Article

Fl. Medit. 35: 167-192
https://doi.org/10.7320/FlMedit35.167
Version of Record published online on 6 December 2025

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Ecology and conservation status of Algerian fir (*Abies numidica*) in Babor-Tababort National Park (Northeast Algeria)

Abstract

Adjrad, S., Tababouchet, M., Zemouri, M., Bouchibane, M. & Bougaham, A. F.: Ecology and conservation status of Algerian fir (*Abies numidica*) in Babor-Tababort National Park (Northeast Algeria). — Fl. Medit. 35: 167-182. 2025. — ISSN: 1120-4052 printed, 2240-4538 online.

The Algerian fir (*Abies numidica*), a species strictly endemic to Algeria and protected under national legislation, has a highly localized distribution area, confined to the Babor-Tababort National Park in the northeast of the country. Our study allowed us to map the species' distribution range, estimate the mature trees of its populations, their altitudinal distribution, and reassess its conservation status according to IUCN criteria. The study was conducted between June 2020, and April 2025. For the counting of mature trees, a systematic sampling was carried out in the Babor forest, while a direct count was conducted in the Tababort forest. The Babor location has a relatively homogeneous and continuous distribution. The Tababort location, characterized by a fragmented distribution. The total population size is estimated to be around 8,561 mature trees, distributed across an area of occupancy of 40 km². The species preferentially occupies the north and northeast slopes, which are cooler and more humid, located between 1500 and 2000 meters in altitude, with a high abundance between 1717 and 1788 meters. It coexists with several forest tree species, including *Cedrus atlantica*, *Quercus canariensis*, *Populus tremula*, and *Acer obtusatum*. A reassessment based on IUCN criteria suggests that the species has to be classified as Vulnerable (VU). Its conservation status is justified by its very restricted distribution and small population size. These results confirm the urgent need to implement targeted conservation strategies based on updated data, in order to ensure the perennity of this relict species, which is particularly vulnerable to both historical and current human pressures, as well as the effects of climate change.

Key words: endemism, habitat, IUCN reassessment, threats, conservation, North Africa.

Article history: Received 31 May 2025; received in revised form 22 November 2025; accepted 27 November 2025; published 6 December 2025.

Introduction

Biodiversity hotspots are regions characterized by high species richness and high levels of endemism, yet they are subject to significant threats from human activities (Hoffmann

& al. 2016). These areas are crucial for conservation, as they host a large proportion of the world's biodiversity (Reid 1998; Bedair & al. 2022). There are 36 hotspots worldwide, covering approximately 3.3 million km², or about 2.3% of the Earth's terrestrial surface (Hoffmann & al. 2016; Ge & al. 2022). They harbor at least 1,500 endemic vascular plant species and have lost more than 70% of their original habitat (Hoffmann & al. 2016).

The Mediterranean biogeographic region is considered the second most important biodiversity hotspot globally (Bedair & al. 2022). It spans more than 30 countries and includes a wide variety of terrestrial habitats, from forests and maquis to coastal wetlands and transitional desert environments. It hosts more than 25,000 flowering plant species, approximately 63.5% of which are endemic (Zahran 2010). At the junction of Europe, Asia, and Africa, the region is influenced by contrasting biogeographical zones, ranging from temperate to arid and tropical climates. Combined with great heterogeneity of soils and topography, this explains its exceptional richness (Thompson 2020). The high endemism is linked to strong specialization of plant species to localized ecological conditions, particularly in restricted habitats such as isolated mountain ranges, islands, or rocky soils. Geographic isolation, topographic and climatic diversity, and the complex geological history of the region have contributed to the persistence of numerous rare species with narrow distribution ranges (Zahran 2010; Thompson 2020; Vargas 2020; Médail 2022).

Algeria, a southern Mediterranean country, is distinguished by exceptional floristic richness, particularly in its northern mountainous areas. Ecological variation, topographic isolation, and climatic diversity within these ecosystems (Bougaham & Moulai 2014) have contributed both to speciation and to the preservation of relict species. Babors Kabylie is a major refuge for floristic diversity (Quézel & Santa 1962-1963; Gharzouli 2007; Bouchibane & al. 2024), hosting unique plant groups and many species with restricted distributions, some of them strictly endemic (Véla & Benhouhou 2007). Among these species is the Algerian fir (*Abies numidica* de Lannoy ex Carrière), strictly endemic to this region.

