The study of desertification in Algerian steppic rangelands: Case of the Djelfa region

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Article Info

ABSTRACT

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The Algerian steppe suffered since several decades a serious problem of desertification, under the combined effect of anthropogenic and natural factors. The Djelfa region, like other steppe regions, is affected by this threat. This study aims to quantify the effects of desertification on the different components of the ecosystem in 11 stations located geographically in the Djelfa region. The floristic analysis identified 153 species belonging to 40 families and 110 genera's. The Edaphic study showed that the studied soils were characterized by high levels of sand and limestone, and low levels of organic matter. In terms of correlations, we find that electrical conductivity decreases when the coarse sand rate increases. The coverage rate of the therophytes is well correlated with the Shannon index with $r = 0.89$ and the specific diversity with $r = 0.74$. The equitability index is correlated with chaméphytes and hemicryptophytes species, respectively with $r = 0.75$ and 0.62 . Concerning the basal coverage parameters, there are no functional relationships between the variables forming this group except stone and block rates with a correlation coefficient of $r = 0.69$.

INTRODUCTION

Desertification is considered one of the most serious environmental problems in recent decades (World Bank 2002; Ozer and Ozer 2005). Desertification refers to a situation of land degradation, linked to the socio-economic context, of the use of natural resources beyond their restoration capacity, often aggravated by fluctuations in climatic conditions (Nedjraoui and Bedrani 2008 ; Moulay and Benabdeli 2012). The desertification leads to a permanent decline in economic activities, entrenching the most vulnerable local populations in poverty and pushing them into a mass exodus. The problem of desertification affects territories occupying 39.2% of the terrestrial globe that is about 51.6×10^6 km² of degraded lands (Thomas 1995).

Algeria is one of the countries most affected by desertification. Recent data showed that this phenomena was caused enormous losses, nearly 600,000 ha of land in the steppe zone are totally desertified without the possibility of biological coverage (Ferchichi 2004).

The study on the sensitivity to desertification in Djelfa region conducted by the Algerian Space Agency (ASAL) in 2010 highlighted the danger that threatens the region: 39,213.83 hectares of desertified land, 48,148.50 hectares of land highly sensitive to desertification, 1,638,633.28 hectares of land sensitive to desertification, 1,300,790.07 hectares of land moderately sensitive to desertification, and finally 200,636.85 hectares are little or not sensitive to desertification.

The objective of the present work is to determine the abiotic conditions in which plant species proliferate in a desertified zone; following a global inventory, then estimate the importance of each of them in the construction of the plant cover, which will provide a device to guide actions to combat desertification.

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MATERIALS AND METHODS

Study area

The study area is located between 34°16' and 35° North latitude and 2°46' and 3°30' East longitude. It is part of the high interior plains of Algeria and is administratively attached to the wilaya of Djelfa (Figure1).

Figure 1. Geographical location of study stations

Our choice is focused on 11 degraded stations under the combined effect between anthropic action and climatic parameters. These stations are characterized by rainfall less than 400 mm (periods 1984-2014), the climate is continental, characterized by contrasting seasons with hot summers and cold winters. The month of January is the coldest month with a minimum of -3,5 °C and the month of July is the hottest month with a maximum of 36,2 °C. The frosts appear from December and extend until March.

The studied stations include a diversity of natural or artificial steppe landscapes and shelter a bio-indicator floristic potential of the conditions prevailing in the environment.

Methodological approach

Given the apparent heterogeneous appearance in our study area we opted for subjective sampling. The surveys were conducted using the quadratic points, method described by Daget and Poissonet (1972, 2010), which is a continuous measurement of the points along a line by counting the number of interceptions of a vertical stem with the plants at regular intervals, this is the most appropriate method for our purpose and the type of vegetation encountered.

We chose a minimum area of 100 m² retained by Djebaili (1984) for the Algerian steppe. Surveys were carried out between early April and late May of 2015 and 2016 during the period coinciding with the floristic optimum. The list of species is based on the 72 surveys installed in the study stations.

The species have been identified according to the new flora of Algeria and the southern desert regions (Quezel and Santa, 1962-1963), the flora of North Africa (Maire 1952 - 1987), the Flora and vegetation of the Sahara (Ozenda 2004) and the practical flora of Morocco (Fennane and al., 2014).

