Restoration Techniques for Degraded Steppe Courses: Diachronic Study in the Laghouat Region (Southern Algeria)

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ABSTRACT

Desertification of Steppe courses has become a major issue for Algeria because of huge loss of areas that have reached an irreversible stage of degradation. Therefore, managers of Algerian state have acted to remedy the consequences of these ecological troubles, due to inappropriate human practices and accentuated by the harshness of the climate. In this diachronic study in the Laghouat region, 540 floristic samples and 180 soil samples were carried out to test some techniques for restoring degraded courses. It is about a combination of the grazing exclosure and some practical developments of soil (tillage) that are subdivided into mechanical methods (decompacting) and biological ones (adding: manure and mulch; watering; sowing of steppe species). The results have shown that these practices have several effects on floristic and soil parameters in short period (2 years). In fact, by these practices, a stimulation of plant species development has been observed. This has been detected by the increase in diversity index, plant cover and litter as well as the soil organic matter rate for all plots with a significant global effect and p value<0.001. On the other hand, the decrease in the bare ground surface. This increase is much greater in plots where decompacting with manure in first order and decompacting with sowing techniques have been applied. The technique of decompacting with mulching had a particular effect in the amount of litter with the technique of decompacting with sowing. The decompacting with watering has influenced phosphorus by promoting its availability. Decompacting all alone, which was the least effective, has increased the rate of coarse elements. Hence, the soil-vegetation balance has been reinstalled by improving soil fertility and structure.

Keywords: Degradation; Overgrazing; Restoration; Grazing exclosure; Laghouat

INTRODUCTION

The courses of Algerian steppes are experiencing an increasingly intense degradation due to various climatic and anthropogenic factors [1-3]. According to Kouba et al., research, the Algerian steppes has been resulted from multiple interactions between several factors that might have either natural or anthropogenic origin [4]. Among the consequences of degradation, we can cite desertification and soil impoverishment due to wind erosion. This latter according to Jendoubi et al., reacts when there is a regression of the vegetation cover (Bare ground susceptible to erosion) [5]. In addition, according to Melzi, the lack of rainfall in the pre-Saharan region and it's inter annual irregularity has significant consequences on the germination and development of ephemeral herbs [6]. In this regard, a huge potential of natural resources risk being irreversibly regenerable because of both climatic conditions and socio-economic changes in the Algerian steppe which represents the natural barrier against the desert. In fact, the phenomenon of desertification is the consequence of an ecological imbalance, resulting from an anarchic exploitation of natural resources combined with climatic and edaphic aridity [7,8]. These results have been also reported by Li et al., and Aidoud et al [9,10]. Livestock is the main economic activity in this region, and overgrazing is one of the major causes of environmental degradation [11]. Overgrazing, according to Le Houérou et al. and Floret and Pontanier, leads to the disappearance of species of good pastoral value because the latters are consumed before they have had time to fructify [1,8]. The various rational developments undertaken using natural resources in the steppe environment, are confronted with the insufficiency of basic scientific studies [12]. Here, it is well recognized that anthropogenic practices such as overgrazing is counted as one of the major problems that the steppe courses are exposed to. Overgrazing might allow regeneration of the vegetation but with a low pastoral value in comparison with another technique of restoration like the pastoral plantations [13].

In fact, the increase of the population and their livestock numbers was followed further by a sedentarization that had a high pressure in the rangelands, confirmed Martínez-Valderrama [14]. For the Algerian state, various procedures have been put in place in order to face these challenges, such as the creation of laws and establishments responsible for limiting the effect of humans on the environment previously weakened by recurring drought sequences. However, several authors have worked on the ecological and pastoral characteristics of these environments, among which we can mention Djebaili, Aidoud, Benaradj, Koerner, Zhang, Pan [15-20]. Over these days, applied ecological restoration constitutes a main axis for science researches. However, the success of innovative techniques in different environments is to be discussed. Assessing the outcomes of these initiatives is important to better drive the following steps of restoration [21]. Beginning to diversify in recent decades, restoration techniques have been applied in several regions around the world to see its short-term and long-term effect. The concept is to stimulate the development of plant communities on respecting the environment and in the most time-consuming. The restoration aims to restore an ecosystem to its initial state. Moreover, several authors have studied this problem and have even proposed solutions such as the grazing exclosure, which have shown their effectiveness [8,13,22-25]. According to Floret and Pontanier: The grazing exclosure of a course is a technique which consists in putting it out of use for a given period to allow the natural vegetation to be reconstituted [8]. According to Cortina et al., this technique has allowed the restoration of large degraded areas (2,800,000 ha in Algeria), by increasing the floristic diversity [11]. The effect of the grazing exclosure was also confirmed by Achour et al., [26]. It is an effective instrument for regenerating courses to induce natural biological recovery according to Acherkouk and Benaradj [3,17]. The effect of the grazing exclosure on the vegetation and soil surface elements in arid zones has been studies by many authors [27-31].

