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Dynamics and threats to floral diversity in Bhawal national park

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Abstract

Bhawal National Park (BNP) situated in Gazipur district of Bangladesh is a crucial site for biodiversity conservation, particularly its Sal (*Shorea robusta*) forests, which dominate the landscape and provide essential ecological services. This review synthesizes recent studies on BNP's floral dynamics and highlights the environmental challenges that threaten its biodiversity. BNP is facing significant biodiversity loss due to anthropogenic pressures such as industrial encroachment, illegal logging, and land-use changes, which have led to deforestation, habitat fragmentation, and the decline of native species. Additionally, climate change, characterized by rising temperatures and erratic rainfall, is further disrupting the park's floral composition by favoring drought-resistant plants over moisture-dependent ones. These threats have caused a significant reduction in species richness. This review emphasizes the urgent need for integrated conservation strategies, including climate adaptation measures, reforestation with native species, and stronger community involvement to preserve BNP's unique biodiversity. Continuous monitoring and research are essential for developing adaptive management strategies that ensure the park's resilience in the face of ongoing environmental changes.

Keywords: Biodiversity loss, climate change impact, floral dynamics, national park, sal forest

Introduction

Tropical forests, such as those in Bhawal National Park (BNP), are essential ecosystems that host a vast array of biodiversity, playing a crucial role in climate regulation and species conservation. However, these ecosystems are increasingly threatened by human activities and climate change, which put their ecological balance at serious risk. Sal forests, dominated by the Sal tree (*Shorea robusta*), are among South Asia's most important tropical ecosystems which is known for their rich biodiversity, and the vital ecological services they provide, remarkably include carbon sequestration and habitat provision (Mishra *et al.* 2021).

In Bangladesh, Bhawal National Park represents one of the largest remaining reserves of Sal Forest, housing a diverse range of flora that supports various ecological functions and species (Habib and Huda 2022). Despite its protected status, BNP faces significant environmental challenges that endanger its floral composition (Mukul *et al.* 2008). Human activities such as industrial expansion, urbanization, and illegal land encroachment have led to substantial habitat loss and fragmentation(Wilson *et al.* 2015). As a result, the park's Sal forests, which make up about 90% of its tree canopy, have deteriorated, contributing to the decline of native species (Kabir and Ahmed 2005).

Rapid industrialization in the areas surrounding BNP, particularly in nearby urban centers, has exacerbated deforestation and increased land surface temperatures, thus altering the park's microclimate (Alam *et al.* 2021). This temperature rise, coupled with a reduced vegetation cover, has been linked to declining forest health and biodiversity (Grover and Singh 2015). Recent research indicates a marked decrease in mature Sal trees, an increase in invasive non-native species, and an overall loss of floral diversity within BNP (Hasan and Karim 2020; Alam *et al.* 2021).

Anthropogenic pressures such as illegal logging, agricultural expansion, and industrial encroachment further accelerate biodiversity loss, undermining the ecological integrity of this protected area (Mishra *et al.* 2021). Climate change also plays a critical role in altering BNP's floral dynamics. Rising temperatures and unpredictable rainfall patterns are expected to shift the distribution of key species, such as Sal, which could have far-reaching effects on the entire ecosystem (Rahman *et*

al. 2010). Research suggests that climate change may disrupt flowering cycles, alter species interactions, and shift plant community compositions, making adaptive management strategies crucial for the park's survival (Naughton-Treves *et al.* 2006).

Given the growing pressures on BNP's biodiversity, it is imperative to develop integrated conservation strategies that address ecological and socio-economic factors. This review aims to provide a foundation for such conservation efforts, emphasizing the need for sustainable and adaptive management to safeguard Bhawal National Park's future.

Methodology

Study area: Bhawal National Park (BNP) is located in the Gazipur district of Bangladesh, covering an area of 5,022 hectares (Jahan et al., 2017) between 24°02'N to 24°11'N latitude and 90°21'E to 90°28'E longitude (Fig.-1). Situated approximately 40 kilometers north of Dhaka along the Dhaka-Mymensingh highway, BNP serves as a critical conservation area in the central region of Bangladesh (Kabir and Ahmed 2005). Established on May 11, 1982, under the Bangladesh Wildlife (Preservation) (Amendment) Act of 1974, the park aims to protect the remaining Sal (Shorea robusta) forest and its associated biodiversity from increasing anthropogenic pressures (Rahman and Vacik 2010). It is classified under the International Union for Conservation of Nature's (IUCN) Management Category IV, underscoring its role in preserving Bangladesh's natural and cultural heritage (Mishra *et al*. 2021). BNP's topography consists mostly of plain land or low hills rising 3.0-4.5 meters above the

