pectinatus	Yellow Daisy	32	70–80	Flower (Ornamental)	Perennial	Herbs	
13	Angelonia angustifolia	Angelonia	32	70–80	Flower (Ornamental)	Perennial	Herbs	
14	Angelonia grandiflora	Angelonia	32	70–80	Flower (Ornamental)	Perennial	Herbs	
15	Polianthes tuberosa	Tuberose	40	75–85	Flower (Fragrant, Ornamental)	Perennial	Herbs	
16	Jasminum spp.	Jasmine	45	80–90	Flower (Fragrant, Medicinal)	Evergreen	Shrubs	
17	Gardenia jasminoides	Gardenia	32	75–85	Flower (Fragrant, Ornamental)	Evergreen	Shrubs	
18	Pterocarpus santalinus	Red Sandal	50	70–80	Timber, Medicinal	Deciduous	Trees	
19	Dyopsis lutescens	Areca Palm	70	85–95	Ornamental, Air Purifier	Evergreen	Trees/Canopy	
20	Couroupita guianensis	Cannonball Tree	50	70–80	Medicinal, Ornamental Flower	Deciduous	Trees	
21	Neolamarckia cadamba	Kadamba	65	75–85	Medicinal, Timber, Ornamental	Deciduous	Trees	
22	Melia dubia	Malabar Neem	100	80–90	Timber, Medicinal	Deciduous	Trees	
23	Bambusa vulgaris (Yellow)	Yellow Bamboo	80	85–95	Timber, Erosion Control	Evergreen	Canopy	

Table 13 contd.

Sr. No.	Botanical Name	Local Name	Average Growth Rate (cm)	Survival rate (%)	Advantage (Medicinal/Timber/Fruit/Flower)	Type (Evergreen/deciduous/perennial)	Layer Canopy/Trees/Herbs	(Trees/Sub Shrubs)
24	Bambusa vulgaris (Green)	Green Bamboo	80	85–95	Timber, Erosion Control	Evergreen	Canopy	
25	Musa spp.	Banana	125	90–95	Fruit, Medicinal	Perennial		Table 13 contd.
26	Wrightia tinctoria	Yezhilai Paalai	50	75–85	Medicinal, Timber	Deciduous		
27	Lagerstroemia speciosa	Legastromia	65	75–85	Timber, Ornamental	Deciduous	Trees	
28	Borassus flabellifer	Koondal Panai	60	80–90	Timber, Fruit, Medicinal	Evergreen	Trees	
29	Alternanthera sessilis	Lachakatta Keerai	25	70–80	Medicinal, Leafy Vegetable	Perennial	Herbs	
30	Bacopa monnieri	Paachan	32	70–80	Medicinal (Brain Tonic)	Perennial	Herbs	
31	Mangifera indica (Banganapalli)	Banganapalli Mango	65	80–90	Fruit	Evergreen	Trees	
32	Citrus limetta	Sweet Lemon	40	80–90	Fruit, Medicinal	Evergreen	Sub Trees	
33	Citrus limon	Lemon	40	80–90	Fruit, Medicinal	Evergreen	Sub Trees	
34	Syzygium samarangse	Water Apple	50	75–85	Fruit, Ornamental	Evergreen	Sub Trees	
35	Mimusops elengi	Indian Cherry	50	75–85	Medicinal, Ornamental	Evergreen	Trees	
36	Malpighia emarginata	West Indian Cherry	40	75–85	Fruit, Medicinal	Evergreen	Sub Trees	
37	Phyllanthus emblica (Small)	Amla (Small)	40	75–85	Fruit, Medicinal	Deciduous	Sub Trees	
38	Terminalia elliptica	Asan	65	75–85	Timber, Medicinal	Deciduous	Trees	
39	Ailanthus excelsa	Ailanthus	65	75–85	Timber, Shade	Deciduous	Trees	
40	Terminalia bellirica	Baheda	65	75–85	Medicinal, Timber	Deciduous	Trees	
41	Annona muricata	Cancer Fruit	40	70–80	Fruit, Medicinal	Evergreen	Sub Trees	
42	Annona squamosa	Sugar Apple	50	75–85	Fruit, Medicinal	Deciduous	Sub Trees	
43	Psidium guajava	Guava	60	80–90	Fruit, Medicinal	Evergreen	Sub Trees	
44	Citrus medica	Citron	40	75–85	Fruit, Medicinal	Evergreen	Sub Trees	
45	Citrus maxima	Bablmas (Pomelo)	50	75–85	Fruit, Medicinal	Evergreen	Sub Trees	
46	Averrhoa carambola	Star Fruit	50	75–85	Fruit, Medicinal	Evergreen	Sub Trees	
47	Litchi chinensis	Litchi Fruit	40	70–80	Fruit, Medicinal	Deciduous	Sub Trees	

Table 13 contd.

Table 13 contd.

Sr. No.	Botanical Name	Local Name	Average Growth Rate (cm)	Survival rate (%)	Advantage (Medicinal/Timber/Fruit/Flower)	Type (Evergreen/deciduous/perennial)	Layer Canopy/Trees/Herbs	(Trees/ Sub Shrubs)
48	<i>Annona reticulata</i>	Ram Sita	50	75–85	Fruit, Medicinal	Evergreen	Sub Trees	
49	<i>Ficus afghanistanica</i>	Fig - Afghan	50	80–90	Fruit, Medicinal	Deciduous	Table 13 contd.	
50	<i>Prunus avium</i>	Cherry	40	75–85	Fruit, Ornamental	Deciduous	Trees	
51	<i>Punica granatum</i>	Pomegranate	40	80–90	Fruit, Medicinal	Deciduous	Sub Trees	
52	<i>Dianthus spp.</i>	Dianthus	25	70–80	Flower (Ornamental)	Perennial	Herbs	
53	<i>Lonicera spp.</i>	Honeysuckle	40	75–85	Flower (Fragrant, Ornamental)	Perennial	Shrubs	
54	<i>Antirrhinum majus</i>	Snap Dragon	32.5	70–80	Flower (Ornamental)	Perennial	Herbs	
55	<i>Cuphea hyssopifolia</i>	Cuphea	25	75–85	Flower (Ornamental)	Perennial	Shrubs	
56	<i>Thunbergia mysorensis</i>	Mysore Clock Vine	40	70–80	Flower (Ornamental)	Evergreen	Shrubs	
57	<i>Passiflora edulis</i>	Passion Fruit	50	75–85	Fruit, Medicinal	Evergreen	Shrubs/Vine	
58	<i>Ipomoea purpurea</i>	Morning Glory	40	70–80	Flower (Ornamental)	Perennial	Shrubs/Vine	
59	<i>Tamarindus indica</i>	Tamarind	65	80–90	Fruit, Medicinal, Timber	Evergreen	Trees	
60	<i>Phyllanthus emblica (Big)</i>	Amla (Big)	65	80–90	Fruit, Medicinal	Deciduous	Trees	
61	<i>Santalum album</i>	Sandalwood	50	70–80	Timber, Medicinal	Evergreen	Trees	
62	<i>Vitex negundo</i>	Nochi	50	75–85	Medicinal, Mosquito Repellent	Deciduous	Shrubs	
63	<i>Lawsonia inermis</i>	Henna	40	75–85	Medicinal, Dye Plant	Evergreen	Shrubs	
64	<i>Terminalia arjuna</i>	Arjuna	65	75–85	Medicinal, Timber	Deciduous	Trees	
65	<i>Saraca asoca</i>	Ashoka	50	80–90	Medicinal, Ornamental	Evergreen	Trees	
66	<i>Artocarpus heterophyllus</i>	Jackfruit	65	80–90	Fruit, Timber	Evergreen	Trees	
67	<i>Bauhinia variegata</i>	Bauhinia	50	75–85	Medicinal, Ornamental	Deciduous	Sub Trees	
68	<i>Nerium oleander</i>	Arali	40	75–85	Ornamental, Medicinal	Evergreen	Shrubs	
69	<i>Ocimum sanctum</i>	Tulsi	30	80–90	Medicinal, Religious	Perennial	Herbs	
70	<i>Pithecellobium dulce</i>	Madras Thorn	65	80–90	Fruit, Nitrogen Fixing	Evergreen	Trees	

Table 13 contd.

Table 13 contd.

Sr. No.	Botanical Name	Local Name	Average Growth Rate (cm)	Survival rate (%)	Advantage (Medicinal/Timber/Fruit/Flower)	Type (Evergreen/deciduous/perennial)	Layer Canopy/Trees/Herbs)	(Trees/ Sub Shrubs)
71	Michelia champaca	Magilam	50	75–85	Timber, Fragrant Flowers	Evergreen	Trees	
72	Swietenia mahagoni	Mahogany	75	75–85	Timber	Deciduous	Trees	
73	Thespesia populnea	Portia Tree	60	80–90	Timber, Medicinal	Evergreen	Trees	
74	Justicia adhatoda	Adhatoda/ Vasaka	40	75–85	Medicinal (Respiratory)	Evergreen	Shrubs	
75	Ixora coccinea	Ixora	32.5	70–80	Ornamental, Medicinal	Evergreen	Shrubs	
76	Madhuca longifolia	Mahua	65	75–85	Fruit, Medicinal, Timber	Deciduous	Trees	
77	Ficus racemosa	Country Fig	50	75–85	Fruit, Medicinal	Deciduous	Trees	
78	Dalbergia latifolia	Rosewood	65	75–85	Timber	Deciduous	Trees	
79	Pterocarpus marsupium	Indian Kino Tree	65	75–85	Medicinal, Timber	Deciduous	Trees	
80	Syzygium cumini	Jamun	65	80–90	Fruit, Medicinal	Evergreen	Trees	

The study of plant survival rates revealed that 46.25% of the species, such as gardenia, tubero, galphi, and clerod endrum, had survival rates ranging from 75-85%. Furthermore, 26.25% of the species which include Malabar neem, jatropha, yellow canna, jasmine, and night queen exhibited a survival rate between 80-90%. The lowest survival rate, between 90-95%, was found in 1.25% of the plant species, namely banana. The average growth rate across all species was approximately 49 cm per year. The minimum recorded growth rate is 25 cm per year, observed in species like Dianthus spp. and Cuphea hyssopifolia. Meanwhile, the maximum growth rate reached 125 cm per year, recorded for Swietenia mahagoni (Mahogany).

The planted species were categorized based on their ecological benefits. Among the total species planted, 28 had medicinal properties, 20 were timber-producing, 18 bore fruit, and 15 were planted for their ornamental or shade-providing attributes. Additionally, 5 species were known for erosion control, 4 contributed to fragrance, 2 had dye-producing capabilities, and one can be utilized for biofuel production. The classification based on plant type showed that 35 species were evergreen, 38 were deciduous, and 7 were perennial. The structural distribution within the green space

ecosystem comprised 45 tree and canopy layer species, 12 sub-tree species, 18 shrub species, and 5 herb species.

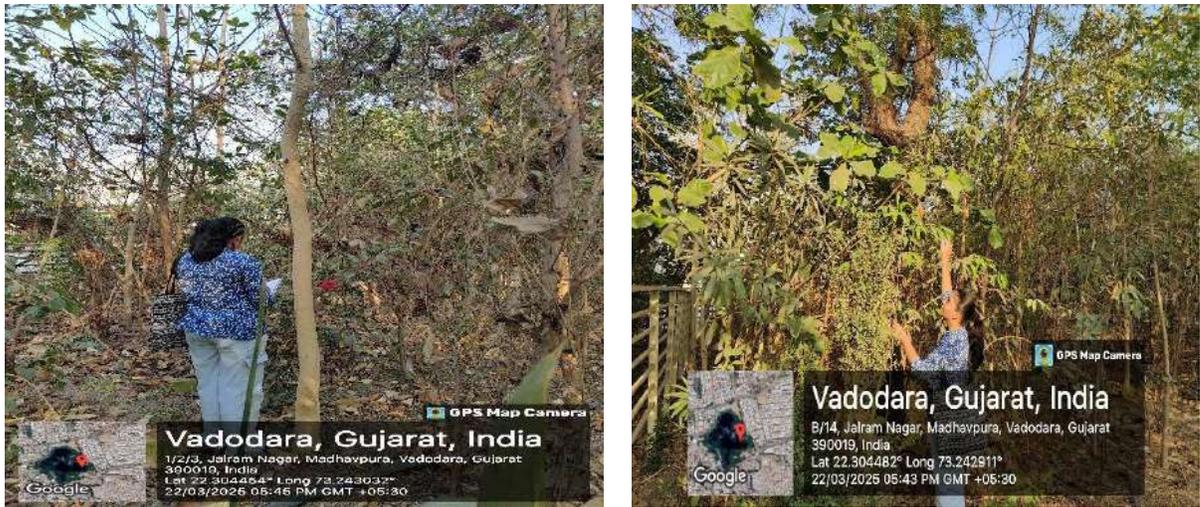


Plate 23: Measuring plant height at site D

#### 4.1.4.4 Fauna Diversity

The study employed a systematic approach to assess biodiversity changes in the Miyawaki green space through respondent interviews. They were initially asked about pre-site conditions, specifically whether baseline surveys documenting insect, bird, and mammal populations had been conducted prior to afforestation. For studies, respondents provided detailed species inventories and population estimates. The interview protocol then focused on post-establishment ecological changes, gathering data on four key aspects observed increases in insect and bird diversity, including species identification and population trends documentation of new mammal species with accompanying behavioral and demographic data evidence of mutualistic species interactions such as pollination and seed dispersal; and records of predator-prey relationships and their ecological consequences.

##### 4.1.4.4.1 Initial Faunal Presence

Before the establishment of the Miyawaki site, a preliminary assessment revealed low biodiversity. The respondent observed common pest species,

with the House Crow and House Sparrow being the predominant bird species. They were reported the presence of snakes in the area prior to afforestation. The low levels of faunal activity were attributed to the absence of suitable habitats.

#### 4.1.4.4.2 Current Faunal Diversity

The site D has demonstrated notable increases in insect biodiversity, as observed by the developer. The establishment of dense vegetation and diverse flowering plants has created an enriched habitat that supports a wider variety of insect species. This ecological enhancement has led to substantial growth in insect populations, with corresponding benefits for overall biodiversity and pollination services. The detailed observations and population estimated for these insect species are presented in Table 14.

**Table 14: Faunal Diversity (Insects Species) at site D**

Sr. No.	Name of the species observed	Estimate population
1.	Common Immigrant Butterfly	20
2.	Plain Tiger Butterfly	30
3.	Common Crow Butterfly	25
4.	Honey bee	225
5.	Dragonflies	35
6.	Damselflies	30

Data on faunal diversity indicated a significant increase in species within the Miyawaki green space. Approximately 225 honey bees, 35 dragonflies, 30 Plain Tiger Butterflies, 30 damselflies, 25 Common Crow Butterflies, and 20 Common Immigrant Butterflies were observed, reflecting the positive impact of afforestation on insect populations.

**Table 15: Faunal Diversity (Birds Species) at site D**

Sr. No.	Name of the species observed	Estimate population
1.	White-browed Fantail Flycatcher	5
2.	House Sparrow	13
3.	House Crow	9
4.	Red-vented Bulbul	12
5.	Jungle Babbler	6
6.	Purple sunbird	8

Data related to Faunal diversity as shown in Table 15 indicated a notable increase in species within the Miyawaki site. Approximately 13 pairs of House Sparrows, 12 Red-vented Bulbuls, 9 House Crows, 8 Purple Sunbirds, 6 Jungle Babblers, and 5 White-browed Fantail Flycatchers were recorded, highlighting the positive impact of afforestation on biodiversity.

**Table 16: Faunal Diversity (New mammal species) at site D**

Sr. No.	Name of the species observed	Notable behaviors/characteristics	Population trends
1.	Indian Palm Squirrel	Nesting in tree cavities, active in mornings	Stable
2.	Rodents (various species)	Burrowing in soil, foraging for food	Increasing

In the Miyawaki site, field observations of mammalian species showed a variety of population trends and behaviors. The Indian Palm Squirrel, which often nests in tree cavities, demonstrated peak activity in the early morning and maintained a steady population. A growing tendency in population was observed for some kinds of rodents viz. Rats and Mice. That are known for their burrowing and feeding habits. These results implied that the key habitats and resources offered by the afforested region supported the survival and adaption of the species.

#### 4.1.4.4.3 Faunal Interaction with Flora

The Miyawaki green space has fostered diverse interactions between fauna and flora, contributing to ecosystem stability and biodiversity enhancement. The proliferation of flowering plants has attracted pollinators such as honey bees, butterflies, dragonflies, and damselflies, which play a crucial role in plant reproduction. Birds, including the Red-vented Bulbul and Purple Sunbird, have benefited from the increased availability of fruits and insects, supporting seed dispersal and natural pest control. Mammals, such as the Indian Palm Squirrel and various rodent species, further aiding in seed dispersal and soil aeration. However, no predator-prey dynamics have been observed within the site ecosystem. These interactions indicate that afforestation has provided essential habitats and resources, promoting species adaptation and ecological balance.