Measures performed

At each plot, measurements of ecological parameters and index calculations were made and subdivided into edaphic parameters, floristic parameters and basal coverage parameter.

The edaphic parameters retained are:

CaT (Total limestone rate), CaA (Rate of active limestone), EC (Electrical conductivity), pH (effective acidity), OM (Rate of organic matter), SG (Coarse sand), FS (Fine sand), LG (Coarse silt), LF (Fine silt), Ar (clay).

The methods for assaying different edaphic parameters are taken from Clément and François (1998-2003).

The floristic parameters selected are:

The overall recovery rate (GR), number of plant species per plot (S), Shannon index (H'), Equitability index (E), recovery rate of the different biological types encountered: chaméphytes (Cham), hemicryptophytes (Hemi), geophytes (Geo), phanerophytes (Phan), therophytes (Ther).

The formulas for calculating the different floristic indices are presented below (Gounot 1969):

$$\bullet \quad RG(\%) = \left(\frac{Nv}{N} \right) \times 100 \quad (Nv : \text{number of vegetation points}, N: \text{number of reading points})$$

$$\bullet \quad H' = - \sum P_i \ln P_i \quad (P_i : \text{proportional abundance of the species } i)$$

$$\bullet \quad E = \frac{H'}{\log_2 S} \quad (S : \text{total number of species surveyed per plot})$$

$$\bullet \quad Cham = \left(\frac{\sum ni}{N} \right) \times 100 \quad (ni : \text{number of points where the chamephyte species were encountered}, N: \text{number of reading points})$$

$$\bullet \quad Hemi = \left(\frac{\sum ni}{N} \right) \times 100 \quad (ni : \text{number of points where the hemicryptophyte species were encountered})$$

$$\bullet \quad Ther = \left(\frac{\sum ni}{N} \right) \times 100 \quad (ni : \text{number of points where the therophyte species were encountered})$$

The basal coverage parameters retained are:

RD (Hard rock coverage), L (Litter coverage), P (Stone coverage), TF (Fine elements coverage), B (Block coverage), RV (coverage of perennial).

Statistical analysis

Variance analysis (ANOVA) at a variation factor ($P < 0.05$) was adopted to determine the effect of the station on the different edaphic, floristic and basal coverage parameters.

The correspondence analysis on the basis of the stations aims to construct graphical representations highlighting the type of relationships between the plant species and the stations studied. The tables selected for this analysis are those of occurrences and specific contributions. The principal component analysis aims to find a representation that accounts for ecological affinities between stations.

RESULTS

Degradation or even desertification is manifested by degradations of vegetation structure and floristic composition as well as a deterioration of the intrinsic properties of the soil (Bourdairé et al. 2017). Therefore, to make an ecological characterization of the degraded steppic rangelands, we have based on three groups of indicators: edaphic, diversity and basal coverage, they are used to describe different ecological systems (Floret and al., 1978). Several selected descriptors have been tested in other areas, for example total species richness, alpha diversity and soil fertility in organic matter (ROSELT / OSS 2004), but their relevance and sensitivity differ from one situation to another. The introduction of the rest of the descriptors such as granulometry, soil cover is implicit and serves to complete our analysis.

We first study the station effect on the selected indicators, in order to determine if there is a significant difference between the rangelands. This test makes it possible to validate each descriptor as a potential indicator, and to constitute thus a minimum kit of measurable or calculable indicators.

Effect of the station on the different variables

At the significance level of 0.05, the station has a significant effect on the majority of the parameters selected apart from the hard rock coverage, the fine elements coverage and the coverage rate of the phanerophytes (Table 1).

The basal coverage in fine elements does not differ significantly between the selected stations as well as the Ph ($P > 0.05$), which these values are close together except for some extreme cases. The coverage in phanerophytes as well as the basal

coverage in hard rocks is null in many surveys which makes their variance insignificant.

Correspondence Analysis (CA) by occurrence of species

The synchronistic comparison of the floristic lists in the area reveals a floristic evolution in relation to the main driving forces, even the anthropic pressure. Dimensions 1 and 2 account for 32.86% of the total variation. Graphical representations of correspondence analysis (AC) on the occurrence matrix allow locating some regionalization of species (Figure 2), and stations (Figure 3).

