Floristic and ecological value of the cork oak forest of Mzirâa (El Kala, North-East of Algeria)

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Keywords: Cork oak forest, cartography, floristic dynamics, ecological conditions, conservation, sustainable Mediterranean ecosystem, north-eastern Algeria

Abstract: The persistence and variety of anthropogenic factors have only accelerated the degradation process of Mediterranean forests. This study focuses on the cork oak forest of Mzirâa located northwest of El Kala in northeastern Algeria. The objective of this study is to evaluate the ecological status (floristic composition and vegetation structure) of the flora in selected areas of the Mzirâa forest. The study is based on the development of a floristic matrix using a systematic sampling method in each study locality. The findings revealed a regressive spatio-temporal dynamism of the flora and vegetation of the forest. In addition, a floristic dynamics and analysis using NDVI for the study area indicated that there is rapid degradation of the Mzirâa forest. This implies that the forest is under serious ecological threats and needs urgent management strategies to protect the forest from further degradation. This study provides crucial information for researchers, policymakers, and forest protection authorities in Algeria.

Introduction

Since the 1980s, conflicts have arisen between preserving the natural characteristics of forest environments and utilizing wood and cork biomass for economic gain. The science of landscape ecology emphasizes the importance of maintaining a balance between nature and its management practices (FAO 2001).

While the rate of deforestation is slowing down, forests face pressure from climate-related stress factors, and the demand for forest products is on the rise (FAO 2024).

The biodiversity of Mediterranean forests is characterized by genetic, species-level and functional richness that should be upheld and supported through development programs (Quézel and Médail 2003). Despite this ecological value, the structure and composition of Mediterranean forest vegetation present challenges in terms of dynamics and dispersal (Quézel et al. 1980, Lacoste and Salanon 2005). The continued presence of anthropogenic factors has worsened the decline of this type of habitat (Ikermoud 2000, Abdelfettah 2014), making it essential to develop effective conservation methods. Over the years, conservation methods, and forest research approaches have evolved, due to numerous research works carried out in this field. These include quantitative and qualitative assessments of biodiversity, evaluation of spatio-temporal dynamics (Huston 1994, Jäger 2000, Gibelin and Decque 2003), studies on the diversity of ever-changing forests. The forest is never static; it functions like a living organism is in a constant evolution (Véla 1998); thus, the state of habitat stratification has an impact on the taxonomic and functional diversity of the flora and fauna of the undergrowth (Naumburg and De Wald 1999, Van Pelt and Franklin 2000, de Coignac 2001, Vennetier 2002, BNEDER 2009).

The Algerian forests cover approximately 4 million ha, which is less than 2% of the country's surface area. However, due to the degradation of this forest ecosystem by repeated fires, overgrazing and agricultural exploitation; only 1.4 million ha are actual forested land, with the rest mainly being scrubland (DGF 2020). The sites of these forests vary greatly; they are often of irregular characteristics, with trees of varying sizes and ages, dense undergrowth that limits visibility and accessibility, and conditions that favor the spread of fires.

The forest of Mzirâa, a cork forest located in the center of the National Park of El Kala (north-east of Algeria) one of the Mediterranean basin's hotspots (Véla and Benhouhou 2007) with a high level of endemism (Sakhraoui et al. 2020), is considered a typical example of Mediterranean forests that often face a high risk of devastating fires. This risk is largely associated with prolonged dry and hot periods due to climate change as well as increasing anthropogenic pressures, such as: fires; overgrazing; logging and the exploitation of forest clearings for agriculture. In this context, this study was conducted, with the main objective of analyzing the floristic diversity and the structure of vegetation of the Mzirâa cork oak forest and the pressures acting upon it, with a focus on assessing the ecological status of its flora.

Material and Methods

Characterization and geographic location of the study area

The study area (forest of Mzirâa) is located in the El Kala National Park in the district of El Tarf (North-Eastern Algeria) near the border with Tunisia (Figure 1). It belongs to the floristic sub-sector of Numidia (K3) previously identified by Quézel and Santa (1962-1963). According to Emberger's climagram (1955), the El-Kala region is situated within the sub-humid bioclimatic zone with warm winters, on the border with the humid zone. However, the topography largely determines the existence of sub-zones, which in turn influence the physiognomic diversity of the habitats. Thus, from the coast to the Medjerda forest massif, three bioclimatic zones can be distinguished: the sub-humid zone with warm winters; the humid zone with warm to temperate winters; and the humid zone with temperate to cool winters.

The area of Mzirâa embodies a mosaic of vegetation varying from maritime pine (*Pinus pinaster* subsp. *pinaster* Ait.) stands/groves on the coastal dunes to cork oak

(*Quercus suber* L.) groves on the Numidian sandstone, located northwest of the town of El Kala. The forest of Mzirâa stretches over an area of 158.35 ha with a state-owned legal status. It belongs to the Mzirâa region, approximately 5 km away from the new port of El Kala. It extends between 8°23′46.7′′ and 8°23′10.1′′ East longitude and from 36°54′39.1′′ to 36°54′24.5′′ North latitude. It is geographically limited to the North by the Mediterranean Sea, to the South-East by Lake Oubéira and to the West by Lake Mellah and Blue Lake. In the study area, eight localities were selected with similar physical characteristics and topography, but with different vegetation structures. These localities are spread out across 4 sites spaced approximately 1 km apart. Each site comprises two localities, one at low altitude and one at high altitude (Table 1).

Table 1. Geographical coordinates of the eight study localities

1. táblázat. A nyolc vizsgálati helyszín földrajzi koordinátái

Study area: Mzirâa cork oak forest				
	Site 1	**Site 2**	**Site 3**	**Site 4**
Low altitude localities	A1: 70 m 36°54'45.27"N, 8°22'28.63"E	A2: 67 m 36°54'45.78"N, 8°22'26.35"E	A3: 73 m 36°54'44.39"N, 36°54'44.39"E	A4: 78 m 36°54'43.57"N, 8°22'16.49"E
High altitude localities	B1: 93 m 36°54'39.38"N, 8°22'28.83"E	B2: 85 m 36°54'43.39"N, 8°22'26.17"E	B3: 85 m 36°54'42.87"N, 8°22'23.36"E	B4: 86 m 36°54'41.36"N, 8°22'16.74"E

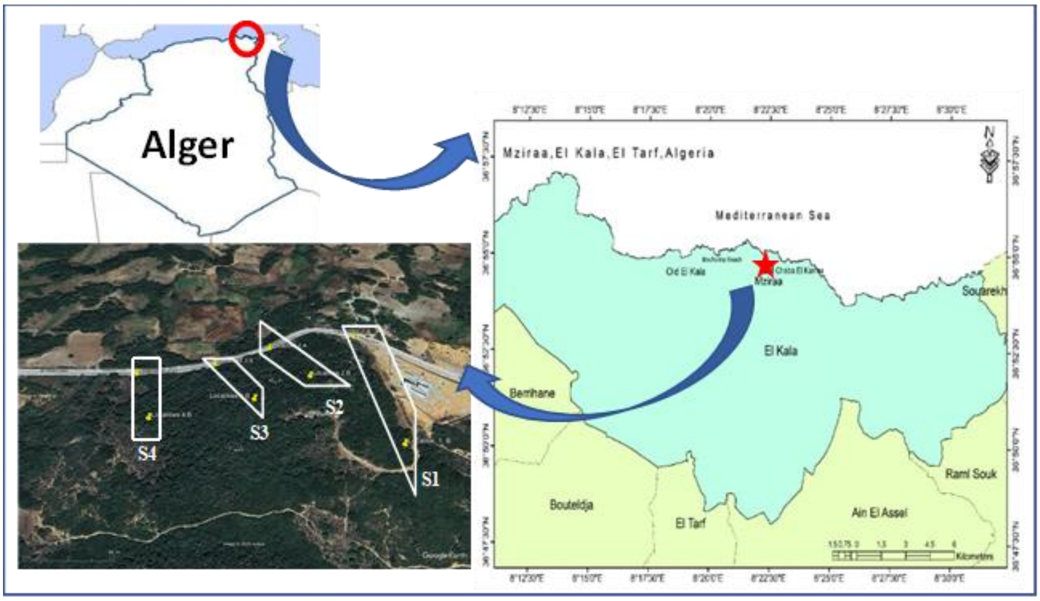

Figure 1. Location map of study area and geographical position of study sites (S1, S2, S3, S4) and localities