Plate 24: Faunal diversity at site D

#### 4.1.4.5 Humidity, temperature and air quality

The Site D has significantly increased local humidity levels, creating a cooler and more comfortable microclimate as reported by the respondent. Temperature differences between the green space and surrounding urban areas were evident, with the dense canopy reducing heat, especially in summer. Previously, the site was bare soil exposed to direct sunlight, contributing to higher surface temperatures. The site

has also improved air quality, with residents reporting fresher air and reduced heat, despite the absence of formal measurements. As reported by the respondents, the project has been widely recognized as a successful environmental initiative, enhancing biodiversity, mitigating the urban heat island effect, and improving overall livability.



Plate 25: Dense plantation at Site D

#### **4.1.4.6 Maintenance and growth**

The Miyawaki site at Moti Bapod Lake has shown steady growth over three years, with regular monitoring ensuring plant health and adequate hydration. One challenge faced was water scarcity during dry spells, which was effectively managed by utilizing lake water for irrigation. Nutrients from the lake enriched the soil naturally, eliminating the need for chemical fertilizers and supporting organic growth. The flowering and fruiting cycles progressed normally, indicating its successful establishment. These maintenance efforts have contributed to a thriving, resilient green space, enhancing biodiversity and environmental sustainability in the area.

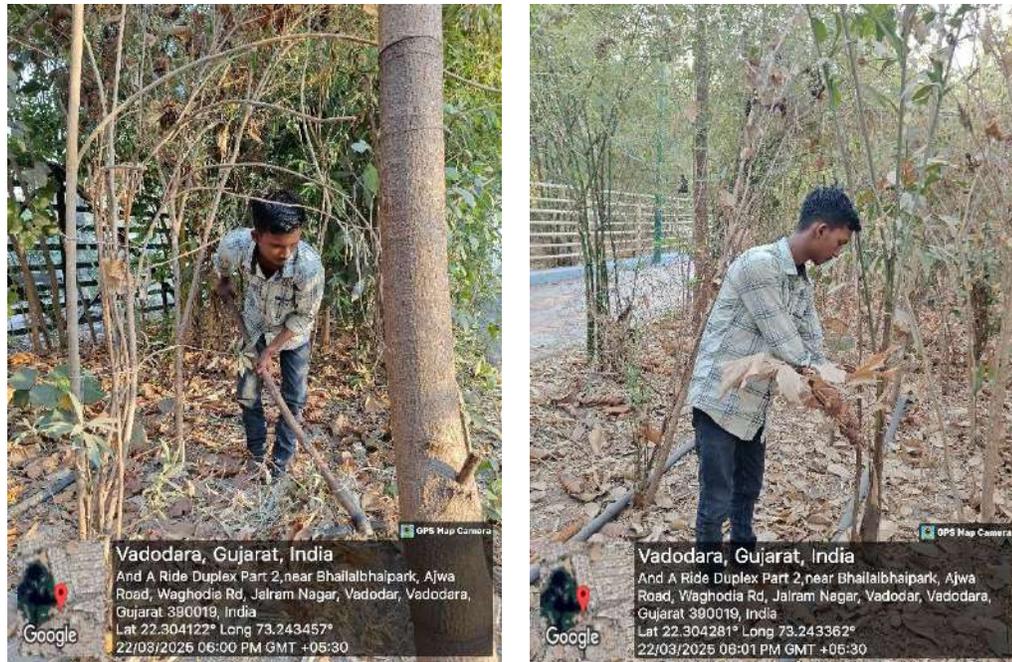


Plate 26: Maintenance process of plants pruning at site D

#### 4.1.5 Case study 5: Site E

##### 4.1.5.1 Profile of the site

The 3,500 square meter Miyawaki site at Ambe School, near Harni area was initiated on June 5, 2022, and is ideally situated close to urban infrastructure. The project's three-plant-per-square-meter planting density aims to reduce urban heat, enhance air quality, and stimulate biodiversity. Through community engagement, the project demonstrates the effectiveness of the Miyawaki technique in quickly turning arid soil into a flourishing ecosystem while promoting sustainable urban greenery. As an example of urban afforestation, this project fosters the sustainable environment and welfare of the people.



Plate 27: Site E located in Ambe School near Harni area of Vadodara District

#### 4.1.5.2 Planning and Implementation

The Catch Foundation's project to establish a lively green area provided funding for developing at Site E. The best soil quality and environmental conditions for afforestation were guaranteed by a comprehensive site study. In order to ensure long-term sustainability, the project integrated optimal planting density, species selection, and irrigation planning in conjunction with a professional designer. The site was successfully built with careful preparation and smooth implementation, improving biodiversity and helping the local people.



Plate 28: Drip Irrigation method was used for Water supply mechanism at site E

#### 4.1.5.3 Flora Diversity

The Miyawaki site at Ambe School Harni is a remarkable urban greening initiative, where a total of 10,500 plants were carefully selected and planted to establish a diverse and self-sustaining ecosystem. The afforestation process incorporated multiple layers, including trees, sub-trees, shrubs, and canopy species, ensuring a balanced and resilient green space.



Plate 29: Measuring plants height at site E

**Table 17: Flora Diversity at site E**

Sr. No.	Botanical Name	Local Name	Average Growth Rate (cm/year)	Survival rate (%)	Advantage (Medicinal/Timber/Fruit/Flower)	Type (Evergreen/deciduous/perennial)	Layer (Trees/Canopy/Trees/Herbs)	(Trees/ Sub Shrubs)
1	Delonix regia	Gulmohar	65	75–85	Ornamental, Timber	Deciduous	Trees	
2	Ficus religiosa	Pipal	55	80–90	Medicinal, Religious	Evergreen	Trees	
3	Ziziphus mauritiana	Borasalli	50	75–85	Fruit, Medicinal	Deciduous	Sub Trees	
4	Aegle marmelos	Bilipatra	40	80–90	Medicinal, Religious	Deciduous	Trees	
5	Ficus racemosa	Umaro	50	75–85	Fruit, Medicinal	Deciduous	Trees	
6	Smilax ovalifolia	Nagol	40	75–85	Medicinal	Perennial	Shrubs	
7	Dalbergia sissoo	Sisam	70	75–85	Timber, Medicinal	Deciduous	Trees	
8	Cassia fistula	Garmalo	65	75–85	Medicinal, Ornamental	Deciduous	Trees	
9	Bixa orellana	Sindur	40	70–80	Medicinal, Dye Plant	Evergreen	Shrubs	
10	Citrus limon	Neembu	40	80–90	Fruit, Medicinal	Evergreen	Sub Trees	
11	Azadirachta indica	Neem	65	85–95	Medicinal, Timber	Evergreen	Trees	
12	Pongamia pinnata	Karen	65	80–90	Timber, Medicinal	Evergreen	Trees	
13	Hibiscus rosa-sinensis	Jasud	40	80–90	Medicinal, Ornamental	Evergreen	Shrubs	
14	Swietenia mahagoni	Mahogany	75	75–85	Timber	Deciduous	Trees	
15	Annona squamosa	Sitafal	50	75–85	Fruit, Medicinal	Deciduous	Sub Trees	
16	Punica granatum	Dadam	40	80–90	Fruit, Medicinal	Deciduous	Sub Trees	
17	Bambusa vulgaris	Bamboo	80	85–95	Timber, Erosion Control	Evergreen	Canopy	
18	Cordia dichotoma	Gunda	50	75–85	Fruit, Medicinal	Deciduous	Sub Trees	
19	Tamarindus indica	Ambli	65	80–90	Fruit, Medicinal, Timber	Evergreen	Trees	
20	Justicia adhatoda	Ardusi	40	75–85	Medicinal (Respiratory)	Evergreen	Shrubs	
21	Nyctanthes arbor-tristis	Parijat	40	75–85	Medicinal, Ornamental	Deciduous	Shrubs	
22	Millettia pinnata	Desi Kanji	50	75–85	Timber, Medicinal	Evergreen	Trees	
23	Melia azedarach	Bakaneem	65	75–85	Timber, Medicinal	Deciduous	Trees	
24	Cassia siamea	Subaval	65	75–85	Timber, Ornamental	Evergreen	Trees	

Table 17 contd.

Table 17 contd.

Sr. No.	Botanical Name	Local Name	Average Growth Rate (cm/year)	Survival rate (%)	Advantage (Medicinal/Timber/Fruit/Flower)	Type (Evergreen/deciduous/perennial)	Layer (Trees/Canopy/Trees/Herbs)	(Trees/ Sub Shrubs)
25	<i>Neolamarckia cadamba</i>	Kadam	65	75–85	Timber, Ornamental	Deciduous	Trees	
26	<i>Syzygium cumini</i>	Jamun	65	80–90	Fruit, Medicinal	Evergreen	Trees	
27	<i>Grewia asiatica</i>	Buch	50	75–85	Fruit, Medicinal	Deciduous	Sub Trees	
28	<i>Psidium guajava</i>	Jamfal	60	80–90	Fruit, Medicinal	Evergreen	Sub Trees	
29	<i>Cassia javanica</i>	Kasid	65	75–85	Ornamental	Deciduous	Trees	
30	<i>Holarrhena pubescens</i>	Kanji	50	75–85	Medicinal	Deciduous	Shrubs	
31	<i>Terminalia arjuna</i>	Arjun	65	75–85	Medicinal, Timber	Deciduous	Trees	
32	<i>Sterculia foetida</i>	Setur	65	75–85	Timber, Ornamental	Deciduous	Trees	
33	<i>Prunus dulcis</i>	Chini Badam	50	75–85	Fruit, Medicinal	Deciduous	Sub Trees	
34	<i>Alstonia scholaris</i>	Saptarni	65	75–85	Timber, Medicinal	Evergreen	Trees	

The study of Plant survival rates showed that 64.70% of the plant species, such as Borasalli, Gulmohar, Umara, and Nagol, had survival rates ranging from 75%-85%. Furthermore, 27.47% of the plant species, including Dadam, Pipal, Bilipatar, Neembu, and Karen, showed survival rates between 80%-90%. About 2.94% of the plant species, notably Sindur, had the lowest survival rate, ranging from 70% to 80%. The average growth rate across all species was 55 cm. The minimum recorded growth rate was 40 cm for multiple species, while the maximum was 80 cm for *Bambusa vulgaris*.

A total of 37 species selected had ecological benefits, including 21 medicinal, 12 timber, 10 fruit-bearing, and 6 ornamental species, with 1 contributing to dye production. The site consists of 18 evergreen, 18 deciduous, and 1 perennial species, ensuring year-round greenery. These species are distributed across different layers, including 25 trees, 1 canopy species, 7 sub-trees, and 4 shrubs. This diverse composition supports biodiversity, improves air quality, and helps mitigate the urban heat island effect, creating a resilient and sustainable green space.

#### **4.1.5.4 Fauna Diversity**

In order to gather this data, respondents were asked if an initial assessment of the fauna which includes insects, birds, and mammals had been carried out before the development of the Miyawaki green space. They were asked to describe the observed species and provide population estimates if such an assessment was done. Respondents were also asked if they had observed an increase in insect and bird species, and if yes, to list the species and their estimated populations in order to assess changes in biodiversity. They were also asked if any new mammal species had appeared since the establishing, along with information on their habits and population patterns. Respondents were also asked if they had witnessed any mutualistic relationships such as birds spreading seeds or insects pollinating plants and to explain their relevance in order to gain a better understanding of the interaction between fauna and flora. Additionally, they were asked if there were any predator-prey relationships in the environment and how these relationships affected ecological balance.

##### **4.1.5.4.1 Initial Faunal Presence**

Before the Miyawaki site was established, biodiversity in the area was minimal as shared by respondent. The bird population was dominated by a few common species, such as the House Crow and House Sparrow, while small mammals, including squirrels, were scarce due to limited food and vegetation. Participants also noted the presence of snakes before afforestation. The lack of suitable habitats contributed to the overall low faunal activity in the region.

##### **4.1.5.4.2 Current Faunal Diversity**

The Miyawaki site has experienced a notable rise in insect diversity, driven by the growth of dense vegetation and flowering plants. This enriched ecosystem has provided favorable conditions for various insect species, leading to increased populations that contribute to biodiversity and

pollination. Additionally, the presence of diverse flora has created microhabitats that support insect survival and reproduction, further enhancing ecological balance. The details of the species observed and estimated population is mentioned in table 18

**Table 18: Faunal Diversity (Insects Species) at site E**

Sr. No.	Name of the species observed	Estimate population
1.	Common Immigrant Butterfly	15
2.	Plain Tiger Butterfly	25
3.	Common Crow Butterfly	20
4.	Honey bee	215

This area has seen a notable increase in species, according to data on faunal diversity. Insect populations benefited from afforestation, as evidenced by the observation of about 215 honey bees, 25 Plain Tiger Butterflies, 20 Common Crow Butterflies, and 15 Common Immigrant Butterflies.

**Table 19: Faunal Diversity (Birds Species) at site E**

Sr. No.	Name of the species observed	Estimate population
1.	White-browed Fantail Flycatcher	5
2.	House Sparrow	15
3.	House Crow	9
4.	Red-vented Bulbul	10
5.	Jungle Babbler	6
6.	Purple sunbird	8

Data on faunal variety showed in Table 19, that the number of species in the Miyawaki green space has significantly increased. The beneficial effects of afforestation on wildlife biodiversity were demonstrated by the approximately 15 of House Sparrows, 10 Red-vented Bulbuls, 9 House Crows, 8 Purple Sunbirds, 6 Jungle Babblers, and 5 White-browed Fantail Flycatchers that were observed.

**Table 20: Faunal Diversity (New mammal species) at site E**

<b>Sr. No.</b>	<b>Name of the species observed</b>	<b>Notable behaviors/characteristics</b>	<b>Population trends</b>
1.	Indian Palm Squirrel	Nesting in tree cavities, active in mornings	Stable
2.	Rodents (various species)	Burrowing in soil, foraging for food	Increasing

Mammalian species observed in the Miyawaki site exhibited varied population dynamics and behavioral patterns as revealed in Table 20. The Indian palm squirrel, which primarily nests in tree cavities, displayed stable population numbers with peak activity occurring during early morning hours. Several rodent species showed marked population increases, likely facilitated by their characteristic burrowing behaviors and flexible feeding habits. These findings indicate that the restored environment provides suitable habitats and resources that promote mammalian adaptation and population maintenance.

#### **4.1.5.4.3 Faunal Interaction with Flora**

Significant connections between flora and fauna have been cultivated in the Miyawaki green space, improving ecological stability and biodiversity. Pollinators like butterflies and honey bees have been drawn to the growing number of flowering plants, which has improved plant reproduction and the sustainability of ecosystems. The availability of fruits and insects' benefits birds, such as the Purple Sunbird and Red-vented Bulbul, which help spread seeds and manage pests naturally. Trees are also used by rodents and animals like the Indian Palm Squirrel for foraging and nesting, which promotes soil aeration and seed distribution. Nevertheless, no dynamics between predators and prey have been noted in the environment. The ecological advantages of afforestation in establishing a self-sustaining ecosystem are demonstrated by these interactions.



Plate 30: Faunal diversity at site E

#### **4.1.5.5 Humidity, Temperature and Air Quality**

Since its creation, Ambe School's Miyawaki site has greatly enhanced the local microclimate by lowering temperatures and raising humidity, especially on sweltering summer afternoons. In comparison to the nearby metropolitan regions, the environment is cooler due to the dense canopy's ability to absorb moisture and create shade. Residents have reported cleaner air and less pollution, despite the lack of official air quality assessments. In accordance to the responders, the site has also developed into a place of peace that promotes general wellbeing by providing a natural setting for rest. Nowadays, the green space is regarded as a priceless natural resource that improves aesthetics, advances ecological benefits that and develops a sense of environmental responsibility among local residents.



Plate 31: Dense plantation at site E

#### 4.1.5.6 Maintenance and Growth

With consistent observation and little upkeep, the Miyawaki site at Ambe School has flourished for more than two and a half years. The plants have adapted successfully, demonstrating the efficacy of the approach by not needing fertilizers after the early phase. Growth was smooth because there were no major obstacles to overcome. The site has successfully established itself as a self-sustaining green space, increasing local biodiversity and environmental health, as seen by flowering and fruiting patterns.



Plate 32: Pruning process a part of Maintenance and care of plants site E

#### **4.1.6 Case Study 6: Site F**

##### **4.1.6.1 Profile of the site**

Established in October 2022, the Miyawaki site at Ashray Green Bhayli region is 6,000 square meters with a dense planting process. It is surrounded by residential neighborhoods and a canal, making it a natural way to reduce pollutants and restore the environment. The initiative intends to improve air and water quality, increase greenery, and lessen the urban heat island effect. By constructing a flourishing green area, it helps the community and the environment while showcasing sustainable urban growth.



