

Analysis of the floristic diversity in a southern Mediterranean ecosystem. Case of Bissa forest, Chlef (Algeria)

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Recibido: 10/06/2020 / Publicado: 23/09/2020

Abstract. The forest of Bissa is a Mediterranean ecosystem, characterized by a high floristic diversity. In order to assess the floristic diversity in this forest, 133 floristic inventories were conducted in this area between 2013 and 2017. As a result, it was possible to identify 151 species, 125 genera and 54 botanical families, with a clear dominance of Asteraceae, Fabaceae and Poaceae. Biologically, this ecosystem was mainly dominated by therophytes (37%). Physiognomically, the phanerophytes were the most dominant types, whereas in term of phytogeography this forest was dominated by the Mediterranean type (50%). According to Shannon-Winner index, this area was characterized by a relatively low diversity (1,3 bit/ind.), with a clear dominance of a few species. Finally, this forest was relatively disturbed (42%) and under a strong Anthropozoic influence.

Keywords: disturbance index; Shannon index; phytogeography; biological types; species richness.

[fr] Analyse de la diversité floristique d'un écosystème du sud de la Méditerranée. Cas de la forêt de Bissa, Chlef (Algérie)

Résumé. La forêt de Bissa est un écosystème forestier Méditerranéen, caractérisé par une diversité floristique importante. Afin d'évaluer la diversité floristique dans cette forêt, 133 relevés floristiques ont été réalisés entre 2013 et 2017. Comme résultats, il a été possible d'identifier 151 espèces, 125 genres et 54 familles botaniques, avec une nette dominance des Asteraceae, Fabaceae et Poaceae. Sur le plan biologique, cet écosystème se caractérise par la dominance des thérophytes, physiologiquement les phanérophytes sont majoritairement dominants, alors que du point de vue phytogéographique cette forêt est dominée par le type Méditerranéen. Selon l'indice de Shannon, cette zone présente une diversité relativement faible (1,3bit/ind.), avec une nette dominance de certaines espèces. Enfin cette forêt est relativement perturbée (42%) sous l'effet de l'action anthropozoïque.

Mots clés: indice de perturbation; indice de Shannon; phytogéographie; type biologique; richesse spécifique.

[es] Análisis de la diversidad florística de un ecosistema del sur del Mediterráneo. Caso del bosque de Bissa, Chlef (Argelia)

Resumen. El bosque de Bissa es un ecosistema mediterráneo caracterizado por una diversidad florística importante. Para evaluar la diversidad florística en este bosque se han llevado a cabo 133 inventarios florísticos entre 2013 y 2017. Como resultado fue posible identificar 151 especies, correspondientes a 125 géneros y 54 familias botánicas con una clara dominancia de Asteraceae, Fabaceae y Poaceae. El espectro biológico de este ecosistema se caracteriza por la dominancia de los terófitos, no obstante, desde un punto de vista fisionómico, son los fanerófitos el hábito dominante. Desde un punto de vista fitogeográfico, este bosque está dominado por el tipo mediterráneo (50%). Según el índice de Shannon, esta zona presenta una diversidad relativamente baja (1,3bit/ind.), con una clara dominancia de algunas especies. Finalmente, este bosque se encuentra relativamente perturbado (42%) bajo el efecto de la acción antrópica.

Palabras clave: índice de perturbación; índice de Shannon; fitogeografía; tipo biológico; riqueza específica.

Introduction

Biodiversity is a hot topic that is receiving more and more attention, it refers to diversity within species, between species and between ecosystems (Baillie & Upham 2012). The recent worldwide decline in the biodiversity is considered by many specialists as an

irreversible process which puts at risk the future of the humanity (Abdelguerfi & Ramdane 2003). In light of this, the assessment of this natural wealth has been the subject of several studies during the last decades (Sedjar 2012; Abdourhamane et al. 2013; Merioua et al. 2013; Benkhetou et al. 2015; Larbi 2015; Slimani & Aidoud 2018). In terms of biodiversity, the

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Mediterranean ecosystems are characterized by minor bioclimatic differences leading up to very diverse forms of vegetation, whereas the variation in the Mediterranean landscape translates into high genetic, specific, and ecosystem diversity. In this context, the Mediterranean is known by an extraordinary floristic richness, with 25000 known species according to Medail & Quezel (1997). Algeria, the largest country in the Mediterranean basin, is also characterized by a very significant diversity. Indeed, according to Quezel & Santa (1962) the Algerian floristic richness estimated is of 3139 species, with 700 endemic species. Unfortunately, apart from the great work of Quezel & Santa (1962, 1963), this floristic richness remains highly unknown and is currently under a strong anthropic and climatic influence.

In this context, the present work aims to study the floristic diversity in an exceptionally woody area in the north of Algeria, namely the cork oak forest of Bissa, in order to assess the floristic diversity, the degree of disturbance in this forest and to ensure its long-term protection and maintain its floristic diversity. Indeed, despite its importance, only few ecological studies have been conducted in this forest.

Materials and methods

Study area

In opposition to most of the cork oak woodlands located in the humid and sub-humid areas in the north-eastern part of Algeria, the forest of Bissa is one of very few cork oak forests in the north-western part of this country, characterized by its high floristic diversity compared to the surrounding areas. The forest of Bissa is located east of Dahra Mountains, in the north of the state of Chlef, it extends over an area of 1487 hectares (Figure 1), between $36^{\circ} 25'$ and $36^{\circ} 28'$ of north latitude and between $1^{\circ} 25'$ - $1^{\circ} 30'$ of east longitude. It is a mountainous area with a rugged topography, characterized by altitudes ranging from 940 to 1152 meters and a main ridge line running along the forest from east to west over 4,5 km and a secondary north-south ridge.