1. ábra. A vizsgálati terület térképe és a mintaterületek (S1, S2, S3, S4), valamint a vizsgálati helyszínek földrajzi elhelyezkedése

Study method and sampling

To evaluate the current state of floral diversity in the Mzirâa cork oak forest, a simple random sampling method was used for the initial survey, combined with systematic sampling within each survey. Each transect is represented by a series of surveys, each covering 25 m^2; there is a 5 m gap between each survey. This involved a series of transects, with four at low altitude and four parallel transects at high altitude. Each transect required several surveys.

A total of 84 surveys were conducted between 2020 and 2023 at the eight localities. Each site was the subject of a series of studies during which a systematic inventory of the flora was carried out and ecological indicators such as vegetation density, taxonomic diversity and the relative species frequency index, the stratification, the biological type, the biogeographical origin of the inventoried flora and the spatio-temporal dynamics of this flora were assessed. Field data collected during this time period, were used to create a matrix, focusing on parameters like changes in floristic richness, dominance-abundance, frequency of occurrence of the inventoried taxa, taxonomic diversity, uniformity, the vegetation stratification of the habitat, and phytoecological structure (Frontier and Pichod-Viale 1991).

Plant species were identified using Algerian and North African floras (Quézel and Santa 1962–1963, Maire 1952–1987). The nomenclature was updated according to Dobignard and Chatelain (2010–2013) and Euro+Med PlantBase (2024).

The level of endemism was deduced from the geographical distribution of taxa, verified in Euro+Med PlantBase (2024) and POWO (2024).

To assess the ecological state of the forest, alpha diversity was calculated as a parameter of habitat composition and structure using Shannon and Weaver H′ index. In addition, we evaluated equitability E to detect changes in the structure and balance of the plant community in our case study (Daget 1989, Frontier and Pichod-Viale 1991).

Normalized difference vegetation index Landsat (NDVI)

Normalized Vegetation Index (NDVI) is used to quantify the greenness of vegetation and is useful for understanding vegetation density and assessing changes in plant health (Kahli et al. 2018, García Cárdenas et al. 2019).

Very low NDVI values (≤ 0.1) correspond to barren rock, sand or snow surfaces. Moderate values (0.2 to 0.3) represent shrubland and grassland, while high values (0.6 to 0.8) indicate forests. To calculate the NDVI, we used the reflectance of the red (R) and near-infrared (NIR) channels measured in the visible band by sensors on board drones or satellites (Abdi 2013, Tagesson et al. 2017), ranging from 0.1 to 0.5 for sparse vegetation and from 0.6 to above for dense green vegetation (Kurnaz et al. 2020).

Correspondence Analysis (CA), also known as Simple Correspondence Analysis, is an exploratory method for analyzing contingency tables (Dagnelie 1975, Godron et al. 1983). During this study, the analysis was based on a matrix of 94 rows and 42 columns for 2020 and 91 rows and 42 columns for 2023. Table 2 shows the inertia of the multi-year factors that best structure the flora inventoried during the fieldwork.

Table 2. CFA analysis method

2. táblázat. CFA elemzési módszer

DiagoRC: General program for two diagonal inner product analysis.			
Total inertia: 0.428141 (CFA Fig 8. Rows and Fig 10. B Columns)			
Num	Eigenval.	R. Iner.	R. Sum
1	+1.4849E-01	+0.3468	+0.3468
2	+4.6906E-02	+0.1096	+0.4564
3	+3.8943E-02	+0.0910	+0.5473
Total inertia: 1.49948 (CFA Fig 9. Rows and Fig 10.A. Columns)			
1	+3.6309E-01	+0.2421	+0.2421
2	1.4863E-01	+0.0991	+0.3413
3	+1.3597E-01	+0.0907	+0.4319

The structural analysis of the data was carried out using the ADE.4 programme, enabling a comparison of two configurations of Correspondence Analysis (CA). The first configuration exhibits moderate total inertia (0.428), with relatively concentrated information, as the first axis accounts for 34.68% of the variance (totalling 54.73% across three axes). Conversely, the second configuration shows a much more pronounced dispersion with an inertia of 1.499, indicating clearer structural differences between the profiles; however, this complexity makes the information more diffuse, with the first axis explaining only 24.21% of the total inertia. These indicators confirm the relevance of a multidimensional approach to interpreting the significant contrasts observed in Figures 8, 9 and 10.

Results

Phyto-ecological analysis

Specific habitat diversity

The specific diversity and equitability of the study sites indicate that the habitat exhibits a taxonomic diversity associated with a moderate distribution balance (Figure 2). This is evident considering the state of senescence that the study area has experienced since 2010, as reported by the Forest Service of El Kala National Park.

Plant stratification

The eight localities have a relatively stable stratified structure, consisting of three strata (herbaceous, shrubby and tree-lined), each with a significant floristic composition. Figure 3 illustrates the dominance in the number of the herbaceous layer throughout the entire study site. The specific richness and complexity of the shrub layer indicate the degraded state of this forest.

During the inventory, conducted from 2020 to 2023, a total of 98 taxa, belonging to 39 genera and 41 families, were identified. Each family and genus includes a group of taxa specific to the forest, clearing, or forest edge, in addition to introduced species resulting from sandification caused by forest destruction.