Plate 33: Site F located in Ashray Green Bhayli area of Vadodara District

#### 4.1.6.2 Planning and Implementation

The Sun Pharma Foundation-funded Miyawaki site in the Ashray Green Bhayli area was meticulously designed to guarantee ideal afforestation. The site's suitability was established by extensive research, and working with a Landscape designer aided in the creation of a sustainable layout. The project proceeded without any significant obstacles and produced a flourishing green area that is a great asset to the city and improves the surrounding environment.



Plate 34: Fully grown trees at site F

### 4.1.6.3 Flora Diversity

A diversified and self-sustaining ecosystem was created by the Miyawaki afforestation project in Ashray Green, Bhayli, which involved the planting of 12,000 plants of 33 types. Improving air quality, reducing the urban heat island effect, and boosting urban biodiversity are the objectives of this project. The chosen species support ecological balance and environmental resilience by being fruit-bearing, decorative, medicinal, and wood plants. The project helped local flora and animals while advancing sustainable urban development by encouraging rapid growth and thick vegetation.

**Table 21: Flora Diversity at site F**

Sr. No.	Botanical Name	Local Name	Average Growth Rate (cm)	Survival rate (%)	Advantage (Medicinal/Timber/Fruit/Flower)	Type (Evergreen/deciduous/perennial)	Layer (Trees/Canopy/Trees/Herbs)	(Trees/ Sub Shrubs)
1	Smilax ovalifolia	Nagod	40	75–85	Medicinal	Perennial	Shrubs	
2	Nyctanthes arbor-tristis	Parijat	40	75–85	Medicinal, Ornamental	Deciduous	Shrubs	
3	Bohmeria racemosa	Asundro	40	70–80	Medicinal	Perennial	Shrubs	
4	Justicia adhatoda	Ardusi	40	75–85	Medicinal (Respiratory)	Evergreen	Shrubs	
5	Pongamia pinnata	Pink Karen	65	80–90	Timber, Medicinal	Evergreen	Trees	
6	Cestrum nocturnum	Ratrani	40	75–85	Ornamental, Fragrant	Evergreen	Shrubs	
7	Jasminum sambac	Mogra	40	75–85	Medicinal, Fragrant, Ornamental	Evergreen	Shrubs	
8	Bixa orellana	Sindur	40	70–80	Medicinal, Dye Plant	Evergreen	Shrubs	
9	Cordia dichotoma	Gunda	50	75–85	Fruit, Medicinal	Deciduous	Sub Trees	
10	Ziziphus mauritiana	Borasalli	50	75–85	Fruit, Medicinal	Deciduous	Sub Trees	
11	Bohmeria purpuria	Kaliari	40	70–80	Medicinal	Perennial	Shrubs	
12	Adina cordifolia	Paras Pipda	65	75–85	Timber	Deciduous	Trees	
13	Cassia fistula	Garmalo	65	75–85	Medicinal, Ornamental	Deciduous	Trees	
14	Prosopis cineraria	Jungli Bavad	65	80–90	Timber, Drought Resistance	Evergreen	Trees	
15	Azadirachta indica	Neem	65	85–95	Medicinal, Timber	Evergreen	Trees	

Table 21 contd.

Table 21 contd.

Sr. No.	Botanical Name	Local Name	Average Growth Rate (cm)	Survival rate (%)	Advantage (Medicinal/Timber/Fruit/Flower)	Type (Evergreen/deciduous/perennial)	Layer (Trees/Canopy/Trees/Herbs)	(Trees/ Sub Shrubs)
16	<i>Dalbergia sissoo</i>	Shesham	70	75–85	Timber, Medicinal	Deciduous	Trees	
17	<i>Holarrhena pubescens</i>	Kanji	50	75–85	Medicinal	Deciduous	Shrubs	
18	<i>Madhuca longifolia</i>	Mahua	65	80–90	Medicinal, Timber, Edible Flowers	Evergreen	Trees	
19	<i>Sapindus mukorossi</i>	Areetha	50	75–85	Medicinal, Soap Substitute	Deciduous	Trees	
20	<i>Pithecellobium dulce</i>	Goras Ambli	50	80–90	Fruit, Medicinal	Evergreen	Trees	
21	<i>Sterculia foetida</i>	Jungli Badam	65	75–85	Timber, Ornamental	Deciduous	Trees	
22	<i>Gmelina arborea</i>	Sevan	70	75–85	Timber	Deciduous	Trees	
23	<i>Terminalia arjuna</i>	Arjun	65	75–85	Medicinal, Timber	Deciduous	Trees	
24	<i>Bohmeria white</i>	-	40	70–80	Medicinal	Perennial	Shrubs	
25	<i>Haldina cordifolia</i>	Kothi	65	75–85	Timber, Ornamental	Deciduous	Trees	
26	<i>Neolamarckia cadamba</i>	Kadam	65	75–85	Timber, Ornamental	Deciduous	Trees	
27	<i>Putranjiva roxburghii</i>	Purtanjiva	65	75–85	Medicinal	Evergreen	Trees	
28	<i>Acacia leucophloea</i>	Bhuj	65	75–85	Timber, Medicinal	Deciduous	Trees	
29	<i>Holoptelea integrifolia</i>	Kanjo	65	75–85	Medicinal, Timber	Deciduous	Trees	
30	<i>Cassia javanica</i>	Kashid	65	75–85	Ornamental	Deciduous	Trees	
31	<i>Ficus glomerata</i>	Umatha	50	75–85	Fruit, Medicinal	Deciduous	Trees	
32	<i>Terminalia bellirica</i>	Baheda	65	75–85	Medicinal	Deciduous	Trees	
33	<i>Carissa carandas</i>	Karonda	40	75–85	Fruit, Medicinal	Evergreen	Shrubs	

The data regarding survival rate indicated that 72.72% of the plant species had survival rates between 75%-85% included that Nagod, Parijat, Ardusi, Mogra, and Gunda. It was also found that 12.12% of plant species had survival rates ranging from 70–80% to 80–90% such as Asundro, Pink karen, Sindur, Kaliari, and Jungle bavad. About 3.03% of the plant species had the lowest survival rate, with range 85–95% of them being neem. The lowest average growth rate recorded is 40 cm, observed in several shrubs like Nagod and Parijat. The highest is 70 cm, seen in

timber trees like Shesham and Sevan. Most species grow at an average rate of 65 cm, with variations depending on plant type and ecological role.

There were 33 plant species in the Miyawaki green space at Ashray Green, Bhayli, and each one supports ecological sustainability. Twelve of these species were used for timber, ten yield edible fruits, and twenty-one have medicinal qualities. There were 18 evergreen species, 14 deciduous species, and one perennial species spread throughout the plant types. The site was structurally made up of 18 different tree species, four of which are in the canopy layer, seven of which were sub-trees, and seven of which were shrubs. This varied layering promotes biodiversity, improves ecological balance, and helps to mitigate urban heat and purify the air.



Plate 35: Measuring plant height at site F

#### 4.1.6.4 Fauna Diversity

The biodiversity assessment for the Miyawaki site project followed a structured interview approach with local respondents. Participants were first questioned about

pre-site baseline surveys, including whether initial faunal inventories of insects, birds and mammals had been conducted, with requests for species lists and population estimates where available. For post-establishment observations, respondents provided data on increased insect and bird diversity, including specific species identification and population trends mammal species sightings with associated behavioral and demographic information documented mutualistic interactions like pollination services and seed dispersal activities observed predator-prey relationships and their ecosystem impacts. This methodology enabled comprehensive tracking of biodiversity changes and ecological dynamics resulting from site establishment.

#### 4.1.6.4.1 Initial Faunal Presence

Biodiversity in the region was low prior to the establishment of the Miyawaki site. A few common species, such the House Crow and House Sparrow, dominated the bird population, while small mammals, like squirrels, were in short supply because of the lack of food and foliage. Snakes were also observed by respondent prior to afforestation.

#### 4.1.6.4.2 Current Faunal Diversity

The development of lush vegetation and flowering plants in the Miyawaki green space has led to a noticeable increase in insect variety. Numerous insect species have found favorable conditions in this enriched ecology, resulting in increasing populations that support pollination and diversification. The details of the species observed and estimated population is mentioned in table 22.

**Table 22: Faunal Diversity (Insects Species) at site F**

Sr. No.	Name of the species observed	Estimate population
1.	Common Immigrant Butterfly	30
2.	Plain Tiger Butterfly	35
3.	Common Crow Butterfly	40
4.	Honey bee	300
5.	Dragonflies	45
6.	Damselflies	40

Faunal diversity data indicated a significant rise in species within the Miyawaki site. The impact of afforestation was evident in the increased insect populations, with approximately 300 honey bees, 45 dragonflies, 40 damselflies, 40 Common Crow Butterflies, 35 Plain Tiger Butterflies, and 30 Common Immigrant Butterflies observed.

**Table 23: Faunal Diversity (Birds Species) at site F**

Sr. No.	Name of the species observed	Estimate population
1.	White-browed Fantail Flycatcher	5
2.	House Sparrow	20
3.	House Crow	9
4.	Red-vented Bulbul	10
5.	Jungle Babbler	6
6.	Purple sunbird	8
7.	Oriental Magpie Robin	13

Faunal diversity data in Table 23 indicated a substantial increase in species within the Miyawaki green space. The positive impact of afforestation on wildlife biodiversity was reflected in the presence of approximately 20 House Sparrows, 13 Oriental Magpie Robins, 10 Red-vented Bulebuls, 9 House Crows, 8 Purple Sunbirds, 6 Jungle Babbler, and 5 White-browed Fantail Flycatchers.

**Table 24: Faunal Diversity (New mammal species) at site F**

Sr. No.	Name of the species observed	Notable behaviors/characteristics	Population trends
1.	Indian Palm Squirrel	Nesting in tree cavities, active in mornings	Stable
2.	Rodents (various species)	Burrowing in soil, foraging for food	Increasing
3.	Indian Hare	Seen foraging at dusk, cautious behavior	Stable

In the Miyawaki site, field investigations of mammalian species revealed as shown in Table 24 a variety of population patterns and behaviors. With early morning activity at its height and frequent nesting in tree cavities, the Indian

Palm Squirrel population remained steady. The number of several rodent species, which are known for their burrowing and feeding habits, increased noticeably. The population of Indian Hares was constant, and they were frequently seen foraging cautiously at dusk. According to these findings, the afforested region has produced resources and habitats that are conducive to these species' adaptability and survival.

#### 4.1.6.4.3 Faunal Interaction with Flora

The afforestation efforts in the Miyawaki green space facilitated diverse interactions between fauna and flora, contributing to ecological stability. The dense vegetation and variety of plant species provided essential resources, including food, nesting sites, and shelter, supporting various faunal populations. Insects such as honey bees, butterflies, dragonflies, and damselflies benefited from the availability of flowering plants, which enhanced pollination and biodiversity. Birds, including the House Sparrow, Oriental Magpie Robin, and Purple Sunbird, utilized the vegetation for nesting and foraging. Additionally, small mammals, such as the Indian Palm Squirrel and Indian Hare, established stable populations within the site, while rodents thrived due to the availability of organic matter and shelter. However, no predator-prey dynamics were observed within the green space ecosystem. These interactions underscored the role of afforestation in fostering faunal diversity and promoting ecological balance.



Plate 36: Faunal diversity at site F

#### 4.1.6.5 Humidity, Temperature and Air Quality

Miyawaki site at Ashray Green Bhayli's had produced a cooler microclimate and greatly increased local humidity, particularly in the summer. When compared to nearby urban areas, the dense canopy's shadow lowers surface temperatures. Although there were no official air quality testing, as reported by the responded find out cooler air and a discernible decrease in daytime heat. The site is regarded as an essential environmental resource by the community since it helped to improve the local ecosystem and reduce the impact of the urban heat island. According to the responders, the region feels more at ease, and they have noticed more insects and birds, which suggests that biodiversity has improved.



Plate 37: Dense plantation at site F

#### 4.1.6.6 Maintenance and Growth

The Miyawaki site at Ashray Green Bhayli has grown well over the past two years and has required little care, regular monitoring ensured healthy development, and no fertilizers were needed after the initial plantation. The site has since flourished naturally, with normal flowering and fruiting patterns, proving that the Miyawaki method was successful in creating a self-sustaining urban green space that benefits the local ecosystem and community.



Plate 38: Water supply mechanism at Site F

#### 4.1.7 Case study 7: Site G

##### 4.1.7.1 Profile of the site

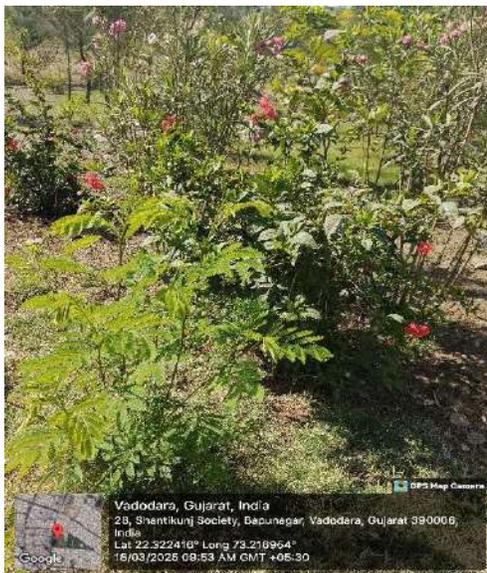
The Miyawaki site project at Nathiba Nagar was established in September 2022 and is situated close to a temple in Sangam Char Rasta, a residential neighborhood in Vadodara city. The project aimed to establish a dense and sustainable green space by afforestation 2,500 square meters with a planting density of three plants per square meter. The main goals of the site establishment were to increase green space, lower pollution, and effectively contribute to a healthy urban environment. The respondents stated that the site had significantly increased the area's greenery, produced a cooler air, and drawn more pollinators and birds, all of which have benefitted the ecology as a whole.



Plate 39: Site G located in Nathiba Nagar area of Vadodara District

#### 4.1.7.2 Planning and Implementation

The municipal corporation chose the location of the Miyawaki site in Nathiba Nagar as part of a development project. Important factors were taken into account to make sure the site was suitable for afforestation. Collaborating with a Landscape designer working in VMC to develop a functional site layout was part of the planning and execution phase. The project was executed efficiently because the entire procedure went off without a hitch and without any major problems.



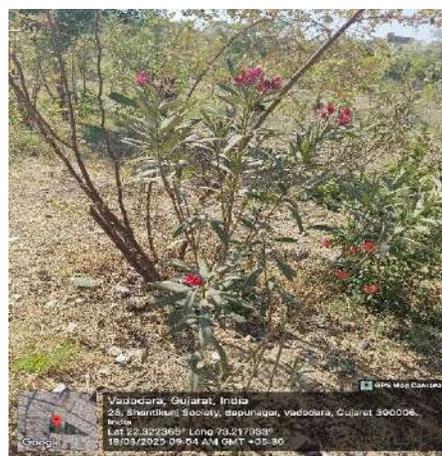
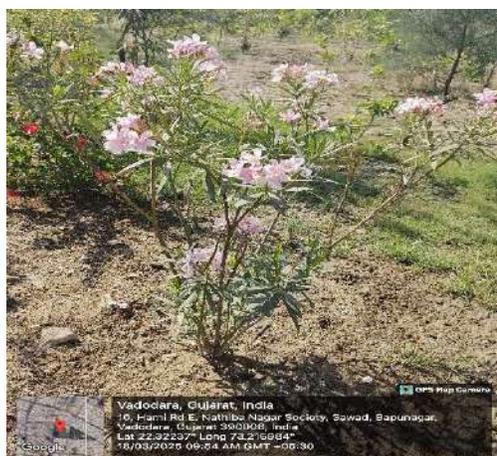


Plate 40: Flowering plants at site G

#### 4.1.6.3 Flora Diversity

Using the Miyawaki approach, 4000 plants were planted at Site G to boost urban greenery and biodiversity. Based on their ecological advantages such as their medicinal, lumber, fruit-bearing, and decorative qualities these plants were chosen. A multi-layered green space structure was ensured by the planted varied mix of trees, shrubs, and sub-trees. By enhancing local biodiversity, lowering the urban heat island effect, and improving air quality, this project seeks to promote environmental sustainability.

Table 25: Flora Diversity at site G

Sr. No.	Botanical Name	Local Name	Average Growth Rate (cm)	Survival Rate (%)	Advantage (Medicinal/Timber/Fruit/Flower)	Type (Evergreen/Deciduous/Perennial)	Layer (Trees/Canopy/Sub Trees/Shrubs/Herbs)
1	<i>Azadirachta indica</i>	Neem	65	85–95	Medicinal, Timber	Evergreen	Trees
2	<i>Bauhinia variegata</i>	Kanchanar	60	75–85	Medicinal, Ornamental	Deciduous	Trees
3	<i>Melia azedarach</i>	Melia Beeliya	65	75–85	Timber, Medicinal	Deciduous	Trees
4	<i>Cedrus deodara</i>	Deodar	70	80–90	Timber, Ornamental	Evergreen	Trees
5	<i>Bixa orellana</i>	Sindoor	40	70–80	Medicinal, Dye Plant	Evergreen	Shrubs
6	<i>Phyllanthus emblica</i>	Amla	50	75–85	Medicinal, Fruit	Deciduous	Trees
7	<i>Delonix regia</i>	Gulmohar	65	75–85	Ornamental, Shade	Deciduous	Trees

Table 25 contd.

