Received: 29.12.2025; Revised: 20.03.2026; Accepted: 21.05.2026; Published: 29.05.2026

UKRAINIAN JOURNAL OF FOREST AND WOOD SCIENCE

UKRAINIAN JOURNAL OF FOREST AND WOOD SCIENCE

Journal homepage: https://forestscience.com.ua/en

Ukrainian Journal of Forest and Wood Science, 17(2)

UDC 630.231:631.41:582.632.2(65)
DOI: 10.31548/forest/2.2026.39

ISSN 2664-4452
e-ISSN 2664-4460

Dynamics of natural regeneration in an endemic and protected Portuguese oak forest in Western Algeria

Sid Ahmed Aouadj*

PhD in Ecology and Environment, Lecturer
Ahmed Zabana Relizane University
48000, Cité Bourmadia, Relizane, Algeria
https://orcid.org/0000-0002-5081-5844

Mohamed Zouidi

PhD in Ecology and Environment, Lecturer
Territory Planning Research Center
25000, Campus Zouaghi Slimane, Route de Ain El Bey, Constantine, Algeria
https://orcid.org/0000-0001-5790-9598

Hadj Habib Houari

PhD in Ecology and Environment, Lecturer
Ahmed Zabana Relizane University
48000, Cité Bourmadia, Relizane, Algeria
https://orcid.org/0009-0003-9131-6886

Belgacem Nouar

PhD in Ecology and Environment, Lecturer
Ahmed Zabana Relizane University
48000, Cité Bourmadia, Relizane, Algeria
https://orcid.org/0000-0002-3502-127X

Hadjer Bekhedda

PhD in Ecotoxicology, Lecturer
Ahmed Zabana Relizane University
48000, Cité Bourmadia, Relizane, Algeria
https://orcid.org/0009-0000-3019-6233

Abstract. Despite the ecological and silvicultural importance of Portuguese oak (*Quercus faginea* Lam.) in North Africa, its population dynamics under increasing anthropogenic pressure remain poorly documented, limiting evidence-based conservation planning. The aim of this study

Suggested Citation:

Aouadj, S.A., Zouidi, M., Houari, H.H., Nouar, B., & Bekhedda, H. (2026). Dynamics of natural regeneration in an endemic and protected Portuguese oak forest in Western Algeria. *Ukrainian Journal of Forest and Wood Science*, 17(2), 39-57. doi: 10.31548/forest/2.2026.39.

Corresponding author (sidahmed.aouadj@univ-relizane.dz)

was to assess the current status of the Portuguese oak ecosystem and examine the effects of human proximity and diameter structure on natural regeneration, as well as to characterise the physicochemical properties of soils at the investigated sites. The study used stratified random sampling based on 100 circular plots of 400 m^2 distributed according to predefined distance classes. Results indicated that the distance from the nearest agglomerations significantly affected stand density across all diameter classes. The coefficients of determination ranged from 0.75 to 0.91, indicating that distance from human agglomerations explained a substantial proportion of the variation in the density of different diameter classes. Stand density increased with distance from human settlements, while seedlings and mature seed-bearing trees predominated and the intermediate diameter classes remained poorly represented. Natural regeneration through seedlings was also found to be associated with diameter structure: seedling density increased with the density of trees in the other diameter classes, with R^2 values ranging from 0.54 to 0.68. Soil pH ranged from 5.0 to 6.3 and generally decreased with depth. The surface horizons contained higher levels of organic matter, carbon and nitrogen, whereas clay accumulation in the deeper horizons was particularly evident at the Djefal and Aïn El Hadjer sites. These findings highlighted the vulnerability of the Portuguese oak ecosystem to anthropogenic pressure and suggest the need for appropriate conservation and restoration measures, particularly the protection of natural regeneration and the reduction of grazing pressure near human settlements. This study could serve as a baseline for monitoring vegetation dynamics and changes and for planning the conservation and restoration of Portuguese oak stands

Keywords: diameter classes; distance; seedling density; human proximity; anthropogenic pressure

Introduction

Mediterranean forest ecosystems had been undergoing profound changes for several decades, exacerbated by global climate changes and the intensification of anthropogenic pressures. In North Africa, and particularly in Algeria, these disturbances threatened the biodiversity and structural integrity of noble forest formations. Among them, the forests of the Portuguese oak (*Quercus faginea* Lam.) occupied a crucial ecological and socio-economic position. Endemic relic species of the Algerian-Tunisian humid and subhumid zone, the Portuguese Oak stood out for its high silvicultural value, its contribution to water regulation, and its role as a refuge for remarkable biodiversity.

However, this unique forest heritage was facing an alarming regressive dynamic, as per investigation conducted by S.A. Aouadj *et al.* (2020), S.A. Aouadj (2021) and B. Babali *et al.* (2025). Historically resilient, the Portuguese oak (*Quercus faginea* Lam.) of the Algerian Tell Atlas was undergoing an accelerated degradation process, characterised by habitat fragmentation and a severe loss of their original area. While climatic fluctuations marked by recurrent droughts weakened these stands, direct anthropogenic actions remained the main driver of this regression. Chronic overgrazing that annihilated natural regeneration, repeated forest fires, illegal logging for timber and heating, as well as excessive branch lopping for livestock, combined to disrupt the sylvan balance. This overexploitation disrupted the cycle of population renewal, leading to the ageing of trees and an opening of the canopy. This phenomenon triggered a downward ecological trajectory.

According to M.A. Sánchez-Sánchez & A. Albacete (2025), it was established that the Oaks (*Quercus L.*, *Fagaceae*) were one of the most important and diverse elements of forest ecosystems in the northern hemisphere. They were common in a wide variety of habitats, including temperate deciduous forests, subtropical and tropical savannas, cloud forests, tropical montane forests, and Mediterranean forests, as per investigation conducted by J. Vieira *et al.* (2022). The deciduous oak forest in Algeria covered an area of nearly 65,000 hectares in 1990. It was mainly composed of the two species, Portuguese oak (*Quercus faginea* Lam.) and *Q. afares Pomel*. However, A. Bouandas *et al.* (2024) noted that these numbers (65,000 in 1990) should be taken with caution given the speed of degradation of the vegetation cover due in particular to fires, deforestation, and grazing, in addition to the difficulty of updating the data.

Among the 25 deciduous species representing the genus Quercus around the Mediterranean basin, Portuguese oak (*Quercus faginea* Lam.) was an endemic and threatened species of the Ibero-Maghreb region (Spain, Portugal, Morocco, Algeria, Tunisia). In order for the forest to best meet the various objectives set in terms of production, conservation, protection, and recreation, several attempts had been made to develop tools for planning growth and production. Few studies on the overall dynamics of Portuguese oak (*Quercus faginea* Lam.) populations in the face of global changes (anthropogenic and climatic) in the Algerian forest since the heavy exploitations of the 1940s posed the problem of knowledge, conservation, and evaluation of wood production (Benabdeli, 1996).

To address this knowledge gap, it was necessary to obtain quantitative evidence on the factors associated with the natural regeneration of Portuguese oak (*Quercus faginea* Lam.) in Algerian forests.

Against this background, the study aimed to assess the current structural condition and natural regeneration of Portuguese oak stands in the Saïda region of Western Algeria. The objectives were to: 1) characterise the overall diameter structure of the stands; 2) determine changes in the density of different diameter classes in relation to distance from nearby agglomerations; and 3) examine the relationship between stand diameter structure and natural regeneration through seedlings.

