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Article · August 2021

DOI: 10.38150/sajeb.11(4).p378-389

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REVIEW ARTICLE

Algerian Argan: Biodiversity, ecological services, and landscapes: A review

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ARTICLE INFO

Article History:

Received: 3 Mar 2021

Revised: 10 May 2021

Accepted: 11 May 2021

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Keywords: Argan, faune, flora, geomorphology, sustainability, Tindouf

ABSTRACT

The Argan is a multipurpose tree, endemic of South-west of Morocco and Algeria. It populates the Sahara and gives it a very particular physiognomy which is that of the sparse forest. The argan forest is a patchwork of species occupying distinct environmental niches across the Hamada of the South-west region of Algeria. It covers a region characterized by the aridity of the climate and extreme xericity with geological and pedological diversity that are the source of the broad range of magnificent landscapes (Hamada, wetlands, escarpments, wadis, Regs, mountains). The association of plants with landscapes, reveals an environmental heterogeneity influencing the richness in species and allowing a dynamic and development of a diversified floristic cover mainly xerophilic and thermophilic. The originality of its flora is ascribed to the presence of Saharo-sindian elements, Mediterranean and endemic. This particular diversity is due to its biological characterization, systematic and phytogeographic. Unfortunately, this ecosystem and its potential for biological resources are today highly threatened and face degradation from disturbances and uncontrolled exploitation of the plant environment by anthropogenic activities, that requires the development of a preservation strategy. Our work emphasizes the importance of this genetic heritage and its original ecosystem, where the preservation must be secured through the establishment of a strict protection system of species throughout their natural range.

1. Introduction

Algeria is the largest country in Africa with an area of more than 2.3 million km². It is home to very diverse ecosystems which are characterized by a remarkable flora richness of great interest. In the southwest of the country, the Argan tree (*Argania spinosa*) is an essential component of the landscape and creates exclusive habitats with a range of flora and fauna serving as a foundation for biodi-

versity. *Argania spinosa* (L.) Skeels is an Algerian-Moroccan endemic species. It is a member of the tropical family Sapotaceae, since it is the only northern representative in the Mediterranean region. It is a forest, forage and fruit tree that provides several economic and social functions. Argan oil has many virtues, appreciated for its nutritional and organoleptic quality, or used in cosmetics (Chaussod et al., 2005). This taxon is the second

forest species behind the Talh (*Acacia radianna*), it forms dispersed populations in Hamada of Tindouf (Baumer and Zeraia, 1999), where their range covers a relatively important geographical area in the North of the wilaya.

Tindouf argan forest suffers from various human impacts that affect its dynamics, in particular an aberrant imbalance which is directly linked to the responses to the socio-economic needs associated with abiotic factors such as climatic hazards, as well as frequent and varied parasitic attacks resulting in risks resulting in irreplaceable species losses. Faced with these impacts, the argan system owes its resilience potential, its ability to resist harsh natural conditions and complex socio-economic issues in its multifunctionality and the intimate relationship of respect and interest of local population towards these ecosystems (Azenfar, 2007).

The argan tree, which represents a source of income for the inhabitants of the southwestern region of the country, and plays an irreplaceable role in the ecological and economic balance, is currently threatened with extinction due to natural hazards and, above all, acts of predation (Ouldsafi et al., 2015). Under the combined effect of pastures and excessive logging, its natural habitat shrinks inexorably, to form only relic stands with different typologies (Benkheira, 2009). Argan forest suffers continuous degradation due to intensified use and the lack of regeneration this affected an already delicate situation (Hamani, 2010).

In Algeria, the preservation of the argan stand is a very important environmental and socio-economic issue. a better understanding of disturbance problems is therefore of great importance. To do this, it is crucial to make a physical and biological characterization of the region to know the different ecological units and the plant and animal species they contain. The main objective of this review article was to provide guidelines for supervising the preservation of this tree populating a fragile Saharan ecosystem, and thus to ensure proper management of this environment.

2. Location of the natural argan tree stand

The Algerian argan forest is located north of Tindouf. Morphologically, the region consists of broad flat expanses (Hamada) with some reliefs in its North West, where it is composed of several compartments or facies landscaping, thus creating a mosaic landscape specific to the areas arid.

