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BIODIVERSITY AND ENVIRONMENTAL IMPORTANCE OF THE DJURDJURA MOUNTAINS, ALGERIA

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Abstract. *This study focuses on the biodiversity and environmental importance of the Djurdjura Mountains in Algeria, a significant ecological region in North Africa. The Djurdjura National Park, located in northern Algeria within the Tell Atlas mountain range, is part of the Kabylies–Numidia–Kroumirie biodiversity hotspot, which is recognized as one of the most important conservation areas in the mediterranean basin. The area is known for its rich ecosystems and has been recognized as a UNESCO Biosphere Reserve due to its high biological diversity and environmental value. The Djurdjura Mountains host a wide variety of plant and animal species, including endemic and endangered species such as the Barbary macaque. Its diverse vegetation includes cedar forests, oak trees, and other Mediterranean species, contributing to the ecological richness of the region. In addition to its biodiversity, the Djurdjura Mountains play a crucial role in climate regulation, water resource management, and the preservation of natural habitats. However, this ecosystem faces several threats, including climate change and human activities. The Djurdjura ecosystem is shaped by the complex interaction between climatic variability, topography, hydrological processes, vegetation structure, and anthropogenic influences. In conclusion, the Djurdjura Mountains represent an essential natural heritage that requires sustainable management and conservation efforts to protect its biodiversity and ecological functions.*

Key words: *Djurdjura Mountains, biodiversity, environmental importance, flora and fauna, ecosystem conservation*

INTRODUCTION

The Djurdjura National Park, located in northern Algeria within the Tell Atlas mountain range, is part of the Kabylies–Numidia–Kroumirie biodiversity hotspot, which is recognized as one of the MOST IMPORTANT CONSERVATION AREAS IN THE MEDITERRANEAN BASIN (UNESCO, N.D.; QUÉZEL & BARBERO, 1989). This region is distinguished by its exceptional natural heritage and high level of ecological diversity, making it a key site for biodiversity studies and environmental protection (Parc National du Djurdjura, 2014).

The park is particularly notable for its rich vascular plant diversity. More than 1,100 species of vascular plants have been recorded, belonging to 91 botanical families (QUÉZEL, 1956; QUÉZEL & SANTA, 1962–1963). This represents approximately 27% of the entire Algerian flora and nearly 50% of the flora of the Djurdjura-Kabylia phytogeographical district, despite the park occupying only a small proportion of the territory (MEDDOUR, 2010).

In addition to its overall richness, the Djurdjura Mountains host a significant number of rare, endemic, and threatened plant species. Around 217 plant species are considered rare, while 45 species are endemic to Algeria (MEDDOUR et al., 2010). Among them, 18 species are classified as rare or threatened according to the International Union for Conservation of Nature (IUCN) (UNESCO, n.d.). Furthermore, 25 plant species are strictly exclusive to the

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Djurdjura region, increasing its scientific and conservation importance (Parc National du Djurdjura, 2014).

The ecological structure of the park is highly diverse, with habitats ranging from forest and pre-forest formations to alpine grasslands, rocky slopes, cliffs, and mountain river ecosystems (QUÉZEL & BARBERO, 1989; MEDDOUR, 2010). These environments are distributed across altitudes from approximately 1,000 meters to over 2,300 meters, creating strong ecological gradients that support diverse plant communities.

Phytosociological studies have identified multiple vegetation units within the park, including cedar and oak forests, shrub formations, rocky vegetation, and alpine meadows (QUÉZEL, 1957; MÉNARD & VALLET, 1988). These communities reflect a complex and structured ecosystem that has been extensively studied in Mediterranean mountain environments (QUÉZEL & BARBERO, 1989).

Despite its ecological richness, the Djurdjura National Park is facing increasing environmental pressures. Human activities, land use changes, and recurrent forest fires have contributed to habitat degradation and biodiversity loss (Direction Générale des Forêts, 2000–2009; FAO, 2007). In recent years, these fires have become more frequent and intense (DGF, 2000–2009). Climate change is also expected to increase ecosystem vulnerability in the future (BRAQUE, 1988; MEDDOUR, 2010).