Materials and Methods

The research was conducted in compliance with ethical standards (Convention on Biological Diversity, 1992). The Tellian Atlas of region of Saïda is located in western Algeria and is characterised by mounts and hilly terrain. It forms part of the forested Saïda Mounts and extends for approximately 20 km west of the city of Saïda. The study area was located, according to the WGS84 (World Geodetic System 1984) geographic coordinate system, between 34.8068° and 34.9674° N latitude and between 0.1120° W and 0.1495° E longitude (Fig. 1). The site characteristics of the 4 sites areas are presented in the Table 1.

Figure 1. The study area

Source: Google Earth

Table 1. Topography and climate characteristics of study sites

	Altitude (m)	Slopes (%)	Exposure	Bioclimate	Annual precipitation (mm/year)	Average annual temperature (°C)
Djefal	1,150	20	N-W	Semi-arid, riparian forest	300	11
Makhnez	1,280	25	N	Semi-arid	350	10
Guetna	1,080	15	N-W	Semi-arid, riparian forest	300	12
Ain El Hadjer	1,000	18	N	Semi-arid	280	12.8

Source: developed by the authors

Given the area of the Saida region and the nature of the stand (a pure stand of Portuguese oak), it was opted for stratified random sampling. Circular plots of 400 m^2 were randomly established. The coordinates of each plot centre, along with altitude and orientation, were recorded using Global Positioning System (GPS). These geographic positions were subsequently mapped at a scale of 1:25,000. In total, 100 circular plots of 400 m^2 each were evenly distributed across four distance classes from the closest villages (Table 2).

Table 2. Ecological characteristics of the stations

Station	Number of Plots	Ecological characteristics
Djefal	25	Belongs to the semi-arid bioclimatic zone, with microclimates and riparian woodlands. The main species present are Aleppo pine and thuja, accompanied by maquis species such as mastic tree (*Pistacia lentiscus*), tree heath (*Erica arborea*), and rough bindweed (*Smilax aspera*).
Makhnez	25	This area shares the same bioclimatic characteristics as the previous site. The vegetation is primarily composed of *Phillyrea* and *Pistacia lentiscus*, accompanied by maquis species such as *Erica arborea* and *Olea europaea*.
Guetna	25	It shares the climatic characteristics recorded at Djefal. The main tree species include Aleppo pine and Thuja, along with maquis species such as *Pistacia lentiscus*, *Erica arborea*, and *Smilax aspera*.
Ain El Hadjer	25	This area belongs to the semi-arid bioclimatic zone. The primary species are Aleppo pine and thuja, accompanied by maquis species such as *Pistacia lentiscus*, *Olea europaea*, Kermes oak, and *Erica arborea*.

Source: developed by the authors

During data collection, the main anthropogenic variables (human and livestock pressure in relation to distance from settlements) and dendrometry characteristics were recorded. These included the density of different diameter classes, seedling density, and the diameter and height of young plants. To characterise each plot, field data sheets were prepared and completed during visits to the sampling plots. A summary of the main ecological characteristics of the study stations is presented in Table 1, Table 2 and Figure 2. During the field survey, individual dendrometry characteristics of the studied species were measured in each plot, including diameter at breast height Diameter at Breast Height (DBH), measured at 1.3 m above ground level, in cm, and total tree height (m). For each plot, mean diameter, mean height, and tree density per hectare were also calculated. To describe the current stand structure of the Portuguese oak (*Quercus faginea* Lam.) forest, tree diameters were classified into the categories proposed by B. Hasnaoui (1992), as presented in Table 3.

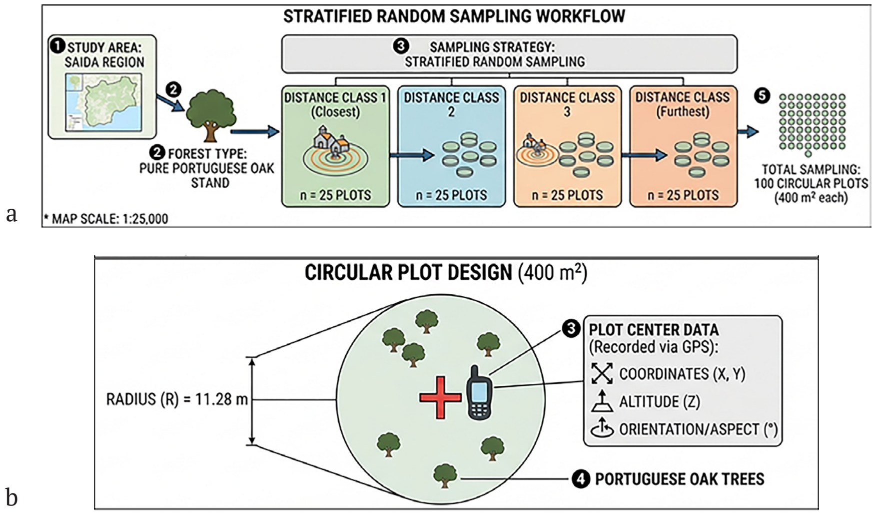


Figure 2. Graphical representation of the mechanism used

Note: a – workflow of the stratified random sampling design applied in the study area; b – layout of an individual circular sampling plot (400 , radius R = 11.28 m) and the data recorded at the plot centre using GPS

Source: developed by the authors

Table 3. Diameter classes used for to represent the diametric structure

Diameter class	Limits and stages of growth	Tree development stage
C1	<5 cm (seedlings)	Very young trees, typically established recently.
C2	5-10 cm (saplings)	Young trees; stems are becoming woodier but are still small.
C3	10-20 cm (low perches)	Reaching middle age; crown competition begins.
C4	20-30 cm (young forest)	Mature enough for light lumber or commercial harvest.
C5	⩾30 cm (old-growth forest)	Fully mature; often vital for wildlife habitats and hollows.

Source: B. Hasnaoui (1992)

To assess the influence of edaphic factors on the dynamics of the Portuguese oak forest, a soil profile was excavated at each station. A total of four profiles were excavated. At each site, two samples were collected at two distinct depths (20 cm/60 cm), for a total of eight soil samples. The physicochemical analyses focused on ten parameters: content of pH: H_2O; fine silt: FSi; coarse silt: CSi; fine sand: FS; coarse sand: CS; clay: C; organic matter: OM; total nitrogen: TN; total carbon: TC; carbon nitrogen ratio: C/N.

The standard protocol for determining soil pH in the laboratory (generally water pH) was based on the ISO 10390:2021 (2021) method (official French technical standard and International Organization for Standardization). The pH meter was first calibrated using buffer solutions (pH 7 and pH 4 for an acidic soil, or pH 7 and pH 10 for a basic soil). Then, 10 g of sieved soil was weighed into a beaker and 50 mL of distilled water was added, maintaining a 1:5 soil-to-water ratio. The suspension was stirred with a magnetic stirrer for 5 minutes to release the ions, then left to rest for at least 2 hours – although, if agitation was thorough, about 1 hour was often enough for complete sedimentation. The pH meter electrode was immersed in the middle of the suspension, avoiding contact with the sediment at the bottom, and the value was read once the display stabilizes.