In terms of climate, the area is sub-humid (Berchouche & Sedaki 2014), marked by ample rainfall around 700 mm/year, mainly recorded between autumn and spring, and an average annual temperature of 16°C . According to the temperature/rainfall ratio (Bagnouls & Gaussen 1953), the dry period extends over a period of 4 months, from June to September.

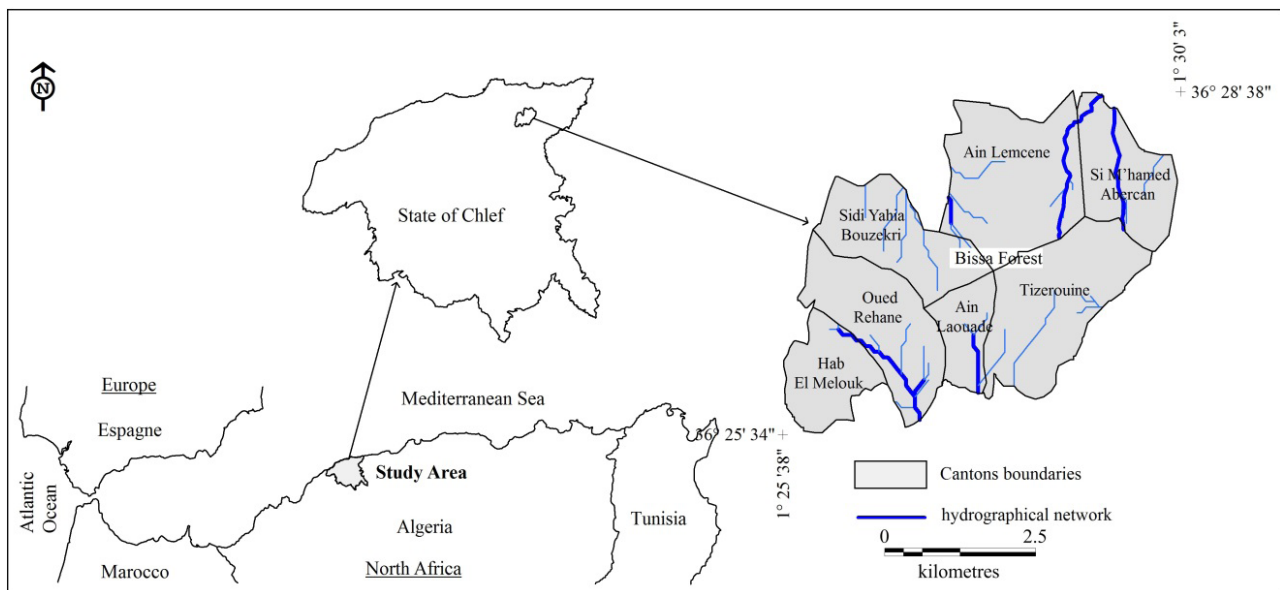


Figure 1. Location of the study area.

Biogeographically the forest of Bissa belongs to the North African Mediterranean domain (Quezel & Santa 1962, 1963), whereas according to the new phytogeographical nomenclature of Meddour (2010) this forest belongs to the Maghreb-Tellian domain.

Sampling

Vegetation ecology surveys were recorded according to a subjective sampling, in homogeneous and representative areas (Gounot 1969; Prodon & Lebreton 1994) between 2013 and 2017, adding up 133 inventories. Each inventory was taken over a minimum area of 100 m^2 (Quezel 1965). In addition to the floristic data, we collected the altitude, latitude, longitude, exposure as well as the Anthropozoic (human-animals) action in each site.

Each recorded species was assigned an abundance-dominance coefficient (Braun-Blanquet 1951), this coefficient is used to determine the species real cover according to Tomaseli's method (Long 1958). The taxa identification was done based on Quezel & Santa (1962, 1963), Dobignard & Chatelain (2010), Le Floc'h et al. (2010) and Dobignard & Chatelain (2011a, 2011b, 2012).

Biodiversity assessment

The study area has been evaluated floristically, biologically and in terms of phytogeography (Quezel & Santa 1962, 1963; Dobignard & Chatelain 2010, 2011a, 2011b, 2012). The floristic diversity was evaluated in terms of species richness, perturbation index, Shannon-Weaver diversity index and equitability.

Disturbance index

The forest degradation was assessed using the perturbation index (PI) as defined by Hebrard et al. (1995) (Equation 1).

$$PI = \frac{\text{Number of chamaephytes} + \text{Number of therophytes}}{\text{Total number of species}} \text{ (Eq. 1)}$$

Shannon-weaver diversity index "H"

The biological diversity is most commonly assessed using the Shannon index (H), this index helps to understand the distribution of species that compose a given habitat. This index is given by equation 2.

$$H' = - \sum p_i \log_2 p_i \text{ (Eq. 2)}$$

Where p_i is the proportion of individuals of one particular species i (n) divided by the total number of all individuals (N).

The diversity index (H) was calculated based on the relative cover of each species in each group, not on the probability of occurrence. This index is expressed in bit per individuals (bit/ind.) with an interval ranging from 0 to 5 bits (Frontier 1983; Frontier & Etienne 1990), the maximum value is reached when all species individuals are distributed evenly (Frontier 1983).

Equitability (evenness)

The specific diversity of a given habitat is generally accompanied by Pielou equitability index (E) (Equation 3) (Legendre & Legendre 1979; Dajoz 2003; Frontier et al. 2008).

$$E = \frac{H'}{\log_2 N} \text{ (Eq. 3)}$$

Where: H' is the Shannon-Weaver Index and N is the total number of species.

Equitability (E) ranges between 0 and 1 (Liyod & Gheraldi 1964; Legendre & Legendre 1984), it is maximal when all the species are evenly distributed and minimal in case of a dominant species.