Figure 2. Factorial plan representation 1-2 of species

Figure 3. Factorial plan representation 1-2 of stations

The analysis of Figure 2 shows a cloud of species points that tends to condense along the axis 1 behind the point of origin and then relax in the positive side, we can discern beginning with the negative side a group formed of *Adonis aestivalis*, *Anabasis articulata*, *Eruca vesicaria*, *Arthrophytum coparium*, *Asteriscus pygmaeus*, *Astragalus armatus*, *Astragalus cruciatus*, *Silybum eburneum*, *Cleome arabica* which are characteristic species of the arid zones accompanied by *Vicia monantha*, *Matricaria chamomilla*, *Koelleria phleoides*, *Evax pygmaea*, *Asparagus officinalis*, *Anacyclus cyrtolipidioides* which are weedy species.

Then individualizes the whole of *Juncus acutus*, *Salsola vermiculata*, *Tamarix articulata* which are halophytic species, follows the whole of *Agave americana*, *Ziziphus lotus*, *Opuntia ficus*

Table 1. Analysis of variance.

		SCE	Ddl	CM	F	P
Basal coverage parameters	RD	1087,299	10	108,7299	1,655426	0,112533
	L	6728,375	10	672,837	9,39036	0,00001*
	P	6620,124	10	662,012	5,80670	0,00001*
	TF	4876,49	10	487,65	1,6167	0,123266
	B	4209,632	10	420,963	5,72689	0,00001*
	RG	10054,99	10	1005,50	5,1354	0,00002*
	RV	12413,6	10	1241,4	4,2381	0,00017*
Floristic parameters	Cham	7660,42	10	766,04	2,2150	0,02846*
	Geo	761,642	10	76,1642	2,30417	0,02272*
	Hemi	1825,619	10	182,562	5,06411	0,00002*
	Phan	1642,582	10	164,258	1,49990	0,161443
	Ther	12921,88	10	1292,19	9,4608	0,00001*
	H'	18,0670	10	1,8067	13,4536	0,00001*
	E	0,71638	10	0,07164	5,509	0,00001*
	S	1309,772	10	130,977	11,9586	0,00001*
Edaphic parameters	AR	2414,934	10	241,493	13,0053	0,00001*
	LF	3226,46	10	322,65	9,2434	0,00001*
	LG	1588,415	10	158,842	4,15178	0,00021*
	SF	2194,77	10	219,48	3,302	0,00178*
	SG	7110,09	10	711,01	10,3784	0,00001*
	pH	8,954	10	0,895	0,879	0,557296
	CE	2,287265E+09	10	228726498	59,3751	0,00001*
	MO	7,01926	10	0,70193	11,2951	0,00001*
	CaTot	2003,202	10	200,320	1,90940	0,06098*
	CaA	129,8108	10	12,9811	2,2416	0,02662*

indica, *Lycium arabicum*, *Saccocalyx satureioides*, *Diploaxis tenuifolia*, *Avena bromoides*, *Scrofularia saharea*, *Psammophyte* species accompanied by *Cistanche phelipaea*, *Cynomorium coccineum* two parasitic species that meet in sandy environments.

There is also a detachment of two distinct groups; the first in the upper right-hand dial formed by *Astragalus hamosus*; *Atractylis carduus*; *Atractylis prolifera*; *Bromus tectorum*; *Centaurea involucrata*; *Delphinium pubescens*; *Erodium triangulare*; *Evax argentea*; *Galactites tomentosus*; *Leontodon saxatilis*; *Malva aegyptiaca*; *Medicago laciniata*; *Nolletia chrysocomoides* and *Sonchus asper* characteristic species of wastelands and lawns. The second group is located in the lower right-hand dial formed by *Alyssum macrocalyx*; *Androsace maxima*; *Astragalus monspessulanus*; *Atractylis polycephala*; *Brachypodium dichotomum*; *Carduncellus pinnatus*; *Carduncellus plumosus*; *Centaurea granatensis*; *Centaurea incana*; *Ceratocephalus falcatus*; *Erysimum incanum*;