However, the problems of the grazing exclosure are generally related to their duration, because the long-term protection can cause a blockage of the biological recovery [11]. Therefore, these actions are not enough to have a rapid biological recovery of the much-degraded ecosystem. They can be combined by tillage techniques and in reality few studies have collected these restoration techniques. It consists essentially in applying the tillage although it is not very accepted within farmers and breeders. Their benefits can be summarized in two points: Save time and reduce development costs (the invested capital and the labor). These developments aim to develop good conditions for the growth of plants by simple tillage with the establishment of grazing exclosures for the restoration of these degraded courses in short duration and while enhancing agricultural by-products. Here, it is not a question of stopping a running degradation and counting on the resilience of the ecosystem, but of the strongly intervening in order to reconstitute the ecosystem and maintain the balance that allows ensuring their vital functions [32]. In this study, the following hypotheses were tested in terms of their consequences on plant communities, on soil parameters and their feasibility in steppe courses: (1) The cessation of grazing allows a gradual return of the establishment of vegetation and the structuring of communities; (2) The superficial decompacting of the soil allows a better infiltration of water, germination in place of the seed bank, also limiting runoff; (3) Water is the main limiting factor in the steppe environment and a punctual watering will allow a faster restoration of vegetation by improving and accelerating its germination; (4) Mulching, manure and sowing of steppe species will increase the organic matter content and therefore the fertility of the soil. So three stations were stopped in the region of Laghouat (southern Algeria) and they were the subject of floristic and pedological monitoring for two years (diachronic study).

MATERIALS AND METHODS

Region of study

In this work, three stations have been determined belong to the region of Laghouat. It is an Algerian region, which is located in the center of the country, 400 km south of the capital Algiers this region extends over an area of 25,000 km^2. It is a pastoral region of Algeria. Besides, it is located at an altitude of more than 750 meters on the Highlands, crossed by the chain of the Saharan Atlas with peaks that exceed 2000 meters ("Djebel Amour" 2200 meters) [33].The rainfall data in the Laghouat region provided by the O.N.M of the KHENEG station for the period (1996-2017) indicate that they are irregular with an annual average cumulative of 148.69 mm [34]. The calculation of the seasonal regime classifies the study region in the APHE type, characteristic of a Mediterranean climate, according to Daget [35]. We note for the same period that the average annual temperature is 19.04 °C. In the period (1996-2014), wind has recorded an average of 3.46 m/s with a maximum in July, marking a continual evolution of winds in this region. While between 2002 and 2012, humidity has recorded 49.47% in average. The region experiences periods of drought that extend throughout the year. It is integrated into the Saharan bio climate with cool winters. Also, the Laghouat region contains vast steppe areas, which a large part has been degraded [36]. The soils are for the most part of typical alluvial supply on an evolved limestone crust, with a light texture and low organic matter content. Thus, it presents constraints for agriculture [36]. Following Khadraoui, three large groups distinguish the Laghouat region, the piedmonts of the Saharan Atlas, the second characterize by the alluvial plain of the “Ouad M'zi” and the other by a plane surface tray with a stony load on the surface [37].

Choice of stations and layout

The choice of stations was motivated by the persistence of degraded land. They are located in the municipalities of “Ksar El-hirane” and “Bennasser Benchohra” in Laghouat region (Table 1).

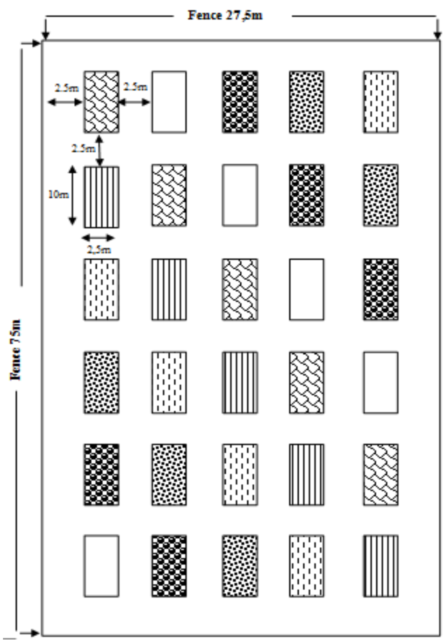
Table 1. Permanent stations of the present study.