Table 25 contd.

Sr. No.	Botanical Name	Local Name	Average Growth Rate (cm)	Survival Rate (%)	Advantage (Medicinal/Timber/Fruit/Flower)	Type (Evergreen/Deciduous/Perennial)	Layer (Trees/Canopy/Sub Trees/Shrubs/Herbs)
8	<i>Peltophorum pterocarpum</i>	Peltophorum	65	75–85	Ornamental, Shade	Deciduous	Trees
9	<i>Bougainvillea glabra</i>	Bougainvillea	50	75–85	Ornamental	Evergreen	Shrubs
10	<i>Nyctanthes arbor-tristis</i>	Parijatak	40	75–85	Medicinal, Ornamental	Deciduous	Shrubs
11	<i>Terminalia arjuna</i>	Arjun	65	75–85	Medicinal, Timber	Deciduous	Trees
12	<i>Terminalia crenulata</i>	Sadam	65	75–85	Timber	Deciduous	Trees
13	<i>Ficus racemosa</i>	Umardo	50	75–85	Fruit, Medicinal	Deciduous	Trees
14	<i>Aegle marmelos</i>	Bili	50	75–85	Medicinal, Fruit	Deciduous	Trees
15	<i>Butea monosperma</i>	Kesudo	65	75–85	Medicinal, Ornamental	Deciduous	Trees
16	<i>Gmelina arborea</i>	Sevan	70	75–85	Timber	Deciduous	Trees
17	<i>Terminalia catappa</i>	Badam	65	75–85	Fruit, Ornamental	Deciduous	Trees
18	<i>Tamarindus indica</i>	Amli	65	80–90	Fruit, Medicinal	Evergreen	Trees
19	<i>Cordia dichotoma</i>	Gunda	50	75–85	Fruit, Medicinal	Deciduous	Sub Trees
20	<i>Jacaranda mimosifolia</i>	Jacaranda	65	75–85	Ornamental	Deciduous	Trees
21	<i>Spathodea campanulata</i>	Spathodea	65	75–85	Ornamental	Deciduous	Trees
22	<i>Tabebuia rosea</i>	Tabebuia	65	75–85	Ornamental	Deciduous	Trees
23	<i>Prunus cerasoides</i>	Cherry	50	75–85	Fruit, Ornamental	Deciduous	Trees
24	<i>Bambusa vulgaris</i>	Bamboo	70	80–90	Timber, Ornamental	Evergreen	Trees
25	<i>Neolamarkia cadamba</i>	Kadamb	65	75–85	Timber, Ornamental	Deciduous	Trees
26	<i>Pongamia pinnata</i>	Pangaro	65	80–90	Timber, Medicinal	Evergreen	Trees
27	<i>Annona reticulata</i>	Ramfal	50	75–85	Fruit	Deciduous	Trees
28	<i>Ficus benghalensis</i>	Vad	65	75–85	Medicinal, Ornamental	Evergreen	Trees
29	<i>Ficus religiosa</i>	Pipari	65	75–85	Medicinal, Ornamental	Evergreen	Trees
30	<i>Tectona grandis</i>	Shetur	70	75–85	Timber	Deciduous	Trees
31	<i>Manilkara hexandra</i>	Rayan	50	75–85	Fruit, Medicinal	Deciduous	Trees

Table 25 contd.

Table 25 contd.

32	Gmelina arborea	Sevan	70	75–85	Timber	Deciduous	Trees
33	Prosopis cineraria	Shami	65	80–90	Timber, Drought Resistance	Evergreen	Trees
34	Psidium guajava	Jamfal	50	75–85	Fruit, Medicinal	Deciduous	Trees
35	Azadirachta indica	Neem	65	85–95	Medicinal, Timber	Evergreen	Trees
36	Phyllanthus emblica	Amla	50	75–85	Medicinal, Fruit	Deciduous	Trees

Plant survival rates indicated that 77.77% of the plant species, including Kanchar, Melia Beeliya, Amla, and Rayan, exhibited survival rates range 75%-85%. Additionally, 13.88% of the plant species, such as Shami, Pangaro, Bamboo, and Deodar, had survival rates ranging from 80%-90%. The lowest survival rate, ranging from 70%-80%, was observed in 2.77% of the species, Sindoor. The lowest growth rate was 40 cm, found in shrubs like Sindoor and Parijatak, while the highest is 70 cm in timber trees like Deodar and Bamboo. Most species grow around 65 cm on average.

The plant species in the list offer various advantages viz. 14 species were medicinal, including Neem, Amla, and Arjun; 12 species provided timber, such as Sevan, Deodar, and Shetur; 9 species bear fruits, like Ramfal, Jamfal, and Vad; and 7 species were ornamental, including Gulmohar, Bougainvillea, and Tabebuia. In terms of layering, 28 species were categorized as trees, including Kadamb and Shami; 5 species as shrubs, such as Parijatak and Sindoor; 3 species as sub-trees, like Gunda; and 2 species as canopy plants. This distribution highlights a diverse mix of ecological benefits, contributing to biodiversity, urban cooling, and environmental sustainability.



Plate 41: Measuring plants height at site G

#### 4.1.7.4 Fauna Diversity

The study employed a systematic approach to assess biodiversity changes in the Miyawaki site through respondent interviews. They were initially asked about pre-site conditions, specifically whether baseline surveys documenting insect, bird, and mammal populations had been conducted prior to afforestation. For studies, respondents provided detailed species inventories and population estimates. The interview protocol then focused on post-establishment ecological changes, gathering data on four key aspects observed increases in insect and bird diversity, including species identification and population trends documentation of new mammal species with accompanying behavioral and demographic data evidence of mutualistic species interactions such as pollination and seed dispersal; and records of predator-prey relationships and their ecological consequences.

#### 4.1.7.4.1 Initial Faunal Presence

Before the Miyawaki green space was created, the area had little biodiversity. While tiny mammals like squirrels were scarce due to a lack of food and greenery, a few common species, such the House Crow and House Sparrow, dominated the bird population. Prior to afforestation, gardener also noticed snakes. Lack of adequate habitats was one of the factors that contributed to the region's relatively low faunal activity.

#### 4.1.7.4.2 Current Faunal Diversity

Insect variety had increased noticeably in the Miyawaki site as a result of the growth of flowering plants and lush vegetation. This richer ecology had provided favorable conditions for many insect species, leading to growing populations that facilitate pollination and diversity. Additionally, the presence of a wide range of plants has created microhabitats that support insect survival and reproduction, enhancing ecological balance. The details of the species observed and estimated population is mentioned in table 26.

**Table 26: Faunal Diversity (Insects Species) at site G**

Sr. No.	Name of the species observed	Estimate population
1.	Common Immigrant Butterfly	25
2.	Plain Tiger Butterfly	15
3.	Common Crow Butterfly	20
4.	Honey bee	200

The faunal diversity data revealed a notable increase in species within the Miyawaki site. Afforestation has significantly impacted insect populations, with observations including around 200 honey bees, 25 Common Crow Butterflies, 25 Common Immigrant Butterflies, and 15 Plain Tiger Butterflies.

**Table 27: Faunal Diversity (Birds Species) at site G**

<b>Sr. No.</b>	<b>Name of the species observed</b>	<b>Estimate population</b>
1.	White-browed Fantail Flycatcher	5
2.	House Sparrow	10
3.	House Crow	9
4.	Red-vented Bulbul	10
5.	Jungle Babbler	6
6.	Purple sunbird	8

The faunal diversity data as in Table 27 demonstrated a substantial rise in species within the Miyawaki site. The beneficial impact of afforestation on wildlife biodiversity was evident in the presence of approximately 10 House Sparrows, 10 Red-vented Bulbuls, 9 House Crows, 8 Purple Sunbirds, 6 Jungle Babblers, and 5 White-browed Fantail Flycatchers.

**Table 28: Faunal Diversity (New mammal species) at site G**

<b>Sr. No.</b>	<b>Name of the species observed</b>	<b>Notable behaviors/characteristics</b>	<b>Population trends</b>
1.	Indian Palm Squirrel	Nesting in tree cavities, active in mornings	Stable
2.	Rodents (various species)	Burrowing in soil, foraging for food	Increasing

Field investigations of mammalian species in the Miyawaki green space as shown in Table 28 revealed diverse population patterns and behaviors. The Indian Palm Squirrel population remained stable, exhibiting peak activity in the early morning and frequent nesting in tree cavities. Additionally, the number of various rodent species, known for their burrowing and feeding habits, showed a noticeable increase. These findings suggest that the afforested region has provided essential resources and habitats, supporting the adaptability and survival of these species.

#### 4.1.7.4.3 Faunal Interaction with Flora

The Miyawaki green space played a crucial role in shaping faunal interactions with the surrounding flora. The establishment of dense vegetation and a variety of flowering plants provided essential resources such as food, shelter, and nesting sites, facilitating the survival of various species. Insect populations, including honey bees and butterflies, thrived due to the abundance of nectar-rich plants, enhancing pollination and contributing to the ecosystem's stability. Birds, such as the Red-vented Bulbul and Purple Sunbird, adapted to the afforested environment, utilizing the vegetation for nesting and foraging. Additionally, small mammals like the Indian Palm Squirrel and various rodent species benefited from the green space structural complexity, which provided suitable habitats for nesting and burrowing. These interactions underscored the positive impact of afforestation on faunal adaptation and biodiversity. However, no predator-prey dynamics were observed within the site ecosystem, suggesting that the faunal community primarily comprised herbivorous and insectivorous species coexisting within the afforested landscape.



Plate 42: Faunal Diversity at site G

#### 4.1.7.5 Humidity, Temperature and Air Quality

Due to the high canopy providing ample shade, the humidity levels have increased since the Miyawaki green space was established at Nathiba Nagar. In addition to having a milder microclimate than the surrounding metropolitan area, the site experiences consistently lower temperatures, especially on the hottest summer afternoons. Previously, concrete covered the location, which resulted in poor water retention and increased temperatures. Its conversion to a green area has enhanced the air quality by raising oxygen levels and supplying fresher air. Although official air quality measures were not performed, developer have reported a more comfortable atmosphere and a substantial decrease in afternoon heat. In addition to providing a refreshing environment and drawing more birds and wildlife, the site has improved the area's quality of life and further enhanced the ecosystem, according to the respondents.



Plate 43: Dense plantation at site G

#### 4.1.7.6 Maintenance and Growth

The Miyawaki site at Site G has been cared for over the past two years by consistent watering, plant health monitoring, and making sure the soil is suitable for growth. The green space was shown to be developing steadily throughout the first year, with plants exhibiting healthy growth. The site maintenance process went smoothly

because there were no major obstacles to overcome. Organic fertilizers were utilized to improve soil fertility and promote plant growth after the original cultivation. The species' documented regular blooming and fruiting patterns point to a robust and healthy ecology.



Plate 44: Mature trees at site G

#### **Section 4.2: Development of Multimedia resource on Miyawaki Technique**

One of the key objectives of this study was to develop multimedia resources to raise awareness among stakeholders about the Miyawaki technique. Two approaches were adopted to achieve this one is the creation of an informative booklet, while the other utilized audio-visual media. The development of the audio-visual aid and booklet began with an extensive review of research papers, journals, and case studies related to urban forests and the Miyawaki technique. This review provided a strong foundation for compiling scientifically backed information on the ecological benefits of dense afforestation, its role in biodiversity enhancement, and its impact on climate resilience.

The booklet was designed to serve as a comprehensive guide on the Miyawaki method, covering its principles, benefits, challenges, and real-world applications, particularly in the Vadodara District. It highlights the role of the Miyawaki technique in promoting sustainable urban development and serves as a valuable resource for urban designers,

landscape architects, policymakers, and environmentalists engaged in ecological restoration. Additionally, it benefits the general public by enhancing their understanding of urban afforestation and inspiring eco-friendly initiatives in residential and public spaces. By providing actionable insights and practical knowledge, the booklet encourages communities to participate in creating greener, healthier urban environments. The booklet was validated by experts from the field of Environment studies, Botany and Expert who have played crucial role in implementing Miyawaki technique in Gujarat and other parts of India. The changes were incorporated as per the suggestion given by them. The final booklet had 29 pages (Refer Appendix V).

A structured audio visual was prepared focusing on the origins of the Miyawaki method, step-by-step guide to its implementation, and its impact on biodiversity and climate. For the audio-visual aid, video clips were obtained from the Vadodara Municipal Corporation (VMC), along with relevant data and information regarding the implementation of Miyawaki forests at Channi Lake, Moti Bapod, and Ashray Green, Bhayli. During the data collection phase, additional video clips were recorded on-site to capture the transformation of these locations and highlight their ecological impact. A significant aspect of the audio-visual aid was the showcasing of real-world applications in Vadodara District, where the technique has been successfully implemented at key sites such as Channi Lake, Moti Bapod, and Ashray Green, Bhayli. The final editing process ensured that the multimedia material was engaging and informative, effectively conveying the significance of urban forests and the urgent need for sustainable green spaces in cities. The script was finalized accordingly. The researcher took help of professionals for voice over and final editing. Initially the video recorded was of 20 minutes which are made to 4 minutes 13 seconds after final editing. The audio-visual aid was reviewed and validated by a panel of experts, including Environmental studies, Botanists, and Expert who have been instrumental in implementing the Miyawaki afforestation technique in Gujarat and various regions across India. There were no changes suggested by them. Their expertise ensured the accuracy, relevance, and practical applicability of the content. The final video was uploaded of you tube for creating awareness about Miyawaki Technique (Refer Appendix V).

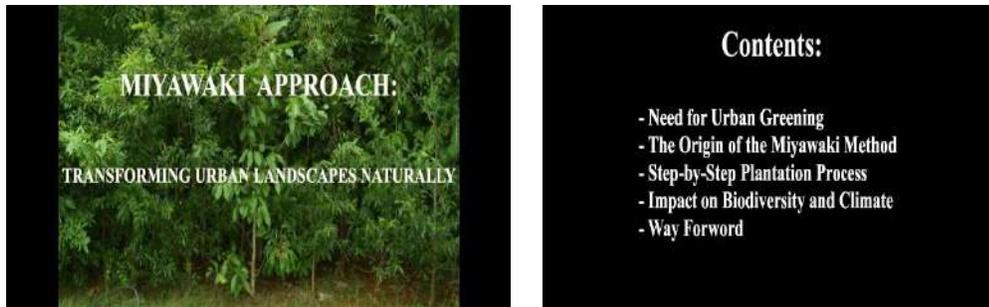


Plate 45: Screenshot of title sequence of an Audio-visual aid

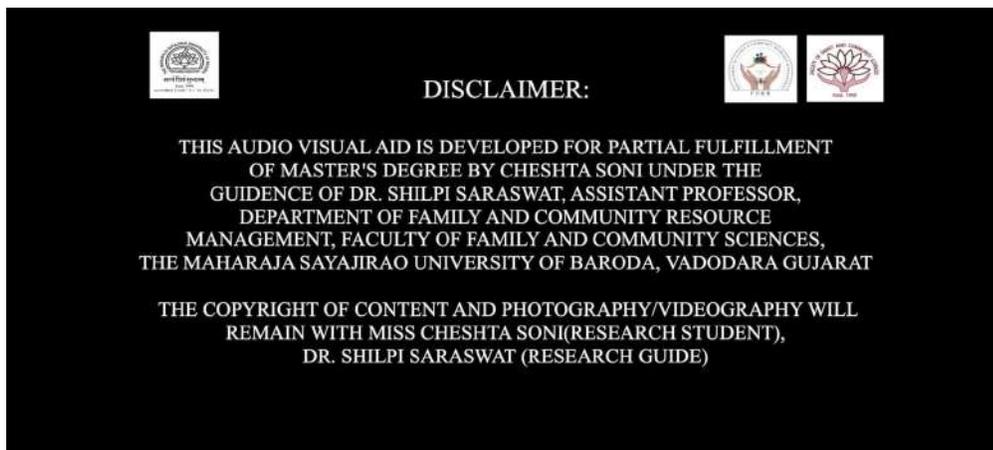


Plate 46: Screenshot of disclaimer of an Audio-visual aid



Plate 47: Screenshot of information regarding need for urban greening

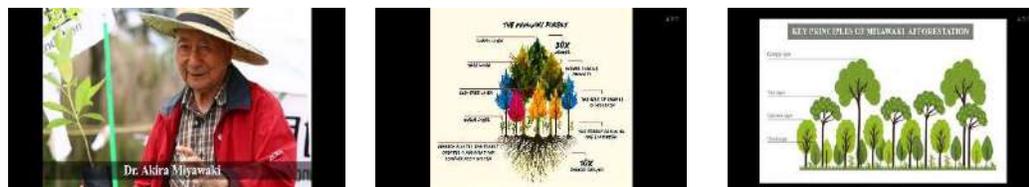


Plate 48: Screenshot of information regarding origin of Miyawaki method



Plate 49: Screenshot of step-by-step plantation process



Plate 50: Screenshot of showing increase in biodiversity

By leveraging both print and digital media, these resources play a crucial role in educating stakeholders, fostering community participation, and promoting sustainable urban development. They serve as a catalyst for action, encouraging policymakers, environmentalists, and the public to adopt the Miyawaki technique in various urban landscapes, thereby contributing to a greener and more resilient future.