Euphorbia bupleuroides; *Euphorbia gyuoniana*; *Helianthemum virgatum*; *Hordeum maritimum*; *Launaea lanifera*; *Leontodon hispidulus*; *Loefflingia hispanica*; *Ononis natrix*; *Paronychia arabica*; *Picris albida*; *Plantago ovata*; *Spitzelia coronopifolia*; *Telephium sphaerospermum*; *Thymelaea hirsuta*; *Thymus ciliatus*; *Thymus hirtus* and *Ammoides atlantica*. These species characterize pre-forest formations; rockeries, mountains and especially matorrals.

Figure 3 illustrate three groups of stations, two isolated and distant groups, formed by a single station (Station 4, 6), it is a culture of *Atriplex canescens* protected from grazing, and a steppe of Alfa (*Stipa tenacissima*), these two stations are characterized by a significant specific richness. The other stations are part of the third group, this indicates that from the point of view occurrence or species diversity; the majority of stations are similar, they are more or less poor and less diversified.

Correspondence Analysis of Specific Contributions of Species

The analysis of the specific frequencies as quantitative descriptors makes it possible to have an idea about the synchronic evolution of the phytocenosis structure. Dimensions 1 and 2 explain 40.89% of the total variation. The graphical representations of the correspondence analysis (AC) on the extent of the specific contributions make it possible to locate a certain regionalization (Figure 4 and 5).

Figure 4. Factorial plan representation 1-2 of species

Figure 5. Factorial plan representation 1-2 of stations

According to figure 4 the cloud of species points is more structured along the two axes than the previous corresponding diagram. Nevertheless the density of the cloud of the species points is higher in the positive side of the axis1. In the positive side of the axis, we can distinguish *Launaea lanifera*; *Leontodon hispidulus*; *Atractylis polycephala*, *Ammoides atlantica*, *Telephium sphaerospermum*; *Helianthemum virgatum*; *Carduncellus pinnatus*; *Thymus ciliates*; *Centaurea incana*; *Thymus hirtus*; *Euphorbia bupleuroides*; *Centaurea granatensis*; *Ceratocephalus falcatus* characteristic species of matorral and rocky grazing, accompanied by arid zone species such as *Spitzelia coronopifolia*, *Picris albida*, *Ononis natrix*, *Plantago ovata*, *Thymelaea hirsuta*, *Euphorbia gyuoniana*, *Paronychia arabica*, *Loefflingia hispanica*, and some commensal annuals of wastelands like *Erysimum*

incanum, *Androsace maxima*, *Hordeum maritimum*, *Brachypodium dichotomum*.

The second group is located in the direction of axis 2 in the upper right-hand dial. It consists of the ruderal and characteristic species of lawns as *Schismus barbatus*; *Galactites tomentosa*; *Bromus tectorum*; *Astragalus hamosus*; *Sonchus asper*; *Erodium triangulare*; *Centaurea involucre*; *Malva aegyptiaca*; *Atractylis carduus*; *Delphinium pubescens*; *Lolium rigidum*; *Nonea micrantha*; *Scabiosa arenaria*; *Calendula aegyptiaca*; *Anacyclus clavatus*; *Koeleria pubescens*; *Onopordon arenarium*; *Scabiosa stellata*; *Plantago albicans*; *Reseda alba*; *Leontodon saxatilis*. These species are accompanied by some species of arid zone like *Medicago laciniata*; *Nolletia chrysocomoides*; *Tamarix gallica*, *Evax argentea*; *Atractylis carduus*; *Aristida pungens*; *Launaea nudicaulis*; *Calendula aegyptiaca*; *Aizoonhis panicum*; *Retama retam*; *Atriplex halimus*. In addition to these species, we add *Atriplex canescens*, species widely used in dune fixation programs. It is noted that species of different ecological affinities disperse throughout the two axes without forming distinct groups.

Figure 5 shows that the stations are divided into four groups. The fourth station is distant from the others and forms the fifth group. Stations 6, 5, 2, 1 and 3 share a shrub stratum composed of *Juniperus phoenicea* and *Pinus halepensis*.