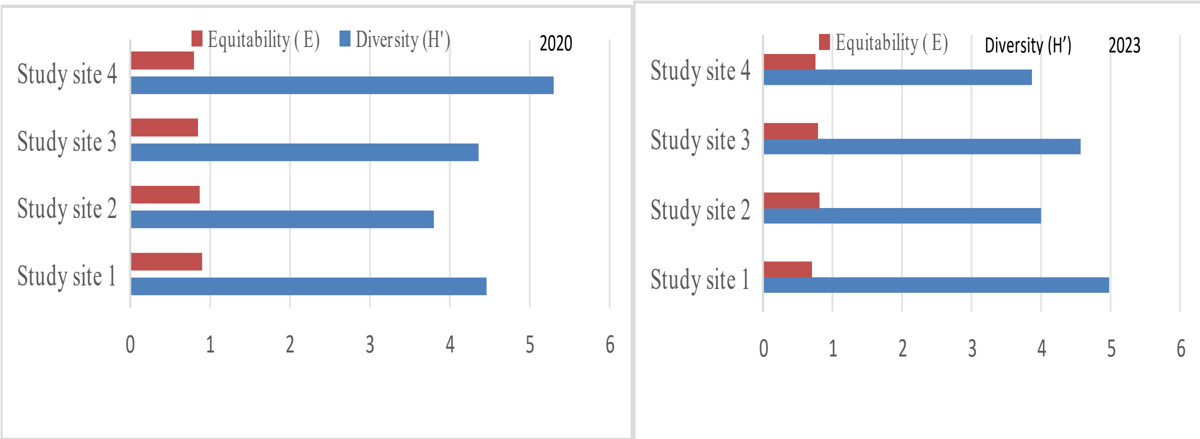

Figure 2. Study sites diversity and Equitability index

2. *ábra.* A vizsgálati helyszínek sokfélesége és egyenlőségi indexe

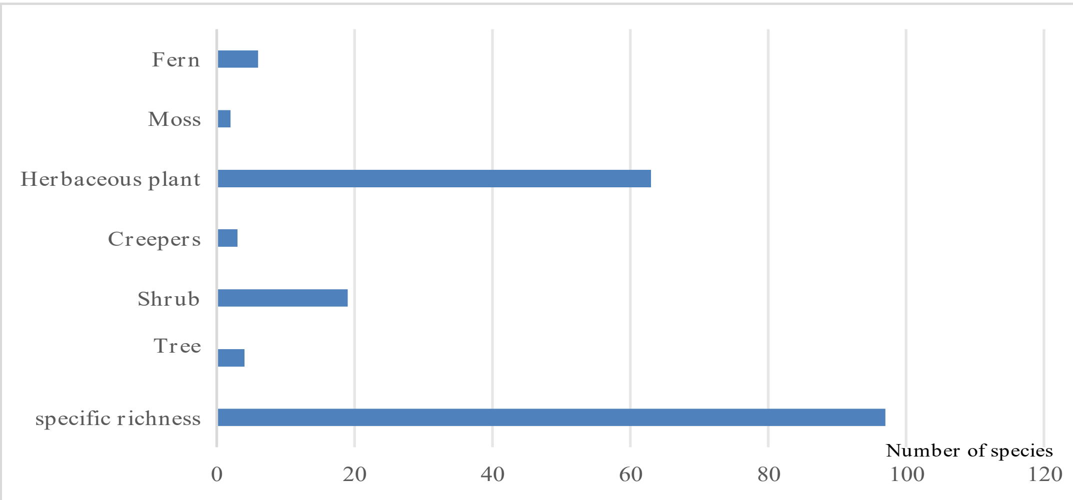

Figure 3. Floristic structure and stratification of the habitat during the sampling

3. *ábra.* Az élőhely taxonómiai szerkezete és rétegződése a mintavétel során

Floristic structure

Distribution of families

In the study area, the Asteraceae family is dominant with eight species, followed by the Geraniaceae and Poaceae with five species each. The Fabaceae, Asparagaceae, Ranunculaceae and Rubiaceae have the same species richness (4 species each). The other families encountered during the fieldwork are represented by only one to three species (Figure 4).

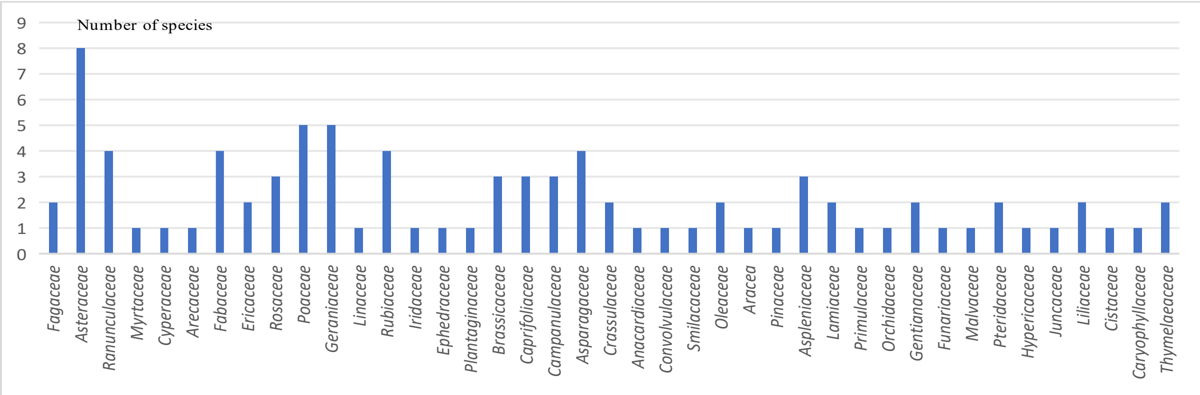

Figure 4. Number of species within the botanical families in the study area

4. ábra. A vizsgálati területen előforduló botanikai családok fajainak száma

Biogeography and endemism

The Mediterranean species predominate (43%) compared to other biogeographical origins (Figure 5). On the other hand, endemic taxa represent 13%, namely *Cyclamen africanum* Boiss. (Mor-Alg-Tun), *Arenaria cerastioides* Poir. subsp. *cerastioides* (Mor-Alg-Tun), *Gagea algeriensis* (Chabert) Batt. (Mor-Alg), *Carduus nutans* subsp. *numidicus* (Coss. & Durieu) Arènes (Alg), *Genista ferox* Poir. (Alg-Tun-Sardinia), *Genista ulicina* Spach (Mor-Alg-Tun), *Hypericum afrum* Lam. (Alg-Tun), *Linaria pinifolia* (Poir.) Thell. (Alg-Tun), *Hyacinthoides aristidis* (Coss.) Rothm. (Alg-Tun), *Solenopsis bicolor* (Batt.) Greuter & Burde (Alg-Tun), *Squilla anthericoides* (Poir.) Jord. & Fourr. (Alg) and *Thymus munbyanus* Boiss. & Reut. (Mor-Alg).

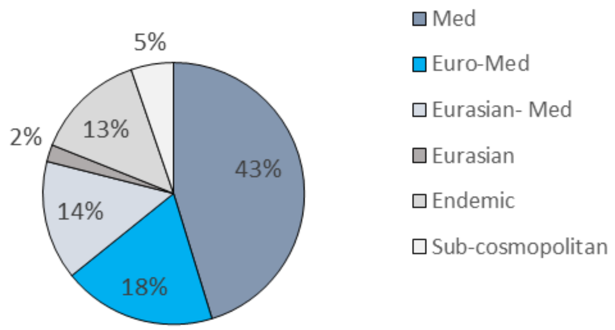

Figure 5. Biogeographical origin of plant species in the study area

5. ábra. A vizsgálati terület növényfajainak biogeográfiai eredete

Biological spectrum of flora

Therophytes have the highest rate (36%) followed by Hemicrytophytes (18,5%). On the other hand, Geophytes, Chamaephytes, Macrophanerophytes, Mesophanerophytes, Microphanerophytes, and Nanophanerophytes have the lowest rates (Figure 6). This distribution is a clear indication of forest and/or pre-forest formation in the study area.

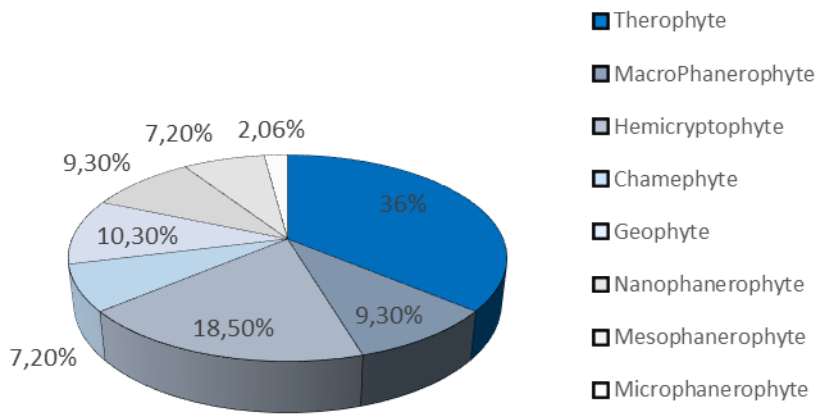

Figure 6. Biological type of plant species in the study area

6. ábra. A vizsgálati területen előforduló növényfajok biológiai típusa

Phyto-ecological analysis (CFA)

Factorial Correspondence Analysis (CFA) highlighted the spatial distribution of the species studied within a habitat, revealing a progressive or regressive evolution depending on the current state of the vegetation. In 2020, the distribution of species follows the plant groupings that make up a cork oak forest: the positive part of axis 2 groups together the edge species that accompany *Pistacia lentiscus* L.; the negative part of axis 1 groups together the co-occurring species of *Olea europaea* L.; the factorial plane groups together all the species characteristic of the undergrowth of *Quercus suber* L.