Station	Geographical coordinates	Altitude (m)	Area (ha)	Sampling year (before application of techniques)	Sampling year (after application of techniques)
Station A	33°43' N 3°8' E	908			
Station B	33°45' N 3°8' E	1070	0.21	2015	2017
Station C	33°45' N 3°2' E	1160			

These three degraded stations, having each an area of 75 m × 27.5 m, were created and protected in 2015 where the same layot was applied "Latin Square" (Figure 1.) and in which five modalities were tested according to the following protocol [38]:

- An uncompacted control plot.
- A decompacted plot (tillage to 5 cm)
- A decompacted plot with sowing seeds of steppe species: Choosing the most representative species of the Algerian steppes: *Stipa tenacissima*, *Artemisia herba-alba* and *Lygeum spartum*. Sowing was carried out manually.
- A decompacted plot with the addition of manure (the amendment with animal discharges).
- A decompacted plot with watering (watering has been done only once a week for 4 months).
- A decompacted plot with the addition of mulching (spreading a thick layer of "about 5 cm" of the harvest residues).

Figure 1. Plot layout diagram (Latin square method). **Note:** Control plot not decompacted; Decompacted plot; Decompacted and watered plot; Decompacted + sowing plot; Decompacted + mulching plot; Decompacted+ manure plot.



Sampling and the statistical tool

Floristic study: For the floristic study, surveys were carried out in these three permanent stations, namely 90 surveys in each station before the application of the techniques (in 2015) and 90 surveys in each station after the application of the techniques (in 2017). In total, there were 540 floristic surveys with a frequency of three surveys per plot. Indeed, the surveys were undertaken during the spring season to obtain a maximum number of species (especially annual ones) (Table 2). A 10 m graduated measure tape was stretched over the vegetation and the reading was made along a transect by contact points, materialized by a fine needle at regular intervals of 10 cm. The vegetation inventory was applicated based on the stigmatic abundance-dominance method of Braun-Blanquet and Bolos [39]. Species richness corresponds to the average number of species present in a sample (survey) of the biotope. Diversity index of H', is the measure of the loss of information due to the loss of an entity [40,41]. It is given by the following formula:

$$\mathbf{H'} = -\sum_{\mathbf{i=1}}^{\mathbf{s}} (\mathbf{p_i \log_2 p_i})$$

Where:

P_i=proportional abundance or percentage of the importance of the species (Csi): P_i=ni / N;

S=total number of species; ni=number of individuals of a species in the survey; N=total number of individuals of all species in the survey.

The evenness E, allowed us to measure the distribution of individuals within species, independently of specific richness. E=H'/Hmax [42].

Where:

H'max=log S (S=total number of species).

Soil surface elements, concern: the Plant Cover (PC) which is theoretically defined as the percentage of the bare ground which would be covered by plants:

PC %=(ni × 100)/N

(With: N: Total number of reading points; ni: Number of vegetation points) [43]. Also the litter; the coarse elements; the Sand and the bare ground.

Table 2. Life cycle and total species, genera and families identified in the study.

Families	Genus	species	Life cycle
Fabaceae	*Astragalus*	*Armatus*	Pe
Asteraceae	*Atractylis*	*Serratuloides*	Pe
		Cancellata	An
		Carduus	An
	Echinops	*Spinosus*	Pe
	Filago	*Pyramidata*	An
	Ifloga	*Spicata*	An
	Launea	*Rresedifolia*	An
	Scorzonera	*Undulata*	Pe
Brassicaceae	*Eruca*	*Pinnatifida*	An
		Visicaria	An
Capparidaceae	*Cleome*	*Arabica*	An
Caryophyllaceae	*Herniaria*	*Fontanesii*	Pe
Chénopodiaceae	*Arthrophytum*	*Acoparium*	Pe
	Anabasis	*Articulata*	Pe
	Bassia	*Muricata*	An
	Salsola	*Vermiculata*	Pe
Cistaceae	*Helianthemum*	*Virgatum*	Pe

		Nummularium	Pe
Illecebraceae	*Paronychia*	*Arabica*	An
Lamiaceae	*Ajuga*	*Iva*	Pe
Orobanchaceae	*Cistanche*	*Tinctoria*	An
Plantaginaceae	*Plantago*	*Albicans*	Pe
Poaceae	*Aristida*	*Pungens*	Pe
	Avena	*Sterilis*	An
	Bromus	*Erectus*	Pe
	Hordeum	*Murinum*	An
	Lygeum	*Spartum*	Pe
	Schismus	*Barbatus*	An
	Stipa	*Parviflora*	Pe
		Tenacissima	Pe
Thymelaeceae	*Thymelaea*	*Microphylla*	Pe
Zygophylaceae	*Fagonia*	*Latifolia*	An
	Peganum	*Harmala*	Pe
Note: An: Annual; Pe: Perennial.			