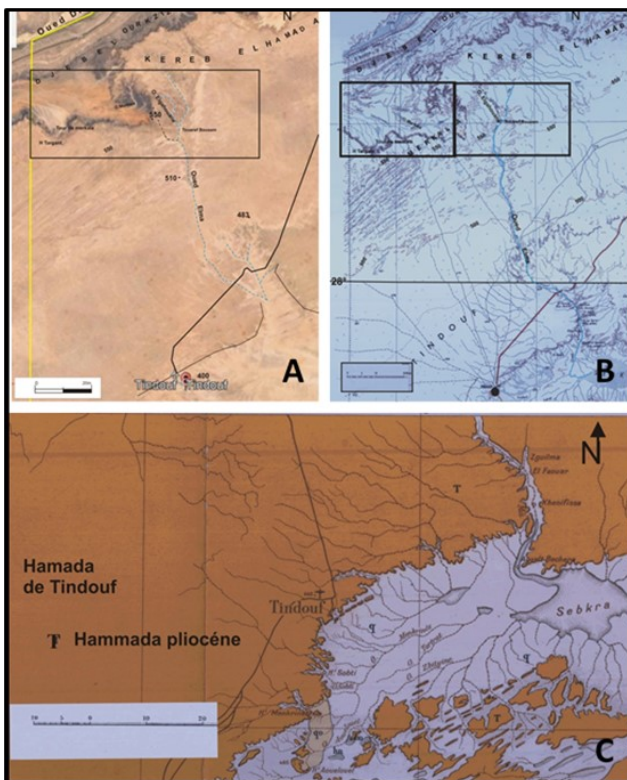


Figure 1: Plate represents location of the natural argan tree.

A: Satellite map

B: Topographic map

C: Geological map

This site is in geomorphological continuity with Djebel Ouarkiz (662m altitude) in the north and integrates the southwestern overflow of Wadi Draâ, 110 km from the main town of the Wilaya. The area covered by the argan tree in its natural environment is varied according to the authors (90644Ha, Kechairi, 2009; 96940 Ha, Kechabar et al., 2013). They occupy the beds of sandy, gravelly and rocky wadis. The very low slope (0 to 6%) on a "rough" Hamada, also the other classes of the slopes designate the K'reb Elhamada cliffs, where it occurs at altitudes from 320 and 630m. There are three perimeters of the argan: Touiref Bouame, Merkala and Oued Tergante.

An appreciation of the pluviometric map made by Dubief (1963), shows that our station is located between the 30 and 50 mm isohyets with the rainfall < 25 mm elsewhere of the wilaya. Precipitation varies little over the year and for the wettest month does not exceed 13 mm. The limit between the arid and the Saharan is marked by rainfall below 100 mm/year. As well as the spatial location of the Algerian argan tree shows that their installation extending more than 222 km beyond the Atlantic Ocean which shifts the limit of 150 km proposed by some authors (Kechairi, 2009). The Argan tree within this perimeter, where the maritime influence

become blurred, is confined along temporary water courses and can be developed only under cover of the necessary water compensation (Quezel et al., 1995) to the extent that the tree has a tendency to become riparian.

3. Natural environment study of Tindouf region

The physical habitat of flora and fauna and of all organisms is a combination of ecological characteristics related to geomorphology and climate, as well as the interaction between the actors. Spatially, the biological structure adopts a particular behavior as it is dependent on the physical structuring of the environment (topography, geomorphology and organization of the soil), particularly in arid and Saharan areas where the physical characteristics of the environments are closely interdependent. These formations induce a behavior of the species marked by the adaptation to environmental conditions, composition, and floristic procession. According to Chan et al. (2006), characterizing the functions of natural environments is a new global trend that facilitates the enhancement of natural environments.

Geomorphology – geology

Morphologically, Tindouf region is characterized by relative uniformity, a few cliffs bordering rigid platters, Eglabes and rocky areas (crystalline basement, peneplain), Erg Iguidi, North East direction, intersecting the central part of the crystalline massif of Eglab, vast plateau of the North and East, mountainous reliefs (Paleozoic basins) covering all its northern central part, depressions and wadis.

The recent superficial geology is represented by the Hamada formation. The Draa Hamada is the largest of the Grandes Hamadas system, which also includes the Guir Hamada and the smaller Daoura Hamada. The Draa Hamada extends into the Tindouf basin between the southernmost Anti-Atlas aureoles (carboniferous series of the Ouarkiz massif) and the Reguibat Precambrian arch. Most of this Sahara plateau consists of Cenozoic continental deposits, loosely assigned to the Miocene-Pliocene and passing upward to Quaternary formation (Zouhri et al., 2008).

The region of Tindouf is exceedingly rich in its varied landscapes as well as the natural habitats they contain ranging from the impressive dunes of Erg Iguidi which has a geological structure with the appearance of stony plateaus and valleys dug by wadis to the Jebel Ouarkiz through the immensity

of the Hamada. The biotopes are diversified: made up of recent terraces, daïas clays, wadi beds with acacia, argan, steep wadis, numerous rocky cliffs, alluvial fans of wadis, Regs, Sebkha, temporary waterfalls, daïas clays and several gueltats, of which the most important is Tafagoumt which is classified as a wetland.

Hydrology

The wilaya of Tindouf is drained by a very low density hydrographic network, whereas the Tindouf sebkha and some small watersheds to the South, with imprecise limits, are endorheic, belonging to the agency of the watershed in the South.

The hydrographic network, characterized by wadis with intermittent flows (W. Tartrat, W. El Ma, W. Mekrines, W. Sobti, Djez...), often dry over the year, light rainfall turned the wadis into a real torrent, which are generally directed towards the axis of Tindouf sebkha. To the east and south-east, the drainage of the Hamada is much less designed. They have always resorted to groundwater to respond to the absence of surface waters. There are four groundwater systems: the Hamadian, Upper Visean, the Lower Devonian sandstone and the Cambro-Ordovician sandstone (Idrotecn, 1979).