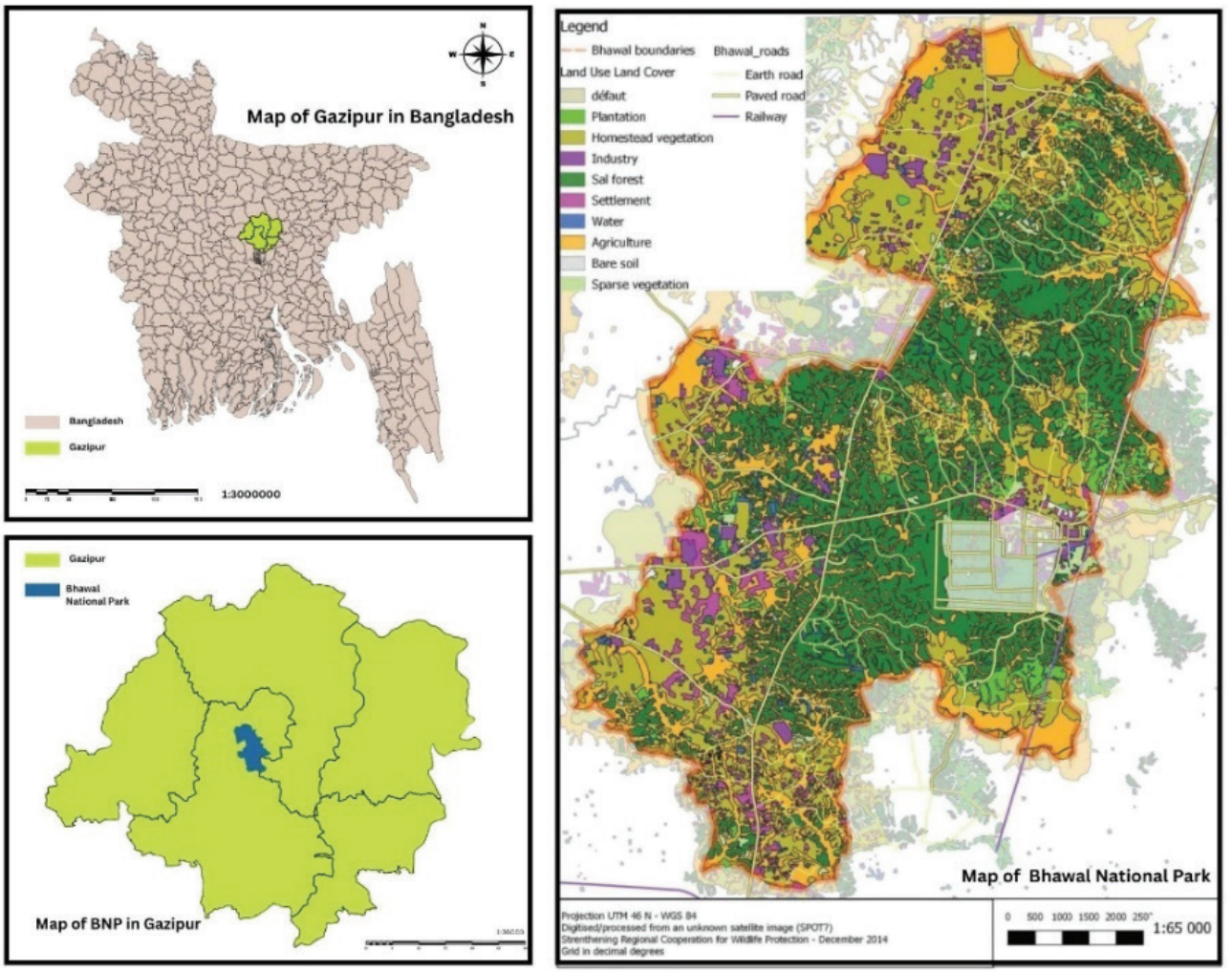


Figure 1: Study area map of Bhawal National Park.

surrounding paddy fields, locally known as 'Chalas,' which are interspersed with numerous depressions or 'bails' (Bhawal National Park Management Plan 2015-2025). The soils are generally acidic to strongly acidic (pH < 5.5), yellowish-red, sandy clay loam, mixed with scattered manganiferous iron ore. These soils are characterized by low organic matter (0.78%) and low fertility, with poor porosity resulting in the soil becoming soft and muddy during the monsoon season (Bhawal National Park Management Plan 2015-2025).

The climatic conditions in BNP are moderate, with temperatures ranging from 15°C in January-February to 42°C in April-June (World Weather Online). The area receives an average annual rainfall of approximately 1500 mm, with the highest precipitation occurring from June to August and the lowest from December to February. The annual relative humidity in the park typically ranges from 60% to 86% (Hasan and Karim 2020; Mo*ndol,* 2021). The park's proximity to Dhaka's urban expansion makes it the only protected area in Bangladesh with industrial establishments within its core zone, adding unique challenges to its conservation efforts (Alauddin *et al*. 2020)

A land cover analysis in BNP identified five major land cover classes, mainly influenced by human activities such as forest plantations, deforestation, settlements, industrialization, and cultivation. The park's core zone is heavily forested, particularly in the Baroipara and Bhabanipur areas, while agricultural and urban development is more prevalent on the park's periphery (Bhawal National Park Management Plan 2014).

Survey: The floral species identification survey was conducted in Bhawal National Park (BNP) from June to August 2024. The primary objective of this survey was to identify the floral species present within the park during the monsoon season. The timing allowed for a wide range of species to be observed, particularly those that are active or flowering during this period.

A stratified random sampling approach was used to ensure that different vegetation zones of the park were represented. The park was divided into five major zones based on vegetation types, including dense Sal Forest, mixed forest patches, grasslands, degraded lands, and aquatic ecosystems. In each zone, field observations were made to document the species present.

Species identification was done visually, with the help of botanical field guides and expert consultation where necessary. Both the local (common) names and scientific names of the species were recorded. Identification tools such as plant keys and photographic records were employed to ensure accuracy.

No additional measurements or ecological parameters were collected during this survey, as the focus was solely on documenting the species present in the park. The results provide a comprehensive list of the floral species observed during the survey period, contributing to ongoing efforts to understand the biodiversity dynamics in Bhawal National Park.

Data analysis: In addition to the literature review, secondary data on BNP's flora were collected through surveys conducted in 1994, 2005. These surveys documented the species present in BNP, including their local and scientific names. To assess changes in biodiversity over the 30 years, biodiversity indices were calculated using the following-methods:

The Rate of Species Decline measures the annual decrease in species numbers across different categories (trees, shrubs, herbs, climbers) over time. This method provides insight into the speed and extent of biodiversity loss.

$$Rate\ of\ decline = \frac{End\ Value - Start\ value}{End\ Year - Start\ year}$$

The Start Value is the species count in the earlier year. End Value is the species count in the later year. End Year and Start Year are the years between which the decline is measured (e.g., 1994 to 2024, 2005 to 2024).

Rates of decline were calculated for 1994 to 2024 and 2005 to 2024, to understand if the rate of species decline has accelerated or slowed. A negative rate of decline indicates a reduction in species numbers, while a positive rate (if applicable) would indicate an increase. These results help quantify how quickly biodiversity is lost in Bhawal National Park.

Results

The detailed survey report on the floral species composition of Bhawal National Park, documented during the study period, is provided in Appendix-1.