Pedological study: For the pedological study, the first 5 cm of soil were taken from each plot of these three stations (Tables 3 and 4). So, 30 surveys from each station before the application of the techniques (in 2015) and 30 surveys from each station after the application of the techniques (in 2017). This totals 180 soil surveys with a frequency of one survey per plot only. The chemical parameters which have been measured on fine earth (less than 2 mm) using the methods described by Aubert are: The pH in distilled water (1/5) and the Electrical Conductivity [E.C. (mS/cm)] on aqueous extract (1/5) "ISO 10390 and ISO 11265 respectively", the available phosphorus [Avai.P (mg/l)] "OLSEN method, ISO 11263" and the organic matter that has been calculated from the organic carbon [MO (%) = 1.72 C (%)] "ANNE method, ISO 14235" [44].

Table 3. Distribution of floristic surveys in permanent stations.

Station	Before the application of techniques	After the application of techniques
Station A	90	90
Station B	90	90
Station C	90	90
Total	270	270

Table 4. Distribution of pedological surveys in permanent stations.

Station	Before the application of techniques	After the application of techniques
Station A	30	30
Station B	30	30

Station C	30	30
Total	90	90

Statistical study: The statistical study was done by the software R version 3.4.3, package of: Rcmdr version 2.4-1 [45,46]. The data used for the vegetation are the abundance dominance according to the Braun-Blanquet method. This abundance-dominance scale was converted to the specific contribution according to the formula of TOMASELI in [47]. Also, for each survey, the different floristic and pedological parameters were determined. A species with a dominance of +; covers 0.1%; Species with a dominance of 1; covers 5%; A species with a dominance of 2; covers 17.5 %; A species with a dominance of 3; covers 37.5%; A species with a dominance of 4; covers 62.5 %; A species with a dominance of 5; covers 87.5% Moreover, we used nonparametric tests because of the "non-normality" of the data. The main nonparametric hypothesis tests used are:

Wilcoxon test: It is a univariate position test used for two paired samples. The description of the test has been provided in several books. Lafaye de Micheaux had reported that we have two paired quantitative series that we want to compare, and then work with the series of differences. In fact, we used this test to see the effect of each technique applied.

Kruskal-Wallis test: According to Genin, the objective of this test is to compare the distribution of a quantitative variable X between K independent groups (Extension to more than 2 groups of the Mann Whitney-Wilcoxon test). It is a nonparametric equivalent of the one-factor ANOVA in the case where the data do not follow a normal distribution. In this study, the Kruskal-Wallis test was applied to test the global effect of all the techniques tested.

RESULTS

Floristic analysis

Diversity index: In ecology, the diversity of a community is measured using index that evaluate the difference between what is observed on a large spatial scale (for example a meta-community, a landscape) and what is observed on a small spatial scale for example a community, a plot. This diversity is an important concept used to describe the renewal in the composition of species at different spatial or temporal scales. The floristic analysis of the stations showed, generally, that the stations are relatively richer after the application of the techniques. The results of this study confirmed the beneficial effect of the grazing exclosure with techniques of improvement of the soil quality. These techniques have generated an increase in the specific richness with a significant global effect ($\chi2=123.28$, $p<0.001$). The effect was marked especially for two techniques: the decompacting with manure and the decompacting with sowing ($p<0.001$).

The examination of the Shannon index values showed a significant variation with a highly significant global effect ($\chi2=124.02$, $p<0.001$) (Table 6). Compared to the control plot, the technique of decompacting with manure and decompacting with watering have the greatest effect ($p<0.001$). Then comes the technique of decompacting with sowing, decompacting with mulching and finally decompacting all alone respectively. The measure of Evenness showed also a significant global effect ($\chi2=38.37$, $p<0.001$). All the techniques have led to the increase of these values at various degrees in comparing them with the control plot. As for the specific richness and the Shannon index, the technique of decompacting with manure had the most important effect on the distribution of species. In addition to that, the techniques of: decompacting with mulching and decompacting with watering ($p<0.001$). The techniques of: Decompacting with sowing and decompacting all alone have generated a light increase of the Evenness which is not significant ($p>0.05$). The total richness indicated an elevation after the applications of all techniques (Table 5).

Table 5. Total specific richness.