The genus *Abies* is considered one of the most complex within the *Pinaceae* family (Parducci & al. 2001). With the exception of *Abies tazaotana* Cozar and *A. pardei* Gaussen, which remain poorly known, Quézel (1998) identifies six species around the Mediterranean basin, divided into two groups. The first, with sharp needles, includes *A. pinsapo* Boiss., *A. maroccana* Trab., and *A. cephalonica* Loudon. The second, with emarginate or blunt needles, comprises *A. numidica*, *A. nebrodensis* (Lojac) Mattei, and *A. cilicica* (Ant. & Kotschy) Car. The Algerian fir is one of the last living indicators of relict North African fir forests (López-Tirado 2023). It forms relict localities in high-altitude limestone habitats, under conditions requiring high atmospheric humidity (De Smet & Bouazza 1984; Kolai 1992). Its distribution is restricted to the northern slopes of Jebel Babor and Tababort, within the Babor-Tababort National Park (JORADP 2019), where it is vulnerable to environmental disturbances intensified by human activities (Tlili-Ait Kaki & al. 2013).

Due to its restricted geographical range, the species was first classified as Vulnerable (VU) by Walter & Gillett (1998), then reclassified as Critically Endangered (CR) by Yahi & al. (2011). It is also listed among the protected plants in Algeria (JORADP 2012). Although studied for its phytochemical properties (Tlili-Ait Kaki & al. 2013; Adjaoud & al. 2024), data on its current spatial distribution and demographic structure remain limited, despite its ecological and heritage value (Quézel & Santa 1962-1963; Hachi-Illoul 2016). Most ecological studies have focused on the Babor forest, whereas Tababort has only been

described in a few early publications, notably by Barbey (1934). Previous conservation assessments (Walter & Gillett 1998; Yahi & al. 2011) were based mainly on historical data. However, growing threats such as forest wildfires, overgrazing, habitat fragmentation, and climate change now increase the risk of genetic erosion by limiting exchanges between localities (De Smet & Bouazza 1984; Barbero & al. 1990; Madoui 2020).

In this context, a precise assessment of the species' conservation status and population size is crucial to guide management and conservation. This study aims to fill the knowledge gap regarding the distribution and ecology of *Abies numidica* within the Babor-Tababort National Park, through: (1) the development of a detailed spatial distribution map across the Babor and Tababort forests; (2) the estimation of its population size; (3) the assessment of the effect of altitude and slope aspect on its distribution; and (4) the reassessment of its conservation status according to IUCN criteria, with identification of priority areas for its preservation.

Material and Methods

Study area. **-** The Babor-Tababort National Park is located in the Babors Kabylie, in northeastern Algeria. Established as a protected area in 2019 (JORADP 2019), it covers an area of 23,656 hectares, across the three wilayas of Sétif, Béjaïa and Jijel (Fig. 1). It is characterized by four forests, which are considered the central zone of the Babor-Tababort National Park, namely Jebel Tenedet, Jebel Zan Oughilas, Jebel Tababort and Jebel Babor (JORADP 2019). Our study was carried out on these last two jebels, which reach an altitude of 1969 m a. s. l. and 2004 m a. s. l. and cover areas of 346 hectares and 1268 hectares respectively (Ledant & al. 1985). These summits dominate a mountainous landscape with diverse ecological and Palearctic bioclimatic conditions shaped by complex geomorphology, high altitudinal gradients, and a climate ranging from subhumid to per-humid (Quézel & Santa 1962-1963; Ledant & al. 1985; Gharzouli 2007). The Tababort and Babor forests host remarkable biodiversity, including endemic and relict species of major biogeographical interest, such as *Abies numidica*, *Erodium battandieranum* Rouy and *Vicia ochroleuca* subsp. *baborensis* (Batt. & Trab.) Greuter & Burdet for the flora (Bouchibane & al. 2024), and the Algerian Nuthatch (*Sitta ledanti* Vielliard) for the fauna (Zemouri & Bougaham 2022). These forests are mainly composed of Algerian fir, Atlas cedar (*Cedrus atlantica* (Manetti ex Endl.) Carrière), Algerian oak (*Quercus canariensis* Willd.), and African oak (*Q. afares* Pomel). Beyond these dominant trees, the area contains rare and endemic plant species of Babors Kabylie, such as Eurasian Aspen (*Populus tremula* L.), *Epimedium perralderianum* Coss., and *Saxifraga numidica* Maire (Quézel & Santa 1962-1963).

Field sampling and distribution mapping. – The identification of Algerian fir locations was based on existing literature sources (Battandier 1888-1890; Quézel & Santa 1962-1963), as well as unpublished personal field observations across the entire distribution range of the species. Surveys were conducted in both the Babor and Tababort forests. In Babor, sampling was carried out between June and July 2020, with 240 points surveyed using systematic sampling along line transects spaced at 100-meter altitudinal intervals (sensu Hacioğullari & al. 2019) (Fig. 2). This method covered the entire forest, extending over seven kilometers. Sampling points were placed every 200–300 meters, with adjust-