Station 6 represents an advanced stage of degradation of forest formation, it is composed only of some relics shrubs. Stations 10 and 11 are so degraded that the physiological difference between them is not significant in terms of the contribution of the plant species. Stations 9 and 7 are approaching geographically.

Station 7 being a Sebkhia sees its vegetation grow on sandy accumulations which makes the correspondence with station 9 which is a dune cordon. Station 8 is a salt station, its vegetation is short except *Tamarix articulata*.

Correlations between variables

The characterization of ecological systems is based on indices that correspond to the real facts and are of known importance which must be more or less correlated (Le Houérou 1995). This is how a regression analysis was carried out between the parameters retained in their specific sub-element groups. The elements are subsystems that interact and integrate into a degrading ecological system, these elements and their hierarchy are defined by the observer, their importance lies in the fact that their properties and interactions lead to specific global properties of degradation or desertification.

In our case, we consider that the system of degradation consists of three elements

Table 2. Edaphic parameter correlation matrix (* correlated).

	AR	LF	LG	SF	SG	pH	CE	MO	CaTot
AR									
LF	-0,05								
LG	0,37	0,46							
SF	-0,66*	-0,16	-0,32						
SG	-0,10	-0,83*	-0,76*	-0,03					
pH	0,14	0,30	0,14	0,36	-0,45				
CE	0,19	0,76*	0,69*	-0,32	-0,79*	0,38			
MO	-0,25	-0,07	0,04	0,17	0,02	-0,21	-0,22		
CaTot	-0,05	-0,24	0,25	0,06	0,06	-0,42	-0,40	0,15	
CaA	-0,16	-0,29	0,27	0,17	0,07	-0,40	-0,40	0,19	0,97

characterized by different speeds of evolution and each composed of coherent descriptive parameters, the first subsystem : physico-chemical represented by the edaphic parameters, the second: living represented by the floristic parameters and the third : interface represented by the basic coverage.

Correlations between the edaphic variables

The interest in edaphic traits is that desertification is in itself a degradation of the soil. Sensitivity to desertification depends on the intrinsic properties of the soil.

Coarse sand rates and electrical conductivity are the most correlated edaphic variables with other edaphic parameters. It is clear that electrical conductivity decreases when the rate of coarse sand increases, as is the case with sandy accumulations. In the opposite case the rates of the fine elements increase with the increase in salinity. For the other variables, they are not correlated.

The pH values are slightly basic and homogeneous between the different stations and the organic matter levels are low everywhere (Table 2).

Correlations of basal coverage parameters

Similarly, the current state of vegetation cover degradation is controlling desertification. We note in Table 2 that the variable stone rate is positively correlated with the rate of the blocks, it is related to the process of pedogenesis following the alteration of the mother rock stand out blocks and stones simultaneously.

Global coverage, litter rates, and fine soil are not correlated with other variables. They are related parameters and influenced by several climatic factors such as temperature, wind and anthropogenic factors such as overgrazing and clearing, the distribution of their values on all the stations does not have a linear tendency (Table 3).

Correlations of floristic variables

Likewise, the physiognomic type and the floristic composition play a determining role in the determination of the state of degradation.

Table 3. Correlation matrix of coverage rates.

	RD	L	P	TF	B
RD					
L	-0,27				
P	0,29	-0,33			
TF	-0,23	0,48	-0,47		
B	0,28	-0,54	0,69*	-0,60	
RG	-0,27	-0,39	-0,53	-0,31	-0,27

All correlations in Table 4 are positive. We note that the Shannon diversity index and the species diversity are correlated with the rate of therophytes because the richness in these environments comes mainly from the annual plant species. The index of equitability is correlated with perennial coverage because it is the species belonging to chaméphytes and hemicryptophytes that are distributed more equitably than the other biological forms. Finally, perennial coverage is correlated with the rate of chaméphytes (Table 4).

We note here the particular importance of the Chaméphytes rate as a perennial component of the arid steppes and which evolves in the same direction as the perennial coverage. The indices H', E and S are mathematically related from a computation point of view but this does not exclude their importance in the segregation of stations.