		Families	Genus	Species	Individuals number	Species contribution (%)
CP	Before	9	15	15	594	23.3
	After	10	21	26	927	39.9
DP	Before	9	14	14	539	21.9
	After	10	20	24	856	36.4
DP	Before	9	16	17	663	23.7
	After	11	20	24	917	37.4
DM	Before	9	12	13	516	18.9
	After	12	23	28	871	36.9
DW	Before	9	12	13	518	19.5
	After	13	19	24	860	35.5
DM	Before	9	16	17	612	22.9
	After	12	22	26	958	38.7
Note: CP: Control plot; DP: Decompacting; plot; DS: Decompacting with Sowing plot; DM: Decompacting with Manure plot; DW: Decompacting with Watering plot; DM: Decompacting with Mulching plot.						

Soil surface elements

Referring to Table 6, the evolution of the Plant Cover (PC) is significantly positive (χ^2=41.92, p<0.001), the dynamic is therefore progressive according to the applied technique. In fact, there is an excellent improvement in the plant cover between the two periods of sampling. Here, we found a percentage of 7.83% in the plot in which the technique of decompacting with manure has been applied then 7.69% in the technique of decompacting with mulching. Subsequently, it is the technique of decompacting with watering and then decompacting all alone respectively. However, the decompacting with the sowing did not bring a high difference. The litter also experienced a positive increase with a significant global effect (χ^2=111.26, p<0.001), highly significant (p<0.001) between the two sampling periods for all techniques (especially decompacting with sowing) except for the decompacting technique all alone which it did not represent an effect on the litter rate (p>0.05). We noted for the ratio of coarse elements, it marked a positive increase with a global effect at χ^2=48.65, p<0.001. It was significant (p<0.01) for the decompacting all alone technique and the decompacting technique with mulching, (p<0.05) for the decompacting technique with watering. However, it is not significant in plots where decompacting with sowing and decompacting with manure has been applied. The sand rate showed a tendency towards silting up in the study region (χ^2=77.04, p<0.001), highly significant (p<0.001) for the technique of decompacting with sowing, (p<0.01) for the technique of decompacting with manure and not significant for the other techniques. Meanwhile, the surface of the bare ground is less important after the protection (χ^2=77.04, p<0.001).

Table 6. Effect of techniques on floristic parameters.

		Diversity index			Soil surface elements (%)				
		Average floristic richness (S)	Shannon index (H')	Evenness (E)	Plant cover	Litter	Coarse elements	Sand	Bare ground
Control plot	Before	2.76 ±	1.13 ±	0.71 ±	13.2 ±	1.93 ±	23.62 ±	1.04 ±	60.2 ±

		1.43	0.69	0.35	13.90	4.20	20.29	3.97	18.08
	After	5.07 ± 2.68	1.8 ± 0.83	0.78 ± 0.25	20.6 ± 13.40	3.02 ± 3.48	19.58 ± 16.62	6.18 ± 14.51	50.62 ± 24.77
	p	***	***	ns	**	*	ns	***	*
Decompacting	Before	2.44 ± 1.18	0.98 ± 0.65	0.67 ± 0.40	11.9 ± 11.04	1.71 ± 3.01	10.4 ± 7.26	5.09 ± 19.28	70.7 ± 23.39
	After	4.82 ± 2.89	1.72 ± 0.9	0.74 ± 0.31	19.02 ± 14.63	2.6 ± 3.67	14.27 ± 9.43	8.87 ± 18.96	55.24 ± 26.67
	p	***	***	ns	**	ns	**	ns	***
Decompacting with Sowing	Before	2.76 ± 1.33	1.06 ± 0.61	0.7 ± 0.33	14.7 ± 13.28	1.16 ± 1.91	11.47 ± 9.17	0.11 ± 0.61	72.5 ± 16.58
	After	5.29 ± 3.17	1.85 ± 0.73	0.84 ± 0.16	20.38 ± 16.04	6.18 ± 5.91	13.27 ± 11.60	8.73 ± 16.32	51.44 ± 26.54
	p	***	***	ns	**	***	ns	***	***
Decompacting with manure	Before	2.04 ± 1.33	0.69 ± 0.68	0.47 ± 0.42	11.47 ± 12.47	1.4 ± 3.56	9.98 ± 8.14	0.06 ± 0.45	77.09 ± 13.13
	After	4.64 ± 3.01	1.62 ± 0.90	0.74 ± 0.29	19.3 ± 15.89	5.22 ± 5.55	10.5 ± 7.29	5.07 ± 11.99	59.8 ± 25.50
	p	***	***	**	***	***	ns	**	***
Decompacting with watering	Before	2.24 ± 1.33	0.81 ± 0.70	0.53 ± 0.41	11.5 ± 12.1	1.18 ± 2.11	9.62 ± 6.77	10.4 ± 26.88	67.2 ± 28.01
	After	4.49 ± 2.81	1.61 ± 0.87	0.75 ± 0.31	19.1 ± 16.40	3.24 ± 3.73	13 ± 7.03	9.11 ± 18.42	55.4 ± 28.91
	p	***	***	**	**	***	*	ns	***
Decompacting With mulching	Before	2.69 ± 1.40	0.95 ± 0.72	0.57 ± 0.38	13.6 ± 12.8	1.18 ± 1.77	7.33 ± 6.81	10.5 ± 27.3	67.38 ± 29.3
	After	5.04 ± 3.08	1.73 ± 0.78	0.8 ± 0.21	21.29 ± 16.10	5.49 ± 5.42	9.67 ± 6.24	9.36 ± 18.83	54.2 ± 28.59
	p	***	***	**	***	***	**	ns	***
Global effect (Kruskal Wallis)	χ^2	123.28	124.02	38.37	41.92	111.26	48.65	47.63	77.04
	p	***	***	***	***	***	***	***	***
Note: ***=p<0.001;**=p<0.01; *=p<0.05; ns=p>0.05									