Soils

In the region of Tindouf, the soil of different lithology, one finds at different proportions the Tertiary continental deposits, the sands (quartzofeldspathic), the gravels, the various alluviums, the limestones, the sandstones and the primary shales (B.N.E.D.E.R., 2002). The argan tree grows in shallow, slightly developed skeletal soils, with the exception of areas characterized by undeveloped climate soils resulting from water and wind erosion processes.

Climatic analyzes

Precipitation is the most important factor in the distribution of vegetal formations in desert regions. The rains in the Sahara are characterized by their low quantitative importance, there is no rainy season in the true sense of the word, they are erratic, occasional and torrential rainfall. However, they cause severe flooding in a short time. As a result, the growing periods of plant are fleeting, irregular and unpredictable.

We based our study on the 30-year climate data measured at the Tindouf Weather Station. Rainfall in the region is characterized by both annual and

seasonal irregularities, it generally does not exceed 60-80 mm/year. October, November, and December witness the most rainfalls, only the autumn season receives more than 40% of the rains, while the winter-autumn semester receives almost 75% of the rains, so the rest of the year receives negligible rainfall to non-existent. The seasonal rainfall regime is of the AWSS type (autumn, winter, spring and summer). The number of rainy days varies between 10 to 20 days.

The period of extreme heat stretches from April to October. The daily temperature range can exceed 20° C. Tindouf is characterized by a continental climate (Saharan) with hot, dry summers (+ 45°C), and short mild winters. This causes a low moisture content of the lower layers of the atmosphere (the average annual relative humidity does not exceed 40%). Because of its vast area and its extremely flat topography, Tindouf region is highly exposed to winds. The prevailing direction are northwest, their maximum speed recorded varies between 6 m/s and 10 m/s in July and August.

Bioclimatically, it shows that the dry period of this station is very important, it spreads over all the months to the extent that the temperature and precipitation curves do not meet. July is the driest month of the year, and the rains reach the maximums in the month of December.

Overall, the study carried out on Tindouf reveals that this region belongs to a Saharan climate, which is characterized by intense evaporation, high daily thermal averages with large temperature differences between day and night. Extremely low rainfall causes drought throughout the year and an increase in the continentality index. The soil has a sandy texture with a low level of limestone.

The approach to the climatic factors of the region has shown that the Algerian argan forest is very adapted to hostile ecological conditions., It occupies the driest and hottest areas marked by the persistence of drought and the random nature of autumn and winter precipitation with very different geographic distribution and quantity.

This tree is very effective to help fight desertification in a very fragile and highly vulnerable area cannot be replaced in its protective and biodiversity function. Despite this meteorological characteristic, the argan tree is quite indifferent to the soil. This territory, typically provides suitable conditions for the growth of this species but also an abundant

plant and wildlife.

These conditions, which are so particular, characterize the functioning of biotopes as the basis of the structuring and maintenance of biocenoses, offer proper conditions for growth of this species but also an abundant fauna and flora, and regulate all activities based on ecosystem services (camels, goats and sheep rearing, gathering plants and mushrooms, etc.).

4. Biodiversity of the argan grove

Floristic diversity

Landlocked between the southern ridges of Jebel Ouarkiz, the "kreb" and the rocky plateau of the Hamada, wadi El-Ma and its junction with Wadi El-Gahouane, this Hamadien geosystem contrasts with a set of linear argan trees that grow along the Wadi edges, along which developed Saharan steppes dominating the entire landscape. The Saharan profile vegetation is exceptional despite the climatic vicissitudes.

The specificity of regional vegetation is two-fold; on the one hand, a certain number of very specialized species have adapted to the rather harsh conditions due to the xeric environment and the hyper-aridity climate, and on the other hand, it is marked by endemism.

In Algeria, the endemism rate is 8%, it is particularly high in the Algerian Sahara (more than 100 species), where it reaches 44% in the South West region (Guenai et al., 2019), due to the existence of diverse ecological conditions and the presence of vast spaces that are unsuited to the lifestyles and which constitute obstacles to dissemination of species (Bounaga and Brac de la Perriere, 1988), this life is the result of the success of morphological, anatomical, and physiological adaptation. Boulos (1997), stated that the relatively high number of indigenous genera in the Saharan region of North Africa reflects the greater impact of the Sahara on the evolution flora of this region compared to the more recent Mediterranean flora.

The vegetation of this region is arranged to the contracted mode, the plant species and their distribution depend on the hydrographic network for their survival, as wadi beds, depressions (Dayas) and basin where the surface waters pile up. However, their density is affected by the intensity of the exogenous disturbance agents, anthropogenic. Draa Hamada has a structure of plant formations

"wooded steppe", where the argan tree is considered the jewel in the crown of the ecosystem around which more than 50 species are identified and form a rich floristic environment and high diversity in vegetation groups.