Overall, the Djurdjura Mountains represent a unique ecological and biogeographical heritage in Algeria. Their high biodiversity, presence of endemic species, and complex ecosystem structure make them a priority area for conservation. Protecting this natural environment is essential to preserve its ecological functions and ensure its sustainability for future generations (UNESCO, n.d.; Parc National du Djurdjura, 2014).

MATERIAL AND METHODS

This study focuses on the Djurdjura National Park, located in northern Algeria within the Tell Atlas Mountain range. The area is characterized by a mountainous relief with altitudes ranging from approximately 1,000 m to over 2,300 m, which strongly influences local climatic and ecological conditions.

Geographic Location

The study site of Tikjda is located on the southern slope of the Central Djurdjura, within the Djurdjura National Park in northern Algeria. It is part of the Tell Atlas Mountain range, a major mountainous system in the Mediterranean region of North Africa.

The geographical coordinates of the site, expressed in the Lambert projection system, range from X: 625 to 629 km and Y: 347 to 352 km. The area is characterized by a mountainous terrain with significant altitudinal variation, which contributes to its ecological diversity and climatic specificity.

Tikjda represents one of the most important high-altitude zones of the Djurdjura massif, and it plays a key role in regional hydrology and biodiversity conservation due to its forested landscapes and mountain ecosystems.

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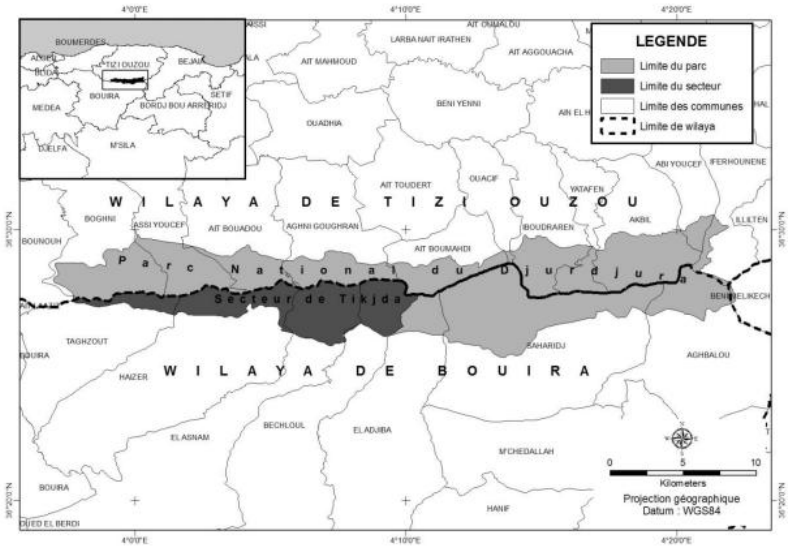

Figure 1. Location map of the Tikjda site (Djurdjura National Park) (PND, 2014)

Hydrology and Hydrography

The Djurdjura massif is characterized, from a hydrological perspective, by karstic carbonate formations that are well supplied with precipitation. According to ABDESSELAM (1995), these geological conditions favor the development of significant aquifers, making the Djurdjura an important natural water reservoir. In addition to direct rainfall input, the massif also contains substantial underground water resources stored within its karstic systems.

Regarding hydrography, the Djurdjura is distinguished by a dense and highly developed drainage network. This network is composed of numerous watercourses ranging from small streams to larger seasonal rivers (oueds), which flow in different directions across the mountain slopes. The hydrographic system is strongly influenced by rainfall patterns and topography.

The rainfall regime in the region is mainly torrential, leading to rapid surface runoff, high discharge rates, and sometimes destructive flow events, particularly during wet periods. These flows may form cascades in steep areas. However, this hydrological activity is highly seasonal, as most watercourses dry up during the summer period. Only springs maintain limited flow during low-water periods, often over short distances (ABDESSELAM, 1987; 1995).