P-value (p) is the probability resulting from the nonparametric test of Wilcoxon (p-value<0.05) between the two sampling periods (45 surveys before *vs.* 45 surveys After) for each technique. The same applies to the ± SD averages. The global effect was tested by the nonparametric test of Kruskal-Wallis ($\chi 2$ *and* p<0.05) for 540 floristic surveys. The asterisks show the significance of the test (***=p<0.001;**=p<0.01; *=p<0.05; ns=p>0.05).

Pedological analysis

The analysis results of some chemical parameters of the soil are mentioned in Tables 7 and 8. The measurement of soil pH, implemented for the different techniques, displayed alkaline values according to Aubert (Table 5) [44]. It varies between 7.88 ± 0.49 and 8.18 ± 0.29. However, the difference is not significant ($\chi 2$=6.45, p>0.05) between the two sampling periods for all techniques. In addition, it is lower after the application of the techniques of: Decompacting with sowing and decompacting with watering. While it is higher after the application of following techniques: Decompacting all alone, decompacting with manure and the control plot. The examination of the values of the Electrical Conductivity (EC) confirmed that the soil is unsalted according to Auber in Table 9.[44].

They vary between 0.14 ± 0.04 and 0.47 ± 0.29 mS/cm. It is higher after the application of all treatments with a global effect at $\chi 2$=77.16, p<0.001. Therefore, we noticed a significant difference in the plots where the decompacting with manure technique was applied and then the decompacting technique all alone (p<0.001).

Subsequently, it is the technique of decompacting with mulching, decompacting with sowing respectively ($p<0.01$). However, the decompacting with watering did not mark a significant difference ($p>0.05$).

Table 11 showed that the available phosphorus values (Avai.P) have decreased even if it is not significant for all techniques ($X^2=17.9$, $p>0.05$), except for the decompacting with watering technique which presented a significant difference ($p<0.05$). Values are situated between 18.76 ± 6.59 and 38.36 ± 28.6 mg/l, which are classified between high contents and very high contents of available phosphorus. However, despite the important difference in the decompacting with sowing technique, it did not present a significant difference. Then comes the technique of decompacting with watering and the technique of decompacting all alone. Then, the technique of decompacting with mulching and decompacting with manure respectively. A point to report, there is no significant difference in the control plots. Finally, we found a clear increase in the Organic Matter levels (OM) in a highly significant difference ($X^2=49.63$, $p<0.001$) after the application of these techniques compared to the period before their application (Table 10). The values oscillated between 0.17 ± 0.11 and 0.74 ± 0.42% and this classifies the soil samples as: Very poor soils to poor soils in organic matter. The established measurement also showed that the plots with a high difference between the two sampling periods are essentially placed in the plots of the technique of decompacting with manure then the technique of decompacting with sowing. Then, it is the technique of decompacting with mulching, decompacting with watering and decompacting all alone respectively.

Table 7. Classification of soil pH.

pH	Soil nature
< 3.5	Hyper acid
3.5-5	very acid
5-6.5	Acid
6.5-7.5	Neutral
7.5-8.5	Alkaline
>8.5	Very alkaline

Table 8. Classification of soils according to their available phosphorus.

Avail.Ph (ppm)	Content in the soil
<10 ppm	low contents
De 10-31 ppm	average contents
De 31-51 ppm	hight contents
>51 pp	very high contents

Table 9. Salinity scale in reference with the electrical conductivity of the soil of the diluted extract 1/5 [44].

E.C (dS/m on 25°c)	Salinity degree
≤ 0.6	not salted Soil
0.6< C.E. ≤ 2	light salted Soil
2< C.E. ≤ 2,4	Salted Soil
2.4< C.E. ≤ 6	very salted Soil
>6	extremely salted Soil

Table 10. Classification of soils according to their organic matter content.