The negative side of axis 2 contains some co-associated species of *Q. coccifera* L., including the existence of *Solenopsis bicolor* a species that follows the seepage in the forest (Figure 7). The analysis revealed that 37 of the 94 taxa recorded in the field during 2020 are the most characteristic of the cork oak forest.

In 2023, this distribution is present on both sides of the factorial axes according to the rate of their contributions. The CFA separates (Figure 8) the flora of the study site into several groups according to two gradients: A gradient linked to the frequency of each species found throughout the habitat; thus, separating rare species such as *Cytisus triflorus* Lam., *Erodium botrys* (Cav.) Bertol., and *Rubus ulmifolius* Schott. from fairly common species such as *Daphne gnidium* L. and *Cistus halimifolius* L., and very common species (or taxa) from all localities such as *Calicotome villosa* (Poir.), *Crataegus oxyacantha* subsp. *oxyacanthoides* (Thuill.) Arcang., *Pistacia lentiscus* L. and *Smilax aspera* L.

A second gradient, linked to the density of vegetation for each studied locality, thus, dividing the habitat into three groups. The first group, located on the edge of the forest, consisted of a psammophilous species such as *Cistus halimifolius* L., *Linaria pinifolia* (Poir.) Thell., *Lobularia maritima* (L.) Desv., *Malcolmia ramosissima* (Desf.) Thell., and *Poa annua* L. The second group, found in forest clearings, included species like *Aira cupaniana* Guss., *Arenaria cerastioides* Poir., *Campanula dichotoma* L., *Erodium botrys* (Cav.) Bertol., *Hypericum afrum* Lam., and *Tuberaria guttata* (L.) Fourr. The final group, strictly forest-dwelling, comprised species such as *Asperula hirsuta* Desf., *Asplenium onopteris* L., *Bellis sylvestris* Cirillo, *Blackstonia perfoliata* (L.) Huds., *Geranium dissectum* L., *Polypodium cambricum* L., and *Teucrium fruticans* L.

The factorial analysis highlights a specific distribution of the surveys in the eight localities managed by the density gradient of the vegetation (Figure 8). This gradient regressively subdivides the study site into three sub-habitats: forest → clearing → edge or always in gradually three sub-habitats: edge → clearing → forest. According to Figure 9, the edge is represented by surveys n°1–4 characterized by less dense and degraded vegetation. Forest glade is represented by surveys n° 5, 6, 7, 8, 9 and 19, which characterize moderately dense vegetation whereas the forest is represented by the other surveys characterizing fairly dense vegetation (Figure 10).

As shown in Figure 10, the vegetation underwent significant physiognomic changes between 2020 and 2023. These shifts are marked by expanding clearings and the transformation of former scrublands into forest edges, reflecting an overall decline in total forest area.

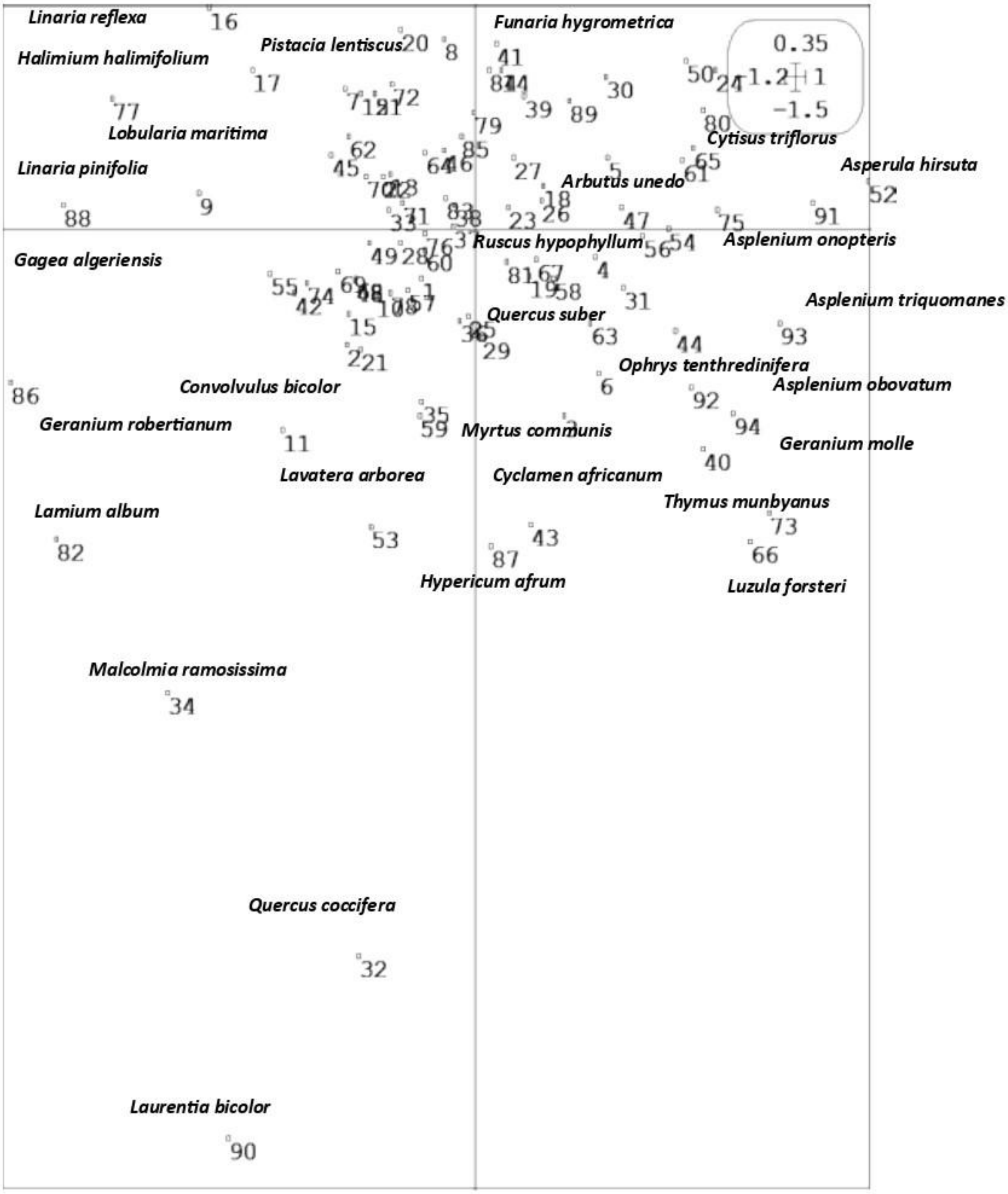

Figure 7. CFA; Axis. 1-2. Distribution of 94 species out of 84 surveys according to following factors: specific frequency and density of vegetation of each studied localities in 2020

7. ábra. CFA; 1-2. tengely: 84 felmérésből származó 94 faj eloszlása a következő tényezők szerint: a vizsgált helyszínek növényzetének fajspecifikus gyakorisága és sűrűsége 2020-ban.