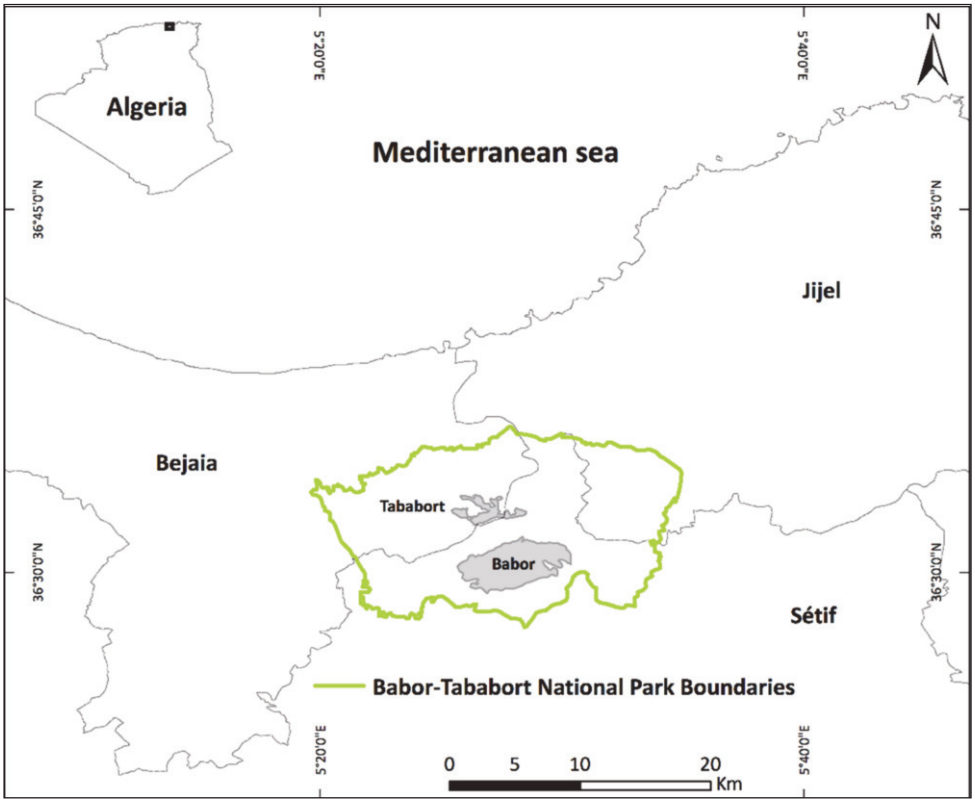

Fig. 1. The study area and field sites within the Babor-Tababort National Park, northeastern Algeria.

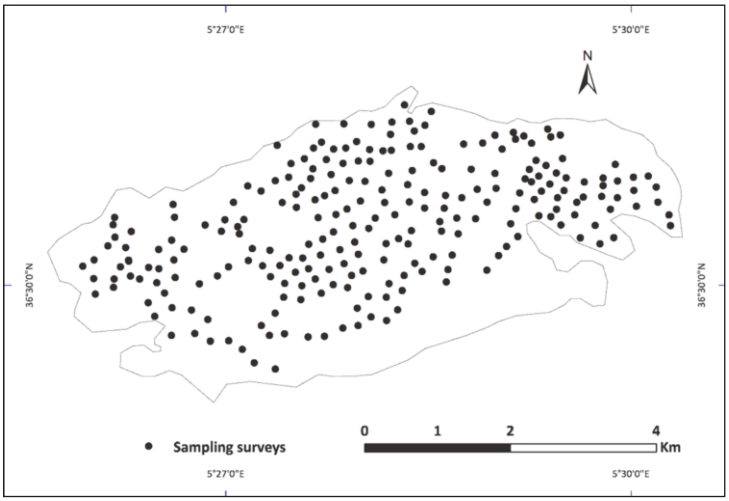

Fig. 2. Sampling points of the Algerian fir in the Babor Forest.

ments only when field access was limited. In Tababort, mature trees were counted by direct observation between March and April 2025. At each site, slope aspect, associated tree species, and GPS coordinates were recorded using a Garmin Map 76CSx.

Using ArcGIS (ArcMap v10.7.1, ESRI 2019), we produced (1) a distribution map of Algerian fir locations and cantons within Babor-Tababort National Park, and (2) a spatial georeferencing of all field-collected data.

Abies numidica ***population size.*** – Two complementary field methods were applied to estimate the total population size of Algerian fir in Babor-Tababort National Park. In Babor, 45 sampling plots of 10,000 m² (100 × 100 m) were established (Pisanu 2009), each centered on a verified occurrence point. The mean number of mature trees per plot was extrapolated to the species' distribution area to estimate the total population size. In Tababort, given the small effective population size and fragmentation, all mature trees were counted directly in the field (Bullock 1996). Mature trees were distinguished from immature ones based on cone production and/or the presence of a central rachis from the previous season. Data from both approaches were combined to estimate the total population size of the species.