OM (%)	Soil nature

<0.5	Very poor soil in OM
De 0.5-1.5	poor soil in OM
De 1.5-2.5	average poor soil in OM
De 2.5-6	Rich soil in OM
De 6-15	Very rich soil in OM

Table 11. Effect of techniques on pedological parameters (chemical analysis).

		pH		E.C (mS/cm)		Avai.P (mg/l)		O.M (%)	
Control plot	Before	7,97	± 0,37	0,14	± 0,04	27,7	±12,26	0,17	± 0,11
	After	8,18	± 0,29	0,47	± 0,29	26,88	±14,55	0,33	± 0,3
	p	ns		***		ns		ns	
Decompacting	Before	7,88	8,06	0,16	± 0,08	35,07	±30,7	0,22	± 0,19
	After	± 0,49	± 0,19	0,47	± 0,35	20,42	±7,12	0,54	± 0,4
	p	ns		***		ns		*	
Decompacting with sowing	Before	8,07	± 0,36	0,17	± 0,08	37,06	±27,62	0,28	± 0,29
	After	8,05	± 0,16	0,4	± 0,26	21,13	±6,49	0,68	± 0,42
	p	ns		**		ns		*	
Decompacting with manure	Before	8,03	± 0,31	0,15	± 0,06	24,61	±15,33	0,33	± 0,26
	After	8,04	± 0,24	0,5	± 0,29	18,76	±6,59	0,74	± 0,42
	p	ns		***		ns		**	
Decompacting with watering	Before	8,02	± 0,46	0,24	± 0,22	38,36	±28,6	0,3	± 0,3
	After	7,99	± 0,19	0,36	± 0,27	22,7	±18,2	0,63	± 0,38
	p	ns		ns		*		*	
Decompacting with mulching	Before	8,01	± 0,35	0,18	± 0,09	35,49	±21,25	0,2	± 0,22
	After	7,98	± 0,25	0,44	± 0,25	27,29	±27,96	0,58	± 0,34
	p	ns		**		ns		*	
Global effect (Kruskal Wallis)	Χ2	6.45		77.16		17.9		49.63	

Note: P-value (p) is the probability resulting from the nonparametric test of Wilcoxon (p-value<0.05) between the two sampling periods (15 surveys Before *vs.* 15 surveys After) for each technique as well as for the ± SD averages. The Global effect was tested by the nonparametric test of Kruskal-Wallis (Χ2 and p<0.05) (180 soil surveys). The asterisks show the significance of the test (***=p<0.001;**=p<0.01; *=p<0.05 ; ns=p>0.05).

DISCUSSION

Grazing exclosure for fighting desertification

Elimination of disturbances by grazing exclosure technique favored vegetation generation, particularly the floristic richness. In fact, the sensitivity of plant communities to grazing can depend on the frequency of the grazing and even on plants adaptation that allow them to avoid or tolerate animals grazi [48-50]. In effect, this technique is much efficient when it is combined with simple tillage techniques. The current study aims to test some techniques for restoring degraded courses in the Laghouat region. The impact has been detected after two years, indicating significant results. Effectively, the improvement of soil properties by simple tillage techniques accelerated the dynamic of the ecosystem, the installation of new species and the evolution of others, which explains the increase in specific richness. By the way, many authors have concluded that bacterial diversity in degraded steppes increased in short-term protection compared with free grazing and long-term protected stations [25,51,52]. Short-term grazing exclosure maintains higher the balance of species abundance, suggested Kouba in their study [53].

Referring to the control plot (no tillage technique was used), the study showed that the elimination of anthropogenic disturbances by grazing exclosure favored a good regeneration of the vegetation and consequently the floristic diversity (S, H', E, PC more elevated after the protection). These values might be compared with those obtained by Achour, by the grazing exclosure of argan groves, they found that the elimination of grazing favors the development of number and cover of the different herbaceous and perennial layers [26]. These species constitute the main floristic procession of the argan ecosystem. Therefore, the grazing exclosure stimulated the dynamics of the degraded ecosystem under the effect of various factors such as the abundance of seeds under the trees but also the density of vegetation, which provides shade and moisture to the young seedlings. These results confirm other studies, which indicated that this progressive evolution of the plant cover between the two sampling periods is due to the "biological recovery" phenomenon [54]. Cortina in their study also confirmed that this technique allows the improvement of the plant cover (increase from 10% to 30-40%), which contributes to a better protection of the soils against erosion and to the improvement of soil fertility [11]. The protection has acted in the floristic richness, which is more important when the rainfall conditions are favorable [55]. In fact, grazing can constrain the ecosystem resilience in drylands according to Visser and Beaugendre [56]. The Shannon index allowed to compare the specific dominance of the plant stand over time and to detect possible evolutions. Shannon's index showed higher values after applying the techniques than before. The grazing exclosure, according to Amghar and Kadi-Hanifi, led to an increase in the Shannon index following the increase in specific richness [57]. The high values of floristic richness index and the absence of trampling explain the important values of Shannon index in grazing exclosures [30,58-60].