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Figure 2. Surface water flow originating from mountain springs in the Djurdjura National Park

Vegetation

The vegetation of the Djurdjura Mountains has been widely studied and described by several authors (LAPIE, 1909; MAIRE, 1926; QUÉZEL, 1956, 1957; QUÉZEL & BARBERO, 1989), highlighting the ecological richness and complexity of this mountainous ecosystem. The strong altitudinal gradients, combined with climatic and edaphic variations, contribute to a high diversity of plant communities.

Within the Tikjda area, MENARD & VALLET (1988) identified five main vegetation types, reflecting a clear structural organization of the landscape. The first formation is the Atlas cedar forest (*Cedrus atlantica*), which represents one of the most emblematic and ecologically valuable forest ecosystems in the region. This formation is generally found at higher altitudes and plays an important role in soil protection, water regulation, and biodiversity conservation.

The second type consists of evergreen oak stands (*Quercus rotundifolia*), forming dense forested areas that are well adapted to Mediterranean climatic conditions. These forests contribute significantly to ecosystem stability and provide habitat for various animal species.

A third formation is the high matorral composed of mixed cedar and evergreen oak species, representing a transitional vegetation stage between forest and shrubland. This formation reflects both natural dynamics and anthropogenic influence.

The fourth type corresponds to shrub formations, which dominate degraded or disturbed areas. These formations are typically composed of sclerophyllous species adapted to dry and harsh environmental conditions.

Finally, the fifth vegetation type is composed of high-altitude grasslands dominated by chamaephytes. These open ecosystems are characteristic of mountain summits and are influenced by climatic severity, grazing pressure, and soil limitations.

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Overall, this vegetation mosaic illustrates the ecological diversity of the Djurdjura massif and highlights the importance of altitude, climate, and human influence in shaping plant community distribution.

Table 1.

Surface distribution of vegetation formations in the Djurdjura National Park (Tikjda area)

egetation type	Cédraie	Chênaie verte	Broussailles (shrublands)	Dissées / grass formations
Area (ha)	53.4	266.89	315.92	327.26
Percentage (%)	5.5	27.7	32.8	33.9

Climate of the Study Area

Climate represents one of the most important environmental factors influencing ecosystem structure and functioning (BRAQUE, 1988). It plays a fundamental role in determining vegetation distribution, hydrological dynamics, and overall ecological balance. In this context, the main climatic parameters considered in the present study include precipitation amounts, temperature variations, and seasonal climatic factors such as frost, snowfall, wind regimes, and the duration of the dry season.

Due to the absence of a meteorological station within the Djurdjura National Park, climatic data had to be estimated using nearby reference stations. In this study, data from the Bouira meteorological station were used, as it is located on the same mountain slope at an altitude of approximately 555 m. These data cover a 20-year period (1990–2009), which allows for a reliable characterization of long-term climatic trends in the region.

Although differences in altitude exist between the Bouira station and the higher zones of the Djurdjura massif, this approach provides a useful climatic approximation for understanding regional patterns. The analysis of these data makes it possible to identify seasonal variability, particularly the contrast between a wet and cold season and a warm and dry season, which strongly influences ecological processes in the study area.

Precipitation Data and Estimation Method

The precipitation analysis in this study is based on data from the Bouira meteorological station, adjusted to the higher altitudes of the Djurdjura massif. According to MEDDOUR (2010), the region exhibits a vertical precipitation gradient of approximately 64 mm per 100 m above 1,000 m on the southern slope of the Djurdjura. Considering the altitude difference between Bouira station (555 m) and Tikjda station (approximately 1,500 m), precipitation values were extrapolated to better represent the climatic conditions of the study area.

The estimated annual precipitation for the Tikjda site is 1,119.5 mm, reflecting a relatively humid montane Mediterranean climate. Monthly precipitation data show strong seasonal variability, with a wet period concentrated in autumn and winter and a marked dry summer season. January records the highest precipitation value (175.47 mm), while July represents the driest month (10.41 mm). These data allow for a detailed characterization of the seasonal rainfall regime influencing the ecological dynamics of the Djurdjura National Park.