To determine the OM content of a soil in the laboratory, it was used the chemical oxidation method of A. Walkley & I.A. Black (1934). First, 1 g of finely ground soil (<0.2 mm) was precisely weighed into a flask. Oxidation was then carried out by adding 10 mL of potassium dichromate followed by the addition of 20 mL of concentrated sulfuric acid, a highly exothermic reaction. The mixture was shaken and left to react for 30 minutes away from light, after which it was diluted with distilled water, a coloured indicator was added, and the excess dichromate was titrated with Mohr's salt solution until the colour changed. A blank test – the same procedure carried out in parallel without a soil sample – served as a control. Once the percentage of organic carbon was calculated using the volume of titrant used, the Van Bemmelen coefficient (1.724) was applied:

$$\%\ \text{organic matter} = \%\ \text{organic carbon} \times 1.724. \quad (1)$$

Granulometric analysis allowed determining the proportions of sand, silt, and C in the soil. In forest research, the official method was the Robinson pipette method (ISO 11277:2020, 2020), based on the sedimentation rate of particles in water (Stokes' Law). Before separating the minerals, it was necessary to eliminate the OM and the limestone that clump the particles together. First, 10 g of air-dried and 2 mm sieved soil was weighed into a large beaker. To destroy the OM, 15 to 20 mL of 30% hydrogen peroxide (H_2O_2) was added, and the mixture was heated on a hot plate until the effervescence (white foam) ended. If the soil was calcareous, the limestone was then destroyed by adding diluted hydrochloric acid (HCl) until effervescence stopped, after which the sample was washed with distilled water to remove the acid. The particles were then chemically and mechanically dispersed: 25 mL of a sodium hexametaphosphate solution ($(NaPO_3)_6$ at 50 g/L) were added as a dispersant, separating the C sheets by saturating the complex with sodium. The mixture was transferred into an airtight bottle and mechanically agitated for 6 to 12 hours (using a rotary or linear agitator) to completely destroy the micro-aggregates.

Separation then proceeded in two steps. In the first step, the sands were separated by wet sieving: the contents of the flask were poured onto a 0.05 mm (50 μm) sieve placed on a large funnel connected to a 1-L graduated cylinder, and rinsed abundantly with distilled water. The sands (particles >50 μm) remained on the sieve; they were dried in the oven at 105°C and then separated by dry sieving into CS (200 μm-2 mm) and FS (50-200 μm). The silts and C (<50 μm) passed into the test tube, whose volume was then filled to 1 L with distilled water.

In the second step, the silts and C were sampled using the Robinson pipette. The contents of the 1 L test tube were shaken with a manual agitator to homogenize the suspension, and a stopwatch was started as soon as agitation stopped. For the FSi and C, after a time calculated by Stokes' law (generally around 4 to 5 minutes depending on water temperature), the Robinson pipette was immersed to a depth of 10 cm and exactly 20 mL of liquid was taken; this was poured into a pre-weighed crucible, dried in an oven at 105°C, and the dry matter was weighed. For the C fraction alone, the test tube was left to sit undisturbed, and after 6 to 8 hours (depending on temperature), the same 20 mL collection was repeated at a depth of 10 cm, then dried at 105°C and weighed.

The determination of TN in the soil was systematically carried out using the Kjeldahl method (ISO 11261:1995, 1995), the reference method in forest research. It was based on the transformation of organic nitrogen into ammoniacal nitrogen through acid mineralization. The first stage, mineralization (digestion), destroyed the OM to release nitrogen in the form of ammonium sulfate ($(NH_4)_2SO_4$). Between 1 g (for organic-matter-rich soil) and 5 g (for sandy or deep soil) of air-dried, finely ground soil (0.2 mm sieve, or 80 mesh) was precisely weighed and placed at the bottom of a glass mineralization tube. About 5 g of catalyst mixture and 10 to 15 mL of concentrated sulfuric acid were then added, and the tubes were placed in the mineralization block and gradually heated to 360-380°C. Heating was maintained for at least 2 hours after the liquid had become clear and light green or blue-green in colour, after which the tubes were left to cool.

The second stage, distillation, transformed the ammonium ions into gaseous ammonia (NH_3), which was carried by steam and trapped. About 30 to 50 mL of distilled water was added to the cooled tube to dilute the acid, and the tube was placed in the distiller. A flask containing 25 mL of coloured boric acid (initially pink/purple) was placed under the outlet tube of the condenser to trap the ammonia. The distiller then automatically injected an excess of NaOH (about 40 to 50 mL) into the tube to make the medium strongly basic, and steam was passed for 4 to 5 minutes: the ammonia escaped, condensed, and was captured by the boric acid, which turned green/blue. Titration allowed the nitrogen trapped in the boric acid to be quantified. The receiving solution (the green Erlenmeyer flask) was titrated with a standard solution of hydrochloric acid (HCl) or sulfuric acid (H_2SO_4) at 0.01 or 0.05 mol/L, and the titration was stopped as soon as the solution turned back to its initial colour (pink/purple), with the volume of acid poured (Vsol) recorded. A blank test, following the same protocol but without soil, was conducted in parallel to record the blank volume (Vblank).

To determine the TC content of the soil, it was applied the method of automated analysis by dry combustion (ISO 10694:1995, 1995). A small amount of soil (approximately 20 to 50 mg) was precisely weighed directly into a metal capsule, which was then automatically introduced into a high-temperature furnace (1,000°C to 1,200°C) under a flow of pure oxygen. All the carbon present in the sample was instantly converted into carbon dioxide, and the gases passed through an infrared detector (NDIR: Non-Dispersive Infrared) that quantified the exact amount of carbon dioxide released. The device then displayed the percentage of TC. The C/N is an indicator of the biological quality of forest soil. It reflects the rate of decomposition of the litter and the availability of nitrogen for the regeneration of trees, in this case, oaks. It is simply obtained by dividing the percentage of Organic Carbon by the percentage of TN in soil sample:

$$C/N = \text{total organic carbon rate} / \text{/total nitrogen rate.} \qquad (2)$$

The statistical study to understand the dynamics of the evolution of diameter classes of Portuguese oak, the authors performed a linear regression using the software XLSTAT version 2020.5.1. First, the linear regression of the diameter classes of Portuguese oak was determined based on the distances closest to human settlements; second, the influence of the different diameter classes of Portuguese oak on its natural regeneration. The study applied simple linear regression to model the annual increase in circumference as a function of initial diameter, validating the fit of the Weibull distribution using the Kolmogorov-Smirnov (K-S) test. All analyses were conducted using a standard significance level of $\alpha = 0.05$.

Results and Discussion

Overall average stem structure by diameter class. Data collected from all plots by distance class, shown in Table 4, reveal that the average diameter distribution of Portuguese oak stands is predominantly represented by two classes: C1 (seedlings) and C5 (mature seed-bearing trees). For individuals in the intermediate classes C2, C3, and C4, the densities are consistently low across all distance classes. Authors' findings align with those of B. Hosnaoui (1994) and A. Aissi (2019), who noted that the diameter structure of Portuguese oak populations suggests an unsatisfactory state, marked in particular by a notable disruption in the growth of young seedlings (Table 4).

Table 4. Change in density ha-1 of each diameter class according to the distances of the nearest agglomerations

	C1	C2	C3	C4	C5	Total
D1	15	4.4	6.8	8	10.3	44.5
D2	43	5.5	7.6	10.8	15.4	82.3
D3	85	9.6	12	15	26	147.6
D4	164	14	17	24	50	269
Average	76.7	8.37	10.8	14.4	25.4	135.8

Note: Diameter class (C): C1: <5 cm; C2: 5-10 cm; C3: 10-20 cm; C4: 20-30 cm; C5: ⩾30 cm. Distance class (D): D1: Immediate/Interface 0-200 metres; D2: Proximal/Functional 200-500 metres; D3: Urban Fringe 500-2,000 metres (0.5-2 km); D4: Periphery 2,000-5,000 metres (2-5 km)
Source: cdeveloped by the authors

This pattern signals a potentially concerning future for these Portuguese oak forests. The reasons behind this condition are likely varied: some are inherent to the studied species in specific environments, some are tied to the nature and composition of the surrounding plant community, and others are shaped by direct or indirect human impact. To describe the structural and demographic characteristics of a forest stand, tree diameter is considered to be an integrating parameter. In fact, the structure and dynamics of the stand can be assessed from the distribution of tree diameters, which indirectly reflects the age distribution. The age distribution can be used to identify different states of plant populations as a function of succession and reproductive strategy, according to demographic models of population ecology (Kohyama, 1991; Kubota, 1995). Interpreting diameter distributions provides information on stand dynamics, which may correspond to different states: stable, declining or degraded (Reader *et al.*, 1995). In this sense, fitting the diameter distribution to the theoretical Weibull distribution provides a better characterisation of the structure of forest stands (Berkowitz *et al.*, 1995). This distribution is characteristic of monospecific stands, dynamic in regeneration and characterised by both C1 (seedlings) and C5 (mature trees), and is right asymmetric or positive asymmetric.

