https://doi.org/10.48047/AFJBS.6.15.2024.14023-14036

African Journal of Biological Sciences

Journal homepage: http://www.afjbs.com

Research Paper Open Access

Mapping of biodiversity and analysis of ecological pressures in the peri-urban forest of Ben Aknoun (Algiers): a refuge for rare species in the face of urbanization

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Volume 6, Issue 15, Oct 2024

Received: 15 Aug 2024

Accepted: 25 Sep 2024

Published: 21 Oct 2024

doi: 10.48047/AFJBS.6.15.2024.14023-14036

ABSTRACT
This study examines the floristic diversity and threats to the peri-urban forest of Ben Aknoun, Algiers, which acts as a refuge for endemic species threatened by urbanization, deforestation, overgrazing, climate change, and pollution. Located 20 km from Algiers, the 300 hectare forest has a Mediterranean climate. Two survey campaigns were conducted in April and June of 2023 and 2024, using Geographic Information Systems (GIS) to map floristic diversity and land use. The study identified six vegetation types, primarily maquis and forests. The floristic inventory recorded 167 species, including 16 introduced and 151 native species, distributed across 52 botanical families, notably Asteraceae, Apiaceae, and Fabaceae. Therophytes and hemicryptophytes dominate, indicating ecological disturbances. Fifteen chorological types are present, with Mediterranean dominance. Sixteen species are of special concern due to their rarity or endemic nature. The overall disturbance index is 45%, with Zone IV being the most affected (63%). Grazing and urbanization are the primary causes of degradation. Conserving this forest is essential for protecting its rare and endemic species. Urgent measures are required to regulate urbanization, control deforestation, and raise local awareness about the importance of biodiversity to preserve this forest for future generations and global biodiversity.

Keywords: Peri-urban forest, Ben Aknoun, disturbance, species, urbanization.

INTRODUCTION

Forest ecosystems play a crucial role in preserving global biodiversity, highlighting the rich floral diversity they encompass. As the third global biodiversity hotspot for plant species,

Algeria stands out with its mosaic of landscapes shaped by Mediterranean, Saharan, and Paleotropical influences (Mittermeier et *al.*, 2004; Médail and Diadema, 2006; Yahi et *al*., 2012). Among these ecologically valuable ecosystems, the peri-urban forest of Ben Aknoun is particularly noteworthy. However, it faces significant pressures resulting from urban expansion, overgrazing, climate change impacts, and pollution. This forest, situated at the intersection of urban and rural zones, represents a transitional space where biodiversity is under threat (Salbitano et *al*., 2017).

Despite the importance of this region, specific research on its floral richness is lacking. Previous studies have primarily focused on entomofauna (Remini, 2007) and agro-pedological aspects (Iftene, 1999), leaving a significant gap in the analysis of plant diversity. Additionally, the national forest inventory conducted by the National Office for Rural Development Studies (BNEDER, 2008) identified the forest in the Algiers region without providing an in-depth assessment of its floral richness.

In this context, our approach aims to map and evaluate the floral diversity of the Ben Aknoun forest by integrating field data with satellite imagery. This project seeks not only to develop a land-use map but also to assess the risks of ecosystem disturbance, thereby contributing to a better understanding and protection of this valuable natural resource. By focusing on plant biodiversity, we also aim to raise awareness of the importance of preserving these fragile ecosystems in the face of growing threats.

MATERIAL AND METHODS

Study area

The peri-urban forest of Ben Aknoun, located about 20 km southwest of Algiers at an average altitude of 50 meters, covers just over 300 hectares and is managed by the Directorate General of Forests of the Wilaya of Algiers. It is bordered to the north by the municipality of Ben Aknoun, to the south by Tixeraine, to the west by El Achour, and to the east by the municipalities of Hydra and Bir Mourad Raïs. Geographically, its boundaries extend from 36° 44' 03" to 36° 24' 06" north latitude and from 3° 00' 21" to 3° 01' 03" east longitude (Figure 1).