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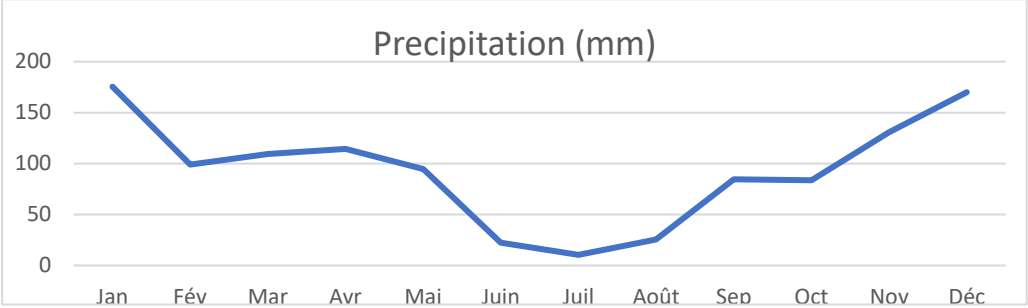

Figure 3. Monthly precipitation at Tikjda station (1990–2009)

Temperature Data and Seasonal Structure

The temperature analysis in this study is based on monthly climatic data from the Tikjda station (1500 m altitude) covering the period 1990–2009. These data include minimum (m), maximum (M), and mean monthly temperatures, which were used to characterize the thermal regime of the Djurdjura mountain environment.

The results show a strong seasonal thermal contrast. The coldest months are December, January, and February, with minimum temperatures frequently below 2 °C, reflecting harsh winter conditions at high altitude. In contrast, the warmest period occurs between June and August, with maximum temperatures ranging from approximately 24 °C to 27 °C.

The calculated mean annual temperature is 11.51 °C, indicating a temperate montane Mediterranean climate. The thermal regime clearly divides the year into two main seasons: a cold season extending from November to April, and a warm season from May to October. This seasonal structure plays a key role in controlling vegetation growth cycles and ecological dynamics within the Djurdjura National Park.

The amplitude between minimum and maximum temperatures also highlights significant daily and seasonal thermal variability, which is typical of mountainous environments and influences ecosystem distribution and biological activity in the region.

Table 2.

Monthly mean air temperature at Tikjda (Djurdjura National Park, 1990–2009)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Mean Temperature (°C)	2.8	3.6	6.16	8.23	13.06	18.44	21.9	21.98	17.71	13.23	7.26	3.76

Fire Data

Forest fire data for the Djurdjura National Park were analyzed for the period 2000–2009, with a particular focus on the southern sector of Tikjda. The dataset includes the total number of fire events as well as the burned surface areas, distinguished between forested and non-forested zones.

A total of 146 fire events were recorded over the study period. The corresponding burned areas include 367.58 hectares of forest, 544.85 hectares of non-forest formations, and a total burned surface of 912.43 hectares. These data were used to quantify the spatial extent and frequency of fire occurrences within the study area.

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In addition, fire distribution according to vegetation types (forests, shrublands, and grass formations) was considered in order to support the ecological analysis of disturbance patterns in the Djurdjura ecosystem.

RESULTS AND DISCUSSIONS

Climate: Precipitation and Temperature

The climatic analysis of the Djurdjura National Park, based on data from the Tikjda station (1990–2009), reveals a typical Mediterranean montane climate characterized by strong seasonal contrasts in both precipitation and temperature.

Precipitation is relatively high, with an estimated annual average of 1119.5 mm. The monthly distribution shows a clear seasonal pattern, with a wet period extending from autumn to spring and a pronounced dry summer season. Maximum precipitation occurs in January (175.47 mm), while the minimum is recorded in July (10.41 mm). This strong seasonality reflects the dominance of Atlantic and Mediterranean climatic influences, combined with the orographic effect of the Djurdjura massif, which enhances rainfall at higher elevations.

Temperature data show a clear altitudinal and seasonal structure. The mean annual temperature is 11.51 °C. Winter months (December to February) are the coldest, with minimum temperatures frequently below 2 °C, while summer months (June to August) are the warmest, with maximum values reaching up to 27 °C. This thermal contrast defines two major seasons: a cold, humid season and a warm, dry season.

