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Review Article

Insights of Biodiversity in Gullele Botanical Garden, Ethiopia

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Abstract

Gullele Botanical Garden, located in Addis Ababa, Ethiopia, serves as a crucial center for biodiversity conservation, ecological research, and environmental education. Established to safeguard the region's unique flora and fauna, the garden plays a significant role in preserving endemic species, many of which are native to the Horn of Africa. With its rich plant and animal diversity, the garden contributes to both scientific advancements and cultural heritage, offering a sanctuary for rare and endangered species. Beyond its conservation efforts, Gullele Botanical Garden is a hub for scientific inquiry, supporting research on plant ecology, climate change adaptation, and sustainable resource management. Researchers and students utilize the garden as a living laboratory, studying plant species crucial for medicinal, agricultural, and ecological purposes. Additionally, the garden fosters environmental awareness through educational programs and public engagement initiatives, encouraging local communities to participate in conservation efforts. Despite its significance, the garden faces numerous challenges that threaten its ecological integrity. Climate change poses risks such as altered rainfall patterns and rising temperatures, impacting plant survival and biodiversity. Urban expansion also exerts pressure on the garden's boundaries, leading to habitat fragmentation and increased human activity. Furthermore, the spread of invasive species disrupts native ecosystems, competing with indigenous flora and fauna for resources. To ensure the long-term sustainability of GBG, strategic conservation measures must be implemented. Strengthening research initiatives, promoting community involvement, and enhancing habitat restoration efforts are essential steps toward preserving this biological hotspot. Additionally, policy interventions and sustainable land-use planning can help mitigate external threats. By reinforcing its role as a center for ecological preservation and education, Gullele Botanical Garden can continue to thrive as a vital natural resource for future generations.

Keywords

Gullele Botanical Garden, Biodiversity, Ecology, Habitat

1. Introduction

Ethiopia is recognized for its exceptional ecological diversity, with numerous species found only within its borders [1, 2]. The country's varied landscapes, from highland plateaus to lowland deserts, have fostered the evolution of unique plant and animal life. Among Ethiopia's key biodiversity conservation sites is the Gullele Botanical Garden in Addis Ababa [3]. Established in 2010, this garden is a crucial sanctuary for endemic and endangered species amidst the expanding urban sprawl. At an altitude of 3,200 meters, Gullele sits within Ethiopia's highlands, characterized by a subtropical highland

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climate with moderate temperatures and seasonal rainfall, providing diverse ecological zones ideal for studying local flora and fauna [4, 5].

Gullele Botanical Garden is home to over 400 plant species, including many endemics, reflecting the distinct evolutionary processes of the Ethiopian Highlands [6, 3]. The garden also supports a variety of animals, particularly birds, insects, and small mammals, many of which are native to the region. Its biodiversity is essential for scientific research and conservation and holds cultural and economic significance for local communities [3, 7]. Many plant species have medicinal and traditional uses, with local knowledge integral to sustainable management [7, 8]. The garden also serves as an educational hub, promoting awareness about the importance of biodiversity conservation and fostering environmental stewardship.

However, Gullele faces several challenges. Urbanization in Addis Ababa is causing encroachment on surrounding ecosystems, leading to habitat fragmentation and declining biodiversity. Climate change also impacts species distribution, with shifts in temperature and rainfall affecting ecosystem functions [9, 10]. Additionally, invasive species threaten native flora and fauna, disrupting the ecological balance [11]. This review highlights the Gullele Botanical Garden's critical role in preserving Ethiopia's unique biodiversity. It examines the garden's plant and animal species, ecological functions, and conservation status while addressing the challenges of urbanization, climate change, and invasive species. The paper underscores the importance of the garden as a research and conservation center and offers recommendations to enhance its efforts. Given Ethiopia's commitment to sustainable development, particularly in biodiversity and climate change, Gullele Botanical Garden is a vital case study for the country's broader conservation goals, emphasizing the need for continued efforts to protect this invaluable ecological resource.