Phytogeographically, these species belong mainly to four biogeographical origins, they constitute the area of Saharo-sindian species 27%. According to Ozenda (2004), the Saharo-Sindian element is still clearly predominant, it represents more than three-quarters flora in the northern Sahara. Thus, an interpenetration between the Saharan and Mediterranean elements represents respectively 16% and 15%. The cosmopolitan elements are represented only by 11% of the species composition. Furthermore, other elements are only marginally present (Saharo-Mediterranean, North Africa and Algerian-Moroccan endemic) with a share of less than 4%.

The phytogeographic analysis shows that the region has a relative importance of the endemic species, hence, the specific taxa of the region are absent from the rest of the Algerian Sahara but found in other countries, particularly in neighboring countries (Morocco). The great floristic similarity between the area concerned and Morocco can be explained by an East-West oriented cross-border floristic connectivity, as opposed to the Nord-South gradients that strongly influence the floristic composition.

The physiognomy and structure of a vegetation are related to the biological types of the different components of the plant community. The relative proportion of each biological type in a vegetation is called the biological spectrum. This biological spectrum of a formation determines the general morphology of the species, which expresses in part its adaptation to the environment. It is also a measure of the environmental conditions, especially climate and the plant function and its adaptation to the environment and pressures exerted by human and herbivorous animals.

The taxa were characterized depending on their growth habit or their morphology according to Raunkiaer's classification, which expresses the plants evolutionary adaptations to the environment (Orshan, 1982). Indeed, the spontaneous vegetation of the region, is distributed within some plant formations, dominating the territory in question. These formations characterize the general geomorphological landscape of the Saharan zone, to con-

stitute pre-steppes that characterize the northern region of Drâa Hamada, largely dominated by therophytes (45%), followed by chamephytic vegetation (*Launaea arborescens*, *Farsetia*, *aegyptiaca*, *Zilla macroptera*, *Gymnocarpus decander*, *Haloxylon scoparium*) which represents 30.5%.

The phanerophytes represent the strata of shrubs and trees compounds in association with the argan tree (*Acacia raddiana*, *Acacia albida*, *Calotropis procera*, and *Phoenix dactylifera*, *Rhus tripartitus*, *Zizyphus lotus*, *Lycium intricatum* and *Lycium afrum*) with a rate of 19.5%. They are developed in several biotopes. The least frequent biological types represented by Hemicryptophytes and Geophytes with respectively 3.5% and 1.5% of the floral composition (Benkheira, 2009).

The inequality of the seasonal distribution of plants is directly related to their adaptation to drought - Ozenda, 1991) and their direct dependence on rainfall patterns (Carriere, 1989; Grouzis, 1992; Lecompte-Barbet, 1975). Indeed, Mackenzie et al. (2000) emphasized that the ephemerophytes are very capricious, they occupy only sporadically and fleetingly the land and that only the perennial species remain constantly. This is marked by the invasion of these plant groups the under clump of *Jujube* (*Zizyphus lotus*).

Among the ephemera, therophytes are more resistant to summer drought than hemicryptophytes and geophytes since they spend the summer as seeds while the others remain in the form of vegetative organs.

The therophytes constitute a rather heterogeneous herbaceous layer and colonize the water flow of the region, as reported by Poilecot (1996), which indicates that the herbaceous layer follows the surface water and settles in the gullies. For the arid and semi-arid Mediterranean areas, it is the therophytes that dominate (Lacoste and Salanon, 2001).

The rate of therophytes is related to the opening of the vegetation and the overall humidity of the environment (Daget, 1980). In this perimeter, the argan populations are dispersed and grouped in a contracted mode, they are confined along the banks of temporary watercourses, where they find the necessary water compensation and benefit from important summer cloud cover, accompanied by a freshness and relative humidity, all due to the Atlantic Ocean influence, the argan traps and re-stored to the soil (Benkheira, 2009).

The Therophytes have a very short annual cycle, they appear as the first rains in October-November that caused its germination, and grow over the rainy season, exploiting the slightest drop of rain that dampen an outer layer of sand. Negre (1966) emphasized that the existence of annual species (Therophytes) is related to the condition of the soil surface. Owing to the completing of their cycle during the wet season, they are considered as very abundant secondary species in the steppic and Saharan areas as adventitious, messicoles and ruderal. On the other hand, the second community of this biological type (permanent) exploits the soil's water reserves and therefore remains green during the dry season, constitutes excellent pastures that are richer and more sustainable, as is the case with the Touaref Bouam and Merkala perimeters. However, in the Targant perimeter, the therophytes are less abundant, due to the state of protection by the inaccessibility to the border with Morocco, the diversity and the vegetal cover increase according to the transect East-West. Barbéro et al. (2001) report that therophysation is considered as the final stage of degradation of different ecosystems with the dominance of sub-nitrophyl species related to overgrazing.