Altitudinal distribution range. **–** To assess the altitudinal distribution of the species across both forests, 51 plots (100 × 100 m) were established, 45 in Babor and six in Tababort. These plots were positioned along altitudinal bands where Algerian fir occurs, providing representative data on local abundance and distribution patterns. Altitudinal classes were determined following Sturges' rule (Sturges 1926):

number of classes = 1 + (3.3 × log n), where n = 51. The resulting number of classes was rounded to the nearest whole number. Class intervals were then calculated as (Highest altitude – Lowest altitude) / Number of classes.

Reassessment of the IUCN conservation status. **–** To reassess the conservation status of Algerian fir, we georeferenced all known forest plots (Quézel & Santa 1962-1963), quantified the Area of Occupancy (AOO) and Extent of Occurrence (EOO), and estimated the number of mature trees. The reassessment was based on 51 occurrence records, 45 from Babor and 6 from Tababort (Fig. 3). We first focused on criteria D, as no reliable historical demographic data were available for criterion A and C, and no extinction probability models for criterion E. Criterion A requires quantitative data on abundance or density spanning at least 10 years or three generations (IUCN 2024), which in this case represents several decades and possibly the maximum capped at 100 years. Criterion E was not applicable, as no quantitative extinction, risk analysis was available. This reassessment was conducted in accordance with the IUCN Red List (2024) categories and criteria, version 16. GPS coordinates from field surveys were used to calculate both Extent of Occurrence (EOO) and AOO using the GeoCAT tool (Bachman & al. 2011, https://geocat.iucnredlist.org/editor). The AOO was estimated with the standard 2 × 2 km grid, as recommended by IUCN (2024). The EOO was calculated as the minimum convex polygon enclosing all confirmed occurrences, excluding unsuitable or unoccupied areas (IUCN 2024; Fig. 3). These values informed the reassessment under criterion B.

Results

Distribution and cartographic representation of **Abies numidica** ***population.*** **-** The Algerian fir population is composed of two separate locations (Babor and Tababort). These

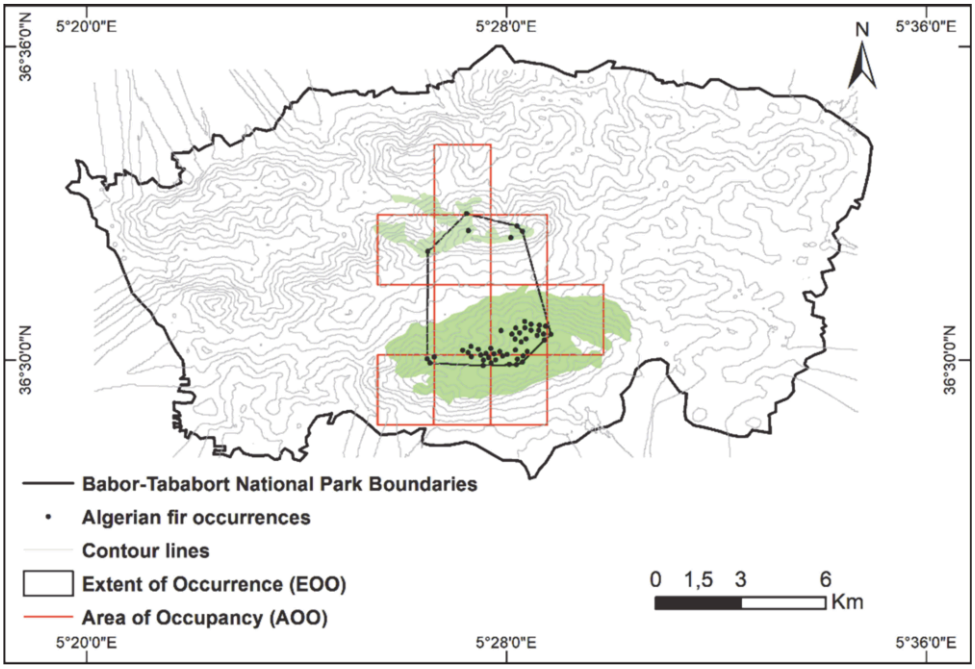

Fig. 3. Calculation of the area of occupancy (AOO) and extent of occurrence (EOO) of the Algerian fir and its potential distribution area according to the UICN tool 'GeoCAT'. (modified by ArcGis).