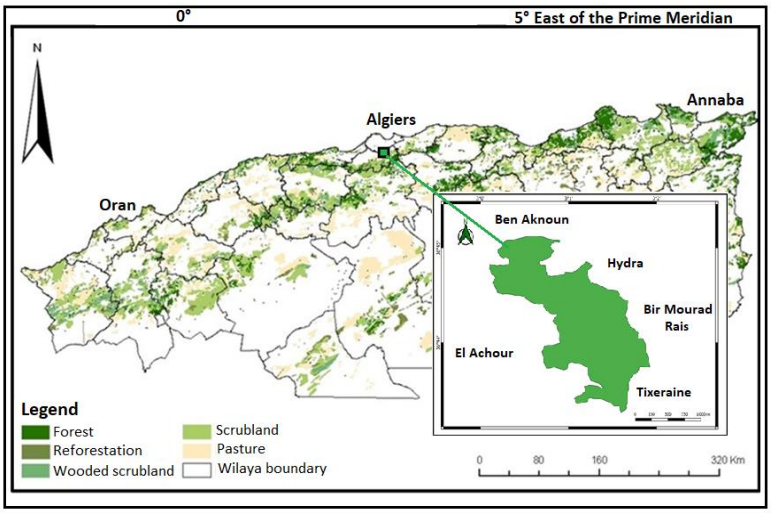

Figure 1. Location of the Study Area

The climate of the region is Mediterranean, characterized by an average annual precipitation of 661.6 mm, with significant seasonal variations. Temperatures range from 7.5°C in February to 35.1°C in August, placing the forest in the subhumid zone with a warm variant according to Emberger's pluviometric quotient.

Moreover, the forest's proximity to a large urban area like Algiers leads to complex interactions between human activities and local ecosystems. These interactions can result in challenges such as pollution, overgrazing, and the invasion of non-native species, which may negatively impact biodiversity. Therefore, an in-depth assessment of the peri-urban forest of Ben Aknoun is essential not only for understanding its ecological dynamics but also for implementing sustainable management measures to protect this vital ecosystem against growing environmental threats.

Methods

The methodology adopted for this study was designed to deepen our knowledge of the flora in the peri-urban forest of Ben Aknoun. This is the first comprehensive floristic study ever conducted in this region, combining a rigorous bibliographic review with field exploration carried out over two campaigns, between April and June of 2023-2024. This integrated approach enabled the collection of significant data on the forest's plant diversity while contextualizing the results within the framework of existing knowledge on Algerian flora.

The phytoecological inventory was based on a sampling methodology inspired by Gounot (1969), known for its relevance in assessing plant diversity. This method was enhanced by using the Synonymic Index of North Africa (Dobignard and Chatelain, 2010-2013),

facilitating the identification and classification of encountered species. Additionally, the APG IV (2016) classification was integrated to ensure accurate and updated taxonomic nomenclature. The floristic surveys also took into account chorological types and species rarity, drawing on previous studies (Zeraia, 1983; Meddour, 1988) that provide a framework for analyzing species distribution in the region.

Floristic diversity mapping was carried out using geographic information system (GIS) tools, specifically QGIS, which allowed for spatial visualization of species distribution. Satellite imagery was also integrated into this analysis to provide an overview of land use and environmental changes within the forest ecosystem (Djelouli et *al*., 2024; Aouadj et *al*., 2023; Lemenkova, 2020; Zanndouche et *al*., 2022; Zanndouche, 2023).

The integration of the disturbance index allowed for the creation of a disturbance index map, a tool used to assess the therophytization of an environment (Loisel et Gomila, 1993). It is formulated as follows:

IP = [(Number of Chamaephytes + Number of Therophytes) / Total Number of Species] X 100

This study highlights the species richness, floristic heritage, biological types, and chorological diversity of this peri-urban forest, while examining the impact of anthropogenic degradation, measured by the disturbance index.