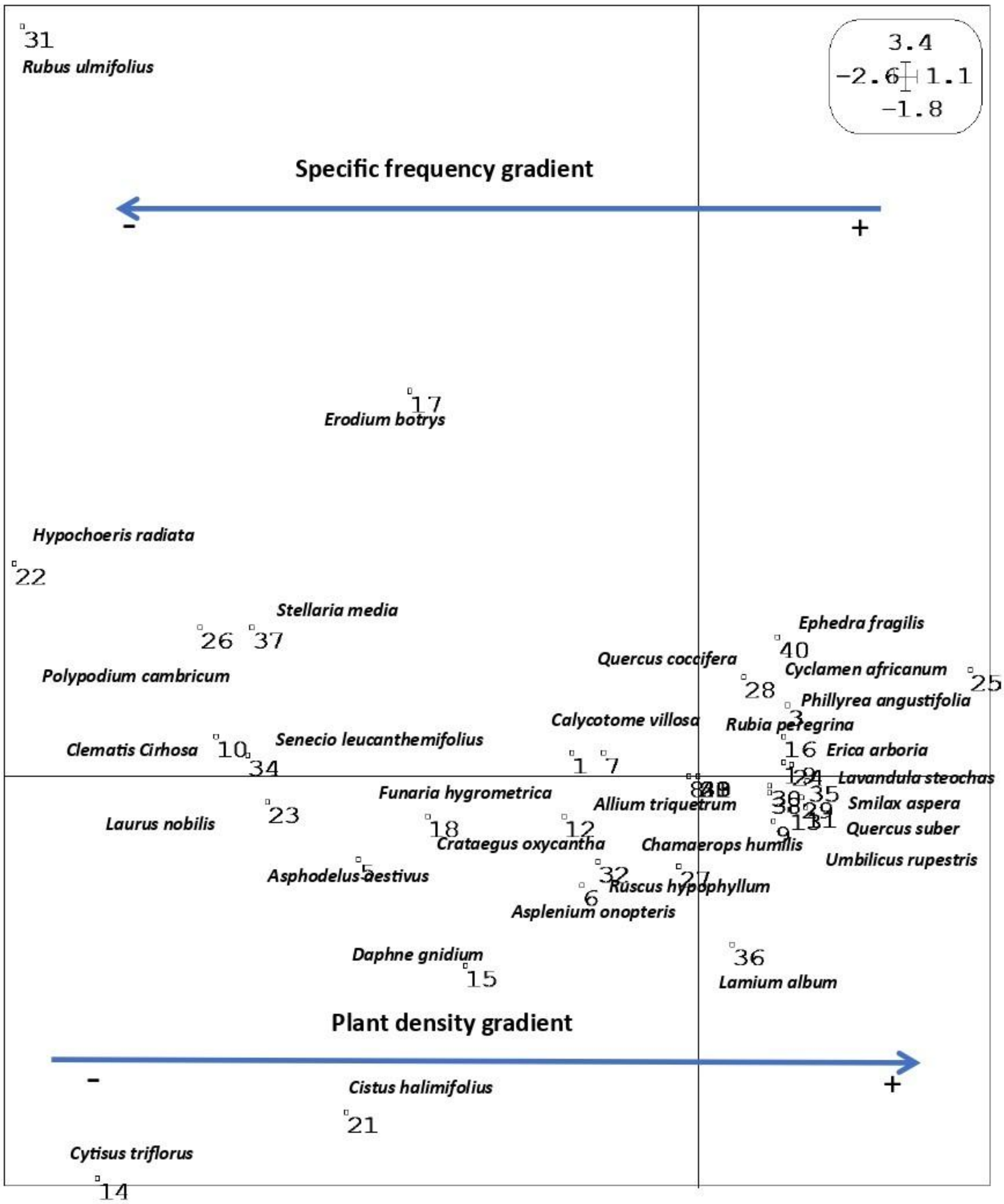

Figure 8. CFA; Axis. 1-2. Distribution of 91 species out of 84 surveys according to following factors: specific frequency and density of vegetation of each studied localities in 2023

8. ábra. CFA; T1-2 tngely: 84 felmérésből 91 faj eloszlása a következő tényezők szerint: a vizsgált helyszínek növényzetének fajspecifikus gyakorisága és sűrűsége 2023-ban

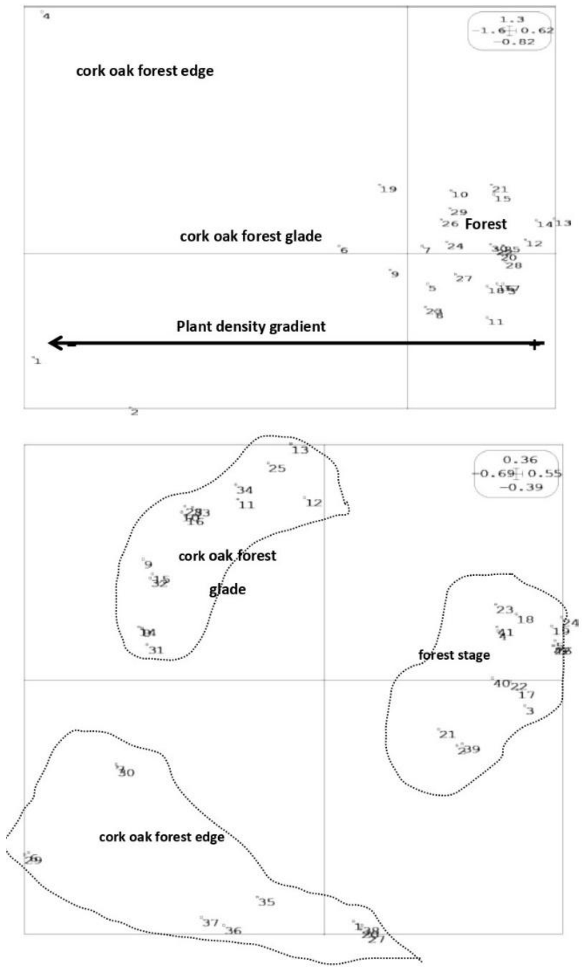

Figure 9. CFA; Vegetation physiognomy across the study area in 2020 (A) and 2023 (B)

9. ábra. CFA; A növényzet fiziognómiájaa vizsgálati területen 2020-ban (A) és 2023-ban (B).

Spatio-temporal dynamics (2020–2023)

Statistical studies on the evolution of the floristic composition of the study site between 2020 and 2023 show a regressive change in the average abundance-dominance of plant species inventoried in the field. In 2020, there were 94 species compared to 91 species in 2023 with a taxonomic composition that differed by 10% between the two sampling periods (Figure 10). The graph shows a total absence of *Arisarum vulgare* O. Targ. Tozz, *Asplenium obovatum* Viv., *Ephedra fragilis* Desf., *Luzula forsteri* (Sm.) DC., *Thymus ciliatus* L. and *Tulipa sylvestris* L. in 2023. In addition, certain species not characteristic of forest habitats, appeared in 2023, such as *Gagea algeriensis* (an endemic species with a very low presence), *Cistus halimifolius* L., and *Lamium album* L.

The variation in the frequency of occurrence of all species recorded during the field study is illustrated in Figure 10. We observe a regressive change in the frequency of forest and clearing species, while edge species and those bordering the forest on grassland have increased their frequency of occurrence within the forest. It should be noted that, in 2020, these species were rare and/or absent.