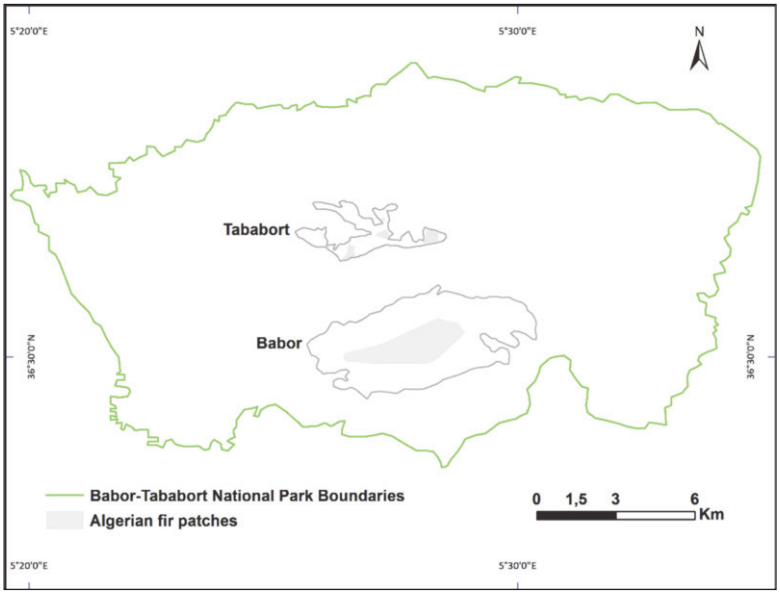

Fig. 4. Distribution of the Algerian fir in the Babor-Tababort National Park.

locations are isolated by a non-forested area, with a distance of approximately 4 kilometers (Fig. 4). In the Tababort location, the species is distributed across four isolated forest patches, covering a more limited area and showing an habitat fragmentation. In Babor, its distribution area extends over a length of 4.5 km and a maximum width of 1.5 km, forming a relatively continuous and homogeneous forest stand.

Overall, the species tends to establish preferentially on the north-facing slopes of the Babor-Tababort National Park. It is found in the moist-facing slopes, particularly the northern (49.01%) and northeastern (29.41%) slope (Fig. 5). In some sites, it forms relatively continuous and extensive pure fir stands. Nevertheless, the species is also present on northwest, west, and east oriented slopes, although less abundantly.

***Population size of* Abies numidica. -** The number of mature trees per sampling plot varies between the Babor and Tababort forests (Table 1). Overall, 1,241 mature trees were recorded, with 1,122 in the Babor and 119 in the Tababort. The mean number of mature trees per sampling plot is 24.93 ± 11.63 in Babor, compared to 19.83 ± 11.47 in Tababort. The total area occupied by the species is estimated at 40 km^2, with approximately 24 km^2 located in the Babor and 16 km^2 in the Tababort. The total population size of the species is estimated at 8,561 mature trees, distributed between 8,302 mature trees in Babor and 259 in Tababort.

***Altitudinal distribution of* Abies numidica. -** The altitudinal distribution of *Abies numidica* varies according to the different altitude classes (Table 2). The class [1717–1788 m] contains the highest proportion of mature trees, with a relative abundance of 26.51% (329 mature trees). It is followed by the classes [1859–1930 m] and [1930–2003 m], which represent 23.85% (296 mature trees) and 18.53% (230 mature trees), respectively. The class [1646–1717 m] also shows a notable presence, accounting for 17.08% of the entire population (212 mature trees). Although the species is also observed at lower elevation, particularly between 1575 and 1646 m a. s. l., where it is significantly less abundant.

Habitat and associated tree species. - The Algerian fir is associated with several other forest tree species. In both forests, it coexists notably with the Atlas cedar, the Algerian oak, the Eurasian Aspen, and Italian Maple (*Acer obtusatum* Walds. & Kit. ex Willd.).

***IUCN redlist status of* Abies numidica. -** The reassessment of the conservation status of *Abies numidica* in the Babor-Tababort National Park, according to the IUCN Red List criteria, indicates that only criterion D can be reliably applied with the available data. Criterion A remains uncertain: historical data from 1934 don't suggest a potential decline of mature individuals that could allow us to use subcriteria A1 or A2, but the lack of precise information on the rate and continuity of this decline prevents a robust assessment. Criterion C might be applicable in situations involving historical decline, but it is not our case. In contrast, criterion D, via subcriteria D2, is directly applicable: the species is known from only two locations (≤ 5), supporting a classification as Vulnerable (VU). Thus, based on the available data, criterion D provides the only solid justification for the current conservation assessment of the species.

Discussion

The Algerian fir in the Babor forest shows a continuous and homogeneous spatial distribution, covering a vast area (Fig. 6a). These observations confirm those of several

Table 1. Number of mature Algerian fir trees in Babor-Tababort National Park. (*) direct estimation in the field.

	Babor	**Tababort**	**Total**
Number of sampling plot	45	6	**51**
Number of mature trees	1122	119	**1241**
Mean ± standard deviation (Extreme values)	24.93 ± 11.63 (6 - 58)	19.83 ± 11.47 (7 - 36)	**24.33 ± 11.62 (6 - 58)**
Occupied area (km²)	24	16	**40**
Total number of mature trees	8302	259*	**8561**

Table 2. Altitudinal range of Algerian fir in Babor-Tababort National Park.