Results

Floristic composition

Through this survey 54 families have been identified in the study area (Figure 2), the most dominant botanical families were respectively the Asteraceae with 15% of the total flora, adding up 22 species and 19 genera, the Fabaceae with 14 species and 11 genera, the Poaceae represented by 11 species and 10 genera and Lamiaceae with 10 species and 9 genera, whereas the remaining families were represented by only 1 to 3 species.

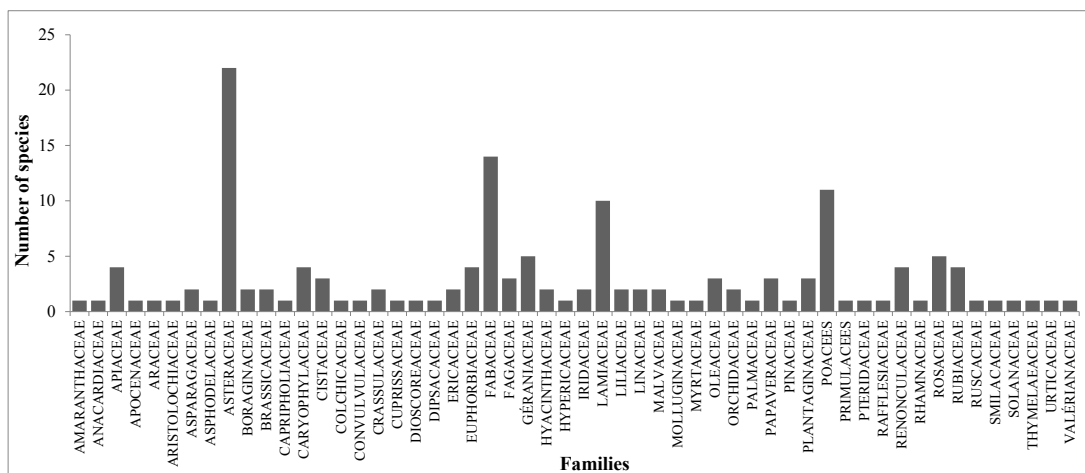


Figure 2. Botanical families listed in the study site.

Biological spectrum

Throughout the study area, therophytes were the most dominant among all the biological types with 37%,

followed by phanerophytes and hemicryptophytes with 24 and 23% respectively. The least represented biological types were geophytes and chamaephytes with 11% and 5% respectively (Figure 3).

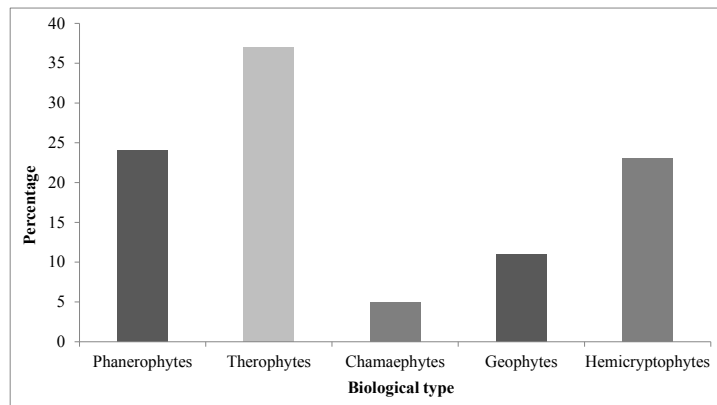


Figure 3. Biological spectrum.

Weighted biological spectrum

In contrast to the biological spectrum, the species cover weighting revealed a clear preponderance of phanerophytes;

up to 88% of all the biological types present in this forest, while the remaining biological types were insignificantly represented with 4% of geophytes, 3% of therophytes and hemicryptophytes and only 2% of chamaephytes (Figure 4).

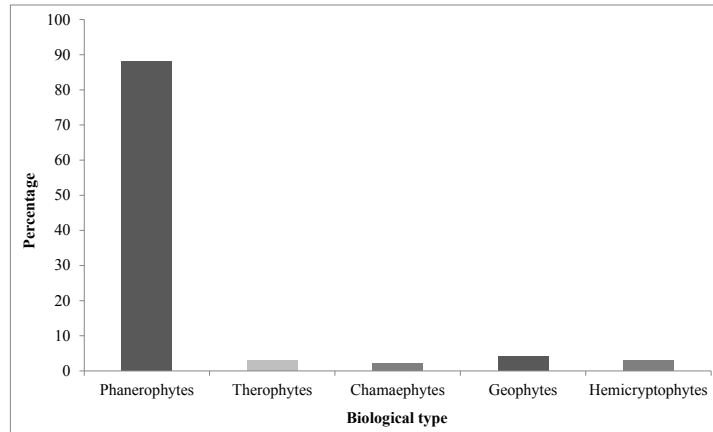


Figure 4. Weighted biological spectrum.

Phytogeographic spectrum

The phytogeographic spectrum (Figure 5) showed a strong preponderance of the Mediterranean type up to

50%, followed by 31% of multi-regional taxa and 15% of Nordic types (Paleo temperate, Eurasian, European), finally 4% of the species were endemic to Algeria, Algeria-Tunisia and Algeria-Morocco.