Species composition: The species composition in Bhawal National Park (BNP) has exhibited notable variation over the years, reflecting the combined impacts of environmental changes and human activities. Survey data from IUCN (1994), Kabir and Ahmed (2005), and our recent survey (2024) revealed significant changes in the distribution of trees, shrubs, herbs and climbers, as visualized in Figure-1 (IUCN 1994; Kabir and Ahmed 2005).

In 1994, the tree species diversity was at its peak, with *Shorea robusta* (Sal tree) as the dominant species. Other important trees included *Albizia lebbeck* and *Gmelina arborea*. However, by 2005, the number of tree species had dropped to 43, largely due to deforestation and illegal logging. Our 2024 survey recorded a partial recovery, with the count rising to 88 species. While *Shorea robusta* remains present, it is increasingly being replaced by fast-growing plantation species like *Acacia auriculiformis,* which poses a threat to the native tree diversity (Kabir and Ahmed 2005). The overall tree decline rate between 1994 and 2024 is estimated at -1.56 trees per year.

Shrub diversity followed a similar trend, with the highest species richness observed in 1994, including species like Clerodendrum viscosum and Lantana camara. By 2005, shrub diversity had been significantly reduced to 19 species. However, our 2024 survey showed an increase to 31 species. Unfortunately, many native shrubs have been displaced by invasive species, such as *Chromolaena odorata* (Hasan and Karim 2020; Alam *et al.* 2021). The decline rate for shrubs is calculated at -3.16 shrubs per year.

Herb species remained relatively stable between 1994 and 2005, with dominant species such as *Imperata cylindrica* and *Cynodondactylon*. By 2024, however, the number of herb species had sharply declined to 20, reflecting significant losses in undergrowth vegetation and the impacts of changing land-use patterns (Mishra *et al.* 2021; Rahman and Vacik 2009). The rate of decline for herbs stands at -3.44 herbs per year.

Climbers, including species like *Pothos scandens* and *Tetrastigmaleucostaphylum*, experienced a gradual decline from 25 species in 1994 to 24 in 2005. By 2024, this number had further dropped to 16 species, likely due to the loss of host trees and other support structures within the park's forest ecosystem (Hasan and Karim 2020; Alam *et al.* 2021). The decline rate for climbers was measured at -0.36 climbers per year.

Our 2024 survey has contributed to important updates by documenting 88 tree species, 31 shrub species, 20 herb species, and 16 climber species (Appendix-1, Figure 1).

A striking decline in the number of IUCN Red-listed species has been observed between 1994 and 2024. In 1994, 25 species in Bhawal National Park were categorized as IUCN Red-listed, indicating their vulnerability or endangerment. However, by 2024, only 5 of these species

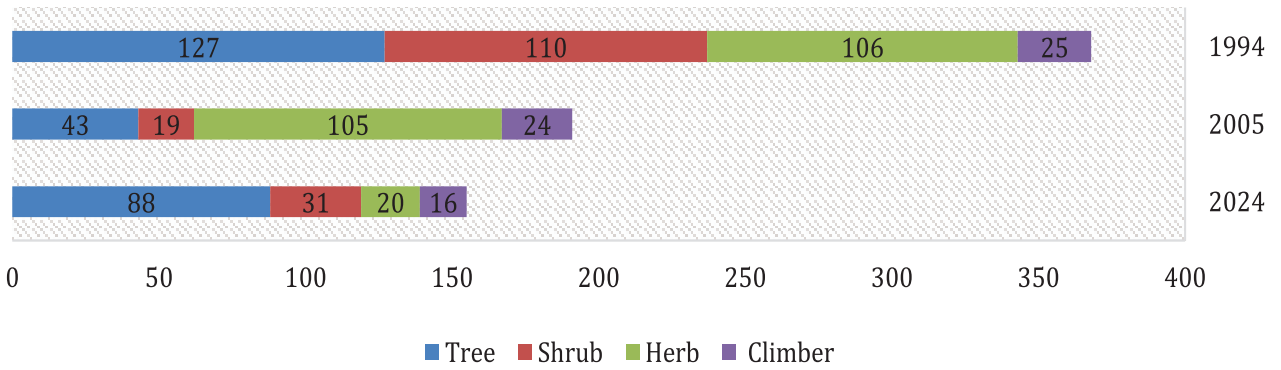


Figure 1. Species richness of Bhawal National park in different survey years.

Table 1. International Union for Conservation of Nature (IUCN) red listed species found in full, 2024

Scientific Name	Local Name	Conservation Status	Habit
Dipterocarpus indicus	Gorjon	Endangered	Tree
Swietenia mahagoni	Mehogony	Endangered	Tree
Aquilaria agalloca	Agar	Critically Endangered	Tree
Dalbergia sissoo	Sishu	Vulnerable	Tree
Swietenia macrophylla	Boro Mehogony	Vulnerable	Tree

were still present in the park (Table-1). This significant reduction highlights the growing pressures on the park's biodiversity and the urgent need for conservation efforts.

Bhawal National Park's biodiversity has declined significantly over the past two decades. With native species like *Shorea robusta* under threat, there is an urgent need for conservation actions to prevent further losses and restore the ecological integrity of Bhawal National Park.

Forest cover change in BNP (2005-2020) : Over the period from 2005 to 2020, significant changes in land classes were observed in Bhawal National Park (Rahman *et al.* 2022). The total forest cover area decreased from 4579.2 ha to 2294.79 ha (Figure-2). In contrast, agricultural land has increased dramatically from 274.95 hectares in 2005 to 2064.24 hectares by 2020. Settlement areas have also expanded, reflecting human encroachment. The land class trends indicate a clear shift from forested areas to agricultural and settlement land uses.

Threats to biodiversity in BNP: Bhawal National Park (BNP) has faced a variety of ecological and anthropogenic pressures over the past few decades. These threats have resulted in a significant loss of biodiversity, including the drastic decline in native species and the proliferation of invasive species. Key threats to BNP's biodiversity include deforestation, land-use changes, industrial encroachment, climate change, and the introduction of invasive species (Table-2).