2. Literature Review and Discussion

2.1. Ecological Context of Gullele Botanical Garden

The Gullele Botanical Garden is strategically situated in Addis Ababa, the capital city of Ethiopia, at an elevation of 3,200 meters above sea level [11, 14]. Its location in the northwestern part of Addis Ababa places the garden in one of Ethiopia's most ecologically rich areas, known for its unique highland ecosystems. This ecological positioning offers a combination of climatic, geological, and biotic factors that contribute to the garden's incredible biodiversity and make it an essential site for conservation and research.

2.1.1. Geographical and Climatic Setting

Gullele Botanical Garden occupies a prime location in the Ethiopian Highlands, a mountain range that extends across much of the country and is often called the "Roof of Africa." Diverse topographies characterize the highlands, including rugged mountains, deep valleys, and plateau systems. These varied landscapes create a multitude of microhabitats that support a high level of biodiversity, with many species adapted to specific ecological niches [12-16]. The Garden's geographical position gives it access to these diverse environments, which, in turn, contribute to the richness of its flora and fauna. The garden is located in an area with a subtropical highland climate, typical of the Ethiopian highlands, characterized by moderate temperatures and seasonal rainfall. The region experiences an annual average temperature range of 15 ℃ to 25 ℃ [17]. The rainy season lasts from June to September, during which the area receives between 1,200 mm and 1,800 mm of rainfall annually [18, 19]. These climatic conditions, combined with the high altitude, support the growth of temperate and tropical plant species, many of which are adapted to cool, moist environments. The cooler temperatures, in particular, create a refuge for species that cannot survive in Ethiopia's warmer lowlands.

Because of the garden's elevation and location on the western escarpment of the Ethiopian highlands, it enjoys a relatively favorable climatic condition compared to other areas of the country. The moderate rainfall and cooler climate make it an ecological hotspot, attracting various plants, birds, and other wildlife specifically adapted to these environments. As a result, the Gullele Botanical Garden plays a critical role in conserving species vulnerable to climatic extremes in different parts of Ethiopia [20-22].

2.1.2. Ecological Zones Within Gullele Botanical Garden

Gullele Botanical Garden's ecological diversity is influenced by its elevation and climate, which contribute to developing different environmental zones [23]. These zones are differentiated by soil types, water availability, and vegetation communities, creating a mosaic of ecosystems within the garden. The main ecological zones within the garden include montane forests, grasslands, wetlands, and riparian zones. Each zone supports distinct flora and fauna and provides various ecosystem services.

(i). Montane Forests

The montane forest zone is one of the most ecologically significant areas within the Gullele Botanical Garden. These forests are typically found at altitudes ranging from 2,500 to 3,500 meters above sea level. They are dominated by tall trees, shrubs, and woody plants that thrive in the cool, moist conditions characteristic of the Ethiopian highlands. In Gullele, the montane forests are rich in endemic tree species such as *Hagenia abyssinica*, *Bersama abyssinica*, and *Erythrina abyssinica* [12, 24, 25]. These trees are vital to the ecosystem, providing food and shelter to various wildlife and playing a significant role in the soil stabilization of the region. The dense canopy of the forest also supports a variety of under-

story vegetation, including ferns, mosses, and small shrubs.

These forests contribute to critical ecosystem services, such as carbon sequestration, water regulation, and biodiversity maintenance. They act as carbon sinks, helping mitigate the impacts of climate change by absorbing significant amounts of carbon dioxide [26]. Moreover, the forests maintain the hydrological cycle, with their roots helping to filter water, prevent soil erosion, and sustain the region's water supplies.

(ii). Grasslands

The grassland zone within Gullele Botanical Garden features open, often expansive areas covered with grasses, herbs, and shrubs [27]. These grasslands typically lie at slightly lower altitudes and have a seasonal vegetation pattern that varies with rainfall. Grasslands are home to various herbaceous species, such as high-altitude grasses, wildflowers, and small shrubs that provide vital resources for grazing animals and pollinators.