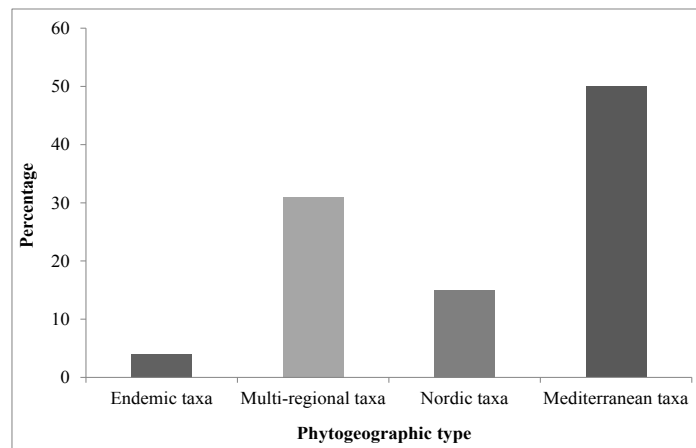


Figure 5. Phytogeographic spectrum.

Weighted Phytogeographic spectrum

The real species cover revealed a high abundance of Mediterranean species up to 84% of all the Phytogeographic

types, 14% were of multi-regional nature, Endemic and Nordic taxa accounted only 1% of the encountered flora (Figure 6).

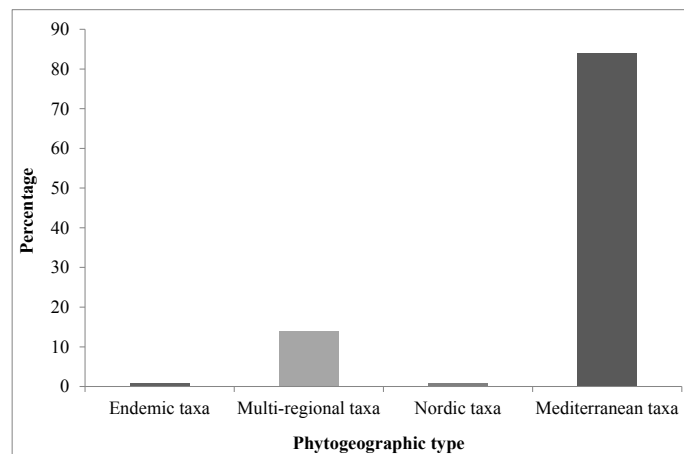


Figure 6. Weighted Phytogeographic spectrum.

Disturbance index

This index increases when the encountered flora is dominated by therophytes and chamaephytes. Based on this index, the forest of Bissa was found to be averagely disturbed with a disturbance index of 42%.

Biodiversity index

Despite its very restricted surface (almost 0,06% of the Mediterranean surface), the forest of Bissa showed a

Table 1. Species richness and diversity indices

Species richness	151
Shannon-Weaver diversity	1,3 bit/ind.
Equitability	0,31%

Discussion

Floristic diversity

Despite the conclusions drawn by Mathez et al. (1985), stating that the Algerian forest has undergone during the last decades a very significant floristic decline, 151 species belonging to 125 genera and 53 botanical families were recorded in the very limited surface, occupied by the forest of Bissa, which is an indicator of a relatively high floristic diversity, this finding was consistent with the finding of Ajbilou (2007) in the Tingitane peninsula in Morocco, according to this author, among several forest formations the highest specific richness was observed in the cork oak forests. Due to its limited surface leading to a climatic and topographic uniformity, the species richness in Bissa forest was less than that observed in areas under similar conditions, but extending on larger surfaces such as the species richness revealed by Sedjar (2012) in Setif, with 367 species belonging to 56 botanical families, Rebbas (2014) in Gouraya National Park in Bejaia with 529 species belonging to 89 botanical families, Babali (2014) recorded 650 species in Moutas in Tlemcen, whereas Belhacini (2011) revealed only 118 species in the Southern matorral (shrubland areas) of Tlemcen.

The specific and very favorable environmental conditions (climate, topography and pedology) characterizing the forest of Bissa, resulted in a very important species richness (151 species) even though the Shannon-Weaver Diversity Index was relatively low (1,3 bit/ind.) indicating an inequality in the abundance and dominance of species in the forest of Bissa, indeed, *Quercus suber* L. covers by itself alone a 17,27%, *Arbutus unedo* L. and *Quercus ilex* L. cover respectively 11,62% and 11,52%. In this forest ecosystem, the specific environmental conditions were highly favorable to the appearance of over a hundred different species, nevertheless the evenness index was relatively low (0,31%), which indicates the dominance of a limited number of species such as: *Quercus suber* L., *Arbutus unedo* L., *Quercus ilex* L., *Cistus monspeliensis* L.

relatively high floristic diversity, indeed the 151 species recorded in this forest accounted for 6,04% of the total Mediterranean flora. However, the Shannon's diversity index (H) of this forest was found to be relatively low (1,3 bit/ind.), the equitability index showed a value of 0,31% indicating the predominance of few species (Table 1).

and *Erica arborea* L., while the remaining taxon were marginally represented. In contrary to Bissa forest, the evenness index recorded by Stiti et al. (2012) in a Tunisian cork oak forest was very high (0,89%), indicating a strong species equitability, while the Shannon-Weaver diversity index was low (1,44 bit/ind.), almost similar to that recorded in Bissa.

Functional diversity

In terms of biological types, Barbero et al. (1990) reported that the human disturbances are diverse and leading to increasingly severe situations, ranging from therophytisation (abundance of therophytes) to shrub encroachment (a step of forest degradation) of the forest, this degradation process is the case of most of the Algerian forests. Indeed according to Le Houerou (1980, 1995), Quezel (2000), Quezel & Medail (2003), Benabadji et al. (2009) most of the Mediterranean forest ecosystems are subject to the phenomena of therophytisation. In the forest of Bissa, and the therophytes, which constitute a form of plants adaptation in arid conditions, appeared to be clearly predominant (37%) compared to the remaining biological types when considering the biological spectrum. Whereas according to the weighted biological spectrum the forest of Bissa was dominated by phanerophytes (88%) mainly for two reasons, firstly because it is a forest ecosystem, secondly the important cover of the phanerophytic species such as oaks. However, compared to adjacent and comparable ecosystems the forest of Bissa showed a slightly lower therophytisation (37%). Indeed, according to Sedjar (2012) the forest of Jebel Boutaleb in Setif, showed 42% of therophytes, in Beni Saf forest, Merioua et al. (2013) listed 40% of therophytes, in the Southern matorral of Tlemcen, Belhacini (2011) recorded 47,5% of therophytes, while in the forest of Djurdjura, Larbi (2015) mentioned a strong predominance of hemicryptophytes (47%), according to Floret et al. (1990) this situation was mainly due to the abundance of rainfall and the winter cold prevailing in this area.