## Conclusion

In conclusion, the Miyawaki site projects implemented across various locations, including Channi Lake, Moti Bapod Lake, Ambe School, Ashray Green Bhayli, and others, have successfully transformed vacant or underutilized urban spaces into lush, thriving green environments. Each project was tailored to address the specific needs of the area, and while some sites faced challenges such as water scarcity, relocation of residents, and soil preparation, these were effectively managed. The overall result has been a substantial enhancement of environmental sustainability, with noticeable improvements in local humidity levels, temperature regulation, and air quality. The dense afforestation and rapid growth of trees have significantly mitigated the urban heat island effect, reduced pollution, and promoted biodiversity, creating a healthier and more livable environment for surrounding communities.

The multimedia resources developed in this study successfully enhanced stakeholder awareness of the Miyawaki technique. Through an informative booklet and audio-visual media, key aspects such as its principles, benefits, and real-world applications in Vadodara were effectively communicated. Highlighting successful implementations at Channi Lake, Moti Bapod, and Ashray Green, Bhayli, these resources demonstrated the technique's potential in ecological restoration and urban sustainability. Continued efforts in awareness-building and policy support will be essential to further promote its adoption, fostering greener and more resilient urban environments.

Furthermore, the success of these projects has demonstrated the power of the Miyawaki method in transforming urban landscapes into green, pollution-free zones, contributing to the well-being of both the local population and the broader ecosystem. These initiatives have also raised awareness about the importance of sustainable urban development, fostering a deeper connection between communities and nature. Ultimately, the Miyawaki projects and the accompanying multimedia learning resource have proven to be invaluable environmental assets, paving the way for future green initiatives in urban planning.

A photograph of a lush, green forest. The scene is filled with tall, slender trees and a dense carpet of green plants and ferns in the foreground. The lighting is bright, highlighting the vibrant green colors of the foliage.

# **SUMMARY, CONCLUSION AND RECOMMENDATION**

## CHAPTER V

### SUMMARY, CONCLUSION AND RECOMMENDATIONS

Rapid urbanization and environmental degradation have necessitated innovative afforestation methods to restore green spaces and promote biodiversity. The Miyawaki technique, known for its high-density plantation and accelerated forest growth, presents a sustainable solution for urban reforestation. This study explores the biodiversity and ecological benefits of Miyawaki afforested areas in Vadodara district by analyzing the diversity of flora and fauna and assessing environmental impacts such as humidity, temperature, and air quality. Additionally, the study aims to develop multimedia resources to effectively communicate the importance of urban forests, the Miyawaki method, and its ecological benefits. These resources include a booklet and an audio-visual aid that provide a step-by-step guide to implementation, address challenges, and showcase real-world applications. The research highlights the significance of integrating Miyawaki afforestation into urban planning and emphasizes the role of educational tools in promoting greener, healthier, and more sustainable cities.

Several studies were found through review of literature highlighted key research trends related to biodiversity enhancement, urban afforestation strategies, and climate change mitigation globally. While studies outside India focused on broad ecological restoration techniques and urban green landscapes, research in India primarily investigated the Miyawaki method in urban settings, emphasizing its impact on air quality, temperature reduction, and biodiversity growth. However, there remains a significant gap in long-term assessments of Miyawaki Technique, particularly concerning their role in ecological succession, biodiversity conservation, and sustained microclimatic benefits. Additionally, limited research has explored the combined effects of Miyawaki afforestation on local biodiversity dynamics, and ecological benefits. Recognizing this gap, the present study aims to contribute valuable insights into the long-term ecological benefits of Miyawaki green space and their potential role in sustainable urban development.

Courses such as Landscape Designing and Gardening are offered at the undergraduate and postgraduate levels in the Department of Family and Community Resource Management. The findings from this research will contribute valuable insights that can enhance the existing curriculum by incorporating relevant environmental and ecological aspects. This, in turn, can help refine course content to better equip students with practical knowledge on sustainable afforestation techniques like the Miyawaki method, ensuring a more comprehensive approach to urban green space development.

### **Statement of problem**

To explore the biodiversity and ecological benefits of Miyawaki afforested areas in Vadodara district, by analyzing flora and fauna diversity, assessing changes in humidity, temperature, and air quality.

### **Objectives of the study**

1. To analyze the diversity of Flora and Fauna within Miyawaki afforested areas in Vadodara district.
2. To find out the perceived changes in ecological benefits such as humidity, temperature and air quality within Miyawaki afforested areas.
3. To develop a multimedia resource to enhance awareness and understanding of Miyawaki Technique for afforestation.

### **Delimitations of the study**

1. The study was limited to areas within Vadodara district.
2. The study was limited to 7 selected Miyawaki afforested areas.

### **Methodology**

The research design of this study was descriptive in nature, focusing on an in-depth analysis of Miyawaki afforested areas in Vadodara district. The site selection was guided by predefined inclusion criteria established for the study. A total of 21 sites developed using the Miyawaki Technique were identified in Vadodara District. However, only seven sites met the research inclusion criteria. The study was conducted in Vadodara district, Gujarat, where afforestation using the Miyawaki technique was implemented. The primary

respondents were land or site owners, but when they were unavailable, information was gathered from the developers responsible for the afforested areas.

The data were collected using an interview schedule as the primary tool. The interview schedule comprised of various aspects of Miyawaki site, beginning with general site details, objectives, and community involvement. It then explored the planning and implementation process, including site selection, planting methods, and encountered challenges. The diversity of flora and fauna was analyzed by documenting plant species, their benefits, growth and survival rates, along with changes in wildlife presence and ecological interactions. Environmental impacts were assessed by humidity, temperature variations, and air quality improvements while also considering community perceptions of heat reduction. Lastly, maintenance and growth practices were reviewed, focusing on sustainability efforts, monitoring, and strategies to address challenges for long-term forest health. A panel of seven judges from The Maharaja Sayajirao University of Baroda and two experts from SOCLEEN reviewed the research scale for clarity, relevance, and proper categorization. An 80% consensus was required for finalization, with minor modifications made based on their feedback. The multimedia resource was developed to raise awareness of the Miyawaki technique, an informative booklet and an audio-visual aid were developed. The booklet covered its principles, benefits, challenges, and applications in Vadodara District, serving as a resource for stakeholders. The audio-visual aid highlighted urban green space importance, the Miyawaki method, and real-world implementations at Channi Lake, Moti Bapod, and Ashray Green, Bhayli. Video recordings were conducted with official permissions, and expert voiceovers enhanced clarity and engagement.

## **Major Findings**

The major findings of the study are presented here.

### **Section I General information**

This section gathered essential details about the Miyawaki sites, including its name, location, establishment date, and the year of evaluation. It also documented its proximity to urban infrastructure, canopy density, afforestation area and density, along with the primary objectives behind its creation, such as enhancing biodiversity or mitigating urban

heat. Additionally, it examined how these objectives were communicated to the community or stakeholders to ensure engagement and awareness. These details provided a comprehensive overview of the site's context, purpose, and potential environmental impact. The Miyawaki afforested sites in Vadodara district illustrate the effectiveness of urban afforestation in enhancing biodiversity, reducing pollution, and improving microclimatic conditions. The Tandalja site, established in 2020, spans 2,000 m<sup>2</sup> and was funded by the Chawla family. It is located near CH Cancer Hospital with a canopy density of 50%. The Ashram Bhill site, developed in 2021 by the Vadodara Municipal Corporation with National High-Speed Railway funding, covers 4,000 m<sup>2</sup> and is situated near an open space and an ashram, with farmland contributing to its canopy density. The Channi Lake site, established in 2022, extends across 1,000 m<sup>2</sup> and plays a crucial role in supporting the lake's ecosystem. The Moti Bapod Lake site, created in 2021 with funding from the Chairman of Bio Soil South NGO, spans 2,500 m<sup>2</sup> and is located near both a lake and a building. The Ambe School Harni site, established in 2022, covers 3,500 m<sup>2</sup> and was funded by Catch Foundation, situated near a river and an army school. The Ashray Green Bhayli site, the largest, spans 6,000 m<sup>2</sup> and was funded by Sun Pharma Foundation, located near a canal and buildings. Lastly, the Nathiba Nagar site, established in 2022, covers 2,500 m<sup>2</sup> and is located near a residential area. Together, these afforestation projects demonstrate the impact of the Miyawaki method in creating dense, self-sustaining green spaces, promoting biodiversity, and fostering urban sustainability in Vadodara.

## **Section II Planning and Implementation**

The selection, planning, and implementation of Miyawaki sites across Vadodara were strategically executed to maximize ecological and urban benefits, with no significant challenges faced during the process. The Tandalja site utilized vacant urban land to create a thriving green space, ensuring biodiversity enhancement and environmental restoration. The Ashram Bill site was developed on municipal land to boost urban greenery, with smooth execution. The Channi Lake site was chosen based on soil quality and water access, with meticulous design ensuring sustainability. The Moti Bapod Lake site leveraged strategic site selection and expert planning for seamless execution. The Ambe School Harni

site optimized afforestation with professional site assessment and species selection. The Ashray Green Bhayli site prioritized sustainability through extensive research and collaborative design. Finally, the Nathiba Nagar site focused on effective land use for urban afforestation. Across all sites, careful site selection and expert planning ensured successful implementation, transforming underutilized spaces into self-sustaining ecosystems.

### **Section III Flora Diversity**

The Miyawaki afforestation initiative in Vadodara District successfully transformed seven underutilized urban spaces into thriving green ecosystems, significantly enhancing biodiversity and ecological sustainability. The sites in Tandalja, Channi Lake, Moti Bapod Lake, Ashray Green Bhayli, Nathiba Nagar, Ambe School (Harni), and Ashray Green Bhayli area were strategically selected based on soil quality, accessibility, and ecological potential. Each site incorporated a diverse mix of native, fruit-bearing, medicinal, and timber species, fostering a self-sustaining multi-layered structure. The plantations, ranging from 3,000 to 12,000 plants per site, demonstrated high survival rates (70%–95%) and impressive growth rates (30–150 cm annually). These sites contributed to urban cooling, air purification, and carbon sequestration while serving as vital habitats for pollinators and wildlife.

### **Section IV Faunal Diversity**

The faunal diversity across seven Miyawaki afforestation sites significantly increased post-implementation. Initially lacking wildlife, the sites observed over 1,150 insects mainly honey bees and butterflies and more than 105 birds, including Red-vented Bulbuls, Jungle Babblers, and Purple Sunbirds. Small mammals like Indian Palm Squirrels and rodents also became more common. The rise in diversity is attributed to increased vegetation and microhabitats, supporting pollination and seed dispersal. No predator-prey interactions were observed, indicating a dominance of herbivores and insectivores. Overall, the Miyawaki method successfully fostered native, biodiverse ecosystems.

## **Section V Humidity, Temperature and Air Quality**

The Miyawaki site across seven sites in Vadodara District have significantly enhanced the local microclimate by increasing humidity, lowering temperatures, and improving air quality. The dense vegetation retains moisture, creating a cooler and more comfortable environment, especially during summer. Previously barren or concreted areas now benefit from extensive tree canopies that provide shade, reduce surface heat, and mitigate the urban heat. While no formal humidity, temperature and air quality measurements were taken, residents have consistently reported fresher air and a noticeable reduction in pollution to the owners. These sites also act as natural sound barriers, absorb carbon dioxide, and contribute to overall ecological balance.

## **Section VI Maintenance and Growth**

The Miyawaki site across various sites in Vadodara have demonstrated successful growth and sustainability through diligent maintenance practices. During the initial phase, regular watering schedules, mulching, and monitoring ensured the healthy establishment of plants, while organic soil enrichment eliminated the need for chemical fertilizers. Across all locations, native species adapted well, forming dense canopies that improved local biodiversity and mitigated urban heat. Despite minor challenges such as water scarcity at some sites, strategic irrigation solutions and the natural resilience of the site allowed them to thrive. The green space have shown flowering and fruiting patterns over time, further enhancing ecological balance. With minimal long-term intervention required, these Miyawaki sites serve as exemplary models of sustainable urban greening, contributing to biodiversity conservation, climate regulation, and improved air quality.

## **Development of Multimedia resource on Miyawaki Technique**

The multimedia resources developed in this study will successfully enhance stakeholder awareness of the Miyawaki technique. Through an informative booklet and audio-visual media, key aspects such as its principles, benefits, and real-world applications in Vadodara District were effectively communicated. Highlighting successful implementations at area viz. Channi Lake, Moti Bapod, and Ashray Green, Bhayli. These resources demonstrated

the technique's potential in ecological restoration and urban sustainability. Continued efforts in awareness-building and policy support will be essential to further promote its adoption, fostering greener and more resilient urban environments.

## **Conclusion**

The present study underscores the transformative potential of the Miyawaki afforestation technique in promoting ecological sustainability and enhancing urban green spaces. By focusing on seven carefully selected sites within Vadodara District, the research provides compelling evidence of the technique's effectiveness in boosting biodiversity, regulating microclimatic conditions, and fostering environmental awareness. The Miyawaki sites studied demonstrated remarkable diversity of flora, high survival and growth rates, and increased presence of pollinators and wildlife indicating strong ecological benefits. Although formal quantitative data on humidity, temperature, and air quality was not recorded, consistent perceptions from residents and site owners highlight a tangible improvement in environmental conditions. These afforested areas have significantly contributed to urban cooling, air purification, and ecological balance, transforming barren urban plots into thriving ecosystems.

The development of multimedia resources including an informative booklet and an audio-visual aid served as a powerful educational and awareness tool. These resources not only documented real-life applications at Channi Lake, Moti Bapod, and Ashray Green, Bhayli, but also offered a step-by-step guide to implementation, thus bridging the gap between theory and practice.

The findings also carry educational value, offering an opportunity to enrich academic curricula in courses such as Landscape Designing and Gardening by integrating sustainable afforestation techniques. This can empower future professionals to actively contribute to climate resilience and ecological restoration. The Miyawaki method presents a scalable, community-engaging, and impactful approach to urban greening. Its integration into city planning and environmental education is essential to building healthier, greener, and more sustainable urban futures.

## **Implications of the study**

The findings of the present study had following implications:

### **For Urban and Landscape Designers**

This study underscores the importance of integrating dense green spaces into urban environments using the Miyawaki afforestation method. Urban and landscape designers can leverage this approach to enhance climate resilience, promote biodiversity, and mitigate urban heat island effects. By incorporating native plant species in compact urban areas, designers can contribute to sustainable urban ecosystems while improving aesthetic and functional landscapes. Future projects should prioritize scalable green infrastructure to maximize ecological benefits.

### **For Interior Designers**

The findings of this study have significant implications for interior designers, particularly in integrating nature into built environments. By understanding the ecological benefits of Miyawaki forests, sustainable green spaces within urban settings. The study highlights how dense afforestation improves air quality, reduces heat, and enhances biodiversity. Additionally, insights from the study can guide the selection of native plants for indoor and semi-indoor spaces, fostering healthier and more resilient environments.

### **For Policymakers and Urban Planners**

This study provides empirical evidence supporting urban afforestation as a strategy for sustainable development. Policymakers and urban planners can use these findings to advocate for green urban policies, such as incentivizing green barren spaces, mandating tree-planting initiatives, and preserving urban green belts. Integrating Miyawaki Technique into city planning can aid in carbon sequestration, stormwater management, and biodiversity conservation. Furthermore, urban planning frameworks should prioritize equitable access to green spaces to ensure community-wide health and environmental benefits.

### **For the Citizens**

The study raises awareness about the ecological advantages of urban green spaces, encouraging community involvement in afforestation initiatives. Public engagement in tree-planting drives and urban gardening can foster a sense of environmental stewardship while enhancing mental and physical well-being. Educational campaigns and participatory urban greening programs can further empower citizens to contribute to sustainable urban development, reinforcing collective responsibility for environmental conservation.