The combined use of these methodologies enabled the production of a detailed floristic inventory, showcasing the present species, their geographic distribution, and their conservation status. This work contributes to a better understanding of the plant biodiversity in the peri-urban forest of Ben Aknoun and provides a solid foundation for future studies and conservation initiatives. By integrating traditional assessment methods with modern technological tools, this study establishes a new benchmark for floristic research in Algeria, while emphasizing the importance of a multidisciplinary approach in ecosystem studies.

RESULTS AND DISCUSSION

Results

This section analyzes the results obtained on land use and the flora of the peri-urban forest of Ben Aknoun. It presents a detailed floristic inventory, highlighting the biological types and phytogeographical characteristics of the entire study area. In total, more than 60 floristic surveys were conducted during two sampling campaigns.

Land Use

The use of geographic information systems (GIS) enabled the creation of a land use map for the peri-urban forest of Ben Aknoun by integrating various digitized layers into a detailed database on cartographic units, vegetation formation, formation type, and its floristic composition. The resulting maps identify six physiognomic types: forests, matorrals, maquis, plantations, riparian vegetation, and grasslands, covering 224.37 hectares (70.90% of the total area). The remaining 92.08 hectares are occupied by various infrastructures such as nurseries, bare soils, recreational areas, a dam, residential areas, parking lots, and road infrastructure (Figure 2).

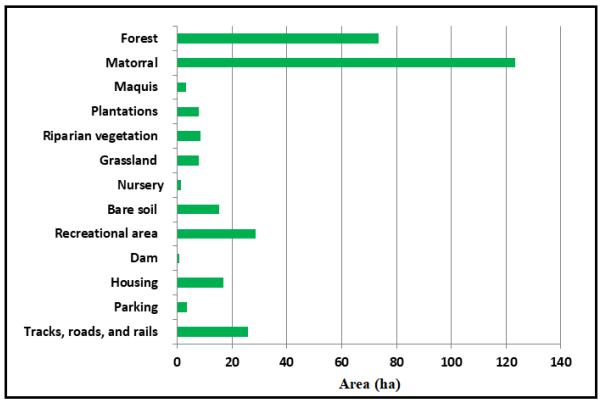

Figure 2. Distribution of area by land-use type

The matorrals, covering 123.3 hectares, dominate the area, indicating a shrubby and bushy vegetation often resulting from forest degradation in Mediterranean or semi-arid regions. The forests, occupying 73.4 hectares, feature significant natural woodland vegetation important for biodiversity, climate regulation, and soil protection. The maquis, with 3.32 hectares, provides essential habitat for various species. The plantations, spanning 8 hectares, suggest agricultural or forestry activities, while riparian vegetation, extending over 8.6 hectares along watercourses, plays a key role in bank protection, water filtration, and biodiversity. The grasslands, representing 7.75 hectares, are open areas that can be used for recreation, agriculture, or as habitat for certain species (Figure 3).