These areas are significant for maintaining ecological balance because they support populations of small mammals, insects, and bird species that depend on these plants for food and shelter. Pollination is a key function of these grasslands, with bees, butterflies, and other insects thriving on the flowers and helping to sustain plant reproduction [28, 29]. Grasslands also play an essential role in herbivores' grazing activities, attracting predators to the area and contributing to maintaining the food web.

(iii). Wetlands and Riparian Zones

The wetlands and riparian zones in Gullele Botanical Garden provide essential habitat for aquatic plants, amphibians, and waterfowl. These zones are crucial for regulating the water cycle, preventing flooding, and filtering pollutants from the water [30, 31]. The garden's wetlands support a wide range of plant species, such as sedges, bulrushes, and water lilies, which contribute to the overall biodiversity of the region.

Riparian zones, or areas along the garden's rivers and streams, are biologically diverse and support plants and animals that depend on moist, fertile soils [32, 33]. These zones are often the sites for critical ecological processes such as nutrient cycling and carbon sequestration and serve as corridors for wildlife movement between different environmental zones.

2.1.3. Flora and Fauna Adaptations

The highland ecosystems within Gullele Botanical Garden have led to the evolution of highly adapted species that thrive in a calm, moist environment [33, 34]. The plants of Gullele, many of which are endemic to the region, have evolved unique adaptations to cope with the challenges posed by high altitudes, such as the ability to store moisture in thick leaves or resist damage from UV radiation. Likewise, many of the animals in the garden, especially birds and insects, have specialized behaviors and physical characteristics that allow them to survive in this environment.

For instance, the Ethiopian bush crow (*Zavattariornis stresemanni*), an endemic bird species, has adapted to life in the montane forests and grasslands of the Ethiopian highlands, where it relies on social structures to forage for food and protect itself from predators [35]. Similarly, pollinators, including various species of bees and butterflies, ensure that the plants in the garden can reproduce while helping to maintain biodiversity.

2.1.4. Ecological Significance

The ecological context of Gullele Botanical Garden provides crucial insights into conserving highland ecosystems. The diverse habitats support a variety of species, many of which are endemic to Ethiopia, making the garden a key site for preserving genetic diversity [3, 36]. The garden's ecosystems are important for biodiversity conservation and their essential ecosystem services, such as soil stabilization, water filtration, and carbon sequestration. Preserving these ecosystems is critical for ensuring the sustainability of natural resources supporting local communities and the broader region.

(i). Biodiversity of Gullele Botanical Garden

(a). Flora Diversity

Gullele Botanical Garden is home to many plant species, including native and endemic species critical to Ethiopia's natural heritage [7, 9, 37]. The garden's diverse plant collection has over 400 species, including trees, shrubs, herbs, and medicinal plants.

Several species of note include:

1. Aloe spp.: Aloe species in the garden, such as *Aloe vera* and *Aloe maculata*, are well-known for their medicinal properties and ecological importance. Aloe vera, in particular, is widely used in the local community for skin care and other health-related purposes.
2. Erythrina abyssinica: This species, endemic to Ethiopia, is notable for its nitrogen-fixing ability, improving soil fertility. The plant also produces vibrant red flowers that attract pollinators such as bees and birds.
3. Hagenia abyssinica: Known for its large leaves, this tree species is crucial for the local ecosystem. It provides shelter to wildlife and contributes to forest regeneration.
4. Bersama abyssinica: Another important endemic tree in the garden, *Bersama abyssinica* plays a role in soil conservation and is used for medicinal purposes in traditional Ethiopian medicine.

Many of the garden's plants are used by local communities for food, medicine, and other traditional purposes. Conserving these species is vital for preserving the communities' traditional knowledge and sustainable practices.