The increase in therophytes and chamaephytes in a given area leads to a higher perturbation index, in this

context the forest of Bissa was averagely disturbed (DI = 42%), this disturbance was mainly caused by fires and Anthropozoic action, indeed, the forest of Bissa is known to be under the influence of repeated and frequent fires leading up to the proliferation of specific species such as *Cistus monspeliensis*, whereas, the influence of animals, especially the excessive grazing (goats in particular), resulted in the appearance of characteristic species such as *Asphodelus microcarpus* Viv., *Iris planifolia* (Mill.) Fiori & Paol. and *Poa bulbosa* L. Compared with some similar and surrounding areas in arid and semi-arid climates the DI of Bissa remains well below that recorded by Belhacini (2011) in Tlemcen (76%), Merioua et al. (2013) in Beni Saf (68%) and Benkhetou et al. (2015) in Nador massif in Morocco (63,6%), while, in humid regions such as the cedar forest of Djurdjura (Tikjda) Larbi (2015) recorded a relatively low DI (31,65%), even though the author reported a clearly visible degradation (fire, clearing, grazing) caused by the human action.

Phytogeographically, as a Mediterranean area, the forest of Bissa showed a notable phytogeographic diversity, but largely dominated by the Mediterranean type. According to Quezel (1985), Medail & Quezel (1997), the multiple and simultaneous paleogeographic events and the contrasting climate cycles around the Mediterranean basin, led to the emergence of high phytogeographic diversity. Indeed comparably to the forest of Bissa, all the phytogeographical studies around the Mediterranean (Ajbilou 2007; Mejias et al. 2007; Messaoudène et al. 2007, Belhacini 2011; Sedjar 2012; Merioua et al. 2013; Babali 2014; Rebbas 2014; Benkhetou et al. 2015; Larbi 2015; Celep & Dirmenci 2017) have highlighted a high phytogeographic diversity dominated by the Mediterranean types, this abundance was reported by Quezel (2000) in all the North African countries, however, Bonnet et al. (1999) in a 60 years diachronic study of the Mediterranean flora of Frioul archipelago in Marseille (France), reported a slight decrease in the Mediterranean type, while remaining the predominant. It was also noted

that the multiregional species were largely represented, indicating a strong anthropozoic pressure, whereas, the endemic species were very limited when compared to the finding of Gavira-Romero et al. (2016) in Malaga, who pointed out 26 regional endemic out of 351 collected taxa, among which 7 taxa exclusive to Malaga.

Conclusion

This investigation contributed to complement the efforts of all botanical researchers around the Mediterranean, and most importantly to expand the Mediterranean floristic database, in the perspective of protecting and valuing the natural resources around the Mediterranean Basin.

Following this survey, it was possible to notice a very important floristic richness in the forest of Bissa, mainly dominated by Asteraceae, Fabaceae, Poaceae and Lamiaceae representing 40% of the total flora. Biologically, therophytes (37%), phanerophytes (24%) and hemicryptophytes (23%) prevail in this ecosystem; however, the weighted biological spectrum revealed a strong dominance of phanerophytes (88%), phytogeographically most of the species are of Mediterranean type.

Despite the high species richness, the forest of Bissa was modestly diverse (H=1,3) and dominated by a limited number of species as expressed by a low equitability index (0,31%). Finally, this forest was moderately disturbed (DI = 42%) under the influence of anthropozoic factors, the frequent fires, illicit tree cuttings, clearing and grazing are the main factors causing the degradation.

Unfortunately, these cork oak forests are very rare and cover very limited areas in the southern Mediterranean, particularly in Algeria. It is very important to multiply the protection measures in order to preserve these valuable and endangered ecosystems.

References

- Abdelguerfi, A. & Ramdane, S. A. 2003. Evaluation des besoins en matière de renforcement des capacités nécessaires à l'évaluation et la réduction des risques menaçant les éléments de la diversité biologique en Algérie. Tome VII. FEM/PNUD. Projet Alg/97/G31. Plan d'action et stratégie nationale sur la biodiversité. Ministère de l'aménagement du territoire et de l'environnement. <https://www.researchgate.net/publication/308762119>
- Abdourhamane, H., Morou, B., Rabiou, H. & Amhamane, A. 2013. Caractéristiques floristiques, diversité et structure de la végétation ligneuse dans le Centre-Sud du Niger: cas du complexe des forêts classées de Dan kada Dodo-Dan Gado. *Internat. J. Biol. Chem. Sci.* 7(3): 1048-1068. <http://dx.doi.org/10.4314/ijbcs.v7i3.13>
- Ajbilou, R., Marañón, T., Arroyo, J. & Ater, M. 2007. Structure et diversité de la strate arbustive des forêts de la péninsule Tingitane (Maroc). *Forêts de Maroc. Acta Bot. Malac.* 32: 147-160.
- Babali, B. 2014. Contribution à une étude phytoécologique des monts de Moutas (Tlemcen-Algérie occidentale): Aspects syntaxonomique, biogéographique et dynamique. Thèse de doctorat, université Aboubakr Belkaïd Tlemcen. <https://www.researchgate.net/publication/317236468>
- Bagnouls, F. & Gaussen, H. 1953. Saison sèche et indice xéothermique. *Bull. Soc. Hist. Nat. de Toulouse* 88: 193-240.
- Baillie, J.E.M. & Upham, K. 2012. Species diversity within and among ecosystems. In: Meyers R.A. (eds.) *Encyclopedia of Sustainability Science and Technology*, pp. 257-271. Springer, New York.
- Barbero, M., Quezel, P. & Loisel, R. 1990. Les apports de la phytoécologie dans l'interprétation des changements et perturbations induits par l'homme sur les écosystèmes forestiers méditerranéens. *Forêt Medit.* 12(3): 194-215.
- Belhacini, F. 2011. Contribution à une étude floristique et biogéographique des matorrals du versant sud de la région de Tlemcen. Mémoire de Magister, université Aboubakr Belkaïd Tlemcen. <http://dspace.univ-tlemcen.dz/bitstream/112/271/1/>