Principal component analysis of ecological characterization

The projection of stations in the foreground of the principal component analysis (PCA) is illustrated in Figure 6. The first two dimensions of the PCA plan account for 51.86% of the total variance. Based on our analysis, we can group the stations into four groups:

Figure 6. Representation of the stations on the factorial plane 1 - 2 of the ecological characterization

- The first is formed of stations 3, 6, 2, 1, 10, 11 and 5. This group contains different types of degradation of tree and shrub formations.

-The second is formed of station 4, it is a plantation of *Atriplex canescens* protected from grazing planted within the framework of a project of fixation of the dunes for more than 30 years

- The third is made up of stations 9, and 7. These are dune fixation projects without fodder interest in addition to vegetations installed on sand dunes

- Finally the last group formed of station 8 (Sbekha).

DISCUSSION

Common mechanisms and specific mechanisms

Hirche et al. (2007) note that drought is recurrent in this area through alternating wet and dry periods. Anthropogenic action, including human exploitation, is very old, as noted in Aïdoud et al. (2006). This action contributed to the degradation of the forest cover by significantly reducing the stratum of phanerophyte in these spaces. Mechanized clearing also leads to the removal of the root network, which ensures a good cohesion with shallow sandy horizons and transforms steppic rangeland into plowing land.

Diagnostic value of desertification

Species richness, vegetation cover and soil surface condition are among the priority data to be

Table 4. Correlation matrix of floristic parameters.

	H'	E	S	Cham	Géo	Hémi	Phan	Thér
H'								
E	0,44							
S	0,87*	0,14						
Cham	0,47	0,75*	0,16					
Géo	-0,13	0,51	-0,36	0,38				
Hémi	0,55	0,62*	0,64*	0,42	0,07			
Phan	-0,27	-0,19	-0,42	0,04	-0,45	-0,56		
Thér	0,89*	0,20	0,74*	0,15	-0,21	0,26	-0,24	
RV	0,37	0,79*	0,04	0,98*	0,43	0,38	0,12	0,04

collected to follow the evolutionary trend of ecological systems. But, they can not all explain the variation between stations.

Non-explanatory variables

It seems clear that the structure of plants differs significantly from one station to another with biodiversity. In our case this vegetation settles either on lean ground or on sand mounds accumulated at the feet of other perennials in bare grounds or even on excessively salty grounds. This suggests that the fine elements coverage (TF) does not construct an explanatory variable of the different forms of degradation, this is confirmed by the analysis of the variance with a probability of 0.12. In the same way the steppe in our zone is not raised, the vertical stratification generally ends on chaméphytes this corresponds to the results found by Aïdoud (1989). The probability of coverage in phanerophytes is 0.16.

The probability of 0.11 attributed to hard rock coverage (RD) is explained by the fact that, despite the degradation of our zone, it has not reached the extreme stage of large rocky plateau surfaces; a typical Saharan landscape (Monod, 1992). The pH of the soils of the region is generally slightly alkaline. This is consistent with Halitim's (1988) results, with a probability of 0.55 indicating homogeneity of the stations.

Explanatory variables

The rest of the descriptors cover an explanatory value of segregation between stations, so they can explain the different faces of soil degradation as well as their mechanism and functioning.

1. Edaphic parameters

The edaphic parameters, despite their lack of priority in determining regressive trends in vegetation, suggest that the soil types of our stations are totally different. These different parameters have a significant effect on the station with a probability ranging from 0.00 to 0.06. The literature indicates that the soils of our zone include calcareous soils, class of raw mineral soils or class of undeveloped soils and salsodic soils with

different physicochemical properties (Halitim, 1988).

The total limestone rate is not correlated with the other edaphic variables, which is explained by the geological origin of the limestone, which is used as alluvial material or bedrock in the formation of soils.

Halitim (1988) notes that the essential character of the geological formations in this zone is, among other things, the presence of limestone. Similarly, the rate of organic matter with low values as a whole is not functionally related to the other parameters. The contribution of organic matter is exogenous on the one hand and the sandy textures as well as the high temperatures and drought contribute negatively to the formation of humus. According to Pouget (1980), the organic matter content does not exceed 2.5% except in forest or matorral soils and negatively affected by the coarse texture of the soil and the aridity of the climate, the level of active limestone being a fraction of the total limestone is naturally correlated with it. The electrical conductivity reflecting the rate of the soluble salts increases with the fine textures ($r = 0.76$) it is the case of the salty zones and decreases with the coarse texture ($r = -0.79$) it is the case of the accumulations sandy.