Anthropogenic Factors: Deforestation, primarily driven by illegal logging, agricultural expansion, and human settlements, poses a significant threat to biodiversity in Bhawal National Park (BNP). Rapid urbanization in nearby Dhaka has intensified demand for land and resources, leading to forest clearance for agriculture and infrastructure for human settlement and industry (Alauddin *et al.* 2020). This deforestation disrupts natural habitats, causing notable declines in species richness and diversity, as indicated by reduced tree and shrub populations (Rocha-Santos *et al.* 2017). Over

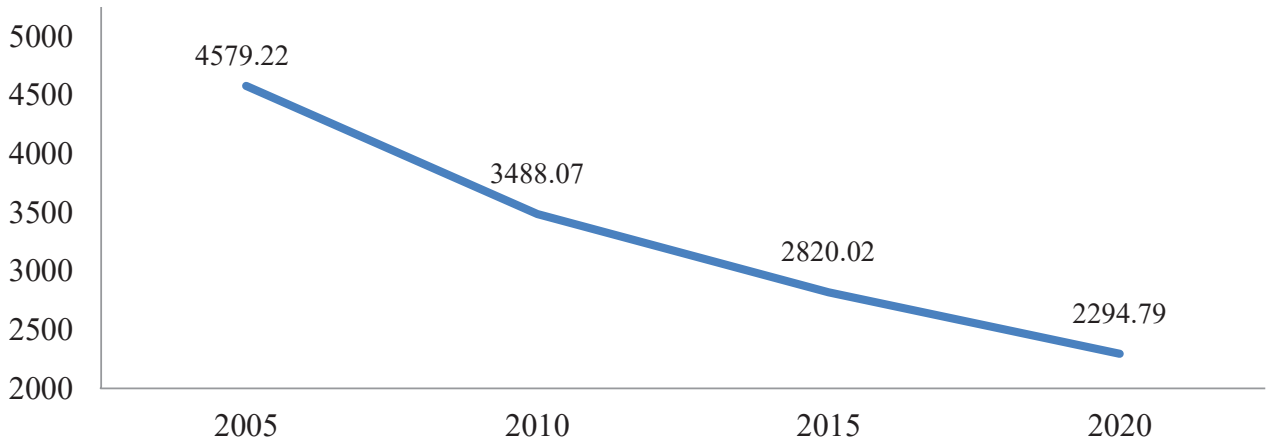


Figure 2. Forest cover area of BNP over year 2005-2020.

recent decades, nearly 70% of forest habitat has been lost, with industrial encroachment and military activities exacerbating the issue. Ground fires, often linked to these activities, destroy valuable flora, including medicinal herbs and shrubs, while firewood collection by local communities depletes essential species like *Shorea robusta* Industrial establishments within BNP's core zone, such as a denim mill and a spinning mill, fragment habitats and increase pollution, negatively affecting flora and fauna (Roshni *et al.* 2022). Over 150 industries in the buffer zone contribute to habitat degradation and water pollution, further stressing the park's ecosystem. Urban sprawl from Dhaka adds to the pressure, intensifying resource depletion within BNP (Hasan and Karim 2020).

Climate change impacts: Climate change poses a significant threat to the biodiversity of BNP. Changes in temperature and rainfall patterns have altered the phenology of native species, leading to shifts in species distribution and abundance (Mishra *et al.* 2021). From 2017 to 2024, maximum temperatures during the summer months have increased significantly (Figure-4). For instance, April temperatures rose from 33°C in 2017 to 42°C in 2024. These rising temperatures stress moisture-dependent species like *Shorea robusta* and increase the risk of wildfires, threatening plant regeneration and biodiversity (Dhungana *et al.* 2023). Rainfall has steadily declined, particularly during the first half of the year (Figure-3). In 2017, there were 66 rainy days with 237.26 mm of rainfall (January-June), but by 2024, rainfall dropped to 92.7 mm with only 19 rainy days. The decreased water availability exacerbates drought conditions, leading to further stress on plant species and habitat degradation (Akıncı and Lösel 2013).

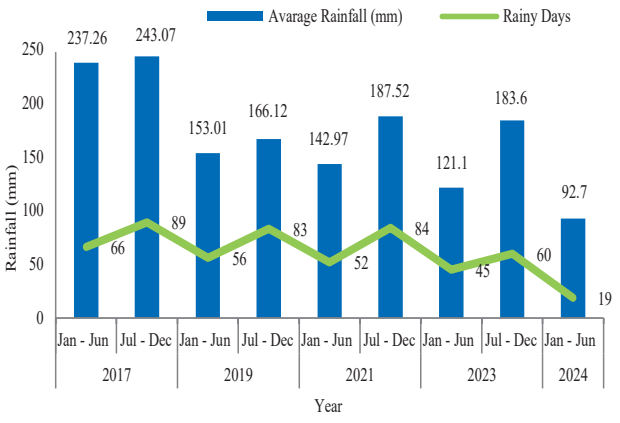


Figure 3. Yearly rainfall (2017-2024) in the study area.

The combination of rising temperatures and reduced rainfall creates drier conditions, threatening flora and fauna(Mantyka-pringle *et al.* 2011). Species requiring moist environments, such as native herbs and shrubs, are particularly vulnerable. Invasive species, resilient to these changes, may increasingly dominate the park's landscape (Mishra *et al.* 2021).

Invasive species: Non-native species such as *Acacia auriculiformis* and *Chromolaena odorata* pose significant threats to BNP's native flora. *Acacia auriculiformis*, a fast-growing species, has dominated some areas, replacing native trees like *Shorea robusta* (Banerjee *et al.* 2023). Similarly, *Chromolaena odorata*, an aggressive shrub, has spread in degraded areas, reducing native shrub and herb diversity (Hasan and Karim 2020; Kabir and Ahmed 2005).

In 2014, reforestation efforts introduced woody perennials like *Acacia hybrid*, *Mangium*, Eucalyptus, and *Akashmoni*.