- Benabadji, N., Aboura, R. & Benchouk, F. 2009. La régression des steppes méditerranéennes: le cas d'un faciès à *Lygeum spartum* L. d'Oranie (Algérie). *Rev. Ecol. Mediterr.* 35: 75-90.
- Benkhetto, A., Azouzi, B., Djili, K., Benkhetto, M., Zedek, M. & Saadi, R. (2015). Diversité floristique du massif du Nador en zone steppique (Tiaret, Algérie). *Europ. Sci. J.* 11(21): 401- 419. <https://eujournal.org/index.php/esj/article/download/6008/5791>
- Berchouche, H. & Sedaki, S. 2014. Contribution à l'étude climatique et bioclimatique de Djebel Bissa-Wilaya de Chlef. Mémoire de Master, université Hassiba Ben Bouali Chlef.
- Bonnet, V., Vidal, E., Médail, F. & Taton, T. 1999. Analyse diachronique des changements floristiques sur un archipel méditerranéen Périurbain (îles du Frioul, Marseille). *Rev. Eco. (Terre et Vie)* 54: 3-18.
- Braun-Blanquet, J. 1951. Les groupements végétaux de la France. *Med. CNRS. Carte des groupements végétaux, Montpellier.*
- Celep, F. & Dirmenci, T. 2017. Systematic and Biogeographic overview of Lamiaceae in Turkey. *Nat. Volatiles & Essent. Oils* 4(4): 14-27.
- Dajoz, R. 2003. Précis d'écologie. Dunod, Paris.
- Dobignard, A. & Chatelain, C. 2010. Index synonymique de la flore d'Afrique du Nord. (Vol. 1). Conservatoire et jardin botaniques, Genève.
- Dobignard, A. & Chatelain, C. 2011a. Index synonymique de la flore d'Afrique du Nord. (Vol. 2). Conservatoire et jardin botaniques, Genève.
- Dobignard, A. & Chatelain, C. 2011b. Index synonymique de la flore d'Afrique du Nord. (Vol. 3). Conservatoire et jardin botaniques, Genève.
- Dobignard, A. & Chatelain, C. 2012. Index synonymique de la flore d'Afrique du Nord. (Vol. 4). Conservatoire et jardin botaniques, Genève.
- Floret, C., Galan, M.J., Le Floch, E., Orshan, G. & Romane, F. (1990). Growth forms and phenomorphology traits along an environment gradient: tools for studying vegetation. *J. Vege. Sci.* 1: 71-80. <https://doi.org/10.2307/3236055>.
- Frontier, S. 1983. L'échantillonnage de la diversité spécifique. In stratégie d'échantillonnage en écologie. Masson les Presses de l'université Laval.
- Frontier, S. & Etienne, M. 1990. Etude de la diversité spécifique par le moyen des diagrammes rang-fréquences: Modélisation, variabilité d'échantillonnage. In: *Biométrie et océanographie, IFREMER*: 145-177.
- Frontier, S., Pichod-Viale, D., Lepretre, A., Davoult, D. & Luczak, C. 2008. Écosystèmes: structure, fonctionnement, évolution. 4^e édition. Dunod, Paris.
- Gavira-Romero, O. N., Hevilla-Ordóñez, S., Cano-García, E. 2016. Aportaciones a la flora de Sierra Alpujata y Sierra Blanca (Cádiz, Málaga). *Bot. Complut.* 40: 75-102. <http://dx.doi.org/10.5209/BCOM.53202>
- Gounot, M. 1969. Méthodes d'étude quantitative de la végétation. Masson et Cie. Paris.
- Hebrard, J.P., Loisel, R., Roux, C., Goumila, H. & Bouni, G. 1995. Incidence of clearing on phanerogamic and cryptogamic vegetation in South Eastern France disturbance indices. *Ext. de technique et documentation. Lavoisier, Intercept Ltd.* 747-758.
- Larbi, R. 2015. Analyse de la diversité floristique et de la phytodynamique de la série de végétation à *Cedrus atlantica* au Djurdjura Centro- méridional (secteur de Tikjda). Mémoire de magister, université Mouloud Mammeri Tizi Ouzou. <https://dl.ummo.dz/handle/ummo/1633>
- Le Floch É., Boulos L. & Vêla E. 2010. Catalogue synonymique commenté de la flore de Tunisie. Ministère de l'environnement et du développement durable, banque nationale de gène.
- Legendre, L. & Legendre, P. 1979. Écologie numérique. 1. Le traitement multiple des données écologiques. Masson, Paris & Les Presses de l'Université du Québec, Montréal. <https://doi.org/10.1002/iroh.19810660515>
- Legendre, L. & Legendre, P. 1984. Écologie numérique. 2. La structure des données écologiques. Masson, Paris & Les Presses de l'Université du Québec, Montréal. <https://doi.org/10.1002/iroh.19810660515>
- Le-Houerou, H-N. 1980. L'impact de l'homme et des animaux sur la forêt méditerranéenne (1 ère et 2 ème partie). *Forêt Medit.* 1-14 et 1-20. http://www.foret-mediterraneenne.org/upload/biblio/FORET_MED_1980_1_31.pdf
- Le-Houerou, H.N. 1995. Bioclimatologie et Biogéographie des steppes arides du Nord de l'Afrique. Diversité biologique, développement durable et désertisation, Options méditerranéennes, sér. B: recherches et études, 1-396.
- Long, G. 1958. Description d'une méthode linéaire pour l'étude de l'évaluation de la végétation. *Bull. Serv. Carte phytogéographique, B III, 2:* 107-128.
- Mathez, J., Quezel, P. & Raynaud, C. 1985. The Maghreb countries. In: Gomez Campo C. *Plant conservation in the mediterranean area*, 141-157
- Medail, F. & Quezel, P. 1997. Hot-spots analysis for conservation of plant biodiversity in the Mediterranean basin. *Ann. Missouri Bot. Gard.*, 84: 112 -127.
- Meddour, R. 2010. Bioclimatologie, phytogéographie et phytosociologie en Algérie, exemple des groupements de la Kabylie Djurdjurenne. Thèse de doctorat, université Mouloud Mammeri Tizi Ouzou.
- Mejías, J.A., Arroyo, J. & Marañón, T. 2007. Ecology and biogeography of plant communities associated with the post-Pleistocene relict *Rhododendron ponticum* subsp. *baeticum* in southern Spain. *Journal of Biogeography.* 34, 456–472
- Merioua, S. M., Seladji, A. & Benabadji, N. 2013. Anthropozoic impact on the floristic biodiversity in the area of Beni Saf (Algeria). *The Open Ecol. J.*, 3: 254-264. <http://dx.doi.org/10.4236/oje.2013.33029>