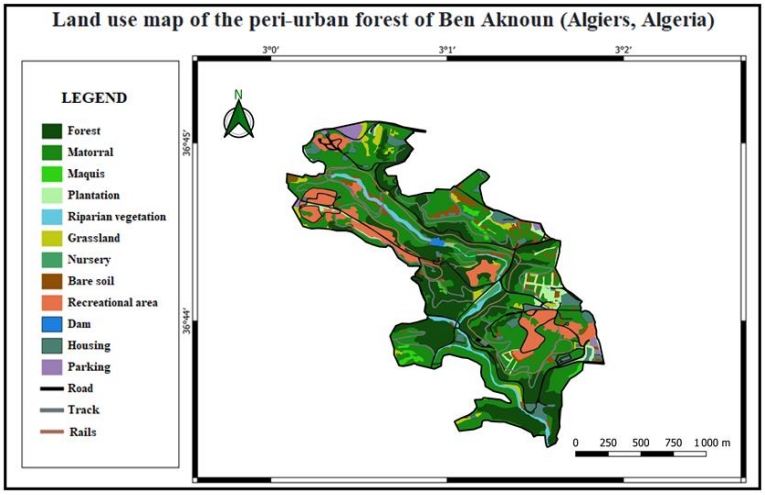

Figure 3. Land use map of the peri-urban forest of Ben Aknoun

Floristic Diversity

The peri-urban forest of Ben Aknoun is a remarkable ecosystem, known for its cultural services that enrich human well-being through recreational, aesthetic, educational, spiritual, and moral values, while also hosting notable floristic diversity. We recorded 167 plant species in this area. Among these, 16 species were introduced for beautification purposes along roads and visitor rest areas, and therefore will not be included in the study on floristic diversity.

Of the 151 spontaneous plant species inventoried, 16 species have a special status (Table 1). Three species are protected under Algerian legislation. Several species are noteworthy in the region due to their taxonomic rarity: three are considered fairly rare, three others rare, six very rare, and one species is identified as extremely rare (Djelid et *al*., 2020). Additionally, three other species are considered endemic.

Table 1: Remarkable Species of the Forest

Category	Species
Fairly Rare	*Mentha aquatic* L.; *Urtica dioica* L.*; Anemone coronaria* L.
Rare	*Vinca major* L.*; Artemisia absinthium* L.*; Daucus carota subsp. maritimus* (Lam.) Batt.
Very Rare	*Linum maritimum* L.*; Torilis japonica* (Houtt.) DC.*; Hydrocotyle vulgaris L.; Achillea odorata* L.*; Hydrocharis morsus-ranae L.; Gnaphalium uliginosum* L.
Extremely Rare	*Onopordum algeriense* (Munby) Pomel.
Protected	*Onopordum algeriense* (Munby) Pomel. ; *Gnaphalium uliginosum* L. *; Bellis annua* L.
Endemic	*Onopordum algeriense* (Munby) Pomel. ; *Plagius maghrebinus* Vogt & Greuter. ; *Genista tricuspidata* Desf.

The 151 spontaneous species in this forest belong to 52 botanical families, with a predominance of asteraceae (29 species), followed by apiaceae (11 species) and fabaceae (10 species). Poaceae and lamiaceae each have 7 species, while rosaceae, asparagaceae, and plantaginaceae each account for 5 species. The other families contain fewer than 5 species, highlighting the floristic diversity of this ecosystem.

Chorological Types

The Ben Aknoun Forest exhibits significant diversity with 15 identified chorological types. Phytogeographic analysis reveals the dominance of the Mediterranean element with 65 taxa, followed by the Eurasian and cosmopolitan elements with 22 and 15 taxa, respectively (Table 2).

Table 2: Chorological Types

Chorological Types	Number of taxa
Mediterranean (Broad Sense)	**82**
Mediterranean (Strict Sense)	65
Mediterranean-Atlantic	8
Mediterranean-African	2
Western Mediterranean	7
Endemic	**3**
North African Endemic	2
Algerian Endemic	1
Northern	**42**
Eurasian	22
Euro-Mediterranean	4
European	3
Paleo-temperate	9
Circum-boreal	4
Widespread	**24**
Cosmopolitan	15
Tropical	1
Paleo-tropical	3
America	5
Total	**151**

Biological types

The inventory of biological types reveals that therophytes and hemicryptophytes dominate the flora of the study area, representing 35% and 32%, respectively, while phanerophytes, though resilient, occupy the third place with 15%. This distribution reflects ecological changes due to

anthropogenic impacts (Grime, 1977). Chamephytes and geophytes, on the other hand, are less represented, with only 10% and 8%, respectively (Figure 4).