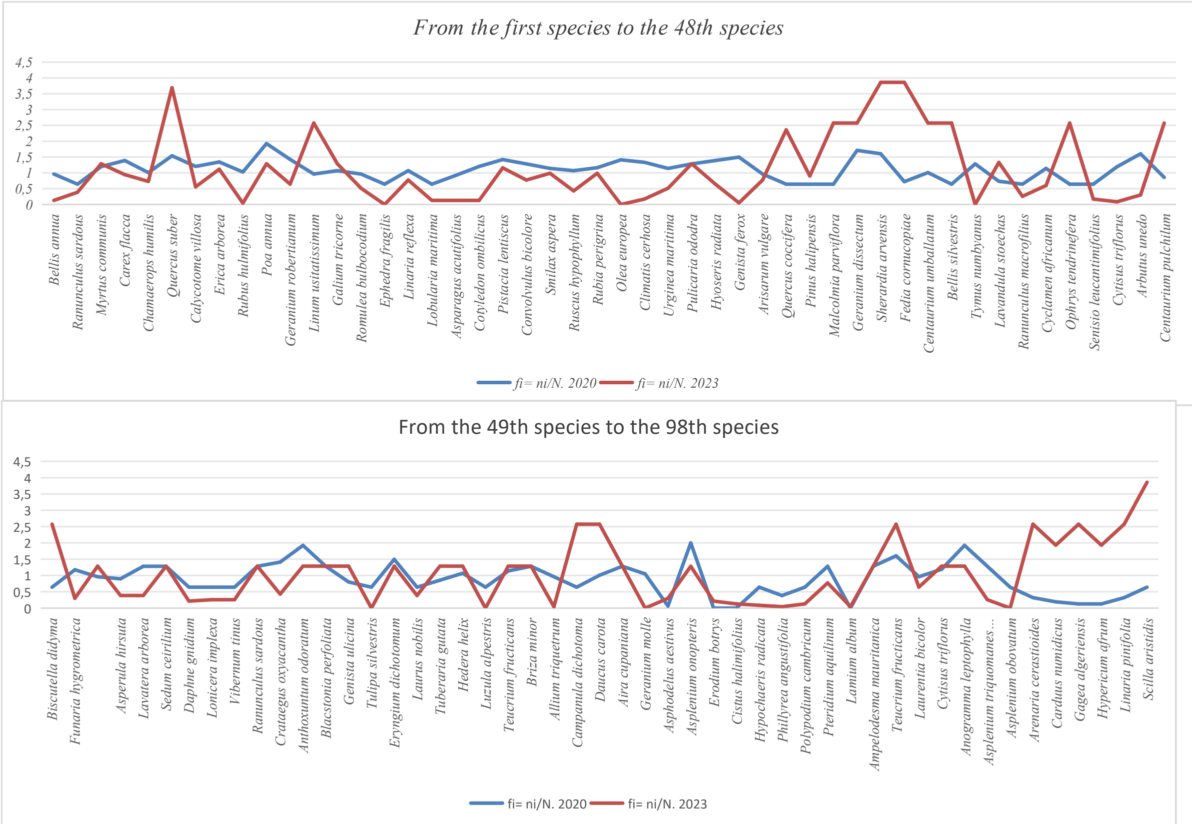

Figure 10. Spatial dynamic of plant species between 2020 and 2023

10. ábra. A növényfajok térbeli dinamikája 2020 és 2023 között

Mapping plant dynamics

The monitoring of vegetation dynamics using cartography, and the assessment of the NDVI index for the El Kala region between 2020 and 2023, clearly show a decline in vegetation density and the appearance of patches dotted with a few populations of herbaceous flora (yellow zones) (Figures 11 and 12), with an index varying between 0.19 and 0.26. Thus, the ecological data mapped for the study area clearly illustrate its degree of degradation.

Spatio-temporal cinetics mapping of the flora of the Mzirâa forest between 2020 and 2023 (Figure 11), highlights not only a decline in the density of certain shrub population characteristic of the forest habitat, such as *Arbutus unedo* L., *Chamaerops humilis* L., *Erica arborea* L., *Genista ferox* Poiret, *Myrtus communis* L. and *Pistacia lentiscus* L., but also a significant decline in the abundance of species indicating forest health, ranging up to the total absence of the population in question, such as *Asperula hirsuta* Desf., *Asplenium triquomanes* subsp. *quadrivalens* D.E.Mey., *Lonicera implexa* Aiton, and *Rubia perigrina* L. The absence of certain species was also noted, such as *Asplenium obovatum* Viv., *Luzula forsteri* (Sm.) DC., *Thymus munbyanus* Boiss, and *Tulipa sylvestris* L.

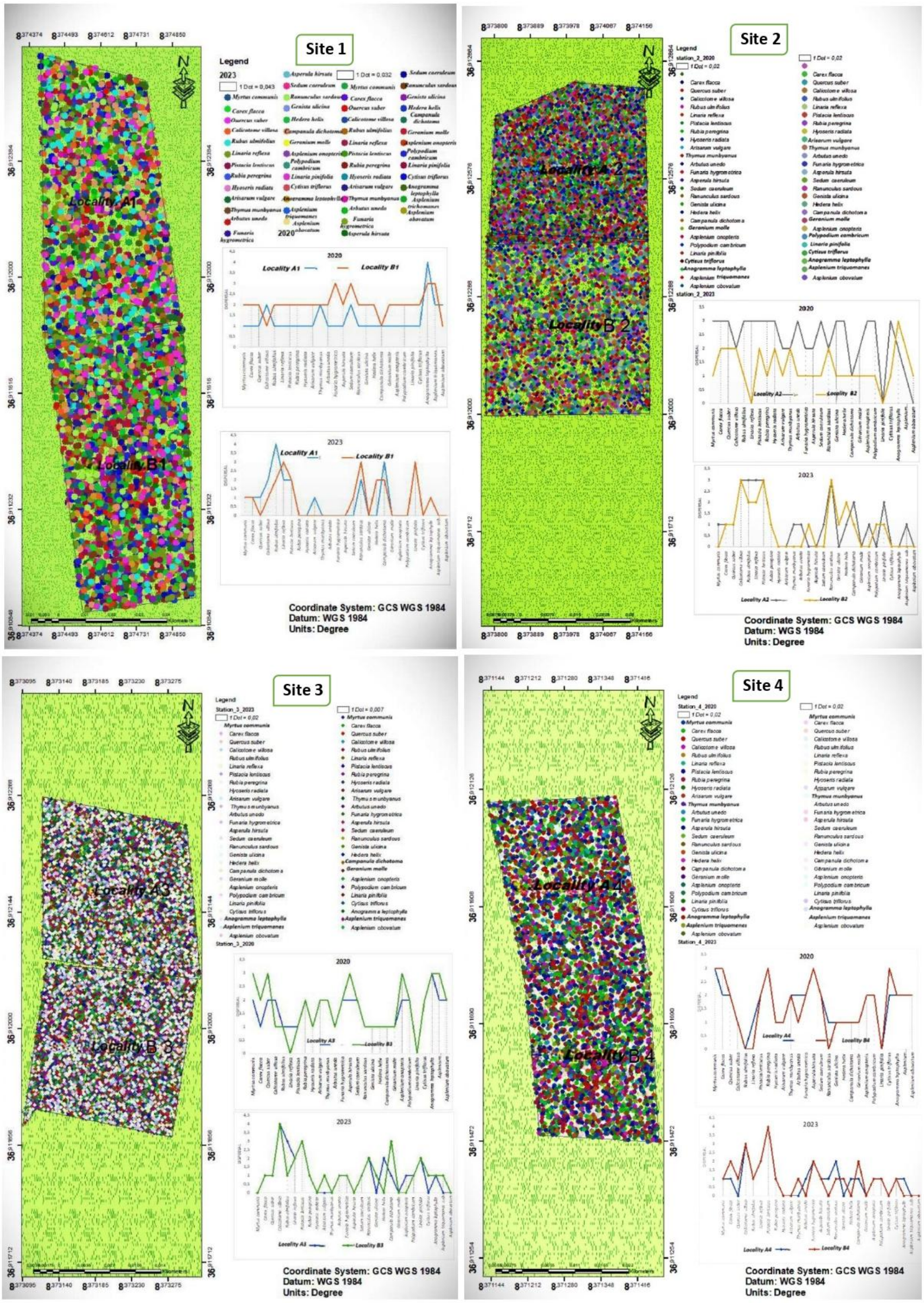

Figure 11. Mapping plant dynamics (The graphs only concern species that show variation in presence and abundance between the two sampling periods)

11. ábra. A növényi dinamika feltérképezése (A grafikonok csak azokat a fajokat érintik, amelyek jelenléte és abundanciája a két mintavételi időszak között eltérést mutat.)