The combination of high precipitation variability and strong summer drought plays a fundamental role in controlling ecosystem dynamics. In particular, the dry and hot summer period increases evapotranspiration stress and creates conditions highly favorable to fire ignition and vegetation degradation.

Vegetation Structure and Ecological Organization

The vegetation of the Djurdjura National Park presents a complex mosaic of forest, shrub, and grass formations strongly influenced by altitude, climate, and human pressure. The main vegetation types identified in the Tikjda area include cedar forests (Cedrus atlantica), evergreen oak forests (Quercus rotundifolia), shrublands (broussailles), and high-altitude grasslands.

Quantitative analysis shows that shrublands and grass formations dominate the landscape, representing more than 60% of the total vegetation cover, while evergreen oak forests occupy a significant but secondary proportion. Cedar forests, although limited in surface area, represent the most ecologically valuable formation due to their high biodiversity significance and ecological stability.

This distribution reflects both natural environmental gradients and long-term anthropogenic influences. The dominance of open and semi-open formations indicates progressive ecosystem openness, often linked to disturbance processes such as grazing, fire, and climate stress.

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Figure 4. Wild macaque observed in cedar forest ecosystem of the Djurdjura Mountains

Fire Regime and Environmental Disturbance

Fire activity constitutes a major ecological disturbance in the Djurdjura ecosystem. Between 2000 and 2009, a total of 146 fire events were recorded, affecting 912.43 hectares, including 367.58 hectares of forest and 544.85 hectares of non-forest formations.

The higher proportion of burned non-forest areas suggests that shrublands and grasslands are more exposed and more flammable than closed forest formations. However, forest ecosystems, particularly cedar and oak stands, are also affected, indicating the spread of fire across different vegetation types.

The recurrence of fires is strongly linked to climatic conditions, especially the dry summer period, which increases vegetation dryness and flammability. In addition, anthropogenic factors such as pastoral practices and land use contribute to fire ignition and propagation.

Over time, repeated fire events can lead to long-term ecological consequences, including vegetation degradation, reduction of forest cover, and increased dominance of fire-resistant shrub species.

Hydrology and Hydrography

The Djurdjura massif is characterized by a complex hydrological system strongly influenced by its karstic geological structure. The predominance of carbonate formations favors the infiltration of precipitation and the development of significant underground aquifers, making the region an important natural water reservoir in northern Algeria.

The hydrographic network is dense and highly hierarchical, composed of numerous streams, springs, and seasonal rivers (oueds). These watercourses are strongly controlled by topography and rainfall distribution, resulting in spatial and temporal variability in water flow across the massif.

The hydrological regime is typically seasonal. During the wet period, especially in winter and spring, runoff is rapid and often torrential due to steep slopes and limited soil retention capacity. This leads to high discharge events, sometimes associated with cascading flows in mountainous areas. In contrast, during the summer dry season, surface water

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availability decreases significantly, and most streams become intermittent or completely dry. Only perennial springs maintain limited flow, generally restricted to short downstream sections.

This strong seasonal contrast in water availability has direct ecological consequences. It influences soil moisture dynamics, vegetation distribution, and ecosystem productivity. Areas with permanent or semi-permanent water sources tend to support denser vegetation cover, while drier zones are dominated by shrub and grass formations. Therefore, hydrology plays a key role in structuring the spatial organization of ecosystems within the Djurdjura National Park.

In addition, the karstic nature of the massif contributes to underground water circulation, which is essential for maintaining base flow during dry periods and sustaining ecological stability in sensitive mountain habitats.

In addition to natural water systems, the hydrology of the Djurdjura region is also influenced by artificial infrastructures such as dams, which play a role in water storage and regulation (Figure 5).