(b). Fauna Diversity

In addition to plant diversity, Gullele Botanical Garden hosts a variety of animal species, particularly birds, insects, and small mammals [3, 19, 38]. The garden's fauna is essential

to its biodiversity, contributing to the ecosystem's balance through pollination, seed dispersal, and pest control.

Key species include:

1. Ethiopian Bush-crow (*Zavattariornis stresemanni*): This endemic bird is a notable garden resident, known for its sociable nature and reliance on the montane ecosystem.
2. Abyssinian Catbird (*Chaimarrornis leucocephalus*): Another endemic bird species, the Abyssinian catbird, is found in the garden's dense forests and is an important indicator species for ecosystem health.
3. Pollinators: Bees, butterflies, and other insects are essential for reproducing many plant species within the garden. They help maintain biodiversity and support the garden's ecological functions.
4. Small Mammals: Rodents, shrews, and bats contribute to seed dispersal and help regulate insect populations within the garden.

Such a diverse array of animals indicates the ecological health of Gullele Botanical Garden and highlights the interdependence between plant and animal life in maintaining biodiversity.

(c). Endemism and Special Species

Endemism is one of the most striking features of the biodiversity found in the Gullele Botanical Garden. Ethiopia is known for its high level of species endemism, with many plants and animals found nowhere else. The garden is home to some endemic species, including plants such as *Erythrina abyssinica* and *Aloe spp*., as well as animals like the Ethiopian bush crow and Abyssinian catbird [28, 31, 38]. Protecting these endemic species is essential for maintaining Ethiopia's biodiversity and preserving unique evolutionary lineages developed in isolation over millennia.

(ii). Conservation Efforts at Gullele Botanical Garden

(a). Conservation Programs and Strategies

The conservation of biodiversity at Gullele Botanical Garden is a priority, with various programs aimed at protecting and sustaining plant and animal species [11, 18, 4]. Some key conservation strategies include:

1. In-situ Conservation: The garden's role as a protected area helps preserve species in their natural habitat. This is crucial for maintaining the integrity of the local ecosystem and preventing the extinction of rare species.
2. Ex-situ Conservation: The garden supports conservation by establishing seed banks, botanical collections, and plant nurseries. These efforts ensure that genetic material from rare and endangered species is preserved for future restoration projects.
3. Habitat Restoration: Reproving degraded habitats is critical to the garden's conservation efforts. This includes reforestation of areas affected by human activities and removing invasive species that threaten native biodiversity.

(b). Research and Scientific Contributions

The Gullele Botanical Garden is pivotal in advancing scientific research and biodiversity conservation in Ethiopia. As a vital conservation area, it serves as an essential research hub for understanding the unique flora and fauna of the Ethiopian Highlands. The garden contributes significantly to plant taxonomy, ecology, and conservation biology by offering a living laboratory for studying endemic and endangered species [37]. Research at Gullele focuses on various aspects of biodiversity, including species identification, distribution patterns, and ecological interactions. The garden's plant collection, with over 400 species, provides an excellent resource for botanical studies, particularly on Ethiopian endemic plants. Studies on the garden's plant species help understand their ecological roles, adaptations to highland environments, and conservation needs in the face of threats like climate change and habitat loss.

Additionally, the garden supports biodiversity monitoring programs that track changes in species populations and the ecosystem's overall health. Researchers also examine the impacts of invasive species and climate change on native flora and fauna. Through collaborations with local and international institutions, Gullele contributes to a growing body of knowledge on the ecological significance of highland ecosystems, promoting sustainable conservation practices and preserving Ethiopia's unique biodiversity.

Research conducted within the garden focuses on:

1. Plant Taxonomy and Ecology: Studies on plant species, their ecological roles, and their interactions within the ecosystem help scientists understand biodiversity dynamics and inform conservation efforts.
2. Biodiversity Monitoring: Long-term monitoring programs track changes in species population dynamics, providing essential data on how environmental factors like climate change and human activities affect biodiversity.
3. Climate Change Research: The garden serves as a site for studying the impacts of climate change on highland ecosystems. Research on species adaptation, shifts in distribution, and phenological changes is crucial for developing strategies to mitigate the effects of climate change.