Linear regression models for different diameter classes. The density of seedlings (C1) shows a significant dependence on the distance to the nearest agglomerations ($P < 0.0001$; $R^2 = 0.91$). This correlation is expected, as there is a clear dominance of Portuguese oak seedlings in plots farther from agglomerations compared to those at closer and intermediate distances. Anthropogenic factors play a major role in the disturbance of Portuguese oak ecosystems in northern Algeria, with denser stands found further from agglomerations, while closer stands face increased grazing pressure, resulting in lower densities. The recent surge in grazing pressure has led to significant consumption of seedlings by livestock (sheep, cattle, and goats) and wild boar.

The abundance of other growth stages saplings (C2), low perches (C3), high perches (C4), and bearing trees (C5) is also significantly correlated with distance from agglomerations, with respective correlation coefficients of ($P < 0.0001$; $R^2 = 0.75$, $R^2 = 0.76$, $R^2 = 0.77$, and $R^2 = 0.8$). Plots more distant from agglomerations are denser, while areas closer to settlements are less dense. Proximity to agglomerations impacts the stability and structure of Portuguese oak populations, with more distant stands showing greater density. The denser stands are often located further from human activities, while those closer experience grazing, tree cutting, and brush clearance. The geographic position of plots relative to agglomerations significantly affects stand density, with greater distances associated with increased density.

This substantial decline in mature trees is primarily attributed to demographic pressures and illicit activities, such as firewood cutting, land clearing, and agricultural expansion. In general, grazing lands no longer meet livestock nutritional needs. Authors' findings are consistent with those of B. Jdadi *et al.* (2014), who observed that as proximity to agglomerations increases, anthropogenic pressures, compounded by population growth, lead to deforestation, overgrazing, and acorn collection. According to these studies, stand density decreases closer to agglomerations, where plots near settlements are heavily frequented by livestock (cattle, sheep, goats, etc.). O. Hasnaoui (2008) and Y. Nasrallah (2014) further demonstrated that overgrazing degrades pastoral resources, reduces vegetation cover, impedes natural seedling regeneration, and increases erosion, destabilizing the entire silvo-pastoral ecosystem.

In line with this, Y. Nasrallah (2014) reported that overgrazing rates in this forest range from 77% to 83%. The average annual decline of seed-bearing trees (C5) with increasing proximity to agglomerations is as follows: 0.75 individuals/ha/year (nearest agglomerations), 0.41 individuals/ha/year (moderately distant), and 0.12 individuals/ha/year (most distant). The annual regression rates for classes C2 and C3 also decrease from the closest to the furthest areas from agglomerations (0.16 and 0.37 individuals/ha/year, and 0.08 and 0.12 individuals/ha/year, respectively). The same study found that plot location relative to agglomerations significantly impacts stand density, with greater distances linked to higher densities (Fig. 3).

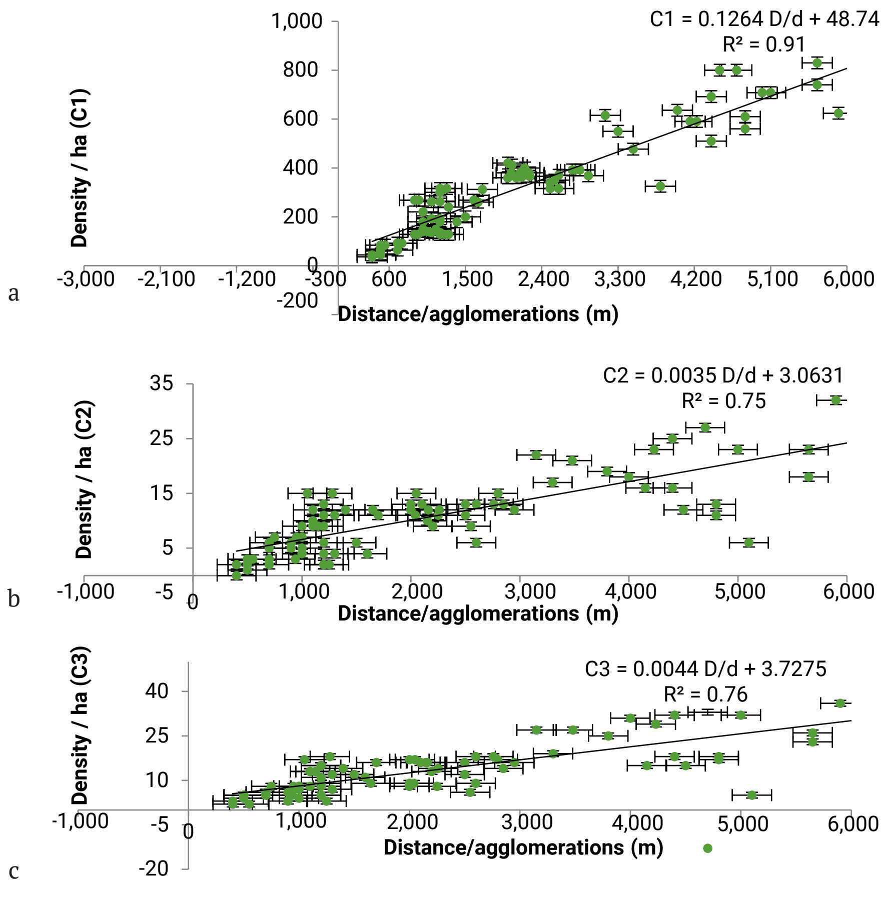
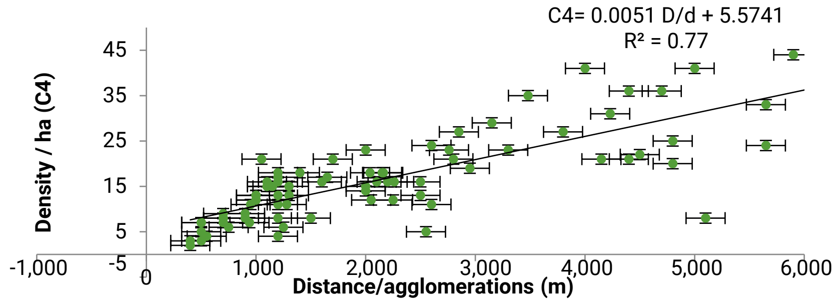


Figure 3, Continued

d



e

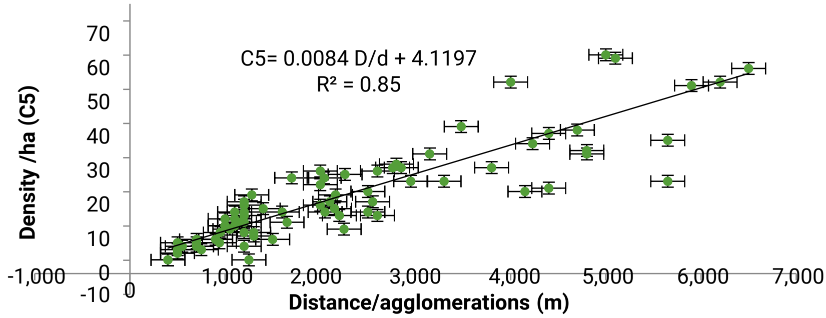


Figure 3. Evolution of the different stages of Portuguese oak according to distances from the nearest agglomerations

Note: a – seedling (C1); b – saplings (C2); c – low perches (C3); d – high perches (C4); e – mature seed-bearing trees (C5)

Source: developed by the authors

Figure 3 shows a consistent positive relationship between distance from the nearest agglomerations and the density of all diameter classes of Portuguese oak. The strongest relationship was observed for seedlings (C1; $R^2 = 0.91$, $P < 0.0001$), indicating that natural regeneration was particularly sensitive to proximity to human settlements. Significant relationships were also found for saplings (C2; $R^2 = 0.75$), low perches (C3; $R^2 = 0.76$), high perches (C4; $R^2 = 0.77$) and mature seed-bearing trees (C5; $R^2 = 0.80$); all relationships were significant at $P < 0.0001$. Thus, stand density increased with distance from agglomerations across all developmental stages, although the particularly low densities of the intermediate classes C2-C4 indicated limited transition from seedlings to mature trees.