### **Recommendations for the Future Studies**

1. A similar study can be conducted in other cities of Gujarat state or other states of India.
2. A longitudinal study can be undertaken to generate more extensive data on biodiversity enhancement, ecological impact, and community engagement in Miyawaki afforested areas.
3. A comparative study can be carried out between multiple cities or regions to analyze variations in afforestation success, species survival rates, and environmental benefits across different landscapes.
4. A study can be conducted to explore the role of Miyawaki forests in improving mental well-being, promoting and fostering environmental stewardship in urban populations.
5. A study can be conducted to evaluate the economic benefits of urban afforestation, including its influence on real estate value, tourism potential, and local employment opportunities.
6. Research can be carried out to assess the effectiveness of integrating Miyawaki forests with smart city initiatives, such as green infrastructure, renewable energy solutions, and sustainable urban planning.
7. A study can be undertaken to investigate the potential of Miyawaki afforestation in rehabilitating degraded lands, improving soil health, and restoring native vegetation in urban and peri-urban areas.
8. A study to explore the integration of Miyawaki forests with water conservation strategies, assessing their role in groundwater recharge, rainwater harvesting, and urban flood mitigation can be undertaken.



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# WEBLIOGRAPHY

## WEBLIOGRAPHY

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2. <https://www.givemetrees.org/blogs/what-is-miyawaki-method-of-plantation.php> What is Miyawaki Method of Plantation? – Give Me Trees Trust Accessed on: MARCH 5, 2025
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# APPENDICES

# APPENDICES I



Institutional Ethics  
Committee for Human  
Research  
(IECHR)

FACULTY OF FAMILY AND COMMUNITY SCIENCES  
THE MAHARAJA SAYAJIRAO UNIVERSITY OF BARODA

## Ethical Compliance Certificate 2024-2025

This is to certify Ms. Cheshta Soni study titled; "Exploring Biodiversity and its Ecological Benefits in Miyawaki Afforested Areas: A Case Study of Vadodara District." from Department of Family and Community Resource Management has been approved by the Institutional Ethics Committee for Human Research (IECHR), Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda. The study has been allotted the ethical approval number IECHR/FCSsc/M.Sc./10/2024/23.

Prof. Komal Chauhan  
Member Secretary  
IECHR

Prof. Mini Sheth  
Chairperson  
IECHR

**Chair Person**  
**IECHR**  
Faculty of Family & Community Sciences  
The Maharaja Sayajirao University of Baroda

## APPENDICES II



DEPARTMENT OF FAMILY AND COMMUNITY RESOURCES MANAGEMENT  
FACULTY OF FAMILY AND COMMUNITY SCIENCES  
THE MAHARAJA SAYAJIRAO UNIVERSITY OF BARODA, VADODARA  
NAAC ACCREDITED "A++" GRADE

### PERMISSION LETTER

To  
Department of Parks and Garden  
Vadodara Municipal Corporation  
Vadodara, Gujarat

Respected Madam,

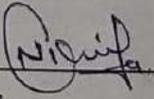
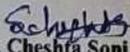
I, Cheshta Soni, an M.Sc. student in the Department of Family and Community Resource Management, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda, am conducting a research study titled "Exploring Biodiversity and its Ecological Benefits in Miyawaki Afforested Areas: A Case Study of Vadodara District" as part of the partial fulfillment of my master's degree.

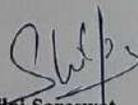
The primary objectives of my study are to analyze the diversity of flora and fauna within Miyawaki afforested areas and to evaluate the perceived changes in ecological factors, such as humidity, temperature, and air quality, within these spaces. This study aims to contribute to the understanding of the ecological benefits associated with the Miyawaki technique in the Vadodara district. To achieve the study's objectives, I intend to collect data from property owners of Miyawaki afforested spaces within Vadodara district. All information gathered will be handled with strict confidentiality, and participants' identities will be protected.

In line with ethical research practices, I kindly request approval for ethical clearance to proceed with this study. I am committed to ensuring that the research adheres to all ethical guidelines laid out by the institution, including informed consent, confidentiality, and the protection of participants' rights. If further information or clarification is needed, I can be reached via:

Phone: 6232808999  
Email: cheshtasoni7@gmail.com

I sincerely hope that you will grant permission to proceed with the research. Thank you for your time and consideration.

Signature of owner:   
  
Ms. Cheshta Soni  
M.Sc. (F.C.Sc.) Research Student  
Department of FCRM  
FFCSc., MSU

  
Dr. Shilpi Saraswat  
Research Guide & Assistant Professor  
Department of FCRM  
FFCSc., MSU

## APPENDICES III



DEPARTMENT OF FAMILY AND COMMUNITY RESOURCES MANAGEMENT  
FACULTY OF FAMILY AND COMMUNITY SCIENCES  
THE MAHARAJA SAYAJIRAO UNIVERSITY OF BARODA, VADODARA  
NAAC ACCREDITED "A++" GRADE

### INFORMED CONSENT FORM

The Department of Family and Community Resources Management, Faculty of Family and Community Sciences, The Maharaja Sayajirao University of Baroda, Vadodara, supports the practice of protection of human participants in research. The following will provide you with information about the research survey that will help you decide whether or not you wish to participate. The purpose of this study is to analyze the diversity of flora and fauna in Miyawaki afforested areas and evaluate the perceived changes in ecological benefits, such as humidity, temperature, and air quality, within these spaces in the Vadodara district. As a participant, you will be asked to provide the following information related to your Miyawaki forest project viz. Name of the Miyawaki forest project, Location of the Miyawaki forest, Date of establishment, and Current year of evaluation, and other related data.

Your participation will involve answering questions during a survey, which is expected to take approximately 20-30 minutes of your time. Your participation in this study is entirely voluntary. You may choose not to participate, or you may withdraw at any time during the research process without any penalty or loss of benefits to which you are otherwise entitled. All information you provide will be kept strictly confidential and will not be associated with your name or identifying details in any way. The data collected will be used solely for research purposes, and any reports or publications will not include any information that could identify you personally. There are no foreseeable risks associated with participating in this research. The information you provide will help contribute to the understanding of the ecological benefits of the Miyawaki technique, which may inform future environmental projects.

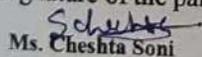
If you have any questions about this research or your participation, please feel free to contact Ms. Cheshta Soni

Phone: 6232808999

Email: cheshtasoni7@gmail.com

By signing below, you indicate that you have read and understood the information provided above, and you voluntarily agree to participate in this study. You also acknowledge that you are free to withdraw from the study at any time without any penalty.

Signature of the participation

  
Ms. Cheshta Soni

M.Sc. (F.C.Sc.) Research Student

Department of FCRM

FFCSc., MSU

  
Dr. Shilpi Saraswat

Research Guide & Assistant Professor

Department of FCRM

FFCSc., MSU

**APPENDICES IV**  
**INTERVIEW SCHEDULE**

Name of the developer: -

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Name of the owner: -

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**1. General Information**

I. Name of Miyawaki forest project:

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II. Location of Miyawaki forest:

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III. Date of establishment:

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IV. Current Year of Evaluation:

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V. Proximity to Urban Infrastructure (nearby landmark):

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VI. Canopy density

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VII. Afforestation area (h or m<sup>2</sup>)

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VIII. Afforestation density (distance between trees)

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IX. What are the primary objectives behind establishing Miyawaki forest?

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X. How were these objectives communicated with the community or stakeholders?

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## 2. Planning and implementation

I. How was the site for Miyawaki site selected?

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II. What were the key considerations?

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III. What were the key steps in planning and implementation of Miyawaki forest?

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IV. Were there any challenges faced during planning and implementation phase?

Yes

No

If yes,

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## 3. Flora Diversity

Sr. No.	Botanical Name	Local Name	Average growth rate (cm)	Survival rate (%)	Advantage (Medicinal/ Timber/ Fruit/Flower)	Type (Evergreen/deciduous/perennial)	Layer (Trees/ Canopy/ Sub Trees/ Shrubs Herbs)

***Growth rate =  $S2-S1/T$***

*S1 - First measurement*

*S2 - Second measurement*

*T – No. of days between each*

***Survival rate = Total number of plants survived / total number of plants originally planted X 100***

- I. What were the selection criteria for the species?
  - a. (Provide details on why specific species were chosen, including considerations like native species, fast-growing plants, etc.)

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#### **4. Fauna Diversity**

##### **4.1 Initial Faunal Presence**

- I. Was there any initial assessment of fauna (insects, birds, mammals) before the establishment of the Miyawaki forest?
  - a. Yes / No
  - b. If yes, please describe the observed species and their population estimates:

---

##### **4.2 Current Faunal Diversity**

- I. Have you observed an increase in the number of insect species?
  - a. Yes / No
  - b. If yes, list the observed species and provide population estimates if available:

<b>Sr. No.</b>	<b>Name of the species observed</b>	<b>Estimate population</b>

II. Have you observed an increase in the number of bird species?

a. Yes / No

b. If yes, list the observed species and provide population estimates if available:

<b>Sr. No.</b>	<b>Name of the species observed</b>	<b>Estimate population</b>

III. Have you observed any new mammal species since the establishment of the Miyawaki forest?

a. Yes / No

b. If yes, please specify the species and any notable behaviors or population trends:

<b>Sr. No.</b>	<b>Name of the species observed</b>	<b>Notable behaviors/characteristics</b>	<b>Population trends</b>

### 4.3 Faunal Interaction with Flora

- I. Are there any observed mutualistic relationships between fauna and flora (e.g., birds spreading seeds, insects pollinating plants)?
  - a. Yes / No
  - b. If yes, please describe these interactions and their significance:

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- II. Have any predator-prey dynamics been observed within the forest ecosystem?
  - a. Yes / No
  - b. If yes, please describe the observed interactions and their impact on the ecosystem:

## 5. Humidity, Temperature and Air Quality

### 5.1 Humidity

- I. Has there been any change in the local humidity levels since the establishment of the Miyawaki forest?
  - a. Yes
  - b. No

### 5.2 Temperature

- I. Have you observed any significant temperature differences between the Miyawaki forest and the surrounding urban areas?
  - a. Yes
  - b. No
- II. What types of surfaces were present before the forest was established (e.g., concrete, asphalt, bare soil)?
  - a. (Describe the types of surfaces and their respective temperatures)

### 5.3 Air Quality Indicators

I. Has the forest had any impact on air quality in the surrounding area?

- a. Yes
- b. No
- c. If yes, please provide details on specific air quality indicators

- Reduction in co2
- Any other

---

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II. Were any air quality measurements taken before and after the establishment of the forest?

- a. Yes
- b. No

### 5.4 Vegetation and Air Quality

I. Have local residents or stakeholders reported a perceived reduction in heat within the area?

- a. Yes / No
- b. If yes, please provide details on the feedback received, including specific comments or trends:

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II. How do local residents perceive the overall environmental impact of the Miyawaki forest?

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## 6. Maintenance and Growth

I. What were the key maintenance practices adopted for the Miyawaki forest?

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II. How was the growth and development of the Miyawaki forest monitored over time?

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III. Were any specific challenges faced in maintaining the Miyawaki forest, and how were they addressed?

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IV. After plantation was done any fertilizer used?

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V. Flowering and fruity pattern of species recorded?

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## **APPENDICES V**

Development of multimedia resource on Miyawaki Technique

## APPENDICES V

**Scan for the Audio-visual aid**



The link for the Audio visual aid: [https://youtu.be/IZ37AKK\\_upE?si=LitGCo11R0H0dfnN](https://youtu.be/IZ37AKK_upE?si=LitGCo11R0H0dfnN)



**ABSTRACT**

## ABSTRACT

Urbanization has led to significant environmental degradation, necessitating innovative afforestation techniques to restore biodiversity and improve ecological conditions. The Miyawaki Technique, a method of dense afforestation using native plant species, has gained prominence for its ability to accelerate forest growth and enhance ecological resilience. Developed by Japanese botanist Akira Miyawaki, this technique involves planting diverse native species in a multilayered structure, mimicking natural forests. It fosters rapid tree growth, improves soil quality, enhances carbon sequestration, and supports diverse flora and fauna. Implemented widely in urban areas, it plays a crucial role in mitigating the Urban Heat Island effect and improving air quality. The objectives of the study to analyze the diversity of Flora and Fauna within Miyawaki afforested areas in Vadodara district, to find out the perceived changes in ecological benefits such as humidity, temperature and air quality within Miyawaki afforested areas, and to develop a multimedia resource to create awareness and understanding of Miyawaki Technique for afforestation. The literature review showed that researches carried out in India were focused on development Miyawaki technique, Impact on Air Quality and Temperature Reduction while researches undertaken outside India focused on Climate Change Mitigation, Green Urban Landscapes and Biodiversity Enhancement.

A descriptive research design was adopted, incorporating seven case studies to evaluate the impact of Miyawaki forests on urban sustainability. Data were collected through an interview schedule, offering comprehensive insights into biodiversity enhancement and environmental improvements. The multimedia resource was developed in this study to enhanced stakeholder awareness of the Miyawaki Technique. The multimedia resources comprised of Booklet and audio-visual aid on Miyawaki Technique.

Findings of the research highlighted Miyawaki afforestation initiatives in Vadodara district successfully transformed urban spaces into dense green ecosystems with a canopy density of 50%. Established between 2021 and 2022, the sites were carefully planned and implemented by landscape designers and experts. Native species such as Banana, Neem, and Ashoka were planted, enhancing flora diversity. Post-plantation, an increase in fauna

diversity including birds, bees, and insects was observed, though no significant predator-prey dynamics were recorded. The sites contributed to microclimate improvement, with respondents reporting decreased temperatures, humidity, and better air quality. Maintenance for the first 2–3 years included regular watering and organic fertilizers, though water scarcity posed challenges. Over time, flowering and fruiting patterns of the planted species were recorded, indicating successful ecological restoration. These self-sustaining forests now serve as urban biodiversity hubs, demonstrating the effectiveness of the Miyawaki method in combating heat islands and enhancing environmental resilience. A multimedia resource prepared in this research to bring awareness on Miyawaki technique. The multimedia resources combined of a Booklet and audio-visual aid. Through an informative booklet and audio-visual media aid, key aspects such as its principles, benefits, and real-world applications in Vadodara were effectively communicated.

# Miyawaki Technique: A Sustainable Approach to Urban Greening



# PREFACE

The Miyawaki technique is a revolutionary afforestation method that promotes rapid, dense, and biodiverse forest growth using native plant species. Developed by Dr. Akira Miyawaki, this technique enhances ecological restoration, combats climate change, and improves urban green spaces. By mimicking natural forests, it ensures self-sustaining ecosystems that require minimal maintenance. This is an attempt to raise awareness about the Miyawaki method, its principles, benefits, challenges, and real-world applications, particularly in Vadodara District. It serves as a resource for urban designers, landscape architects, policymakers, and environmentalists committed to sustainable urban planning and ecological restoration.



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# Need for Urban Green Spaces

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Rapid urbanization has led to deforestation, loss of biodiversity, and increased urban temperatures due to the Urban Heat Island (UHI) effect. Cities experience heightened pollution levels, decreased air quality, and reduced groundwater recharge. Green spaces, especially dense and biodiverse forests, are crucial in reversing these negative trends. This phenomenon exacerbates energy consumption, air pollution, and public health risks. Additionally, urbanization disrupts ecosystems, reducing habitats for wildlife and diminishing biodiversity. The decline in green cover also impairs air quality by limiting the natural filtration of pollutants, while reduced infiltration surfaces decrease groundwater recharge, worsening water scarcity. To mitigate these impacts, integrating dense, biodiverse green spaces such as urban forests, parks, and green roofs into city planning is essential. These natural solutions help regulate temperatures, improve air quality, enhance water absorption, and restore ecological balance, making them a critical strategy for sustainable urban development (Oke, 1982).

# ORIGIN OF MIYAWAKI TECHNIQUE

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Dr. Akira Miyawaki, a renowned vegetation ecologist, introduced the Miyawaki technique, an ecological approach to restoring forests based on Potential Natural Vegetation (PNV). Developed by German ecologist Reinhold Tuexen in 1956, PNV assesses an area's natural vegetation potential despite human impact (Miyawaki, 2004).

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While researching in Germany in the 1950s, Dr. Miyawaki studied PNV, biocoenosis, and phytosociology. After returning to Japan, he mapped the country's vegetation and studied sacred groves ("Chinju-no-Mori") to restore native forests. His findings revealed a severe decline in evergreen forests (Miyawaki, 2004).

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Source:<https://spicetreemunnar.com/complete-guide-miyawaki-method/>

Recognizing Japan's environmental degradation, Dr. Miyawaki implemented his method, planting diverse native species in dense clusters. In 1971, he created the first Miyawaki forest at Nippon Steel Corporation, pioneering a globally recognized afforestation technique (Miyawaki, 2004).

# BENEFITS OF MIYAWAKI TECHNIQUE

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Miyawaki forests, a method of dense afforestation are gaining popularity as an effective solution for urban greening. This technique involves planting diverse native species close together, enabling rapid growth and the development of self-sustaining ecosystems. Unlike traditional afforestation methods, Miyawaki forests grow up to 10 times faster, absorb more carbon, and support a higher diversity of flora and fauna. These forests not only enhance urban biodiversity but also provide multiple environmental, ecological, and social benefits.