Classes (m)	**Individual number**	**Relative abundance (%)**
[1504-1575[	141	11.36
[1575-1646[	20	1.61
[1646-1717[	212	17.08
[1717-1788[	329	26.51
[1788-1859[	13	1.05
[1859-1930[	296	23.85
[1930-2003]	230	18.53

Table 3. Estimation of extent of occurrence (km²), and area of occupancy (km²) for Algerian fir in Babor-Tababort National Park.

	Babor	**Tababort**	**Total**
Extent of occurrence (EOO)	2.914	1.720	**15.20**
Area of occupancy (AOO)	24	16	**40**
Number of locations	2		

authors who consider this forest an ecological refuge, representing the main conservation bastion for this endemic species (Beauverie & Barbey 1934; Quézel 1956; De Smet & Bouazza 1984; Kolai 1992). The species benefits from favorable ecological conditions for its survival, including relatively deep and well-drained soils, limited exposure to desiccating winds, and a relatively stable hydrological regime (Kolai 1992). According to Quézel (1985), as with all Mediterranean fir species, *Abies numidica* is strictly associated with calcareous-dolomitic bedrock, particularly on karstified landscapes. These factors contribute to a well-structured forest composition and continuous natural regeneration processes, as indicated by the presence of individuals across multiple age cohorts (De Smet & Bouazza 1984). Furthermore, the low anthropogenic pressure, due to the site's difficult accessibility, limits human-induced disturbances and contributes to the preservation of this endemic species in its natural habitat (Aussenac 2002; Tlili-Ait Kaki & al. 2013).

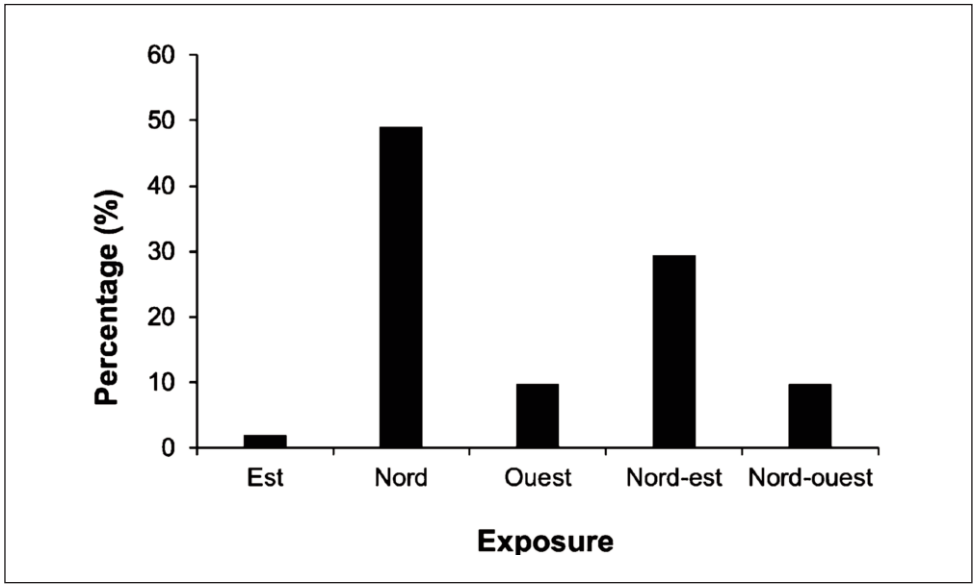

Fig. 5. Percentage of Algerian fir trees according to their slope aspect in the Babor-Tababort National Park.

In contrast, in the Tababort forest the species presents a fragmented distribution, occurring as small, isolated forest patches (Fig. 6b). This situation reflects a continuous process of habitat degradation (Médail & Quézel 1999; Fischer & Lindenmayer 2007). For centuries, different human societies present in North Africa have played a major role in the decline of forest ecosystems (Madoui 2020). This process, caused by war conflicts, agricultural activities, overgrazing, repeated fires, and logging, continued until the 16th century and persisted, in various forms, until the 19th century. By that period, approximately half of the native forests had already been lost (Quézel 1976). The decline of forested areas is estimated at an annual rate of 1 to 2%, highlighting the severity of the situation and the threats facing some forest species, such as the Algerian fir (Barbero & al. 1990). Endemic species with limited geographic ranges are especially susceptible to habitat deterioration, often caused by anthropogenic activities, which also compromise their capacity for natural regeneration (Saidi & al. 2016).