The lower density of Portuguese oak seedlings and trees recorded near human settlements may reflect greater anthropogenic pressure in these areas. S.A. Aouadj (2021), in a study of ecological restoration in the degraded forests of the Saïda Mountains, highlighted the importance of controlling anthropogenic disturbances to support vegetation recovery. This finding is consistent with the present results, which showed increasing stand density with greater distance from nearby agglomerations. Nevertheless, because grazing intensity, tree cutting and other forms of human disturbance were not measured directly, their effects should be interpreted as possible explanations rather than confirmed causal factors.

Effect of different diameter classes on the regeneration of Portuguese oak through seeding. Regeneration is the basis of silviculture. Portuguese oak regenerates by natural seeding, stump germination and suckering, and by assisted regeneration (Messaoudene, 1989). Mature stands of Portuguese oak regenerate naturally from their own seed. In the case of assisted regeneration, prior selection of elite seedlings using intrinsic and extrinsic criteria and based on data collected from the plots, authors assessed the impact of diameter structure on the density of Portuguese seedlings (C1). Natural regeneration corresponds to the seedling stage, when the young plants have not yet grown beyond the herbaceous layer and are between 15 and 40 cm in height. According to Figure 4, there is a significant effect ($P < 0.001$) of different diameter classes C2 ($R^2 = 0.58$), C3 ($R^2 = 0.54$), C4 ($R^2 = 0.54$), and C5 ($R^2 = 0.68$) on seedling density (C1). The same figure generally shows that seedling numbers increase with the density of other diameter classes (C2, C3, C4, and C5) (Fig. 4).

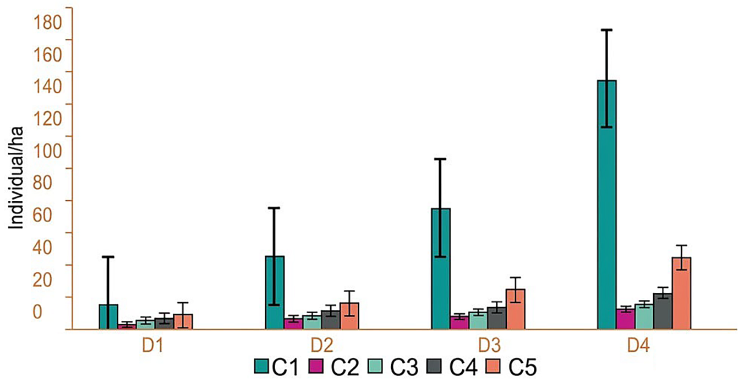


Figure 4. Distribution of Portuguese oak stems by each diameter class as a function of distances from metropolitan area

Source: developed by the authors

According to Figure 4, the average distribution of the diameter classes of Portuguese oak stands in Saida region was dominated by 2 classes seedlings C1 and seed trees) C5. Regarding individuals belonging to each intermediate classes C2, C3 and C4, the average numbers of individuals are low for all the distance classes. Low densities in classes C2, C3, C4, and C5 reflect challenges faced by the Portuguese oak ecosystem in naturally regenerating through seedlings (Fig. 5).

Indeed, these low densities across different diameter classes result from the interplay between orographic factors (slope, altitude, and exposure) and anthropogenic factors (proximity to the nearest agglomerations). It is evident that germination and seedling establishment are considerably hindered by human activities and livestock, with the cutting of both underbrush and trees for various uses, such as firewood and charcoal production. A. Letreuch-Belarouci *et al.* (2009) demonstrated that excessive pruning has been damaging, as over-pruning weakens trees, making them more susceptible to drought and disease. Furthermore, significant thinning of tree canopies allows light-demanding species to invade the understory, degrading the Portuguese oak ecosystem. Y. Nasrallah (2014) observed that selective grazing by livestock tends to eliminate more palatable flora in favour of toxic and unpalatable species, leading to an imbalance in vegetation structure and hindering natural regeneration through seedlings.