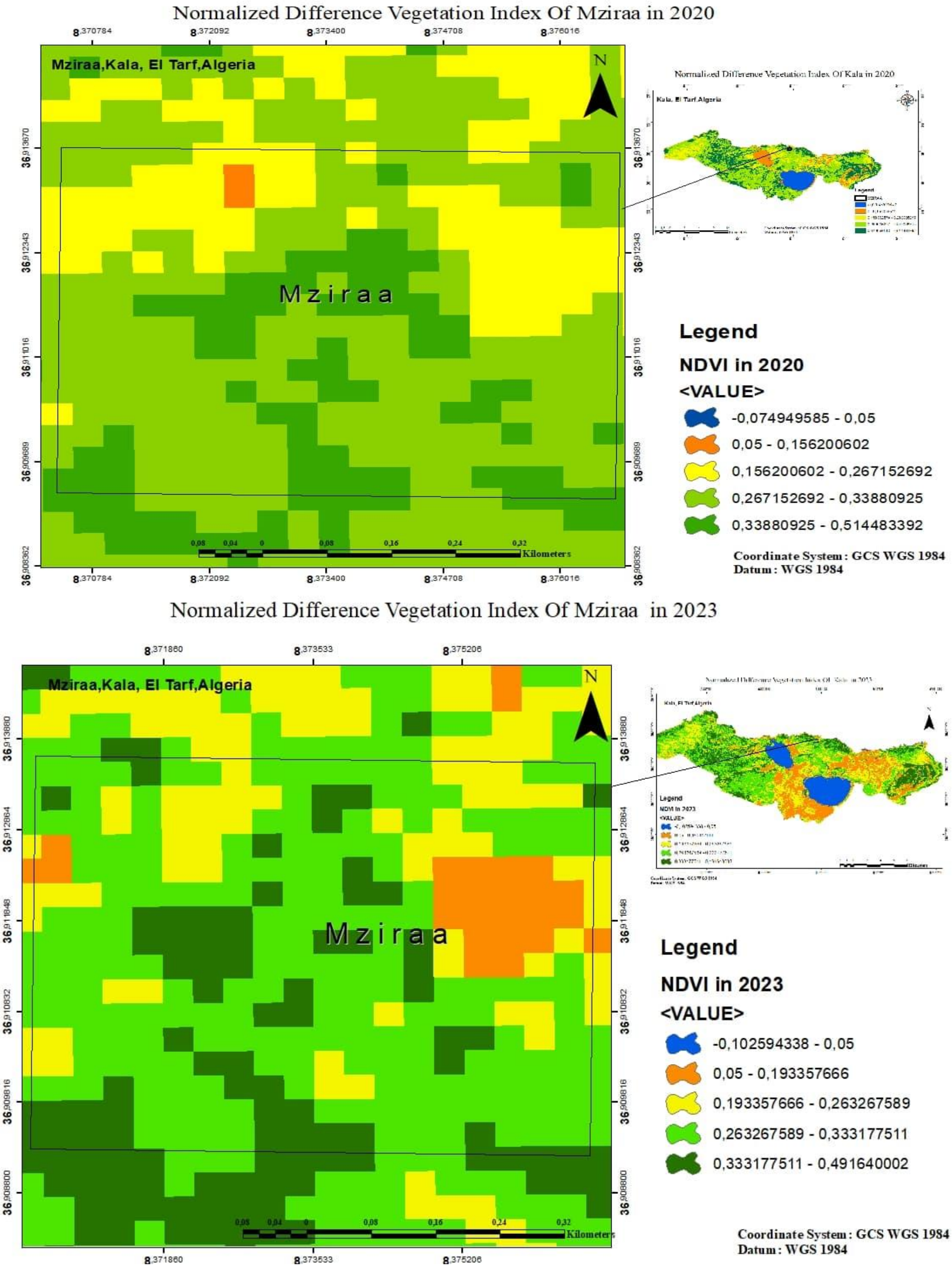

Figure 12. Normalized difference vegetation index (NDVI) of El Kala between 2020 and 2023

12. ábra. El Kala normalizált növényzetindexe (NDVI) 2020 és 2023 között

Discussion

Estimating diversity is crucial for evaluating the balance of a habitat. A high value of H′ indicates a habitats with a rich variety of species whose abundance is evenly distributed. Conversely, a low value suggests a habitat with few species (Frontier and Pichod-Viale 1991, Huston 1994).

The specific diversity (H′) in the studied habitat is quite high, indicating a structural complexity nearing climax, as supported by previous research (Barbault 1995, Haou et al. 2011, Haou and de Bélair 2019). Due to the inadequate management and restoration efforts in the study area, the forest is rapidly moving towards ecological imbalance. This is exacerbated by various human activities, such as urban waste in clearings, unsustainable timber harvesting, and unregulated and illegal agriculture at the forest's edge. All of these factors have led to the replacement of the tree and shrub layers in certain parts of the forest with a tangle of lianas. Additionally, the sand encroachment has caused *Cistus halimifolius* L. to invade the forest edge. Field observations, along with statistical analysis, allowed the classification of the site as a cork forest in a regressive evolutionary phase but with a specific distribution balance.

Diversity varies depending on the richness of the community and the distribution of its species. The higher the richness, the more balanced the distribution of abundance, leading to greater diversity (Blondel and Bonin 2018). In all of the study locations, four out of the 98 recorded species are considered to be a highly consistent with stable abundance and dominance, making up 9.75% of the floristic composition. These species include *Erica arborea* L., *Lavandula stoechas* L., *Quercus coccifera* L. and *Q. suber* L. They have a high relative frequency ($80 < F < 100\%$) indicating their dominance and optimal adaptation to the habitat conditions. These species have a broad ecological range within the habitat and play a significant role in the formation of thermo-xerophilic matorrals in the study site. Among these four species, *Q. coccifera* and *Q. suber* show a stable presence compared to *E. arborea* and *L. stoechas.* They are thermo-xerophilic species that thrive on a siliceous soil with a high percentage of stones. These species characterize the floristic procession that accompanies *Lavandula stoechas* in the Mediterranean forest composed of cork oak, holm oak and kermes oak brush (de Coignac 2001, BNEDER 2009, Haou and de Belair 2019, Zennir and Khallef 2023).

To better highlight the balance of species distribution, the equity index (E) is added to H'. This index ranges from 0.8 to 0.9 across the four study sites in 2020 and from 0.7 to 0.81 in 2023. Therefore, we can talk about a decline not only in taxonomic diversity but also in the imbalance of population distribution for each inventoried population.