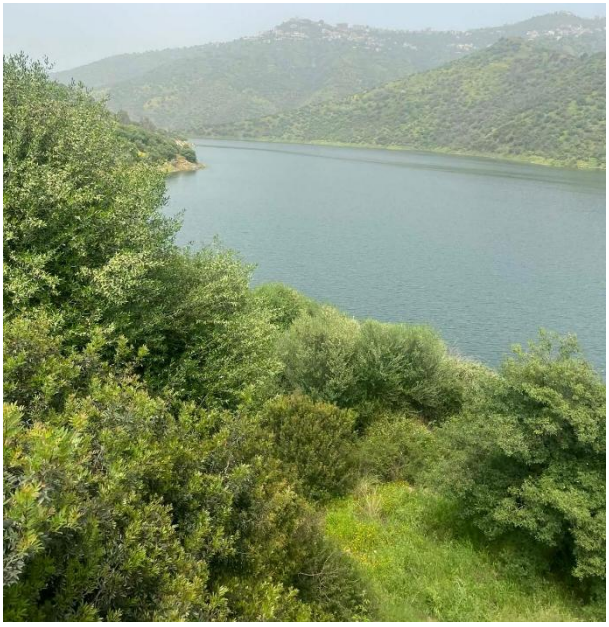

Figure 5. Dam reservoir in the Djurdjura region showing anthropogenic influence on water resources

Integrated Ecological Interpretation

The interaction between climate, vegetation, and fire disturbance defines the overall functioning of the Djurdjura ecosystem. The Mediterranean montane climate creates strong seasonal constraints, while the complex topography generates ecological heterogeneity.

Vegetation patterns are closely linked to these climatic conditions, with forests dominating humid and stable areas, and shrublands expanding in more disturbed zones. Fire acts as a key regulating factor that accelerates vegetation transformation and contributes to landscape openness.

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Overall, the Djurdjura National Park represents a dynamic ecosystem where natural climatic variability and anthropogenic pressures interact to shape biodiversity distribution and ecosystem stability. Increasing fire frequency, combined with climatic stress, may represent a long-term threat to the ecological integrity of this mountain system.

CONCLUSIONS

Djurdjura National Park, located in northern Algeria, represents a significant Mediterranean mountain ecosystem characterized by high ecological complexity and pronounced environmental gradients. The present study of the Tikjda region highlights the fundamental role of climate, vegetation, hydrology, and fire disturbances in shaping the structure, functioning, and dynamics of this mountain environment.

The climatic analysis reveals a humid montane Mediterranean regime, marked by relatively high annual precipitation and strong seasonal variability, with wet and cold winters contrasted by hot and dry summers. These climatic conditions exert a major influence on ecological processes, particularly through water availability, temperature constraints, and seasonal stress affecting biological activity.

The vegetation cover is structured into a heterogeneous mosaic dominated by shrublands and grasslands, while forest formations such as Cedrus atlantica and Quercus rotundifolia constitute key ecological components despite their relatively limited spatial extent. This organization reflects both natural environmental gradients, such as altitude and exposure, and the long-term effects of anthropogenic pressures, which have contributed to ecosystem fragmentation and the expansion of open formations.

From a hydrological perspective, the Djurdjura massif is strongly influenced by its karstic geological structure, which facilitates groundwater infiltration and the formation of important aquifers. The hydrographic network is dense but highly seasonal, with significant variations in water flow between wet and dry periods. These hydrological dynamics play a critical role in regulating soil moisture, vegetation distribution, and ecosystem resilience.

Fire disturbance emerges as a major factor influencing ecosystem dynamics in the region. The high frequency of fire events, combined with climatic conditions such as summer drought and human activities, contributes to vegetation degradation, reduction of forest cover, and alterations in landscape structure. These disturbances increase ecosystem vulnerability and may have long-term consequences on biodiversity and ecological stability.

Overall, the Djurdjura ecosystem is shaped by the complex interaction between climatic variability, topography, hydrological processes, vegetation structure, and anthropogenic influences. This interplay highlights the ecological sensitivity of the region and underscores the importance of implementing sustainable management practices, effective fire prevention strategies, and long-term conservation measures to preserve its biodiversity and ensure the resilience of this valuable mountain ecosystem.

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