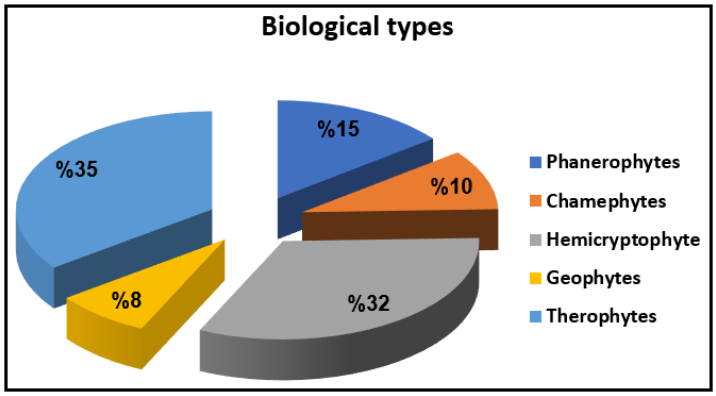

Figure 4. The biological spectrum of the flora

The predominance of therophytes and hemicryptophytes is due to environmental disturbances caused by overgrazing and drought, with therophytes being characteristic of arid Mediterranean areas (Daget, 1980; Barbero et *al*., 1990).

Disturbance Index (DI)

The overall disturbance rate, measured at 45%, indicates a significant level of alteration within the studied forest ecosystem, primarily due to human activities. This figure reveals that changes caused by urbanization, overgrazing, and other anthropogenic interventions have had notable effects on local vegetation and biodiversity. The work of Loisel and Gomila (1993) highlights that such disturbance indices can serve as excellent indicators of environmental conditions, enabling the assessment of ecosystem health and identification of conservation needs.

In our study, zone IV stands out as the most affected area, with a disturbance index of 63%. This zone, located near dense urban areas, is subject to constant pressures. The increase in urbanization leads to habitat degradation, fragmentation of species populations, and a reduction in plant resources, thereby compromising the resilience of local flora and fauna. Intensive agricultural and grazing practices in this region exacerbate these impacts, resulting in an ecological imbalance that may lead to biodiversity loss.

In contrast, zones I and II show lower disturbance indices, at 30% and 40%, respectively. While these areas are also impacted by human activities, they benefit from more sustainable management and protective measures, which allow for relatively high biodiversity. These

zones host less altered habitats where native vegetation can thrive and play their ecological roles.

The differences between the disturbance indices across zones underscore the importance of a differentiated approach to ecosystem management. The most affected zones, such as zone IV, require immediate intervention to restore biodiversity and re-establish ecosystem integrity. Possible measures include natural regeneration, habitat rehabilitation, and community-based initiatives to raise awareness about conservation (Figure 5).

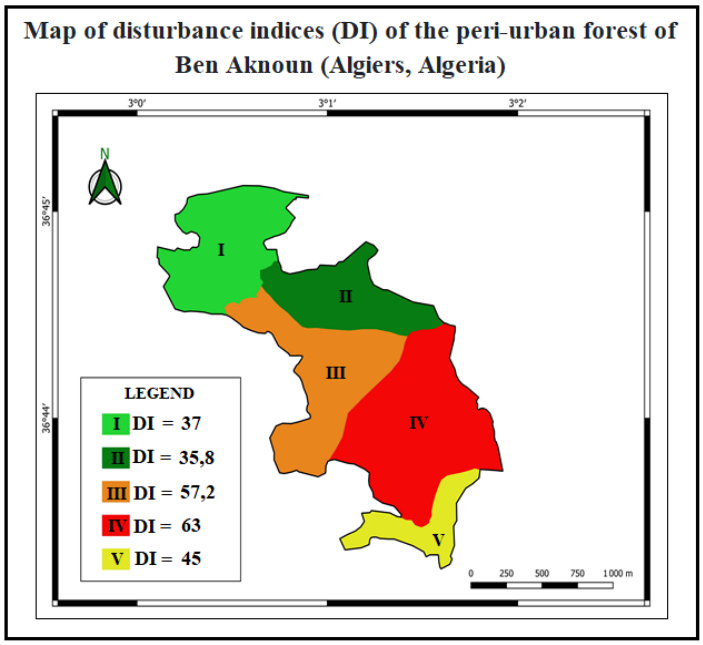

Figure 5. Map of Disturbance Indices

The disturbance index of 45% highlights the impact of human activities on the Ben Aknoun forest ecosystem, with significant variations across the different study zones. It is imperative to adopt appropriate conservation and management strategies to protect this valuable ecosystem and ensure the sustainability of its biodiversity.