Threat Type Key Drivers Impact Deforestation & Human Activities Illegal logging, agricultural expansion, urbanization, firewood collection, industrialization Habitat loss, species decline, reduced biodiversity Climate Change Impact Rising temperatures, declining rainfall, wildfire risk, altered phenology Disrupted species distribution, increased stress on moisture-dependent plants

Invasive species acacia auriculiformis, Chromolaena odorata, competition with native flora Outcompete native species, alter soil conditions, reduce biodiversity Forest Encroachment Agricultural practices, illegal settlements, industrialization, military activities, human-wildlife conflict, soil erosion Loss of forest cover, habitat fragmentation, decreased plant diversity While these species grow quickly, they outcompete native plants, further altering soil conditions and reducing biodiversity (Hasan and Karim 2020).

Invasive species disrupt nutrient cycling and water availability, making it difficult for native plants to survive. These resilient species, coupled with changing climate conditions, exacerbate biodiversity loss (Alauddin *et al.* 2020).

Table 2. Key threats to biodiversity of Bhawal National Park.

Threat Type	Key Drivers	Impact
Deforestation & Human Activities	Illegal logging, agricultural expansion, urbanization, firewood collection, industrialization	Habitat loss, species decline, reduced biodiversity
Climate Change Impact	Rising temperatures, declining rainfall, wildfire risk, altered phenology	Disrupted species distribution, increased stress on moisture-dependent plants
Invasive Species	Acacia auriculiformis, Chromolaena odorata, competition with native flora	Outcompete native species, alter soil conditions, reduce biodiversity
Forest Encroachment	Agricultural practices, illegal settlements, industrialization, military activities, human-wildlife conflict, soil erosion	Loss of forest cover, habitat fragmentation, decreased plant diversity

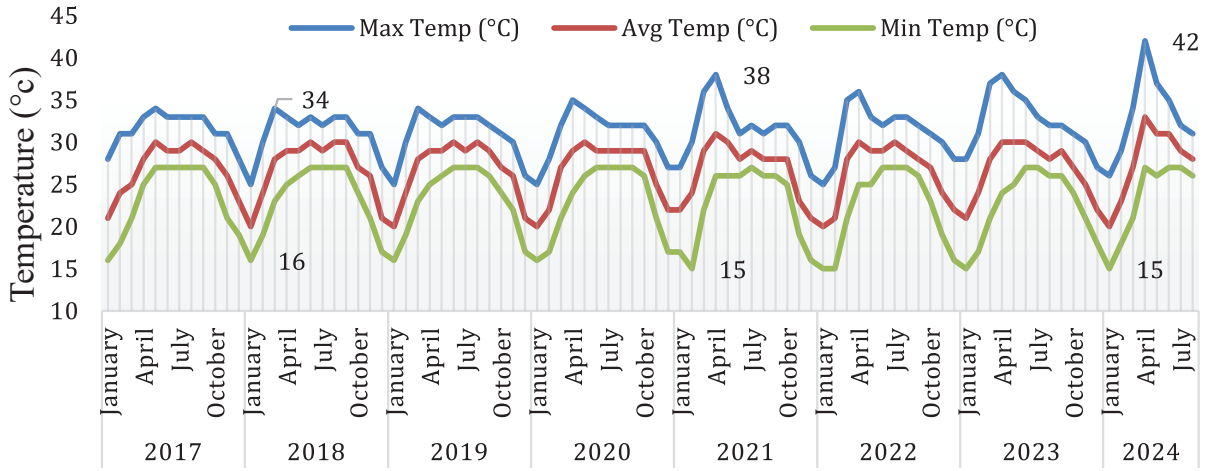


Figure 4. Yearly temperature data of Bhawal National Park from 2017-2024.

Forest encroachment: Agricultural practices and illegal settlements within the boundaries of BNP have resulted in significant forest encroachment (Masum *et al.* 2015). The conversion of forested areas into agricultural land for crops like rice and jute has reduced the park's forest cover, disrupted wildlife habitats and decreased plant diversity (Hasan and Karim 2020). Encroachment has also increased the incidence of human-wildlife conflict, further endangering both plant and animal species within the park.

Furthermore, forest encroachment has led to soil erosion and degradation, particularly in areas where traditional slash-and-burn agriculture is practiced. The removal of vegetation exposes the soil to erosion during the monsoon season, resulting in the loss of fertile topsoil and negatively affecting the regeneration of native species (DeVilleneuve *et al.* 2023).

Discussion

The findings from the literatures and surveys of Bhawal National Park are consistent with the global trends, where climate and land use are the major factors driving the changes in biological diversity (IUCN 2002). Species richness generally increases with higher air temperatures and greater precipitation. However, as climate shifts over the next century, biodiversity is expected to change significantly. Under various climate scenarios, many forest types currently adapted to monsoon temperatures are predicted to migrate northward. In contrast, isolated communities of species may face the risk of extinction within their current habitats.

This has serious implications for conservation strategies in protected areas like Bhawal National Park. As evidenced by

the forest cover area changes from 2005 to 2020 (Figure-2), the park has experienced a marked reduction in forest cover, alongside an increase in agricultural and settlement areas. These land-use changes, combined with shifting climate conditions, are likely to accelerate the loss of species and disrupt the ecological balance of the park. The following paragraphs outline the key considerations for conserving the resources of Bhawal National Park (BNP):

Effectiveness of conservation strategies: Community involvement programs like the Integrated Protected Area Co-management (IPAC) initiative have shown potential in engaging local populations in forest management. However, while these programs have reduced illegal logging and forest encroachment in some areas, their long-term success depends on continued funding and local incentives. High poverty levels in surrounding areas continue to drive unsustainable resource extraction (Alauddin *et al.* 2020). Thus, economic alternatives for forest-dependent communities should be prioritized to reduce pressures on BNP's natural resources.

Reforestation efforts, particularly those initiated in 2014, helped stabilize degraded areas, but these initiatives have often focused on fast-growing, non-native species like *Acacia auriculiformis* and *Eucalyptus*, which have limited biodiversity benefits (Hasan and Karim 2020). The dominance of such species has negatively impacted native flora like *Shorea robusta*, which is crucial for the long-term stability of BNP's ecosystem. Future reforestation efforts should prioritize native species to restore ecological balance and enhance biodiversity.