(c). Community Involvement and Education

The garden plays a vital role in raising public awareness about biodiversity conservation. Educational programs are designed to engage local communities, schoolchildren, and visitors in learning about the value of biodiversity and sustainable practices [1, 2, 17]. Through workshops, guided tours, and community outreach, Gullele helps foster a sense of environmental stewardship among the public. This educational outreach is essential for building local support for conservation initiatives and ensuring the garden's long-term success.

3. Challenges to Biodiversity Conservation at Gullele

3.1. Urbanization and Habitat Loss

One of the biggest challenges facing the Gullele Botanical Garden is urbanization. As Addis Ababa expands, surrounding areas are experiencing rapid development, threatening the integrity of the garden's ecosystems [32, 36]. Encroachment, land conversion, and pollution from nearby urban areas can disrupt habitats and reduce biodiversity.

3.2. Climate Change

Climate change poses a significant threat to the biodiversity of Gullele Botanical Garden. Increased temperatures, changing rainfall patterns, and extreme weather events have already begun to affect species distribution and ecosystem dynamics [21]. Some plant species may be forced to migrate to higher altitudes, while others may face extinction if they cannot adapt to the changing conditions.

3.3. Invasive Species

Invasive plant and animal species are a growing concern at Gullele. Non-native species often outcompete native species for resources, leading to declining biodiversity [6, 14, 23]. The introduction of invasive plant species like *Lantana camara* and *Eucalyptus spp.* It threatens native vegetation and disrupts the balance of local ecosystems.

4. Future Directions for Research and Conservation

4.1. Enhancing Research Capacity

Future research efforts at Gullele should focus on long-term biodiversity monitoring and developing adaptive management strategies to cope with climate change. Greater collaboration with national and international research institutions will be necessary to address emerging challenges in biodiversity conservation.

4.2. Expanding Conservation Initiatives

Expanding the protected area of the garden and increasing habitat restoration efforts will be essential for safeguarding vulnerable species. This includes restoring montane forests, wetlands, and grasslands and removing invasive species.

4.3. Strengthening Community Engagement

Increased community involvement in conservation efforts will be critical. Engaging local communities in sustainable land-use practices and biodiversity conservation will help preserve Gullele's ecosystems for future generations.

5. Conclusion

The Gullele Botanical Garden is a vital ecological resource for conserving Ethiopia’s unique biodiversity, serving as a sanctuary for both endemic and endangered species. Its rich plant diversity and diverse fauna highlight the garden's ecological significance in preserving Ethiopia’s highland ecosystems. Through its conservation efforts, including habitat restoration, seed banking, and the promotion of sustainable land-use practices, Gullele contributes to the broader goals of biodiversity protection in the face of growing urbanization and climate change pressures. In addition to its ecological value, Gullele plays a critical role in scientific research and education. It provides researchers with valuable data on plant and animal adaptation, species distribution, and the effects of climate change on highland ecosystems. Furthermore, it serves as an educational hub, raising public awareness about the importance of biodiversity and fostering a greater understanding of sustainable conservation practices. As Ethiopia faces increasing environmental challenges, the continued protection and expansion of Gullele Botanical Garden will be crucial for safeguarding the country’s natural heritage. Enhanced conservation strategies, ongoing research, and active community engagement will ensure that Gullele remains a cornerstone of biodiversity conservation in Ethiopia and a model for similar initiatives across the region.

Abbreviations

GBG Gullele Botanical Garden

Author Contributions

Gudeta Chalchisa Diribsa is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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Research Field

Gudeta Chalchisa Diribsa: Biodiversity, Botany, Ecology, Forestry, Environmental science