In arid and semi-arid zones of North Africa, overgrazing is generally considered as an essential cause of the natural ecosystem's degradation (Le Houerou, 1968). Floret and Pontanier (1982) reported that the more a system is influenced by humans (overgrazing, cultivation), the therophytes are becoming more important.

Therophytes result in drought resistance through seed survival (Monod, 1992). This form seems to be the most adapted to the high temperatures of arid environments (Kaabèche, 1990). If the seed remains a conservation organ well suited to long dry seasons, the reduction of the plant cycle is a very effective strategy (Poilecot, 1996).

The abundance of chamephytes at the expense of phanerophytes is the result of environmental degradation because the first type has an adaptation to summer aridity and light than the second biological type. Benabadji and Bouaza (2002) showed that chamephytes are more adapted to the drought than phanerophytes, they are more xerophilous, and usually they produce a lot of seeds. Grazing also has favored the chamephytes rejected by herds (Kadi-Hanifi, 1998).

The tree layer of the arid zone is very dispersed in

space (Ozenda, 1964). The hydrographic network offers a remarkable landscape to this region which is formed by lithological variations: the continental Tertiary deposits, sands, gravels, various alluviums, limestones, sandstones, and primary schists.

The argan tree has powerful root system that extends over a large area, the roots are very deep, so they can search out water into the rocky soils. As well as the most water-fed environments such as wadi beds are covered by a predominantly phanerophyte stratum, playing a decisive role in settlement a range of flora (Lecompte-Barbet, 1975). The proportions of geophytes and hemicryptophytes are minority due to the high temperatures of arid environments. In general, Hemicryptophytes reflect the effect of rainfall and cold (Floret et al., 1990).

Argan forest ecosystems have changed significantly, these changes have been particularly rapid over the last fifty years, which induces a fragility of ecological balance.

In Tindouf, anthropogenic pressures considerably modify the distribution area, argan stand structure and constitute a threat to its durability, with the consequent lack of natural regeneration (Kaabèche et al., 2010). The farming is the important factor for the regression of the Argan trees, but also other forage ligneous species (Delperugia, 1970; Aouad, 1989).

Argan polymorphic features is very striking, where the argan structure variability (spatial structure, diameter and height structure) observed at different scales. There are extremely varied forms depending to the sectors and the stage of tree development. Sometimes it has the majestic appearance of an oak tree, other times its gnarled trunk and twigs make it look like an olive tree (Radi, 2003).

The southwest region is of great interest from a floristic and phytogeographical point of view, hosting the only naturally cultivated argan trees in the country and represents a link between the Algerian and Moroccan flora, where the open forest of acacias and argan trees announces the Sahara. It allows the development of a very diversified floristic cover. It is believed that this is mainly due to the presence of a mosaic environment in the Hamada du Draa: pre-steppes, wadis, ergs, Dayas, depressions and rocky outcrops, forming a variety of habitats, each with particular characteristics.

Argan also plays an irreplaceable ecological role,

providing shade and shelter against the effects of extreme evapotranspiration, it serves as a natural tool against desertification with its powerful root system, it grows in areas where the soils are poor and shallow, so it contributes to retain the soil and helps fight against the wind and water erosion.

We noted that the rates of distribution of the biological types are variable with each season, particularly in the Saharan environment, where rainfall and its variability are the main components of aridity. Indeed, it seems that the Therophytes reflect the importance and variations of this climatic factor.

A remarkable degradation of vegetation on the eastern sides of the Algerian Argan forest is caused by the local population and nomads by overgrazing (camel and goat), associated with illegal logging and charcoal, with the result being increased pressure on rangeland and the species most palatable, exposing argan trees to serious environmental damage that impact on the biodiversity and changes in floristic composition of Argan forest threaten ecosystem health and many endemic species.

The pressure is mainly exerted on the *A. tortillis* and the argan tree, as well as other trees and shrubs (*A. albida*, *A. ehrebergiana*, *Balanites* and *Maerua crassifolia*) which are taken and are used as fodder for goats and camels when grassy plants have become scarce.

In addition, these ecosystems suffer from abusive felling timber excessive logging, large-scale poaching with firearms and pastoral pressure, but particularly from persistent drought which sometimes spans ten years. The physiognomy of argan stands observed today is the result of interaction between human and natural factors.

Agricultural holdings in such an environment is often a source of imbalances which are accentuated by the insufficiency or ignorance of adequate management rules, as evidenced by the new developments which have increased in recent years on the Hamada of Tindouf and close to other urban centers, such as Oum Lassel.

Due to the dynamics of the environment- prevailing production systems relationships in the region, namely pastoralism, the extent of urban sprawl, with what it generates as the extraction of different aggregates designed for urban worksites or roads, there are major ecological imbalances resulting in the degradation of biodiversity but also in changes

in social attitudes.

Fauna diversity

Argan stands contribute to the connectivity of Saharan natural environments, thus allowing the biological components circulation and transition with large but not homogeneous ranges. This region certainly represents a shelter for an important biomass, it is characterized by its original and particular faunistic richness (mammals, birds, reptiles etc.), where the majority of the species belonging certainly to the Saharan regions but whose adaptability to this climate are proven, and they find in the argan tree, a favourable ecosystem for the establishment of shelters.