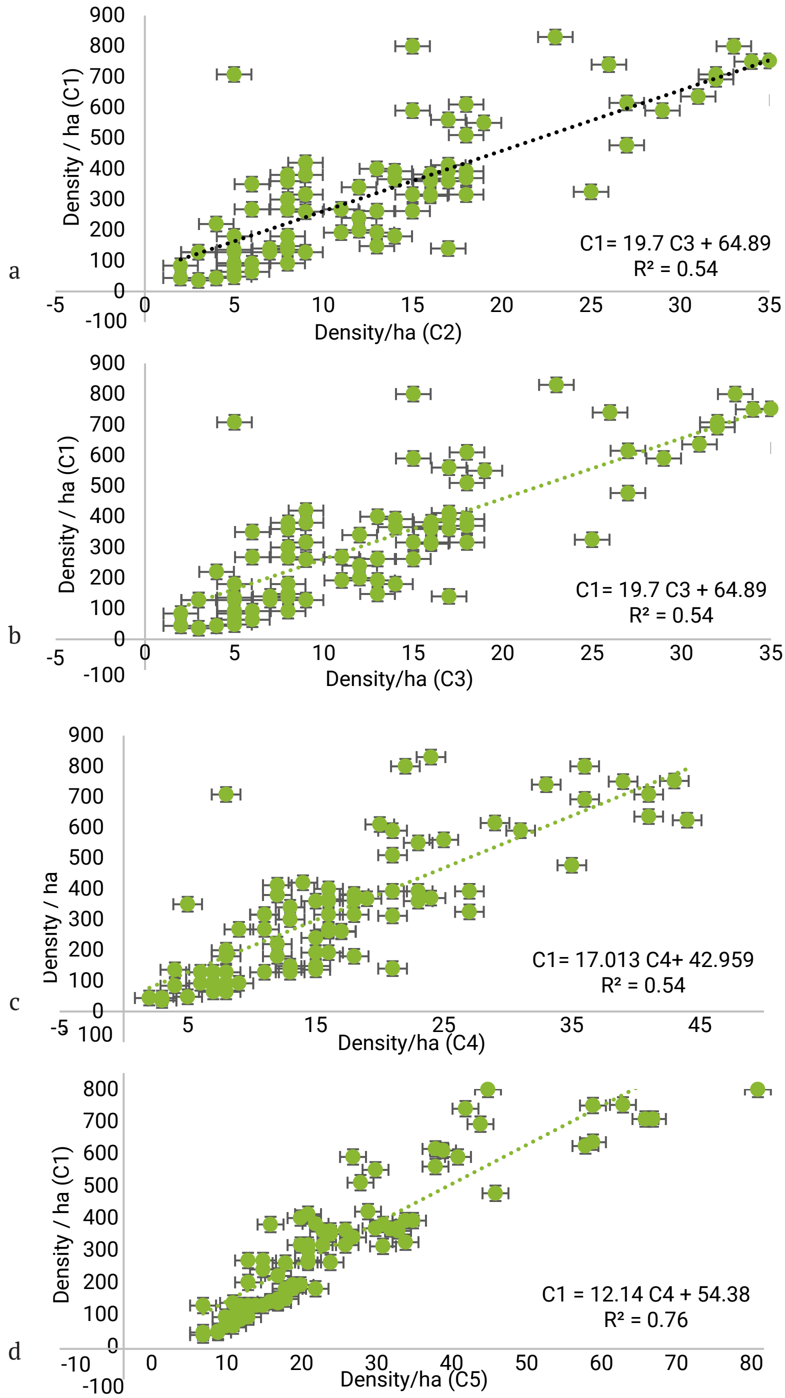


Figure 5. Influence of diameter classes on natural regeneration by seedlings of Portuguese oak
Note: a – effect of saplings (C2); on seedling density (C1); b – effect of low perches (C3) on seedling density (C1); c – effect of high perches (C4) on seedling density (C1); d – effect of mature seed-bearing trees (C5) on seedling density (C1)
Source: developed by the authors

Ecologically, the observed aggregation of trees can be explained either by variation or heterogeneity in environmental characteristics, or by genetic characteristics and behaviour of organisms of the same species, which often tend to group (Dale, 1999; Dajoz, 2006). In the open forest of Saida, the aggregated pattern of spatial distribution of trees can be explained by variations in soil characteristics. The soil is stony on the hilltops, whereas it is relatively deep and fine on the flanks and towards the shallows. In addition, the spatial structure determines the local environment surrounding each tree (in particular the number of neighbours) and thus its growing conditions. This local environment can lead to local monospecific composition (Barot *et al.*, 1999a; Barot *et al.*, 1999b) by modifying the expression of natural processes such as stand growth, mortality and regeneration. This trend is confirmed for the Saida open forest.

M.R.T. Dale (1999), R. Dajoz (2006) and S. Barot *et al.* (1999a; 1999b) state that density is a particularly important concept in forest management because it is an indication of the degree of stand occupancy. In the case of the Saida open forest, the fact that there is a balance in terms of natural regeneration means that there is no need to introduce other species for reforestation. Furthermore, the density of 50 trees/ha is within the range known for Africa (Sonké, 1998). However, the density of trees observed in the Saida open forest indicates that there is intense competition between these trees for resources. More information about the future of this ecosystem is provided by the behaviour of the juvenile stage of the Saida open forest. Regenerating a species depends on the density and spatial distribution of individuals (Dubourdieu, 1997). The predominance of seedlings in the Saida forest is therefore a sign of balanced regeneration. This conclusion confirmed the observations of Y. Kubota (1995), R.J. Reader *et al.* (1995) and A.R. Berkowitz *et al.* (1995).

Analysis of soil samples collected in the 4 sites. To characterise the edaphic conditions associated with Portuguese oak stands, soil samples collected from the four study sites were analysed at two depths: 0-20 cm and 20-60 cm. The analysis covered the principal physicochemical properties of the soil, including pH, particle-size distribution, TC, TN, OM content and the C/N. Comparing the surface and deeper horizons made it possible to identify both spatial differences among the study sites and vertical changes in soil properties. The results of the soil analyses are presented in Table 5.

Table 5. Analysis of soil samples collected in the 4 sites

Site		pH H_2O	Particle size fractions (%)					% of CT	% of NT	% of MO	C/N
			CS	FS	CSi	FSi	C				
Djefal	S_1(0-20 cm)	5.9	30	32	8.1	9	20.9	0.7	10	13	4.5
	S_2(0-60 cm)	5.1	24	5.5	2.2	2.2	66.1	0.4	7	9.5	2.2
El Makhnez	S_1(0-20 cm)	5.6	11.5	47	12.6	12.8	10.5	0.8	11	12	5.3
	S_2(0-60 cm)	5.3	23	38	11.9	12.8	09	0.5	6	10	3.1
Guetna	S_1(0-20 cm)	6.3	13	22	22	23	13.7	0.8	10	13	5.2
	S_2(0-60 cm)	5.4	18	09	20	21	26.6	0.4	5	13	4.3
Ain El Hadjer	S_1(0-20 cm)	6.1	30	40	8	8	7.9	0.4	9	16	6.4
	S_2(0-60 cm)	5	26	8	4	5	52	0.2	4	14	4.1

Note: S; C/N; CS; NT; FS; CSi; OM; FSi; CT; C
Source: developed by the authors

The table presents the physicochemical properties of soil samples collected from four distinct study sites (Djefal, El Makhnez, Guetna, and Ain El Hadjer) at two different depths: S_1: (0-0 cm, surface horizon) and S_2: (20-60 cm, deep horizon). The parameters analysed include pH, texture (grain size fractions) and C/N, and OM content. The socio-environmental and physico-chemical analyses reveal significant structural variations among the four studied sites, as well as a marked vertical stratification between the surface S_1 and deeper S_2 horizons (Table 5). Overall, soil pH H_2O ranges from 5.0 to 6.3, indicating an acidic to moderately acidic environment. Across all monitored sites, a systematic acidification of the soil matrix occurs with increasing depth. This trend is particularly pronounced at Ain El Hadjer, where the pH drops by 1.1 units from the surface to the lower horizon. This vertical decrease reflects the leaching of exchangeable bases Ca^{+2} and Mg^{+2} driven by water percolation, combined with the potential buffering effect of OM accumulated in the upper layer. Regarding particle size distribution, the soil texture fractions highlight two distinct pedogenetic behaviours: an intense illuviation process characterises the Djefal and Ain El Hadjer sites. The dramatic increase in C content at depth reaching 66.1% and 52.0%, respectively demonstrates the downward migration of colloids, strongly suggesting the development of a diagnostic argillic B_t accumulation horizon. Conversely, the El Makhnez and Guetna sites display more balanced, loamy-sandy profiles. El Makhnez is notably characterised by a high proportion of FS (47.0% at the surface), which imparts greater macroporosity to the soil but consequently elevates its vulnerability to erosion and leaching processes.

The organic component of the analysed soils exhibits highly specific characteristics. OM contents are exceptionally high for topsoils, ranging from 10.5% (El Makhnez) to 16.0% (Ain El Hadjer). Such substantial accumulation of surface biomass suggests specific environmental constraints such as low temperatures or seasonal waterlogging that restrict the overall activity of mineralizing decomposers. In line with classical pedological distribution models, a vertical decrease in OM, TC, and TN is observed across all sites. However, the most striking finding lies in the particularly low C/N, which range between 2.2 and 6.4. A C/N below the critical threshold of 8 to 10 theoretically indicates an extremely advanced stage of humification and rapid mineralization of organic nitrogen. The drastic decline of this ratio at depth (reaching a minimum of 2.2 at Djefal) reflects a near-total depletion of easily biodegradable carbon fractions in favour of a highly stable nitrogenous matrix. This configuration could be explained by a preferential accumulation of nitrogen-enriched microbial necromass in deeper horizons, or by historical exogenous nitrogen inputs that narrow the C/N baseline of the local microflora.

The soil properties recorded at the four sites differed from those reported by M. Zouidi *et al.* (2018) for arid Aleppo pine forests in western Algeria. M. Zouidi *et al.* (2018) identified predominantly sandy soils with an alkaline pH above 8, whereas the soils examined in the present study were acidic to moderately acidic and displayed greater textural variation among the sampling sites and soil depths. These differences may be related to forest composition, parent material, topographic position and local climatic conditions, demonstrating that soil characteristics reported for arid coniferous forests cannot be directly extrapolated to Portuguese oak stands in the Saïda region.