Impact of climate change on species distribution and ecosystem function: Climate change poses a substantial threat to BNP's biodiversity. Rising temperatures and erratic rainfall have altered the ecological balance, with significant impacts on moisture-dependent species such as *Shorea robusta*. Higher temperatures are stressing native species, increasing the risk of wildfires, and shifting species distributions to favor drought-resistant flora. These changes can disrupt the phenology (e.g., flowering and fruiting cycles) of native species, which in turn affects species interactions, pollination dynamics, and overall ecosystem function.

In line with global trends, BNP's biodiversity is expected to shift significantly as climate scenarios evolve. Species once suited to the monsoon climate may become restricted to smaller, more isolated areas, leading to increased extinction risk. Meanwhile, invasive species such as *Acacia auriculiformis*, more resilient to temperature fluctuations and lower water availability, may continue to increase, further altering the park's ecosystem.

Synergistic effects of climate change and land-use alterations: Land-use changes in BNP driven by urbanization, agricultural expansion, and industrial encroachment exacerbate the impacts of climate change on biodiversity. Deforestation and habitat fragmentation have not only reduced the area available for native flora but also increased the park's vulnerability to invasive species and climate variability. For instance, the reduction in forest cover leads to microclimatic shifts, such as increased soil temperatures and reduced humidity, further stressing plant species already coping with climatic changes.

This combination of climate change and land-use alteration creates a feedback loop, where reduced forest cover amplifies climate effects, and vice versa. This feedback accelerates biodiversity loss and disrupts the ecosystem services BNP provides, such as carbon sequestration and habitat provision. Thus, understanding the combined effects of these drivers is crucial for developing effective conservation strategies.

Anthropogenic and industrial pressures: Another significant factor contributing to the degradation of BNP is the presence of industries within and around the park. The presence of industries within and around BNP creates a complex challenge for conservation efforts. While industrial development offers economic benefits, it comes at the expense of significant environmental degradation. The expansion of industries has not only contributed to deforestation and habitat loss but has also contaminated the park's fertile soil and water bodies, further destabilizing the ecosystem. Effective governance and strict implementation of environmental rules and regulations are essential to mitigate these negative impacts (Roshni *et al.* 2022). The need for participatory forestry programs (PFP) and stronger forest governance is evident, particularly in areas with degraded Sal Forests, where

previous management strategies have shown limited success (Roshni *et al.* 2022).

Gaps in research and future conservation needs: Despite extensive studies on Bhawal National Park (BNP), crucial research gaps persist, limiting the effectiveness of conservation strategies. Much of the existing research centers on the Sal tree (*Shorea robusta*), often overlooking the broader plant diversity, including shrubs, herbs, and climbers. A comprehensive inventory of BNP's vegetation is needed to fully understand its ecological interactions and to design inclusive conservation approaches. Another gap is the absence of long-term monitoring data; without it, assessing biodiversity trends and evaluating the success of conservation initiatives is challenging. Establishing a systematic monitoring program would improve conservation management by supporting adaptive practices.

Although threats like industrial pollution, illegal logging, and tourism have been recognized, detailed studies on their specific impacts on plant communities are limited. Understanding the effects of pollutants and disturbances on various species is essential for developing targeted mitigation strategies. Additionally, the ecology of BNP's water bodies, such as lakes and ponds, remains unstudied, though these aquatic habitats likely play a vital role in the park's biodiversity. This area presents an important avenue for future research.

Research on the impacts of climate change on BNP's vegetation is also minimal. While some studies address its effect on Sal distribution, broader concerns, such as shifts in plant-pollinator interactions, species composition, and phenology, are underexplored. Incorporating climate models into ecological studies would help predict these changes and inform conservation strategies. Addressing these gaps will deepen our understanding of BNP's ecological dynamics and support more effective, evidence-based conservation practices.

Strategies for floral conservation in BNP: Floral conservation in Bhawal National Park (BNP) requires a multifaceted approach, addressing both ecological and socio-economic factors. Below are several strategies aimed at preserving the park's unique biodiversity:

Prioritize the conservation of *shorea robusta* (Sal): Instead of replacing *Shorea robusta* with other species, efforts should focus on increasing the productivity of Sal forests, as they are the species' natural habitat. Research shows that protected Sal coppices can be more productive per hectare than block plantations.

Agroforestry over woodlots: Agroforestry, which integrates trees and agriculture, should be prioritized over traditional woodlot management, as it offers a more financially viable solution and helps maintain biodiversity.

Replant with native species: Reforestation efforts should prioritize native species, particularly *Shorea robusta*, and its natural associates, including *Terminalia bellerica*, *Dillenia pentagyna*, *Albizia procera*, and *Lagerstroemia parviflora*, to maintain ecological balance.

Protect and study medicinal plants: BNP's Sal forests host a variety of medicinal plants. Identifying, protecting, and studying these plants can not only preserve biodiversity but also provide socio-economic benefits.

Mitigate anthropogenic disturbances: High levels of human disturbance, coupled with the introduction of invasive species, are detrimental to biodiversity. Reforestation efforts should avoid using fast-growing, non-native species that could threaten the natural flora and fauna.

Preserve old-growth forests: Old-growth forests tend to support higher species diversity than younger plantations, particularly in areas with moderate anthropogenic disturbance. Protecting these forests is crucial for maintaining biodiversity.

Engage local communities: Engaging local communities through co-management approaches can empower them to protect natural resources while also benefiting from sustainable practices. This can be key to ensuring long-term conservation success.

Address historical management challenges: Learning from past management mistakes is essential. For instance, the introduction of bamboo to BNP and the large-scale planting of exotic species have proven ineffective. Furthermore, picnicking and other recreational activities within BNP have contributed to its degradation.

Strengthen capacity and resources: Addressing the lack of well-trained human resources and securing political, legal, and financial support is crucial for effective management. Implementing well-researched, long-term conservation strategies requires adequate funding and political backing.

Conclusion

The review of floral dynamics and biodiversity threats in Bhawal National Park (BNP) highlights the urgent need for strategic conservation efforts. The park's Sal forests and diverse ecosystems are under immense pressure from deforestation, habitat fragmentation, industrial encroachment, and invasive species. These threats, compounded by the impacts of climate change, such as rising temperatures and erratic rainfall are altering species composition and stressing BNP's fragile ecosystems. The combined effects of natural and anthropogenic factors are accelerating the decline of native flora, disrupting habitats, and reducing biodiversity.