Argan tree supports a rich array of fauna, including 15 species of mammals, 83 species of birds, of which 34 are sedentary or breeders, while around fifty come to overwinter there or are migrating (Moali, 2017). In this context we mention the presence of the Dorcas Gazelle and a strong presumption about the existence of the Gazelle Dama and the antelopes. As for the canids and the striped Hyena also finds a favourable environment. It is in the Ouarkiz region that the southernmost population of the Berberian squirrel is still found and is in serious decline and seems to have disappeared from all Saharan atlas (Ahmim, 2019). Its presence has been proven in the region, at some locations, notably in Wadi's narrow sides and especially the rocky escarpments. Cape Ratel also frequents this ecosystem through sporadic appearances. The large wadi beds and wetlands act as biological corridors necessary for the movement of gazelles, camels, migratory birds, nomads and their knowledge.

Drought is an aggravating factor in rarity of species due to the decline in habitat quality. The other threat is hunting and large-scale poaching with firearms, which are ubiquitous and constitute a systematic danger to the entire ecosystem by displacing animals to remote, isolated places that are difficult to penetrate and inaccessible to humans, such as rocky escarpment of hamada and confined sides of wadis.

The nomadic lifestyle does not seem to be the main threat to ungulate populations, but the motor vehicle traffic of poachers is certainly the main threat, as it is intense for the Houbara Bustard (*Chlamydotis undulata*), another emblematic species of the steppe and pre-Saharan areas. The latter

is outright the subject of expedition by poachers coming from the Gulf countries without consideration of the precautions to conserve numbers of the species in order to ensure the sustainability of its population (Moali, 2017).

Hunting and poaching are thus responsible for more than 70% of the bustard mortality observed in certain wintering areas (Combreau et al., 2001). Habitat degradation also has a significant impact on bustard populations. For example, overgrazing changes the availability of animal and plant resources, causes disturbance of females during incubation and reduces the plant cover (Le Loc'h, 2015).

Herpetofauna are essential elements of many ecosystems because their existence can have a significant impact on the survival of many other species, including humans by affecting terrestrial and aquatic food webs. Where nature lacks diversity, humans also lack a quality of life that technology will never be able to replace (Nöllert and A Nöllert, 2003).

The diversity of amphibians in Algeria is much less important than the diversity of reptiles; the Saharan areas are not rich in amphibians which are more abundant in wetlands, but reptiles find their kingdom here, nevertheless, Tindouf is distinguished by a richness in herpetofauna compared to the other Saharan zones (Beddek, 2017). This is due to the mountainous and hilly character of the Draa region in the interior of the Hamada, as well as the climatic conditions offer favourable conditions for the existence of a well-diversified herpetofauna in a desert environment very poor in species.

The temporary watercourses and the sources (Targant, Tafagoumt) which appear in the Hamada are humid areas which give shelter to many Batrachians and Reptiles. Amphibians are important for ecology and biodiversity studies, and the peculiarities of their physiology make them sensitive indicators of the quality of environments they inhabit. Among the batrachians, two species are common in waterholes: these are the Mauretanian toad and the North African green frog, while the Brongersma toad is rare (Moali, 2017). The latter is an endemic species in Morocco, it is probably present along the Algerian-Moroccan border of Tindouf and Bechar. This species is likely to decline significantly due to habitat degradation thus making populations vulnerable (Rouag, 2012).

The decline of Amphibians makes these organisms good indicators for biodiversity assessment, and their role in the problem of the biodiversity crisis is increasingly important (Beebee, 2005; Semlitsch and Bodie, 1998). Amphibians are the primary biomass of vertebrates in many wetlands and they have a key role in the ecosystem trophic chain (Bouiedda, 2012). They are good indicators of environmental disturbances and a biological model used to study the impact of climate change on biodiversity (Pounds et al., 1999).

The argan forest is populated by various species found throughout the Saharan zone, especially in its western part which is the originality of biological diversity in the class of reptiles such as (*Stenodactylus sthenodactylus*, *Sphenops boulengeri* (Audouin's sand-skink) and *Stenodactylus petriei* (Petrie's Gecko),...). In this region, species richness of reptiles is 23 species, most of which are Saharan and well adapted to life in these conditions, more lizards than snakes (Moali, 2017), the latter are only represented by the ubiquitous Horned Viper (*Cerastes cerastes*) which uses the various refuges (both surface and deep, burrows for example) to shelter and to regulate its temperature (Le Berre, 1989), and to a lesser extent by the Horseshoe snake in inhabited areas where rodents are abundant (Moali, 2017). As for lizards, the species House Gecko (*Tarentola annularis*) is among the three rare species of Algerian herpetofauna, it generally frequents rocky areas, and described only in the region of Tindouf, where it is relict in this Sahara (Rouag, 2012).