As with the circum-Mediterranean fir species, slope aspect appears to be an important ecological determinant influencing the spatial distribution of the Algerian fir in the Babor-Tababort National Park (Aussenac 2002). This species shows a strong affinity for north-facing slopes, which offer more moist and cooler bioclimatic conditions, favoring both its regeneration and vigorous development (Quézel & Médail 2003; Gharzouli 2007; Caudullo & Tinner 2016). In contrast, its rarer presence on south-facing slopes may be explained by less favorable climatic conditions, compounded by topographic constraints and the effects of historical deforestation (Kolai 1992; Tlili-Ait Kaki & al. 2013). Indeed, this species is absent from the southern slope of Babor, where the more arid climatic conditions and desiccating temperatures are not conducive to its growth (Kolai 1992; Madoui 2020).

Fig. 6. Photos showing the Babor forest (a) and the Tababort forest (b).

The variation noted between the two Algerian fir locations is reflected in the mean mature tree density per sampling plot, which is higher in Babor than in Tababort. Our results do not confirm the estimates by Barbey (1934), who assessed the Algerian fir in Babor as ranging between 2,000 and 3,000 individuals, with densities sometimes exceeding 30 trees per hectare in areas where the species predominates. The high variability observed in our study reflects marked heterogeneity among the sampling plots. This trend aligns with the observations of De Smet and Bouazza (1984), who highlighted strong variability in the proportions of the species (between 15% and 40%) depending on the forest types in Babor, linked to altitude, slope aspect, and the intensity of local disturbances. According to Barbey (1934), only a few stunted individuals, deformed by snow and wind stress, survived in Tababort, although the area was likely once more continuously covered by fir stands. We note that we do not have any other comparison data regarding the popu-

lation size of the species in the Babor-Tababort National Park. Furthermore, Barbey (1934) does not clarify whether his estimate includes only mature trees or also immature ones in the total count.

The high abundance of *Abies numidica* trees between 1717 and 2003 meters of altitude suggests that this altitudinal range constitutes the optimal development zone for the species, due to microclimatic conditions particularly favorable to its growth. Indeed, in their natural ranges, with the exception of *A. bornmuelleriana* Mattf., which can be found at very low altitudes, different fir species generally develop above 400 meters, with some even reaching 2400 meters (Aussenac 2002). This trend is also observed in the Moroccan fir, Abies marocana, which is localized between 1600 and 2000 meters (Barbero & Quézel 1975). High-altitude areas receive abundant rainfall in autumn and spring but may be subject to severe summer droughts (López-Tirado & al. 2022). Overall, the species develops in a region characterized by a low annual temperature range, compared to other forest formations (Aussenac 2002). In contrast, lower altitudes, notably between 1575 and 1646 meters, show lower abundances, suggesting a greater sensitivity of the species to high temperatures and interspecific competition. These results do not align with the observations of De Smet and Bouazza (1984), who reported a complete absence of the Algerian fir below 1750 meters on the northern slope. According to De Smet and Bouazza (1984), the species in the Babor forest is showing a dynamic expansion, characterized by its progression through the colonization of Atlas cedar stands at lower elevations.

The Algerian fir associates with *Cedrus atlantica*, *Quercus canariensis*, *Populus tremula*, and *Acer obtusatum*, forming plant communities typical of moist montane forests (Kolai 1990; Gharzouli & Djellouli 2005). These associated species share the same ecological niche and are found in habitats characterized by cooler and wetter conditions. Their presence highlights the importance of habitat structural diversity for the conservation of Abies numidica. Because of its shade-tolerant trait, this species can persist in the understory for several decades until a canopy gap enables it to ascend to the dominant forest stratum (De Smet & Bouazza 1984). An appropriate plant canopy optimizes growth conditions for juvenile firs, facilitating their natural regeneration by decreasing water loss, increasing soil moisture, mitigating the effects of late frosts, and stimulating more efficient photosynthetic activity, leading to better growth than observed in exposed sites (Aussenac 2002).

The species can be reassessed as Vulnerable (VU) based on the application of criteria D (subcriterion D2), following the IUCN (2024) categories and criteria. Previous assessments have successively classified the species as ″Vulnerable″ (VU) (Walter & Gillett 1998) and later as ″Critically Endangered″ (CR) (Yahi & al. 2011). However, these assessments were primarily based on literature reviews (Maire 1952, Quézel & Santa 1962-1963, Technoexportstroy 1970) and applied criterion B of the IUCN classification. Similarly, the Saharan cypress (*Cupressus dupreziana* A. Camus), classified as ″Endangered″ (EN) (Abdoun 2013), has a Moroccan subpopulation estimated at 6,650 mature trees, compared to only 233 mature trees recorded in the Algerian Sahara. This situation reflects a broader pattern of vulnerability of Mediterranean montane forests, particularly in the southern Mediterranean region (Barbero & al. 1990). Several endemic and geographically isolated fir species, such as *Abies marocana*, *A. pinsapo*, and *A. nebrodensis*, currently face a high risk of extinction (Médail & Quézel 2003). The species' conservation status results from the combined impact of several factors, including forest wildfires, fuel wood harvesting

and seasonal grazing by livestock (Yahi & al. 2011; Madoui 2020). Moreover, natural regeneration through seedling emergence appears to be limited by dense understory vegetation and snow accumulation during winter (De Smet & Bouazza 1984). Although the limited accessibility to these forests, especially during winter, provides some degree of protection, threats to this endemic species are regarded as persistent. This situation further highlights the urgency of implementing coordinated conservation measures in response to the growing impacts of climate change.