- Messaoudene, M., Laribi, M. & Derridj, A. 2007. Étude de la diversité floristique de la forêt de l'Akfadou (Algérie). *Bois et Forêt des tropiques*, 291(1): 75- 81. <https://doi.org/10.19182/bft2007.291.a20359>
- Prodon, R. & Lebreton, J.D. 1994. Analyses multivariées des tableaux espèces- milieu: structure et interprétation écologique. *Vie et Milieu*, 44(1): 69-91
- Quézel, P. 1965. La végétation du Sahara Du Tchad à la Mauritanie. Masson. Paris.
- Quézel, P. 1985. Definition of the Mediterranean region and the origin of its flora. In: Gomez-Campo: Plant conservation in the Mediterranean area. Junk. Dordrecht, 9-24.
- Quézel, P. 2000. Réflexion sur l'évolution de la flore et de la végétation au Maghreb méditerranéen. Ibis Press, Paris.
- Quézel, P. & Medail, F. 2003. Écologie et biogéographie des forêts du bassin méditerranéen. Elsevier, Paris.
- Quézel, P. & Santa, S. 1962. Nouvelle flore de l'Algérie et des régions désertiques méridionales (Vol. 1). CNRS, Paris.
- Quézel, P. & Santa, S. 1963. Nouvelle flore de l'Algérie et des régions désertiques méridionales (Vol. 2).CNRS, Paris.
- Rebbas, K. 2014. Développement durable au sein des aires protégées algériennes, cas du Parc National de Gouraya et des sites d'intérêt biologique et écologique de la région de Béjaïa. Thèse de doctorat, université Ferhat Abbas Sétif, Algeria.<http://dspace.univ-setif.dz:8888/jspui/handle/123456789/1088>
- Sedjar, A. 2012. Biodiversité et dynamique de la végétation dans un écosystème forestier- Cas de djebel Boutaleb- Mémoire de magister, université Ferhat Abbas Sétif, Algeria.
- Slimani, H.& Aidoud, A. 2018. Quarante ans de suivi dans la steppe du sud-oranais (Algérie): changements de diversité et de composition floristiques. *Rev. Ecol. (Terre et Vie)*, 73: 293-308. <http://hdl.handle.net/2042/68142>
- Stiti, B., Mannai, Y., Khaldi, A. & Henchi, B. 2012. Richesse spécifique et distribution spatiale de la strate arbustive de la subéraie de Ain Snoussi, Tunisie. *IOBC/wprs Bulletin*, 76:9-16