The ecoregions in desert environments are, at the same time, both, hostile and very fragile, various biotic and abiotic factors influence faunal distribution. Arthropods and amphibians are a good indicator of environmental disturbances, because they have a key role in the ecosystem trophic chain.

In the face of threats to wildlife and its environment, the identification and assessment of the status of the various threatened species or on the brink of extinction, has become a necessity in order to carry out programs for the reintroduction of species into eco-geographically favorable habitats and protected areas.

5. Resources to enhance, function and structure of an ecosystem to "heal"

The degradation of the argan forest vegetation is caused by the local population and the nomads by

overgrazing (camel and goat), where the most widespread farming system is the pastoralism revolves exclusively around the use of argan-based forest courses, associated with illegal logging and charcoal, resulting in increased pressure on the most palatable rangelands and species, exposing the argan forest to serious environmental damage that has an impact on biodiversity and changes in the floristic composition of the forest threaten the health of the ecosystem and many endemic species (figure 2).

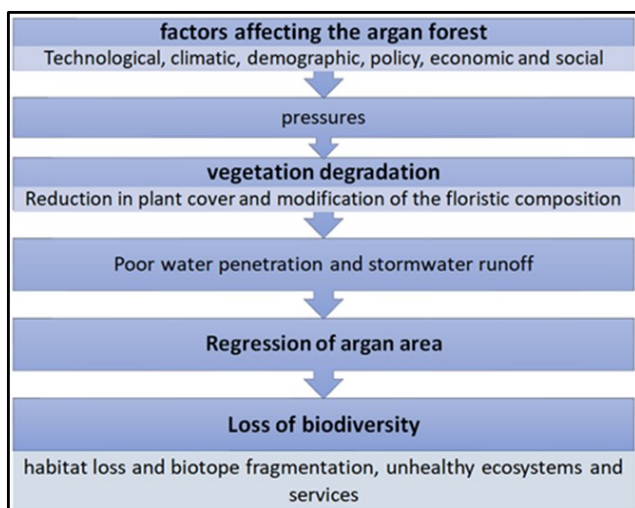


Figure 2: Process of arganeraie ecosystems degradation.

The Algerian Arganeraie is an area of remarkable diversity and an invaluable cultural and natural heritage. This endemic element is a precious asset that should be preserved in order to allow it to play its essential role in achieving and maintaining an ecological balance in the broadest sense and to value it in various economic opportunities.

This argan tree stand has an impact on the development of biodiversity, the protection of this heritage is an essential prerequisite for any attempt to remedy the degradation of the biodiversity of this ecosystem, which means great attention to showcase all of its assets and overcome the various pressures on this territory.

The diversity of natural environments fauna and flora is still significant, preparation must be made for the implementation of strategic protection actions for endangered habitats and key species for their conservation and enhancement. It was for this purpose that urgent measures have been taken by the Algerian authorities in recent years where only the Touaref Bou-âam perimeter argan grove is protected by Wilaya decree in February 2008 over an area of 635.90 km², but the protection of a single perimeter is still insufficient and the application of

this provision in practice is not appropriate and would at all be feasible, particularly in the lack of establishment of protected area system by grazing ban.

To this end, conservation objects have been identified to protect priority sites in order to maintain biodiversity, these are the argan tree stand which must benefit from a classification as a nature reserve, large wadis with acacia trees and rangelands for which emergency management plan is required and large mammals such as gazelles, barbary sheep and the Getulie squirrel (*Atlantoxerus getulus*).

The Tindouf region is also aboundin many species of aromatic, condiment and medicinal plants such as Gartoufa (*Cotula cinerea*), mugwort (*Artemisia judaica*), atil (*M. crassifolia*), talha (*A. albida*) and cedra (*Ziziphus lotus*) without forgetting (*Argania spinosa*) and the nutritional virtues of argan oil and its vocation in cosmetology have the effect of promoting this tree species after it was poorly known. In addition, during the rainy season, a lot of truffles (*Terfezia leptoderma*) are harvested and transported to the northern markets or directly exported.

The forested massif is a potential source of foreign currency likely to have greatest impact on economic recovery, the ecosystem services are many and varied: camel and goat breeding, medicinal plants and pharmacopoeia, crafts, camels and goats shearing, hunting, gathering plant for foods, camel milk products. The potentialities of this region are immense for the Saharan ecosystem which offers a diversity of natural and cultural sites, outstanding landscapes and locations which can generate high value added, with possibilities of stunning varied circuits, where ecotourism can also be developed on the basis of the diversity of landscapes, flora, fauna, knowledge making of the nomadic population transmitting important cultural diversity, knowledge and heritage. The landscape heritage and prehistoric archaeological sites make this region one of the richest in Algeria, displaying great originality. Great sites must be quickly placed under protection and better documented for their conservation and use in tourist itineraries if they were to materialize. Handicrafts can be revived if social demand is expressed, weaving, domestic artefacts, leather and plant baskets, leather work, pottery, etc.