## Benefits of Miyawaki Forests

### Environmental Benefits

- **Rapid Carbon Sequestration:** Miyawaki forests absorb more CO<sub>2</sub> than conventional plantations.
- **Cooling Effect:** Helps mitigate the urban heat island effect by lowering temperatures.
- **Improved Air Quality:** Dense greenery reduces airborne pollutants like PM2.5 and PM10.

### Ecological Benefits

- **Supports Biodiversity:** Creates habitats for birds, butterflies, and small mammals.
- **Improves Soil Quality:** Enhances soil fertility and prevents erosion.

### Social Benefits

- **Aesthetic Value:** Makes urban spaces greener and visually appealing.
- **Health & Well-being:** Encourages physical activity, reduces stress, and improves mental health.
- **Community Engagement:** Involves local communities, students, and organizations (Sharma & Gaur, 2021).

# Benefits of Miyawaki Forests



## Environmental Benefits



### Rapid Carbon Sequestration

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### Cooling Effect

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### Improved Air Quality

Dense greenery reduces airborne pollutants like  $\text{PM}_{2.5}$  and  $\text{PM}_{10}$ .



## Ecological Benefits



### Supports Biodiversity

Creates habitats for birds, butterflies, and small mammals

### Improves Soil Quality

Enhances soil fertility and prevents erosion

## Social Benefits



### Aesthetic Value

Makes urban spaces green and visually appealing



### Community Engagement

Involves local communities, students, and organizations

# Principles of the Miyawaki Method

## Use of Native Species



## Use of Native Species

Indigenous trees and shrubs are selected based on their adaptability to local climate and ecological conditions, ensuring resilience and biodiversity

## Dense Plantation



## Dense Plantation

Trees are planted closely (3-5 saplings per square meter) to mimic natural forests, leading to accelerated growth due to competition for light and nutrients

## Multi-Layered Forest Structure



## Multi-Layered Forest Structure

The species are arranged in different layers, including shrubs, sub-trees, canopy trees, and emergent trees, which fosters a stable ecosystem

## Soil Enrichment



## Soil Enrichment

Organic compost, bio-fertilizers, and mulching materials such as rice husk and coco peat are incorporated to enhance soil fertility and structure

# Steps INVOLVED IN MIYAWAKI PLANATATION

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The Miyawaki method is an innovative afforestation technique that creates dense, fast-growing native forests. By mimicking natural forest ecosystems, this method enhances biodiversity, improves soil quality, and contributes to climate resilience. The following steps outline the process of establishing a Miyawaki forest, from soil preparation to long-term maintenance.

## **Step 1: Examine the Soil Texture and Measure Biomass**

Examining soil texture is essential as it helps determine fertility, water retention, and percolation. These factors influence the growth and longevity of the forest. Next, the existing biomass of the soil should be measured. To enhance soil quality, the following biomass components can be added:

- **Organic Fertilizers:** Essential for plant nutrition, including cowpat, goat muck, and vermicompost.
- **Perforating Materials:** Improve root penetration using rice husk, wheat husk, or groundnut shells.
- **Water Retainers:** Boost soil moisture retention with coconut coir and peat moss.
- **Mulch:** Protects soil from excessive heat and moisture loss using decaying leaves, dried bark, or compost.

# Steps INVOLVED IN MIYAWAKI PLANTATION

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## Step 2: Select Native Species for Plantation

Choosing native plant species is crucial for creating a self-sustaining ecosystem. Plants must be categorized based on their genus (deciduous or evergreen), height, and ecological impact.

- 40-50% of the trees should be the most commonly found species in the region.
- 25-40% should be moderately found native species that support the primary species.
- The remaining 10-25% should be minor native species to enhance biodiversity.
- Saplings should be at least 60-80 cm in height before plantation.

# Steps INVOLVED IN MIYAWAKI PLANTATION

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## Step 3: Prepare the Ground and Equip the Forest Area

Before planting, the site must be cleared of debris and weeds and should receive at least 8–9 hours of sunlight daily.

- Install irrigation systems to ensure adequate water supply.
- Create 100 sq. meter mounds and mark the plantation area before sowing.

## Step 4: Start the Plantation Process

Miyawaki forests are planted densely—3 to 5 saplings per square meter. This encourages competition, making trees grow faster and taller."

- Dig small holes in the soil and carefully remove root bags from saplings before planting.
- Place saplings in the holes and gently level the soil around their stems.
- Provide supporting sticks for taller saplings to ensure stability.

# Steps INVOLVED IN MIYAWAKI PLANATATION

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## Step 5: Take Care of the Forest for the Next 3 Years

The forest requires active maintenance for the first three years to ensure healthy growth:

- Daily watering in the initial stages.
- Weed and plastic removal to prevent competition and pollution.
- Regular mulch replacement for at least one year, ensuring it does not smother young saplings.
- No trimming, chemical pesticides, or artificial fertilizers should be used.
- Allow fallen leaves to remain, as they contribute to soil enrichment.

After three years, the Miyawaki forest becomes self-sustaining, requiring minimal human intervention while providing long-term ecological benefits (Poddar, 2021)

# Challenges and Solutions

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The Miyawaki method is an effective technique for rapid afforestation in urban areas, enhancing biodiversity, improving air quality, and mitigating climate change. However, its implementation faces several challenges, including space constraints, poor soil quality, and water scarcity. The following are key challenges and their solutions to ensure successful afforestation.

## 1. Space Constraints

**Challenge:** Urban areas often have limited land availability for afforestation.

**Solution:** Utilize small vacant spaces such as school grounds, roadside areas, corporate campuses, and underutilized public spaces.

## 2. Poor Soil Quality

**Challenge:** Urban soils are often degraded, compacted, and lacking nutrients.

**Solution:** Improve soil fertility by adding organic compost, biofertilizers, and aeration techniques like mixing perforators.

## 3. Water Scarcity

**Challenge:** Maintaining young saplings requires water, which can be a challenge in arid and semi-arid regions.

**Solution:** Implement efficient irrigation methods such as drip irrigation and apply mulch to retain soil moisture and reduce evaporation.

## 4. Lack of Awareness and Public Participation

**Challenge:** Many urban dwellers are unaware of the benefits of Miyawaki forests.

**Solution:** Organize workshops, awareness campaigns, and community tree plantation drives. Encourage schools and colleges to participate in afforestation programs (Tripathi & Joshi, 2023).

# MIYAWAKI TECHNIQUE AND URBAN ENVIRONMENT

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Miyawaki forests, a method of afforestation that utilizes native plant species, offer numerous environmental benefits. These compact, dense forests contribute to air purification, temperature regulation, and flood control, all of which are crucial in urban settings. By focusing on native species and ensuring rapid growth, Miyawaki forests play a pivotal role in improving air quality, combating the Urban Heat Island effect, and managing water-related challenges in cities.

## **Air Purification**

Miyawaki forests help clean the air by absorbing pollutants like carbon dioxide, nitrogen oxides, and sulfur dioxide. Their dense foliage traps dust and particulate matter, improving air quality. This reduces respiratory issues and makes urban areas healthier (Sharma & Gaur, 2021; Tripathi & Joshi, 2023).

## **Temperature Regulation**

The dense canopy of Miyawaki forests provides shade and cools the surroundings, lowering urban temperatures by a few degrees. They help combat the Urban Heat Island effect, making cities more comfortable. The increased greenery also enhances humidity and overall climate balance.

## **Flood Control**

Miyawaki forests improve rainwater absorption, reducing surface runoff and preventing waterlogging. Their deep-rooted trees help groundwater recharge and stabilize soil. This makes them effective in managing urban floods and erosion control (Sharma & Gaur, 2021).

# Community Participation

Miyawaki afforestation projects present a valuable opportunity to involve communities and organizations in environmental conservation. Initiatives such as tree plantation drives in schools and colleges, citizen science programs, and corporate social responsibility (CSR) activities play a vital role in promoting urban greenery. These collaborative efforts not only raise awareness about biodiversity and sustainability but also cultivate a shared sense of environmental stewardship. Engaging diverse stakeholders ensures greater community involvement and supports the long-term success and impact of these green initiatives.

**Engaging Schools & Colleges:** Organizing tree plantation drives helps students understand the importance of urban greenery and biodiversity. Hands-on participation fosters a sense of environmental responsibility (Tzoulas et al., 2007).

**Citizen Science Projects:** Encouraging residents to monitor plant growth and biodiversity increases community involvement. This creates awareness and helps in tracking the long-term benefits of Miyawaki forests.

**Corporate Social Responsibility (CSR):** Businesses can contribute by funding afforestation projects and providing resources. Such initiatives promote sustainability while enhancing a company's environmental commitment (Sharma & Gaur, 2021).

# Future Prospects & Policy Recommendations

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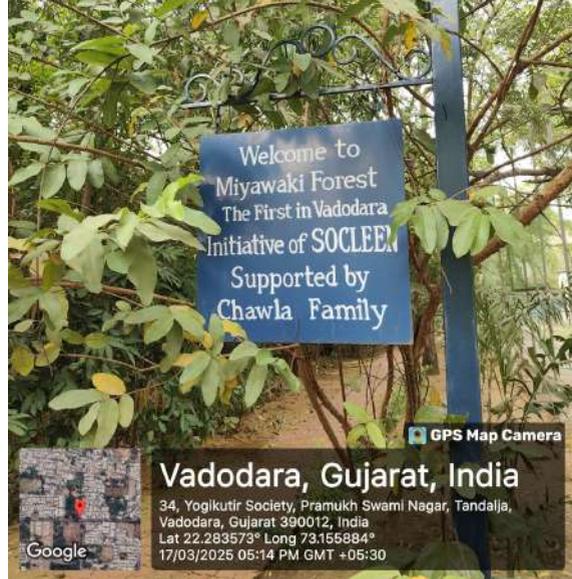
Incorporating Miyawaki forests into urban planning presents a sustainable approach to enhancing green spaces in cities. By integrating these forests into smart city frameworks, we can significantly improve air quality, increase green cover, and build climate resilience.

- **Integration into Smart Cities:** Incorporating Miyawaki forests into urban planning can enhance green cover, improve air quality, and support climate resilience. These forests should be a key component of sustainable city development (Tripathi & Joshi, 2023; Tzoulas et al., 2007).
- **Government Support:** Providing tax incentives, subsidies, and designated land for afforestation projects can encourage large-scale implementation. Policy support will make urban greening more feasible and widespread (Kumar & Rao, 2020).
- **More Research:** Studying the long-term ecological, social, and economic benefits of Miyawaki forests will help refine techniques. Continuous research can optimize species selection, soil preparation, and maintenance strategies for different urban settings (Sharma & Gaur, 2021).

# CASE STUDIES OF SITES DEVELOPED THROUGH MIYAWAKI TECHNIQUE IN VADODARA DISTRICT

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## Site A



- **Profile of the site:** The Miyawaki forest project in Vadodara, established in October 2020 at the Tandlaja area near CH Cancer Hospital, covers 2000 m<sup>2</sup>. The project uses the Miyawaki afforestation technique to promote urban greenery, biodiversity, and mitigate the urban heat island effect by densely planting native species.
- **Planning and Implementation:** The planning and implementation involved extensive land preparation, including soil enhancement through mulching and organic composting. A careful selection of 30 native species, including evergreen, deciduous, and perennial plants, was made to create a multi-layered ecosystem. The high-density plantation (three plants per square meter) ensured rapid growth and ecological balance.
- **Flora Diversity:** The forest hosts 30 different native species, including medicinal, timber, fruit-bearing, and ornamental plants. This diversity promotes a self-sustaining ecosystem, enhances biodiversity, and ensures year-round greenery. The presence of varied plant types helps support the local ecosystem's stability and growth.

# CASE STUDIES OF SITES DEVELOPED THROUGH MIYAWAKI TECHNIQUE IN VADODARA DISTRICT

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## Site A

- **Fauna Diversity:** The forest has attracted a wide range of wildlife, including numerous insect species, butterflies, birds, and mammals. Observed increases in bird populations and new mammal species, like the Indian Palm Squirrel, demonstrate the successful establishment of a thriving ecosystem. The mutualistic relationships between plants, birds, and insects, such as pollination and seed dispersal, further enhance the biodiversity.
- **Humidity, Temperature, and Air Quality:** The dense canopy of the forest has improved the local microclimate by increasing humidity levels and reducing the surrounding temperature, making the area cooler and more comfortable. The forest also significantly improves air quality by absorbing pollutants, filtering CO<sub>2</sub>, and releasing oxygen, thus enhancing the environmental health of the area.
- **Maintenance and Growth:** The forest's growth has been carefully monitored, with regular watering and mulching to support plant development. Despite challenges with water scarcity, strategic watering techniques have ensured the forest's survival. The forest thrives without the use of chemical fertilizers, promoting organic growth and contributing to the long-term sustainability of the ecosystem.

# CASE STUDIES OF SITES DEVELOPED THROUGH MIYAWAKI TECHNIQUE IN VADODARA DISTRICT

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## Site B

- **Profile of the Site:** The Miyawaki Urban Forest was established in December 2021, covering 4000 square meters. Located near Ashram Bill, the forest was created with a high plant density of three plants per square meter, rapidly transforming the area into a dense, green habitat. The forest helps mitigate pollutants, regulate temperature, and restore ecological balance to the nearby urban environment. The project was funded by the National High-Speed Railway and executed by the Vadodara Municipal Corporation (VMC).
- **Planning and Implementation:** The planning of the Miyawaki Urban Forest involved evaluating the site's biological potential, soil quality, and accessibility. High-density planting using native species was the core strategy, supported by proper soil preparation and irrigation systems. The collaborative effort ensured the smooth execution of the project, turning the unused land into a thriving green space. This urban afforestation model has become a successful example of ecological restoration and biodiversity enhancement.
- **Flora Diversity:** The forest consists of 7,000 plants across 18 native species, which include fruit-bearing, medicinal, timber, and ornamental plants. The species were carefully selected to promote ecological balance and sustainability. The forest supports various layers, such as trees, canopy species, sub-trees, and shrubs, enhancing biodiversity. Survival rates for most species are high, with notable growth rates recorded. The plant types include evergreen, deciduous, and perennial trees, which contribute to the overall ecological stability.

# CASE STUDIES OF SITES DEVELOPED THROUGH MIYAWAKI TECHNIQUE IN VADODARA DISTRICT

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## Site B

- **Fauna Diversity:** Before the forest's creation, the area had limited biodiversity, with only a few bird species and mammals. After the afforestation, there was a significant increase in insect and bird populations. For instance, species like butterflies (Common Immigrant, Plain Tiger, Common Crow) and honey bees have thrived. Bird species such as the Oriental Magpie Robin, Red-vented Bulbul, and House Sparrow were also observed. Additionally, new mammal species, like the Indian Palm Squirrel and various rodents, have taken residence. These species contribute to mutualistic relationships, including pollination and seed dispersal, further enhancing the forest ecosystem.
- **Humidity, Temperature, and Air Quality:** The dense canopy of the Miyawaki forest has improved the local microclimate by increasing humidity, reducing temperatures, and providing shade. The increase in humidity and cooling effect helps mitigate the urban heat island effect, creating a more comfortable environment. This has positively impacted the surrounding area, providing cleaner air and lowering energy consumption in nearby buildings.
- **Maintenance and Growth:** Over the past three years, the forest has been regularly maintained through strategic watering and mulching to address challenges like water scarcity. Conservation measures, such as the use of drought-resistant species and water supply tanks, have ensured the forest's growth. No chemical fertilizers have been used, promoting a natural and self-sustaining ecosystem. As the forest matures, flowering and fruiting patterns have emerged, demonstrating the success of the afforestation initiative.