2. Basal coverage parameters

There is no functional relationship between the variables forming this group except for the rates of stones and blocks with a correlation coefficient of 0.69; this is explained by the simultaneity of their formations during the processes of pedogenesis and the alteration of the source rock, the litter is of an external contribution therefore it is not directly influenced by the residues resulting from this alteration.

3. Floristic parameters

The coverage rate of therophytes is well correlated with the Shannon index with $r = 0.89$ and the specific diversity with $r = 0.74$. The diversity of the floristic cortege of our stations is due to the therophytes, this fact is observed by Bouazza et al. (1994).

The index of equitability is positively correlated with chammephyte and hemicryptophyte rates, which means that the regularity of the species distribution increases when the rates of these two perennials are high. The correlation between the perennial coverage and the rate of chaméphytes ($r = 0.98$) largely means that these are the most important component in terms of contribution in the vegetal cover of the perennials in our zone. This finding is supported by the remarks made by Aidoud, (2008) noting that chaméphytes are the most suitable persistent species for drought.

Operational value of desertification

The evolution of the soil is very slow to be detected and monitored on the scale of human life, but those of the soil cover (basal in our case) and the floristic evolution in its two dimensions composition and structure, can be observed but still at the scale of several decades. A synchronic approach has been adopted in our situation to detect the evolution of desertification between its different faces.

Synchronic evolution of floristic composition

The scheme proposes an aridity gradient along the axis 1 starting with the arid and Saharan zone species where the water deficit is almost present, followed by halophytes where, despite the approach of the water table the stress of salinity remarkably reduces the specific diversity, follows the psammophytes characteristic of the silted zones, the high rate of the sands in the soil decreases the water retention and favors a particulate structure and the absence of the aggregates facilitates the erosion, aridity in the last two cases is edaphic. Axis 2 highlights an anthropozoic degradation gradient from pre-forest formations to lawns and wastelands, overgrazing and clearing are implemented.

Concerning the evolution of the stations, station 4 corresponding to a dune fixation project by a plantation of *Atriplex canescens* and station 6 corresponding to a degraded alfa (*Stipa tenacissima*) formations. The rest of the stations are similar in terms of occurrence.

Synchronic evolution of the structure of the phytocenosis

The distribution of species points on the factorial plane (1, 2) of the scheme proposes a distribution in groups of species of matorral and stony pastures; annual commensal species of fallow land; ruderal species; species of arid zones and a dispersion of species with different ecological affinities, the indicator value of the ecological characteristics of the environments is lost with ordinary floristic processions and a low vegetation cover composed essentially of therophytes well adapted to these environments. The diagram of the distribution of the stations highlights the vertical evolution of the vegetal stratum combined with the basal coverage and the floristic richness, the forage plantation corresponding to the station 4 in this analysis is still highlighted.

ACP and synthesis

Following the analysis of the scheme proposed by the ACP, it is deduced that the different parameters studied vary enormously according to the degree of disturbance and not the degree of stress, this finding is similar to that of Gamoun et

al. (2010) and Gamoun et al. (2012). The ecological traits are different between the groupings of stations but the segregation is done according to the destitution of the pastoral value and the protection of the rangelands, which leads us to say that a resting of the rangelands contribute to their improvement as Khalid and al. (2015) confirms it. It can be said that the planting of *Atriplex canescens* under present circumstances is a likely solution to the problem of desertification, as confirmed by Amghar and al. (2016).

CONCLUSIONS

In an anthropogenic context of clearing and overgrazing; and under a climate constraint, a diagnosis of degraded environments is needed in order to implement an effective action plan. Our contribution has shown that the diversity and evolution of degraded landscapes can be appreciated by indicators of basal coverage, floristic biodiversity and soil quality. The structure of the flora is less important than its composition in determining the mechanisms of regressive evolution. The planting of *Atriplex canescens* is a promising alternative to desertification.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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