Stopping the process of increasing degradation of the argan stand will be based on the establishment of management models that define shared objec-

tives between all social actors, ensuring the commitment of users (local population and nomads) in the argan regeneration programs.

6. Important actions to recommend

The main modern principles to ensure sustainable management of forest resources are based on the extent of these resources. This requires a development of the argan tree in the region through the improvement of technical activities such as reforestation operations and production of plants in the nurseries. Therefore, in the current situation, it is necessary to reinvigorate existing argan tree nursery and launch the creation of a modern nursery because several factors combine to optimize the germination of argan seeds which are very lignified (Hamani et al., 2018), and even to develop *in vitro* culturing techniques for the argan long-term conservation. This nursery will help boost production of argan seedlings and thus the extension of this tree and the contribution to the improvement of the culture of this saharan tree, as well as the production of other local woody species adaptable to the region of Tindouf (Acacias, Balanites, rhus, etc). A technical program sheet should also be developed to replanting and enhancement of these indigenous species. Thus, it would be wise to update the socioeconomic study to control the management of goat herd attendance in argan areas (Touiref Bouam, Targant, Oued Bouyadhine, Oued el Ma, Ouad Gahouane) which strongly affects the growth of seedlings. All these activities are not feasible without increasing human resources as well as for site surveillance.

The actions that will have to be taken to fight against all forms of nuisance should be proactive while remaining within the feasibility and respect for the principles of sustainable development. The planned actions must be directed at development actors after having been identified with precision and appreciate the relative importance of the interventions of each actor such as the local authorities, the local communities, the breeders, the nomads in relation to their role in maintaining biodiversity through their pastoral activities and assessment of ecosystem services, as well as the premises of changes in society through its urbanization and concentration in certain localities.

On this bases, the development of conservation strategy could be developed in order to align characteristics of the environment with the preliminary guidelines that have been identified to maintain

the integrity of ecosystems and preserve biodiversity by: effective management of semi-arid and arid areas, rehabilitation of degraded systems, increase the pre-forest areas of Acacia and Argan tree, implementation of accompanying measures to improve the living standards of populations who benefit from ecosystem services, education and awareness, scientific research and monitoring-evaluation; develop responsible tourism and ecotourism, which can contribute to the sustainable development of territories and local economies, while taking part in the respect for cultural diversity and heritage.

7. Conclusion and perspectives

The Algerian Sahara is characterized by variations in temperature, rainfall, elevation, and soil. These ecoregions harbor distinct communities of plants and animals. Tindouf hosts many ecoregions due to its climate affected by the depressions of the Atlantic Ocean. It is estimated to include hundred species of plants, among these plants, we found Argan, which contributes to the connectivity of Saharan natural environments, it characterized by its original and particular faunistic richness; endotherms such as birds and mammals are the least pronounced in these biotopes conversely to ectotherms like reptiles and amphibians.

In the Hamada of Tindouf, the argan tree ceases to form a compact stand. This current fragmentation proves a natural expansion of this tree and probably with a higher density. Thus, these stands settle less than the ecological conditions of those of Morocco, forming the most continental and eastern station, resistant to climatic hazards. Unfortunately, in addition to this abiotic factor, the situation is aggravated by overgrazing, illegal logging, and pests.

Few animals, have adapted to survive in the hottest desert regions with extreme conditions. they have evolved several strategies to resist, like (i) lose little water through urination and perspiration (ii) have humps to store fat; (iii) have large ears radiate body heat and help keep them cool; (iv) living in burrows during the day to avoid extreme heat.

The recent socio-economic enhancement of argan oil stimulates conservation and protection efforts for this taxon and other rare fauna and flora species in the region, but this requires a set of actions that address sustainable development programs. For this, we recommend:

- Adapt technical itineraries for the argan tree regeneration (reproduction and transplantation) ac-

cording to ecogeographic conditions, and the application of deferred grazing after planting, based on participatory approaches with the local population;

- Prohibit all cutting and contribute to the reduction of anthropogenic pressure on the forest;

- Controlling the trade and exploitation of wildlife products and timber;

- The establishment and application of legislative and regulatory texts which have direct or indirect link with argan protection and management in the Tindouf region;

- improving quality of life for the local population (water, electricity, etc) while protecting the environment by the development of the rural world compatible with conservation;

- Promotion of local products, which is an asset for the development of ecotourism, the latter constitutes a niche for publicize and making profitable the natural and cultural heritage;

- Install water and soil conservation development schemes, thus raising public awareness of sustainable consumption and resource use;

- The development of monitoring and operating techniques according to the balancing load;

- The creation of seed banks and an argan tree orchard, as well as the identification of areas that are likely to maintain adequate habitat conditions for key species of the argan stand.

Finally, with the covid -19 pandemic, we have noticed that the containment measures have helped to relieve anthropogenic pressure on the argan forest. We hope that this will allow a spontaneous reconstitution of the set ecosystem.

Acknowledgement

The author thanks all the people who supported the writing of this paper.

Conflicts of interest: The authors declare no conflicts of interest.

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