Threats and conservation recommendations. **-** The evaluation of ecological data and the determination of the conservation status of *Abies numidica* in the Babor and Tababort forests highlight the application of differentiated conservation strategies, each adapted to the particularities and current situation of each location, within an integrated management framework at the scale of the Babor-Tababort National Park.

The Babor forest is the strategic core habitat for the preservation of the Algerian fir; it is therefore essential to maintain this dynamic by reinforcing in situ conservation measures. Classified as an integral zone of the Babor-Tababort National Park (JORADP 2019), this forest should be placed under controlled access and monitoring by conservation officers to prevent deforestation, wildfires and overgrazing (Yahi & al. 2011; Madoui 2020). It is particularly important to preserve the optimal habitat of this species, located in the summit zone between 1717 and 2003 m a. s. l., which represents the most favorable environment for its development and natural regeneration (De Smet & Bouazza 1984). This area should be placed under strict protection to prevent any form of ecological disturbance, particularly through the establishment of exclusion zones, the control of human impact, and the maintenance of natural forest dynamics. Furthermore, regular ecological monitoring is necessary to track the evolution of the species in Tababort forest (age classes, mortality rate, natural regeneration) (De Smet & Bouazza 1984) and to detect early signs of decline or water stress related to climate change. The species at Tababort shows a low density of mature trees and fragmentation, which impedes natural regeneration and heightens its susceptibility to disturbances such as recurrent wildfires, overgrazing, and habitat loss. It is therefore essential to prioritize forest ecosystems rehabilitation efforts, including the establishment of habitat corridors to link forest patches and the initiation of afforestation programs. These measures must be supported by strict fire prevention measures, rigorous regulation of grazing pressure, and close surveillance of natural regeneration in restored sites, particularly through the deployment of exclusion zones. It is imperative to recognize the vulnerable situation of the species in the Babor-Tababort National Park, which is exposed to a high risk of extinction in the medium term. Targeted conservation actions must be undertaken to enhance its protection. These include the establishment of a seed bank and ex situ collections housed in specialized arboreta or experimental stations, in order to preserve the species' genetic diversity and support potential restoration programs (De Smet & Bouazza 1984; Hachi-Illoul 2016). Encouraging detailed investigations into the species' resilience to climatic fluctuations and its capacity to withstand hydric stress, with a view to predicting climate-driven changes and informing adaptive management, is recommended. Additionally, the installation of a meteorological station is recommended to enable real-time adaptation of management strategies in response to fluctuating environmental variables. The association of this endemic conifer with other species such as *Cedrus atlantica*, *Quercus canariensis*, *Populus tremula* and *Acer obtusatum* highlights the importance of preserving the structural complexity and floristic composition

of these mountain forests (Bouchibane & al. 2024). Maintaining a vegetation cover improves the forest microclimate, facilitates natural regeneration of Algerian fir and reinforces the forest's stability in the face of climatic variations. Finally, engaging local human populations in conservation initiatives is crucial. Environmental education initiatives, the development of sustainable ecotourism, and the adoption of participatory management approaches can all contribute to strengthening local community support for the conservation objectives targeting this endemic and relict species in Algeria.

Conclusion

The Algerian fir is well developed in the Babor forest, which is characterized by its homogeneous spatial distribution. In contrast, the species distribution at Tababort is fragmented and subject to historical and current disturbances, compromising its natural regeneration. The species shows a marked ecological affinity for altitudes between 1717 and 2003 m a. s. l., where microclimatic conditions are optimal. Its spatial distribution is also influenced by slope aspect, with a preference for cooler and more humid exposures. The species coexists with other forest species, and its survival depends on the maintenance of a structured forest cover. The conservation status of the species has been updated to Vulnerable (VU), reflecting its limited distribution restricted to only two known locations. This situation highlights the urgent need to implement coordinated conservation measures, combining in situ and ex situ strategies, to ensure the long-term viability of this relict species of North African mountain forests. It is particularly important to conduct in-depth research on the dieback observed in the field for *Abies numidica*, in order to determine its causes and ecological impacts within the context of ongoing climate change.

Acknowledgements

We extend our sincere gratitude to the ″Direction Générale de la Recherche Scientifique et du Développement Technologique (DGRSDT)″ for its valued support of our research laboratory.

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