Analysis of the biological spectrum of flora in the study area revealed a higher composition of Therophytes (38%), comprising a fairly rich variety of herbaceous plants, and 25% Phanerophytes represented by shrubs and trees, including Macrophanerophytes, Mesophanerophytes, Microphanerophytes and Nanophanerophytes. Geophytes are mainly represented by rupicolous plants. Barbero and Quézel (1989) and Jäger (2000), explain that the high number of Phanerophytes is evidence of an ecological succession of vegetation from the pre-forest stage to the forest stage. This phenomenon is confirmed in the study sites by the fact that the shrub layer exhibits an importance competitive interaction with the tree layer, even though the region is subsequently recognized as a reference habitat for the study of post-fire ecological succession (Rambal 2008, Zennir and Khallef 2023). This regression effect of evolution is justified by the settlement of Chamaephytes and Therophytes in the habitat. According to Barbero et al. (2001) and Blondel et al. (2010), therophytization (settlement of nitrophilic plant species), is considered a sign of degradation, which is linked to the effects of overgrazing. According to Le-Houerou (1992) and as in our case, associated with the presence of urban solid wastes. The presence of Hemicrytophytes enriches the organic matter in the forest soil (Barbero and Quézel 1989, Blondel et al. 2010, Blondel and Bonin 2018). Despite the degradation it is beginning to undergo, the site still maintains significant biological diversity, as well as a varied architectural stratification. Quézel (2000) and Quézel and Medail (2003) justify this diversity in all Mediterranean African habitats as a result of floristic migration from the tropical region during the Miocene era, coinciding with climate change. Based on observations made in the field, three factors contributing to human-induced environmental disturbance have been identified: grazing, trampling and solid waste (particularly plastic). These factors are all present in the study area, with trampling being significantly prevalent in all study localities, followed by waste observed in the first two localities. Grazing was minimally observed in the second study site. The high levels of trampling and urban waste are attributed to the combined impact of beach visitors (2 to 3 km from Mzirâa forest) and travelers using the road near the forest's northern side. This type of tourism has diverted the traditional livestock paths towards paths established by residents, even within the forest, leading to habitat degradation (Vennetier 2002, Abdelfettah 2014). De Coignac (2001) concludes in his research that the forest has a vital role, and must be protected and restored.

Since independence in 1962, annual reforestation and restoration campaigns in Algeria have only managed to increase forest cover to between 10% and 12%, with vegetation constantly under threat from fire, parasites, poaching and overgrazing. These practices contribute to desertification; furthermore, the water table in the study area has fallen by half over the last 70 years (DGF 2020). This clearly indicates a catastrophic phenomenon, as seen in the NDVI of the El Kala wetland catchment areas from 2020 to 2023, where the study site is situated, showing a decline ranging from 0.04 to 0.26, signifying low density and unhealthy vegetation (Kurnaz et al. 2020). This mapping is supported in the field by a spatio-temporal dynamics map showing the regression in the natural succession of Mzirâa forest vegetation. This deterioration affects not only the structure and arrangement of the flora, but also the silting up of the forest edge, increasing competition and sometimes even exclusion of forest flora by psammophilous flora. The field observations revealed that loamy texture is the most prevalent across the entire study site compared to clay and sand textures. The determination of a soil's porosity and water regime is linked to its texture, a stable characteristic that changes over the long term (Gobat et al. 2004, Inoussa et al. 2011).

The abundance of silt in the soil indicates a structure highly vulnerable to degradation, as it easily separates from the soil matrix and can be carried away by the wind (Le-Houérou 1992, Quézel and Médail 2003, Rambal 2008). This helps explain the soil erosion observed in the study area. In contrast, coarse sand, while less easily displaced has low cohesion (de Bélair 1996). However, the study site has a high clay content, which aids in water retention despite the generally low soil moisture levels found there. This clay enrichment also contributes to the abundance of mosses, notably *Funaria hygrometrica* Hedw., facilitating the pedogenesis, a process characterized by a slowing of water flow during dry periods in Mediterranean habitats (Quézel and Médail 2003). This observation is likely due to the high temperatures observed during the dry season, which caused the soil to crack and led to significant water loss through evaporation. Regarding soil color, a predominance of yellow-red hues was observed. Daget (1977), Santonja et al. (2015), and Zribi et al. (2017) confirm that this is decarbonation, which results in an increase in organic matter content. This highlights the high sensitivity of the Mzirâa forest ecosystem to degradation, particularly soil erosion, which could significantly influence vegetation distribution. Analysis of the floristic diversity of the study area identified approximately 100 plants between 2020 and 2023, characterized by their taxonomic and biological diversity (family, genus, biological type and biogeographical origin). Despite this diversity, the study site is experiencing severe degradation due to human intrusion, which is altering the evolution of its vegetation over time and space. This has led to a significant presence of Chamaephytes, which is associated with overgrazing in the study area.

Conclusion

The study of the ecological status of a habitat is strictly based on the knowledge of the flora and assessment of its composition and architecture, including the determination of anthropogenic actions that influence the evolution of plants over time and space. This study focuses on the Mzirâa cork oak forest, located in the municipality of El Kala.

The assessment of these parameters and characteristics revealed that the Mzirâa forest is experiencing severe ecological degradation and anthropogenic intrusion. This intrusion is currently altering the evolution of its vegetation over time and space. Despite this ecological imbalance, the floristic composition of the study area, still shows significant taxonomic diversity and a specific balance of distribution between plant strata in certain small forest plots. This implies that the forest is resilient in nature even with the threats of anthropogenic activities. Thus, protecting the flora of this forest against overgrazing and other anthropogenic actions is crucial for the sustainability of this forest ecosystem. One possible approach to achieve this is through ecological restoration of riparian forests situated on the edge of the Mzirâa forest. This study is important because it provides critical baseline information that will enhance the stability and sustainability of this forest for the current and future generations.

Author Contributions

Conceptualization, Louhi Haou S.; methodology, Louhi Haou S.; validation, Louhi Haou S., Sakhraoui N. and Boussouak R.; formal analysis, Louhi Haou S. and Zaoui S.; data collection, Louhi Haou S. and Zaoui S.; interpretation of data, Louhi Haou S. and Zaoui S.; writing—original draft preparation, Louhi Haou S.; writing—review and editing, Sakhraoui N., Louhi Haou S. and Sioud I. All authors have read and agreed to the published version of the manuscript.

Acknowledgement

The authors would like to thank Pr. Jerome G.N. Nyenka from the College of Agriculture and Forestry, University of Liberia, and Dr. Moses Fayiah from the Department of Forestry, School of Natural Resources Management, Njala University, Sierra Leone, for reviewing the English; the anonymous reviewers for their corrections which improved the manuscript; and the forest rangers of the El Kala region for their collaboration and assistance in the field. Funding: This research received no external funding. Data availability: A matrix is apload as supplementary material. Conflicts of Interest: The authors declare no conflict of interest.

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A Mzirâa paratölgyerdő florisztikai és ökológiai értékelése (El Kala, Északkelet-Algéria)

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Kulcsszavak: paratölgyerdő, térképezés, növényzeti dinamika, ökológiai viszonyok, természetvédelem, fenntartható mediterrán ökoszisztéma, Északkelet-Algéria

Abstract: Az antropogén hatások tartós fennállása és sokfélesége jelentősen felgyorsította a mediterrán erdők degradációs folyamatait. Jelen tanulmány az Algéria északkeleti részén, El Kalától északnyugatra fekvő Mzirâa paratölgyerdőre összpontosít. A kutatás célja a Mzirâa-erdő kijelölt területeinek ökológiai állapotfelmérése a flóra fajösszetételének és a vegetáció szerkezetének vizsgálata alapján. A vizsgálat alapját a mintaterületeken alkalmazott szisztematikus mintavételi módszerrel összeállított florisztikai adatmátrix képezte. Az eredmények a flóra és a vegetáció regresszív tér- és időbeli dinamikáját igazolták. Emellett a florisztikai dinamika elemzése, valamint a vizsgálati terület NDVI (Normalizált Differenciált Vegetációs Index) alapú értékelése a Mzirâa-erdő gyors ütemű degradációját mutatta ki. Az eredmények arra utalnak, hogy az erdő súlyos ökológiai veszélyeztetettségnek van kitéve, ezért további állapotromlásának megakadályozása érdekében sürgős természetvédelmi és erdőgazdálkodási intézkedések bevezetése szükséges. A tanulmány fontos információkkal szolgál a kutatók, a döntéshozók és az algériai erdővédelmi hatóságok számára.