Conservation efforts so far have been inconsistent, with some interventions proving counterproductive. The large-scale planting of non-native species and the introduction of unsuitable flora, such as bamboo, have disturbed the park's natural balance. Industrial and recreational activities within BNP further degrade its habitats. However, opportunities remain for reversing these trends through sustainable management practices. A holistic approach combining ecological restoration, community involvement, and effective governance will be essential to preserve BNP's floral diversity. With timely interventions and adequate support, the park can continue to serve as a vital refuge for biodiversity in Bangladesh, safeguarding its natural heritage for future generations.

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Appendix 1. Species Checklist for Bhawal National Park (BNP): This checklist presents the tree, shrub, herb, and climber species identified in Bhawal National Park (BNP) during the survey conducted in 2024. The species are categorized based on their local names, scientific names, family, and their place of occurrence in the park—whether in the sal forest, cultivated lands, or near human settlements.

Sl. no	Local name	Scientific name	Family	Place of occurrence		
		Tree		Sal forest	Cultivated land	Human settlement
1	Sal	*Shorea robusta*	Dipterocarpaceae	√		
2	Garjan	*Dipterocarpus indicus*		√		
3	Telsur	*Hopea odorata*		√		
4	Ata	*Annona squamosa*	Annonaceae	√		√
5	Nona	*Annona reticulata*		√		√
6	Fonseti	*Alphonsea lutea*		√		
7	Gandhi gajari	*Miliusavelutina*		√		
8	Debdaru	*Polyalthia longifolia*		√		√
9	Kuti kadam	*Miliusavelutina.*		√		
10	Pine	*Pinus carabiana*	Pinaceae	√		
11	Nagasher	*Maesa nagessarium*	Primulaceae	√		
12	Akashmoni	*Acacia auriculiformis*	Fabaceae	√		√
13	Sonalu	*Acacia mangium*		√		√
14	Polash	*Butea monosperma*		√		
15	Radachura	*Caesalpinapulcherima*		√		√
16	Mingeri	*Cassia siamea*		√		√
17	Korai	*Albizia procera*		√		√
18	Asoke	*Saraca indica*		√		
19	Babla	*Acacia nilotica*		√		
20	Krishnochura	*Delonix regia*				√
21	Ban sonalu	*Cassia nodosa*		√		
22	Sherish	*Albizia lebbeck*				√
23	Bador Lathi	*Cassia fistula*				√
24	Kalo korai	*Albizia odoratissima*				√
25	Shil korai	*Albizia procera*				√
26	Sisoo	*Dalbergia sisoo*		√		
27	Raintree Koroi	*Samanea saman*				√
28	Mander	*Erythrina variegata*				√
29	Tetul	*Tamarindus indica*				√
30	Mander	*Erythrina indica*				√

Sl no	Local name	Scientific name	Family	Place of occurrence		
		Tree		**Sal forest**	**Cultivated land**	**Human settlement**
31	Belatikoroi	*Albizia odoratisema*	Fabaceae	√		√
32	Sheild koroi	*Albizia lucidia*			√	√
33	Sherish Koroi	*Albizia lebbeck*				√
34	Champa	*Bauhinia variegata*		√		√
35	Jam	*Syzygiumcumini*	Myrtaceae			√
36	Golap Jam	*Syzygiumjambos*		√		√
37	Eucalyptus	*Eucalyptus spp.*		√		√
38	Ban Jam	*Eugenia fruticosa*				√
39	Payera	*Psidium guajava*				√
40	Bakul	*Mimusopselengi*	Sapotaceae	√		√
41	Agar	*Aquilaria agalloca*	Thymelaeaceae	√		
42	Chalta	*Dillenia indicum*	Dilleniaceae			√
43	Kurchi	*Holarrhenaantidysentrica*	Apocynaceae			√
44	Satim	*Alastoniascholaris*				√
45	Dudhi	*Wrightia tomentosa*		√		√
46	Ghora Nim	*Melia samperbirans*	Meliaceae			√
47	Deshi Nim	*Azadirachta indica*				√
48	Boro Mehogoni	*Swietenia macrophylla*		√		
49	Mehogoni	*Swietenia mahagoni*		√		√
50	Royna	*Aphanamixispolystachya*	Moraceae			√
51	Bot	*Ficus bengalensis*		√		√
52	Chapalish	*Artocarpus chaplasha*				√
53	Pakur	*Ficus religiosa*				√
54	Jag Dumur	*Ficus recemosa*				√
55	Sheora	*Streblus aspera*				√
56	Dehua	*Artocarpus lacucha*				√
57	Dumor	*Ficus hispida*		√		√
58	Kathal	*Artocarpus heterophyllus*				√
59	Amm	*Mangifera indica*	Anacardiaceae			√
60	Ziga	*Lanneacoromandelica*		√		√
61	Amra	*Spondius pinnata*		√		
62	Kakuasingh	*Rhus succedanea*		√		
63	Khajur	*Phoenix dactylifera*	Arecaceae			√
64	Tal	*Borassus flabellifer*				√
65	Narikel	*Cocos nucifera*				√
66	Desi Gab	*Diospyos peregrina*	Ebenaceae			
67	Gab	*Diospyros spp.*				
68	Kamranga	*Averrhoea carambola*	Oxalidaceae			√