Discussion

The use of Geographic Information Systems (GIS) in this study has proven essential in documenting the diversity of vegetation types within the peri-urban forest of Ben Aknoun, while also illustrating the significant impact of human activities on this ecosystem. As a global biodiversity hotspot, this region is home to a large number of endemic species, highlighting its ecological importance and the need to preserve its diversity (Myers et *al*., 2000). However, our findings reveal that this biodiversity is increasingly threatened by anthropogenic pressures.

Among the main degradation factors are deforestation, often caused by urban expansion and unsustainable agricultural practices, as well as overgrazing, which leads to soil degradation and the loss of vegetation. These phenomena, widely documented in the Maghreb region (FAO and Plan Bleu, 2013), highlight the ongoing conflict between human needs and biodiversity preservation. The cumulative impact of these pressures leads to habitat fragmentation, recognized as one of the most serious threats to local biodiversity.

Habitat fragmentation has profound consequences for ecosystems, limiting species' ability to migrate, reproduce, and feed. This can lead to reduced genetic diversity and isolated populations, increasing the risk of species extinction (Basavaraj et *al*., 2024). In the case of the Ben Aknoun forest, although the observed floristic diversity is rich, it could be compromised by the reduction of available habitats. The disturbance index of 45% already reveals the detrimental effects of these pressures, showing a significant alteration in the structure of vegetation and biodiversity.

It is also crucial to consider the socio-economic aspects of natural resource management. Therefore, conservation efforts should not only focus on protecting biodiversity but also involve local communities in sustainable management practices. This could include reforestation programs and the adoption of sustainable grazing practices, thus reducing pressure on the ecosystem while supporting local livelihoods.

CONCLUSION

The study of the peri-urban forest of Ben Aknoun has highlighted its exceptional floristic biodiversity, encompassing a variety of rare and endemic species that play a crucial role in the region’s ecological balance. This biological richness is not merely a result of the number of species but also reflects a complexity of ecological interactions that support the life and well-being of local communities. However, despite its ecological significance, the sustainability of this unique ecosystem is severely compromised by factors such as rapid urbanization and intensive overgrazing.

Urban expansion, often poorly managed, not only leads to direct habitat loss but also causes ecological disturbances that affect plant and animal populations. Additionally, overgrazing exacerbates soil degradation and hinders natural regeneration of plant species. Therefore, it is crucial to take immediate action to limit these threats to ensure the survival of this vital ecosystem.

To protect the peri-urban forest of Ben Aknoun, a proactive conservation strategy must be adopted, including stricter regulations on urban development and sustainable land management practices. This could involve establishing protected areas, promoting sustainable agriculture, and developing urban green spaces that integrate biodiversity. Moreover, raising awareness among local communities and policymakers about the importance of biodiversity and ecosystem conservation is essential. Educational programs and community participation initiatives can play a key role in promoting environmentally friendly practices and valuing the ecosystem services provided by the forest.

Ultimately, the preservation of the peri-urban forest of Ben Aknoun is not just about conserving biodiversity but also about ensuring the quality of life for future generations. By taking action now to protect this precious ecosystem, we contribute to balancing human development and nature conservation, a crucial goal in the context of the ongoing global ecological crisis. It is our collective responsibility to ensure that the natural wealth we inherit is passed on to future generations, enabling them to benefit from the advantages of this unique biodiversity.

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