The higher OM content observed in the surface horizons may be associated with the accumulation and decomposition of plant litter and the greater concentration of fine roots near the soil surface. At Djefal and Aïn El Hadjer, the increase in C content in the deeper horizons indicated pronounced vertical differentiation of the soil profiles. Such differences in soil texture may affect water retention, aeration and root penetration, thereby creating different conditions for the establishment and subsequent development of Portuguese oak seedlings. J. Vieira *et al.* (2022) showed that environmental conditions influenced seasonal and daily stem-diameter variation in Portuguese oak, confirming the sensitivity of this species to changes in resource availability. The observed spatial variation in soil properties may therefore be among the factors contributing to differences in stand growth and regeneration, although this relationship requires further statistical assessment.

The identified soil heterogeneity should also be considered when planning the restoration of degraded stands. S.A. Aouadj (2021), based on research conducted in the forests of the Saïda Mountains, highlighted the importance of adapting restoration measures to the ecological characteristics of individual sites. Accordingly, the management of Portuguese oak stands should take into account not only their distance from human settlements and exposure to anthropogenic pressure but also local soil acidity, texture and OM content. Site-specific assessment may therefore improve the selection of areas suitable for natural regeneration, protection or assisted restoration.

The sustainable management of natural areas relies on a careful balance between pastoral use, the preservation of flora, and the rehabilitation of degraded land. Optimizing grazing requires the implementation of a methodical rotation of plots. Dividing the land into several enclosures allows the vegetation to regenerate after each grazing period. This approach must be coupled with strict control of stocking rates limiting the number of animals per hectare to prevent overgrazing and destructive soil compaction. Furthermore, regularly moving watering points and adhering to a seasonal schedule that excludes livestock at the onset of the rains ensure an even distribution of grazing pressure and sustain the regrowth of herbaceous vegetation.

Conclusions

The diameter-structure analysis of the Portuguese oak forest showed the dominance of seedlings (76.7 individuals/ha) and mature seed-bearing trees (25.4 individuals/ha**)**, while saplings (8.37 individuals/ha)**,** low perches (10.8 individuals/ha) and high perches (14.4 individuals/ha**)** were less abundant. Lower densities of all diameter classes were recorded near agglomerations, which may reflect greater anthropogenic pressure, including overgrazing. However, the effects of individual anthropogenic factors were not measured directly. Natural regeneration was present, but the low abundance of intermediate diameter classes indicated limited transition of seedlings to subsequent developmental stages. The effect of overgrazing on the density of different diameter classes is very noticeable in all the studied plots. The abundance of other growth stages saplings (C2), low perches (C3), high perches (C4), and bearing trees (C5) is also significantly correlated with distance from agglomerations, with respective correlation coefficients of ($P < 0.0001$; $R^2 = 0.75$, $R^2 = 0.76$, $R^2 = 0.77$, and $R^2 = 0.8$).

Soil analysis revealed acidic soils (pH 5 to 6.3) that became more acidic with depth, particularly at Aïn El Hadjer. The surface layer was naturally rich in carbon, nitrogen, and OM (up to 16%). These levels dropped sharply with depth, consistent with the expected biological decomposition gradient, and the resulting low C/N indicated rapid and active mineralization of OM. The Djefal and Aïn El Hadjer sites showed evidence of vertical leaching, with significant C accumulation in the deeper soil layers. The differences in soil acidity, texture and OM content indicated considerable edaphic heterogeneity among the four study sites, which should be considered when planning the protection and restoration of Portuguese oak stands. This dataset will serve as a database for the monitoring and conservation of this species. Monitoring the dynamics of Portuguese oak in the face of global changes is always continuous and ongoing. In future work authors will try to develop dendrometric equations for predicting future regeneration based on diameter classes.

Acknowledgements

The authors thank Mr. Seddiki Abdel Kader, Mr. Torchi Djamel and Mr. Kelleleche Mohamed, the officers of the Forest Conservation of Saida, for their logistical support.

Funding

None.

Conflict of Interest

None.

References

[1] Aissi, A. (2019). *Algerian small leaf oak in the Aures: Cartography, ecology and taxonomy*. (Doctoral dissertation, University of Batna 1, Batna, Algeria).

[2] Aouadj, S.A. (2021). *Impact of ecological restoration techniques on the dynamics of degraded ecosystems in the Saida mountains: Case of the forests of Doui Thabet – (Western Algeria)*. (Doctoral dissertation, Aboubakr Belkaid University, Tlemcen, Algeria).

[3] Aouadj, S.A., Nasrallah, Y., Hasnaoui, O., & Khatir, H. (2020). The rare, endemic and threatened flora of the mounts of Saida (Algeria). *Revue Agrobiologia*, 10(1), 1986-1998.

[4] Babali, B., Bouazza, N., Cherifi, K., & Hassani, F. (2025). Approach on the population dynamics of *Quercus Faginea* subsp. *Tlemcenensis* from the Moutas-Tlemcen reserve (North-West Algeria). *AIP Conference Proceedings*, 3431(1), article number 030002. doi: 10.1063/5.0291483.

[5] Barot, S., Gignoux, J., & Menaut, J.-C. (1999a). Demography of a savanna palm tree: Predictions from comprehensive spatial pattern analyses. *Ecology*, 80(6), 1987-2005. doi: 10.1890/0012-9658(1999)080[1987:DOASPT]2.0.CO;2.

[6] Barot, S., Gignoux, J., & Menaut, J.-C. (1999b). Seed shadows, survival and recruitment: How simple mechanisms lead to dynamics of population recruitment curves. *Oikos*, 86(2), 320-330. doi: 10.2307/3546449.

[7] Benabdeli, K. (1996). *Physiognomic-structural aspects and dynamics of forest ecosystems facing anthropozoogenic pressure in the Tlemcen and Dhaya Mountains*. (Doctoral thesis, University of Sidi Bel Abbès, Algeria).

[8] Berkowitz, A.R., Canham, C.D., & Kelly, V.R. (1995). Competition vs. facilitation of tree seedling growth and survival in early successional communities. *Ecology*, 76(4), 1156-1168. doi: 10.2307/1940923.

[9] Bouandas, A., Belhoucine-Guezouli, L., Oliva, F., Gaouar Semir, B.S., Bendjebbar, K., Vázquez Pardo, F.M., & Pujade-Villar, J. (2024). Morphological and taxonomic analysis of the complexes *Quercus faginea* and *Quercus canariensis* (Fagaceae) complexes in Algeria. *International Journal of Plant Biology*, 15(4), 927-943. doi: 10.3390/ijpb15040066.

[10] Convention on Biological Diversity. (1992, June). Retrieved from https://zakon.rada.gov.ua/laws/show/995_030#Text.

[11] Dajoz, R. (2006). *A concise guide to ecology* (8th ed.). Paris: Dunod.

[12] Dale, M.R.T. (1999). *Spatial pattern analysis in plant ecology*. Cambridge: Cambridge University Press. doi: 10.1017/CBO9780511612589.

[13] Dubourdieu, J. (1997). *Forest management manual: Sustainable and integrated management of forest ecosystems*. Paris: Lavoisier.

[14] Google Earth. (n.d.). Retrieved from https://earth.google.com/web.

[15] Hasnaoui, O. (2008). *Contribution to the study of dwarf palm stands in the Tlemcen region: Ecological aspects and mapping*. (Doctoral dissertation, Aboubakr Belkaïd University, Tlemcen, Algeria).