Annex 1: Species listed in the study area

Species listed in the study site	
<i>Aegilops triuncialis</i> L.	<i>Lamium amplexicaule</i> L.
<i>Ampelodesmos mauritanicus</i> (Poir.) T. Durand & Schinz	<i>Lavandula dentata</i> L.
<i>Anacyclus clavatus</i> (Desf.) Pers.	<i>Lavandula stoechas</i> L.
<i>Anacyclus radiatus</i> Loisel.	<i>Lavatera arborea</i> L.
<i>Anagallis arvensis</i> L.	<i>Linum tenue</i> Desf.
<i>Anemone palmata</i> L.	<i>Linum strictum</i> L.
<i>Anthemis</i> sp.	<i>Lolium rigidum</i> Gaudin
<i>Arbutus unedo</i> L.	<i>Lonicera implexa</i> Aiton
<i>Arenaria serpyllifolia</i> L.	<i>Lotus edulis</i> L.
<i>Arisarum vulgare</i> Targ. Tozz.	<i>Malva sylvestris</i> L.
<i>Aristolochia baetica</i> L.	<i>Marrubium vulgare</i> L.
<i>Asparagus acutifolius</i> L.	<i>Medicago littoralis</i> Rhode ex Loisel.
<i>Asphodelus microcarpus</i> Viv.	<i>Melilotus infestus</i> Guss.
<i>Avena bromoides</i> Gouan	<i>Mentha pulegium</i> L.
<i>Bellis annua</i> L.	<i>Mercurialis annua</i> L.
<i>Bellis sylvestris</i> Cyr.	<i>Mollugo cerviana</i> (L.) Ser.
<i>Beta vulgaris</i> L.	<i>Muscari neglectum</i> Guss. ex Trin.
<i>Biscutella didyma</i> L.	<i>Myrtus communis</i> L.
<i>Briza maxima</i> L.	<i>Nepeta multibracteata</i> Desf.
<i>Bromus fasciculatus</i> C. Presl	<i>Nerium oleander</i> L.
<i>Bromus hordeaceus</i> L.	<i>Olea europaea</i> L.
<i>Calicotome spinosa</i> (L.) Link	<i>Ophrys tenthredinifera</i> Willd.
<i>Carduus</i> sp	<i>Ornithogalum umbellatum</i> L.
<i>Centaurea pullata</i> L.	<i>Phagnalon saxatile</i> (L.) Cass.
<i>Chamaerops humilis</i> L.	<i>Phillyrea angustifolia</i> L.
<i>Cheilanthes acrostica</i> (Balb.) Todaro	<i>Phillyrea latifolia</i> L.
<i>Chrysanthemum coronarium</i> L.	<i>Picris cupuligera</i> (Durieu) Walp.
<i>Chrysanthemum</i> sp.	<i>Pinus halepensis</i> Mill.
<i>Cistus ladaniferus</i> L.	<i>Pistacia lentiscus</i> L.
<i>Cistus monspeliensis</i> L.	<i>Plantago amplexicaulis</i> Cav.
<i>Cistus salviifolius</i> L.	<i>Plantago coronopus</i> L.
<i>Clematis cirrhosa</i> L.	<i>Plantago lagopus</i> L.
<i>Clinopodium calamintha</i> (L.) Kuntze	<i>Poa bulbosa</i> L.
<i>Colchicum filifolium</i> (Cambess.) Stef.	<i>Prunus avium</i> (L.) L.
<i>Convolvulus althaeoides</i> L.	<i>Pulicaria odora</i> (L.) Reichb.
<i>Crataegus oxyacantha</i> subsp. <i>monogyna</i> (Jacq.) Regel	<i>Quercus canariensis</i> Willd.
<i>Crepis vesicaria</i> L.	<i>Quercus ilex</i> L.
<i>Cynoglossum creticum</i> var. <i>pictum</i> (Soland.)	<i>Quercus suber</i> L.
<i>Cytinus hypocistis</i> (L.) L.	<i>Ranunculus paludosus</i> Poir.
<i>Cytisus villosus</i> Pourr.	<i>Ranunculus repens</i> L.
<i>Dactylis glomerata</i> L.	<i>Reichardia picroides</i> (L.) Roth
<i>Dactylorhiza markusii</i> (Tineo) H. Baumann & Künkele	<i>Rhamnus alaternus</i> L.
<i>Daphne gnidium</i> L.	<i>Rochelia disperma</i> (L.f.) K. Koch
<i>Daucus carota</i> L.	<i>Rosa canina</i> L.
<i>Dioscorea communis</i> (L.) Caddick & Wilkin	<i>Rubia peregrina</i> L.
<i>Drimia maritima</i> (L.) Stearn	<i>Rubus ulmifolius</i> Schott
<i>Erica arborea</i> L.	<i>Ruscus aculeatus</i> L.
<i>Erodium cicutarium</i> (L.) L'Hér.	<i>Salvia verbenaca</i> L.
<i>Erodium moschatum</i> (L.) L'Hér.	<i>Sanguisorba minor</i> Scop.
<i>Erophaca baetica</i> (L.) Boiss.	<i>Scabiosa stellata</i> L.

Eryngium campestre L.
Euphorbia helioscopia L.
Euphorbia peplus L.
Euphorbia segetalis L.
Filago argentea (Pomel) Chrtk & Holub
Filago exigua Sibth.
Foeniculum vulgare Mill.
Fumaria bastardii Boreau
Fumaria bicolor Sommier ex Nicotra
Fumaria parviflora Lam.
Gagea algeriensis Chabert
Galactites tomentosus Moench
Galium mollugo L.
Galium verrucosum Huds.
Genista tricuspidata Desf.
Geranium malviflorum Boiss. & Reut.
Geranium robertianum L.
Geranium rotundifolium L.
Herniaria hirsuta var. *cinerea* (DC.) Loret & Barrandon
Hypericum caprifolium Boiss.
Hypochaeris laevigata (L.) Ces. & Pass. & Gibelli
Inula montana L.
Iris planifolia (Mill.) Fiori & Paol.
Iris tingitana Boiss. & Reut.
Juniperus oxycedrus L.
Lagurus ovatus L.
Schismus barbatus (L.) Thell.
Scolymus hispanicus L.
Scorpiurus muricatus L.
Sedum pubescens Vahl
Senecio vulgaris L.
Sherardia arvensis L.
Silene conica L.
Silybum marianum (L.) Gaertn.
Sinapis arvensis L.
Smilax aspera L.
Spartium junceum L.
Stachys ocymastrum (L.) Briq.
Stellaria pallida (Dumort.) Piré
Teline linifolia (L.) Webb & Berthel.
Teucrium fruticans L.
Torilis arvensis (Huds.) Link
Trifolium angustifolium L.
Trifolium campestre Schreb.
Trifolium stellatum L.
Tulipa sylvestris L.
Umbilicus horizontalis (Guss.) DC.
Urtica membranacea Poir.
Valerianella discoidea (L.) Loisel.
Vicia sativa L.
Withania frutescens (L.) Pauquy