# CASE STUDIES OF SITES DEVELOPED THROUGH MIYAWAKI TECHNIQUE IN VADODARA DISTRICT

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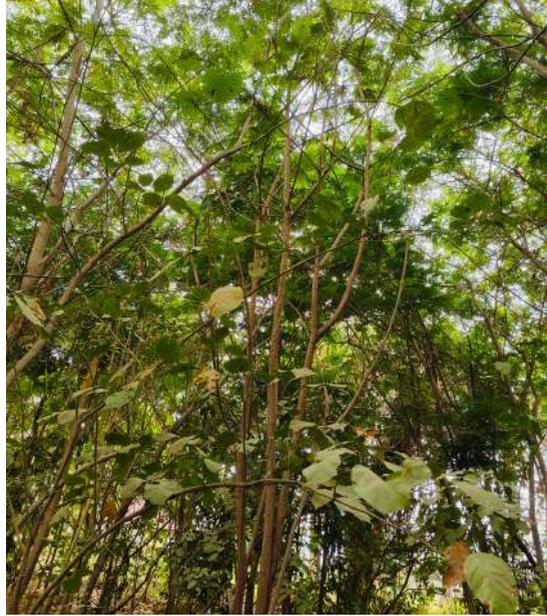
## Site C



- **Profile of the Site:** The Miyawaki Urban Forest at Chhanni Lake, Vadodara, was established in November 2022, covering 1,000 square meters. The forest was created using high-density planting (three plants per square meter), quickly transforming the area into a dense, green habitat. The project aims to reduce pollutants, regulate temperature, and enhance ecological balance. The project was funded and executed by the Vadodara Municipal Corporation (VMC).
- **Planning and Implementation:** The planning involved evaluating the site's biological potential, soil quality, and accessibility. The focus was on high-density planting of native species, with careful soil preparation and irrigation systems to ensure the forest's success. This collaborative effort resulted in a successful transformation of unused land into a thriving green space, serving as a model for urban ecological restoration.
- **Flora Diversity:** The forest consists of 3,000 plants from 37 species, including medicinal, timber, fruit-bearing, and ornamental plants. These species were selected to support ecological balance and sustainability. The forest has different layers (trees, sub-trees, shrubs, and canopy species) that contribute to its biodiversity. The species have shown high survival rates, and their growth is robust, with a variety of evergreen, deciduous, and perennial trees enhancing the overall ecosystem stability.

# CASE STUDIES OF SITES DEVELOPED THROUGH MIYAWAKI TECHNIQUE IN VADODARA DISTRICT

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## Site C

- **Fauna Diversity:** Before the creation of the Miyawaki forest, the Channi Lake area had minimal biodiversity, with only a few common species of birds and mammals. After the afforestation project, there has been a significant increase in insect and bird populations. Species such as the Common Immigrant Butterfly, Plain Tiger Butterfly, Common Crow Butterfly, and honey bees have flourished. Bird species like the White-browed Fantail Flycatcher, House Sparrow, House Crow, Red-vented Bulbul, and Jungle Babbler have been observed. Additionally, new mammal species, including the Indian Palm Squirrel, rodents, and the Indian Hare, have taken residence.
- **Humidity, Temperature, and Air Quality:** The Miyawaki forest at Channi Lake has significantly improved the local microclimate. The dense tree canopy has led to increased humidity and reduced temperatures, effectively mitigating the urban heat island effect. The cooling effect has been particularly noticeable during warmer months, offering a more comfortable environment for both residents and wildlife. The forest's ability to absorb pollutants and release oxygen has contributed to better air quality, providing cleaner air for the surrounding urban area.
- **Maintenance and Growth:** Over the past three years, the Miyawaki forest at Channi Lake has been regularly maintained with strategic watering, especially during dry periods, and mulching to address water scarcity. The use of drought-resistant species and a dedicated water supply system has ensured the forest's continued growth and sustainability. No chemical fertilizers have been used, allowing the ecosystem to develop naturally and self-sustain. The forest has also demonstrated healthy flowering and fruiting patterns.

# CASE STUDIES OF SITES DEVELOPED THROUGH MIYAWAKI TECHNIQUE IN VADODARA DISTRICT

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## Site D

- **Profile of the Site:** The Miyawaki forest at Moti Bapod Lake, established in March 2021, spans 2,500 square meters and features a high planting density of three plants per square meter. Situated near a residential area, the project enhances local biodiversity, improves air quality, and mitigates urban pollutants. The initiative aims to create a greener space, reduce pollution, and engage stakeholders, highlighting its contributions to temperature regulation and mitigating the urban heat island effect.
- **Planning and Implementation:** Funded by the chairman of Bio Soil South NGO, the project aimed to transform Moti Bapod Lake into a vibrant green space. Site selection was based on soil quality, water access, and proximity to urban facilities. A landscape designer from the Vadodara Municipal Corporation (VMC) developed a tailored strategy to maximize plant density and species selection. The project's smooth implementation reflects the importance of preparation, stakeholder involvement, and collaboration.
- **Flora Diversity:** The Miyawaki afforestation technique at Moti Bapod involved planting 7,000 native species to enhance biodiversity and address urban heat. The diverse plant species selected have contributed to rapid vegetation growth and ecological resilience. The plant species varied in medicinal, timber, and ornamental benefits. The survival rates for most species were high, and growth rates varied, with some species exhibiting exceptional growth.

# CASE STUDIES OF SITES DEVELOPED THROUGH MIYAWAKI TECHNIQUE IN VADODARA DISTRICT

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## Site D

- **Fauna Diversity:** The biodiversity of insects, birds, and mammals has significantly improved in the Miyawaki forest. Insect populations, including honeybees, butterflies, and dragonflies, have flourished due to the diverse flowering plants. Birds like the House Sparrow and Red-vented Bulbul have increased in number, benefiting from abundant food sources and improved habitats. Mammals such as the Indian Palm Squirrel and various rodents have established stable or increasing populations, demonstrating the forest's role in supporting various species. The interactions between fauna and flora, such as pollination and seed dispersal, contribute to ecosystem stability.
- **Humidity, Temperature, and Air Quality:** The establishment of the Miyawaki forest has positively impacted local climate conditions. Humidity levels have risen, and temperatures have decreased, particularly during hot summer months, creating a cooler microclimate. The dense canopy helps regulate the temperature and improve air quality, with residents reporting fresher air.
- **Maintenance and Growth:** The Miyawaki forest at Moti Bapod Lake has seen steady growth over three years, with regular monitoring and management ensuring plant health. Water scarcity during dry periods was managed by utilizing lake water for irrigation, and natural soil enrichment from the lake eliminated the need for chemical fertilizers. The forest has progressed through its flowering and fruiting cycles, indicating successful establishment.

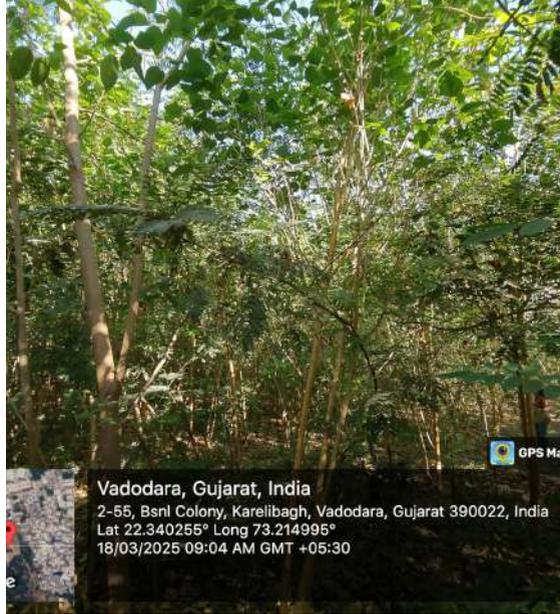
# CASE STUDIES OF SITES DEVELOPED THROUGH MIYAWAKI TECHNIQUE IN VADODARA DISTRICT



## Site E

- **Profile of the Site:** The Miyawaki forest at Ambe School, located near the Harni area, covers 3,500 square meters and was established on June 5, 2022. This urban afforestation project, with a planting density of three plants per square meter, aims to reduce urban heat, improve air quality, and foster biodiversity. It utilizes the Miyawaki technique to transform arid soil into a thriving ecosystem while encouraging community participation in sustainable urban greenery.
- **Planning and Implementation:** The Catch Foundation funded the Miyawaki forest project at Site E, ensuring optimal soil and environmental conditions through comprehensive site studies. The planning included ideal planting density, species selection, and irrigation design, and the project was implemented smoothly with the help of professional designers.
- **Flora Diversity:** The forest at Ambe School consists of 10,500 carefully chosen plants across 37 species, with an emphasis on medicinal, timber, fruit-bearing, and ornamental plants. The species were distributed across trees, sub-trees, shrubs, and canopy layers, ensuring a balanced ecosystem. The species include notable plants such as Gulmohar, Neem, and Pipal, which offer various ecological benefits. A study of plant survival rates revealed that most species had a high survival rate, with an average growth rate of 55 cm per year.

# CASE STUDIES OF SITES DEVELOPED THROUGH MIYAWAKI TECHNIQUE IN VADODARA DISTRICT



## Site E

- **Fauna Diversity:** Before the forest's establishment, the area had minimal faunal presence. Since the afforestation, there has been a significant increase in insect and bird species. Notable insects include honey bees, Plain Tiger Butterflies, and Common Immigrant Butterflies, while bird species such as House Sparrows, Red-vented Bulbuls, and Jungle Babblers have been observed. The mammal population has also increased, with species like the Indian Palm Squirrel and various rodents thriving in the area.
- **Humidity, Temperature, and Air Quality:** The Miyawaki forest has positively impacted the local microclimate by lowering temperatures and raising humidity, especially during the hot summer months. The dense vegetation provides shade and moisture absorption, which has led to cooler surroundings. While there have been no official air quality assessments, residents have reported cleaner air and reduced pollution.
- **Maintenance and Growth:** Over the past two and a half years, the Miyawaki forest has flourished with minimal maintenance. The plants have adapted well and no longer require fertilizers after the initial phase. The forest has become a self-sustaining green space, with visible growth in terms of flowering and fruiting.

# CASE STUDIES OF SITES DEVELOPED THROUGH MIYAWAKI TECHNIQUE IN VADODARA DISTRICT

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## Site F



- **Profile of the Site:** The Miyawaki forest at Ashray Green, Bhayli, was established in October 2022, covering 6,000 square meters. The project was strategically located near residential areas and a canal, making it an effective means to reduce pollutants and contribute to environmental restoration. The goal of the forest is to improve air and water quality, increase greenery, and mitigate the urban heat island effect, ultimately benefiting both the community and the environment by promoting sustainable urban growth.
- **Planning and Implementation:** The Miyawaki forest was funded by the Sun Pharma Foundation, and its design was carefully planned to ensure optimal afforestation. The project was executed smoothly, resulting in a thriving green area that serves as a valuable asset to the city, enhancing both the local environment and surrounding area.
- **Flora Diversity:** The afforestation project resulted in the planting of 12,000 plants across 33 species. The diverse range of plants, including timber, medicinal, and fruit-bearing species, was carefully selected to improve air quality, reduce the urban heat island effect, and enhance urban biodiversity. The forest's varied plant layers, including trees, sub-trees, shrubs, and herbs, support ecological balance and resilience. The survival rate of most species is between 75% and 85%, and the average growth rate varies, with tree species reaching up to 70 cm per year.

# CASE STUDIES OF SITES DEVELOPED THROUGH MIYAWAKI TECHNIQUE IN VADODARA DISTRICT

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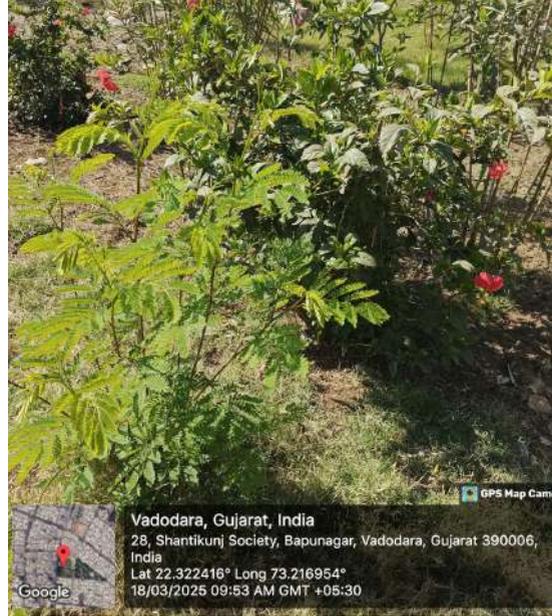


## Site F

- **Fauna Diversity:** The establishment of the Miyawaki forest at Ashray Green, Bhayli, led to a significant increase in faunal diversity. Insects like honey bees, dragonflies, and various butterflies flourished due to the availability of flowering plants, contributing to pollination and biodiversity. Birds such as the House Sparrow, Oriental Magpie Robin, and Purple Sunbird also benefited from the dense vegetation for nesting and foraging. Small mammals like the Indian Palm Squirrel and Indian Hare found stable habitats, and rodents thrived in the new ecosystem.
- **Humidity, Temperature, and Air Quality:** The Miyawaki forest at Ashray Green has successfully created a cooler microclimate, increasing local humidity, particularly in the summer months. The dense canopy reduces surface temperatures, offering a respite from the urban heat island effect. Although no official air quality tests were conducted, respondents observed cooler air and a reduction in daytime heat, contributing to an improved local ecosystem.
- **Maintenance and Growth:** Since its establishment, the Miyawaki forest at Ashray Green has shown strong growth with minimal maintenance. Regular monitoring has ensured healthy development, and the forest has naturally flourished without the need for fertilizers after the initial planting. The forest's successful self-sustaining growth, including regular flowering and fruiting.

# CASE STUDIES OF SITES DEVELOPED THROUGH MIYAWAKI TECHNIQUE IN VADODARA DISTRICT

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## Site G

- **Profile of the Site:** The Miyawaki forest at Nathiba Nagar was established in September 2022 in Vadodara, near a temple in a residential area. Covering 2,500 square meters, the project aimed to enhance green space, reduce pollution, and contribute to a healthier urban environment. It featured a planting density of three plants per square meter, leading to a significant increase in greenery, cooler air, and an influx of pollinators and birds, which contributed to the overall ecological benefits of the area.
- **Planning and Implementation:** The project was initiated by the municipal corporation, which carefully selected the site at Nathiba Nagar as part of a larger development effort. Factors such as suitability for afforestation and collaboration with a landscape designer ensured the success of the project.
- **Flora Diversity:** A total of 4,000 plants were introduced to Site G using the Miyawaki technique, with a focus on species offering medicinal, timber, fruit-bearing, and ornamental advantages. The forest was designed with a multi-layered structure that included trees, shrubs, and sub-trees. The selected plants have enhanced biodiversity, reduced the urban heat island effect, and improved air quality, contributing to environmental sustainability. Plant survival rates varied, with many species thriving at a rate of 75%-85%, providing a diverse range of ecological benefits.

# CASE STUDIES OF SITES DEVELOPED THROUGH MIYAWAKI TECHNIQUE IN VADODARA DISTRICT

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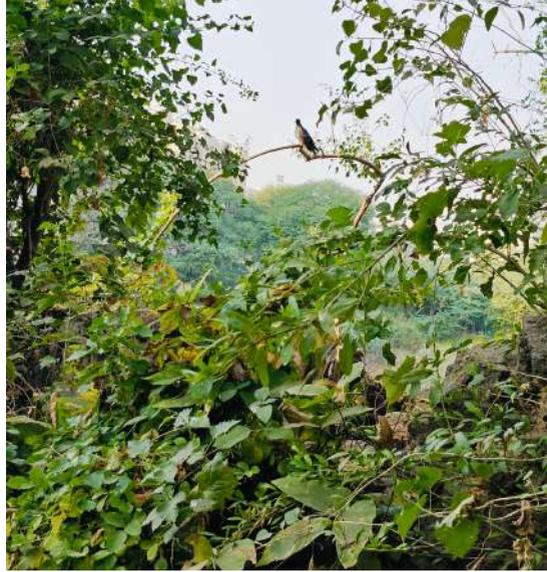


## Site G

- **Fauna Diversity:** The Miyawaki forest boosted faunal diversity by attracting insects, birds, and mammals, creating a thriving ecosystem. The dense vegetation provided essential resources like food and shelter, supporting mutualistic interactions such as pollination and seed dispersal. However, no predator-prey dynamics were observed, indicating a focus on herbivorous and insectivorous species.
- **Humidity, Temperature, and Air Quality:** The Miyawaki forest at Nathiba Nagar has contributed to a more favorable microclimate by increasing humidity and lowering temperatures, particularly on hot summer afternoons. Respondents noted the more comfortable atmosphere and significant reduction in afternoon heat, leading to improved life quality in the area.
- **Maintenance and Growth:** Over the past two years, the Miyawaki forest at Site G has been maintained through consistent watering, plant health monitoring, and soil management. The forest showed steady growth, with plants thriving in their first year. Organic fertilizers were used to support soil fertility and plant development, and the forest has exhibited regular blooming and fruiting, demonstrating the success of the ecological restoration and the overall health of the forest.

# Conclusion

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The Miyawaki technique provides an innovative and effective solution for urban afforestation by creating dense, diverse, and self-sustaining native forests that enhance biodiversity, improve environmental quality, and mitigate the urban heat island effect. This booklet give the knowledge about the need for urban green spaces and offers a concise overview of the Miyawaki method covering its benefits, principles, step-by-step plantation process, challenges with solutions, and the role of community participation. Showcasing successful implementations in Vadodara, it highlights how underutilized urban areas can be transformed into thriving ecosystems. With growing urbanization, the Miyawaki approach emerges as a scalable and impactful strategy for ecological restoration and sustainable city development, serving as a valuable resource for urban planners, policymakers, and environmentalists.

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