[16] Hosnaoui, F. (1994). *North Algerian oak groves ecology and regeneration*. (Doctoral thesis, University of Aix-Marseille III, Marseille, France).

[17] ISO 10390:2021. (2021). *Soil, treated biowaste and sludge – determination of pH*. Retrieved from https://www.iso.org/standard/75243.html.

[18] ISO 10694:1995. (1995). *Soil quality – determination of organic and total carbon after dry combustion (elementary analysis)*. Retrieved from https://www.iso.org/standard/18782.html.

[19] ISO 11261:1995. (1995). *Soil quality – determination of total nitrogen – modified Kjeldahl method*. Retrieved from https://www.iso.org/standard/19239.html.

[20] ISO 11277:2020. (2020). *Soil quality – determination of particle size distribution in mineral soil material – method by sieving and sedimentation*. Retrieved from https://www.iso.org/standard/69496.html.

[21] Jdadi, B., Hosnoui, A., Baussadi, F., Abbas, A., & Hosnoui, A. (2014). Dendroclimatological approach and productivity of *Quercus Afares* (Pomel) and *Quercus Canariensis* (Willd). *Annales de l'INRREF*, 19, 210-212.

[22] Kohyama, T. (1991). A functional model describing sapling growth under a tropical forest canopy. *Functional Ecology*, 5(1), 83-90. doi: 10.2307/2389558.

[23] Kubota, Y. (1995). Effects of disturbance and size structure on the regeneration process in a sub- boreal coniferous forest, northern Japan. *Ecological Research*, 10(2), 135-142. doi: 10.1007/BF02347935.

[24] Letreuch-Belarouci, A., Medjahdi, B., Letreuch-Belarouci, N., & Benabdeli, K. (2009). Floral diversity of the cork oak forests in Tlemcen National Park (Algeria). *Acta Botanica Malacitana*, 34, 77-89.

[25] Messaoudene, M. (1989). *Dendroclimatological approach and productivity of Quercus Afares (Pomel) and Quercus Canariensis (Willd) in Akfadou and Beni-Ghobri forests, Algeria*. (Doctoral dissertation, University of Aix-Marseille III, Marseille, France).

[26] Nasrallah, Y. (2014). *Characterization of the morphological variability of the 21 Algerian provenances of holm oak (Quercus rotundifolia* Lam..*), evaluation of their ecological adaptation in the semi-arid region of Saida*. (Doctoral dissertation, National Higher School of Agronomy, El Harrach, Algeria).

[27] Quezel, P., & Bonin, G. (1980). The broadleaved forests of the Mediterranean region: Their constitution ecology, present situation and prospects. Revue Forestière Française, 32(3), 253-268. doi: 10.4267/2042/21408.

[28] Reader, R.J., Bonser, S.P., Duralia, T.E., & Bricker, B.D. (1995). Interspecific variation in tree seedling establishment in canopy gaps in relation to tree density. *Journal of Vegetation Science*, 6(5), 609-614. doi: 10.2307/3236431.

[29] Sánchez-Sánchez, M.A., & Albacete, A. (2025). Distribution and dendrometry evolution of gall oak (*Quercus faginea* Lam.) forest stands in the region of Murcia (Southeastern Spain) as an indicator of climate change. *Forests*, 16(3), article number 494. doi: 10.3390/f16030494.

[30] Sonké, B. (1998). *Floristic and structural studies of the forests of the Dja Faunal Reserve (Cameroon)*. (Doctoral dissertation, Université Libre de Bruxelles, Bruxelles, Belgium).

[31] Vieira, J., Campelo, F., & Nabais, C. (2022). Environmental controls seasonal and daily cycles of stem diameter variations in the Portuguese oak (*Quercus faginea* Lambert). *Forests*, 13(2), article number 170. doi: 10.3390/f13020170.

[32] Walkley, A., & Black, I.A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science*, 37(1), 29-38. doi: 10.1097/00010694-193401000-00003.

[33] Zouidi, M., Borsali, A.H., Allam, A., & Gros, R. (2018). Characterization of coniferous forest soils in the arid zone. *Forestry Studies*, 68(1), 64-74. doi: 10.2478/fsmu-2018-0006.

Динаміка природного поновлення в ендемічному та охоронюваному лісі португальського дуба на заході Алжиру

Сід Ахмед Ауадж
Доктор філософії з екології та довкілля, викладач
Релізанський університет Ахмеда Забани
48000, квартал Бурмадія, м. Релізан, Алжир
https://orcid.org/0000-0002-5081-5844

Мохамед Зуїді
Доктор філософії з екології та довкілля, викладач
Дослідницький центр з питань облаштування території
25000, кампус Зуагі Сліман, шосе Айн-ель-Бей, м. Константіна, Алжир
https://orcid.org/0000-0001-5790-9598

Хадж Хабіб Хуарі
Доктор філософії з екології та довкілля, викладач
Релізанський університет Ахмеда Забани
48000, квартал Бурмадія, м. Релізан, Алжир
https://orcid.org/0009-0003-9131-6886

Белгасем Нуар
Доктор філософії з екології та довкілля, викладач
Релізанський університет Ахмеда Забани
48000, квартал Бурмадія, м. Релізан, Алжир
https://orcid.org/0000-0002-3502-127X

Хаджер Бекхедда
Доктор філософії з екотоксикології, викладач
Релізанський університет Ахмеда Забани
48000, квартал Бурмадія, м. Релізан, Алжир
https://orcid.org/0009-0000-3019-6233

Анотація. Незважаючи на екологічне та лісівниче значення португальського дуба (*Quercus faginea* Lam.) у Північній Африці, динаміка його популяцій в умовах зростаючого антропогенного тиску залишається недостатньо вивченою, що обмежує можливості науково обґрунтованого планування природоохоронних заходів. Метою цього дослідження була оцінка сучасного стану екосистеми португальського дуба та вивчення впливу близькості до людських поселень і діаметральної структури деревостану на природне поновлення, а також характеристика фізико-хімічних властивостей ґрунтів на досліджуваних ділянках. У дослідженні застосовано стратифіковану випадкову вибірку на основі 100 кругових пробних ділянок площею 400 м², розподілених за заздалегідь визначеними класами відстані. Результати показали, що відстань до найближчих населених пунктів суттєво впливає на густоту деревостану у всіх діаметральних класах. Коефіцієнти детермінації коливалися від 0,75 до 0,91, що свідчить про те, що відстань до людських поселень пояснює значну частку варіації густоти дерев різних діаметральних класів. Густота деревостану зростала зі збільшенням відстані від населених пунктів, при цьому переважали сіянці та зрілі насіннєносні дерева, тоді як проміжні діаметральні класи були представлені слабко. Було також встановлено зв'язок природного поновлення (через сіянці) з діаметральною структурою: густота сіянців зростала зі збільшенням густоти дерев інших діаметральних класів, при значеннях R^2 від 0,54 до 0,68. Показник pH ґрунту коливався від 5,0 до 6,3 і, як правило, знижувався з глибиною. Поверхневі горизонти містили вищі рівні органічної речовини, вуглецю та азоту, тоді як накопичення глини у глибших горизонтах було особливо помітним на ділянках Джефаль та Айн-ель-Хаджер. Отримані результати підкреслюють вразливість екосистеми португальського дуба до антропогенного тиску та вказують на необхідність відповідних заходів з охорони та відновлення, зокрема захисту природного поновлення та зниження тиску випасу худоби поблизу населених пунктів. Це дослідження може слугувати базовим орієнтиром для моніторингу динаміки та змін рослинності, а також для планування охорони та відновлення насаджень португальського дуба

Ключові слова: діаметральні класи; відстань; густота сіянців; близькість до людини; антропогенний тиск