Sl no	Local name	Scientific name	Family	Place of occurrence		
		Tree		**Sal forest**	**Cultivated land**	**Human settlement**
69	Arjun	*Terminalia arjuna*		√		√
70	Kat Badam	*Terminalia catappa*	Combretaceae	√		
71	Hartoki	*Terminalia chebula*		√		
72	Bohera	*Terminalia bellerica*		√		
73	Shemul	*Salmaliamalabaricum*	Malvaceae			√
74	Shemul Tula	*Bombax ceiba*				
75	Sajna	*Moringa olitera*	Moringaceae			√
76	Kadam	*Anthrocephalus chinensis*	Gentianaceae			√
77	Jarul	*Lagerstroemia speciosa*	Lythraceae	√		√
78	Amloki	*Emblica officinalis*	Phyllanthaceae	√		
79	Kamela	*Mallotusphilippinensis*	Euphorbiaceae	√		
80	Ban Borai	*Zizyphus jujuba*	Rhamnaceae	√		
81	Baroi	*Zizyphusmauritiana*		√		
82	Bel	*Aegle marmelos*	Rutaceae			√
83	Jambura	*Citrus grandis*				
84	Bhui Kadam	*Hymenodictyonexcelsum*	Rubiaceae			√
85	Polash	*Adina cordifolia*		√		
86	Lichu	*Litchi cinensis*	Sapindaceae			√
87	Shegun	*Tectona grandis*	Oleaceae	√		
89	Bonak	*Schima wallichii*	Theaceae	√		√
			Shrub			
1	Akanda	*Calotropis procera*	Apocynaceae			√
2	Nishinda	*Vitex negundo*	Oleaceae	√		
3	Dadmortan	*Cassia alata*	Fabaceae			√
4	Ban jam	*Ardisia solanacea*	Primulaceae			√
5	Jaba	*Hibiscus rosa-sinensis*	Malvaceae			√
6	Bonghagra	*Urena lobata*		√		
7	Dat majon	*Glycomis arborea*	Rutaceae			√
8	Khudi Jam	*Antidesmaghaesembilla*	Phyllanthaceae			√
9	Bilimbi	*Averrhoa bilimbi*	Oxalidaceae			√
10	Sitka	*Clerodendrum inerme*	Lamiaceae			√
11	Ulatkombal	*Abroma augusta*	Sterculiaceae			√
12	Dalim	*Punica grantum*	*Lythraceae*			√
13	Bala Dumur	*Ficus heterophylla*	*Moraceae*	√		√
14	Kola	*Musa sapientum*	*Musaceae*			√
15	Pepe	*Carica papaya*	*Caricaceae*		√	
16	Mushanda	*Mussendaroxburghii*	*Rubiaceae*	√		

Sl no	Local name	Scientific name	Family	Place of occurrence		
		Tree		**Sal forest**	**Cultivated land**	**Human settlement**
17	Ban tejpata	*Melastomamalabathricum*	*Melestomataceae*	√		
18	Tola Bas	*Bambusa tulda*	*Poaceae*	√		√
19	Basni Bas	*Bambusa valgaris*		√		√
20	Muli Bas	*Melicannebaccifera*		√		√
		Herb				
1	Sheal Kata	*Argemone mexicana*	*Papaveraceae*	√		√
2	Bhat	*Clerodendrum viscosum*	*Lamiaceae*	√		
3	Tulshi	*Ocimum sanctum*		√		
4	Ban tulshi	*Ocimun americanum*		√		
5	Teki Lata	*Stenchlaena palustris*	*Blechnaceae*			√
6	Shetodrum	*Laucascephalotes*	*Arecaceae*		√	
7	Dolkolmi	*Ipomoea fistula*	*Convolvulaceae*		√	
8	Pitraj	*Aphanamixiaspolystachia*	*Meliaceae*		√	√
9	Dutura	*Duturametel*	*Solanaceae*	√	√	
10	Ban tamak	*Nicotiana plumbaginifolia*		√	√	
11	Forgacha	*Hoya parasitica*	*Apocynaceae*	√		
12	Kalomegh	*Andrgraphis paniculata*	*Acanthaceae*		√	
13	Jagatmorthon	*Justicia gendarusa*			√	
14	Bashak	*Adhatoda zeylanica*				√
15	Thankuni	*Centella asiatica*	*Apiaceae*		√	√
16	Hati Chara	*Elephantopusscaber*	*Asteraceae*	√		√
17	Pesah	*Eupatorium odoratum*		√		
18	Kumarialata	*Smilax zeylanica*	*Smilacaceae*	√		
19	Kachu	*Amaranthus gangeticus*	*Acanthus*		√	
20	Upathlengha	*Achyranthes aspera*	*Amaranthaceae*			
21	Pithapata	*Peperomia pellucida*	*Piperaceae*		√	√
22	Nilshapla	*Nymphaea nouchali*	*Nymphaeaceae*			√
23	Lal shapla	*Nymphaea rubra*		√		√
24	Mukhi kochu	*Pueraria phaseoloides*			√	√
25	Khesari	*Lathyrus sativus*	*Fabaceae*	√		
26	Alkushi	*Mucuna pruriens*		√		
27	Deotara	*Alpinia malaccensis*	*Zingiberaceae*	√		
28	Ban haldi	*Curcuma aromatica*		√		
29	Bon ada	*Zingiber zerumbet*		√		
30	Kachuripana	*Eichhornia crassipes*	*Pontederaceae*		√	√
31	Watermoss	*Salvinia auriculata*		√		√

Sl no	Local name	Scientific name	Family	Place of occurrence		
		Tree		**Sal forest**	**Cultivated land**	**Human settlement**
			Climber			
1	Anantamul	*Hemidesmus indicus*	*Apocynaceae*	√		
2	Sham Lata	*Ichnocarpusfruticens*		√		
3	Gojpipul	*Scindapus officinalis*	*Araceae*	√		
4	Jali Bet	*Calamus viminalis*		√		
5	Karak Bet	*Calamus latifolius*		√		
6	Kadam Bet	*Calamis erectus*	*Arecaceae*	√		
7	Sundi Bet	*Calamus guruba*		√		√
8	Gola Bet	*Daemonoropsjenkinsianus*		√		
9	Assam Lata	*Mikania cordata*	*Asteraceae*	√		
10	Gila Lata	*Derris trifoliata*	*Fabaceae*	√		
11	Bish lata	*Millettia pachycarpa*		√		
12	Pipul Lata	*Piper longum*	*Piperaceae*	√		
13	Kanchan Lata	*Bauhinia nervosa*		√		
14	Shatamuli	*Asparagus racemosus*	*Asparagaceae*	√		
15	Telakucha	*Coccinia cordifolia*	*Cucurbitaceae*	√		
16	Makal	*Trichosanthesbracteata*		√		