Evenness informs that more abundant a taxon (it dominates the others), diversity appears lower. Here, it has been also noticed a positive increase in Evenness index. On the other hand, Amghar and Kadi-Hanifi and Rahmoun have found that the non-protected stations have higher values in Evenness [57,61]. This can be explained by the effect of grazing which consequently leads to a lower number of species equally distributed. Indeed, soils have been affected by biotic and abiotic factors, and then the spatial distribution of plants, which makes differences in Eveness index [62]. Le Houérou has found that the grazing exclosure promote the development of the litter [63]. In the arid environment, perennial species maintained basal cover in both inside and outside of the grazing exclosure by developing morphological and physiological strategies to reduce the impact of water limitation. The decrease of plant cover has reduced biodiversity by altering plant composition and consequently, the litter [64]. The study of Al-Rowaily, confirmed that in degraded rangelands of the western Saudi Arabia exclosures had a positive effect on vegetation cover, vegetation diversity and community composition [65].

Effect of tillage techniques

Moreover, the effect of tillage techniques with the grazing exclosure is much greater and leads to the restoration of degraded or much degraded environments in short time. Therefore, an improvement in the floristic and pedological parameters has been noticed. The values displayed for the other plots highlighted a positive significant influence of the techniques on the ecosystem dynamic. This effect is remarkable through the increase in S, H', E and PC and then the rate of litter in the plots decompacted with sowing. Following Rabefiraisana, plant debris is the main source of litter [66]. The higher values of litter is the consequence of the mortality of plants-annual and perennial-as a react toward the climate harshness. This leads to a traded-off between their vegetative and flowering phenology and consequently, they might complete their life cycle before the drought period [67]. The same results has been showed in the decompacted plots with manure. In fact, the high amount of litter stimulates interactions between soil micro-organisms (e.g. fungi and bacteria) and the dominant litter inputs [68,69]. These interactions lead to liberate organic carbon that affects soil nutriment availability and hence, plants growth [17,70,71]. These results has informed about the level of diversity in these plots, which is followed by the decrease of bare ground.

Also, this plant cover had consequences on the increase in the rate of the sand by the trapping of sand particles. On the other hand, this increase is probably caused by the effects of the severe climatic conditions that the region has experienced, namely strong winds. Moreover, it has been shown that the rate of net soil loss, quantified by wind erosion in rainfed crops in the agricultural area of Mokrane (in Laghouat region), is around 62 Mg ha^{-1} per year (*i.e.* five times higher than the tolerable rate of soil loss from wind erosion) [72]. This plant cover with the litter, in the developed plots has contributed significantly to the decrease in the surface of the bare ground that has been confirmed by [54]. Indeed, Amghar proposed that the percentage of bare ground should be the primary indicator chosen to evaluate the state of restoration of a plot, with the objective of evaluating the impacts of developments on degraded courses [31]. The tillage by decompacting (in order to reduce the bare silty crust) increases, according to Roose, the detachability and erodibility of the soil, which explains the high rate of coarse elements [73]. In addition, Fox in their study on the bare silty crust concluded that the latter closes certain soils rich in silt and fine sand and poor in organic matter [74]. Therefore, a simple decompacting has an effect on the rooting and then the growth of the plant. According to Chamizo the improvement of the soil structure and porosity can be insured by the decompacting of crust, permitting the liberation of the organic matter [75]. It should be noted that the bare silty crust was not found in the present stations for the two sampling periods because of the application of these restoration techniques but also the short duration of the protection. From this point of view, many authors have concluded that vegetation has various effects on the soil: (1) A direct effect on the reduction of the bare silty crust and improvement of infiltration (protection against rain); (2) An indirect effect such as the enrichment of the soil with organic matter therefore chemical fertility. That situation stimulates faunistic activity, which can itself reduce the severity of the crust [76]. The amount of bare ground rate has reduced, a consequence of the increase in plant cover and litter. In fact, the frequent trampling influences the soil surface that becomes bare and exposed to wind erosion [77]. In addition, the litter can contribute significantly on the diminution of the bare ground rate in protected stations [54]. Nevertheless, the decompacting is not sufficient all alone, it must be accompanied by techniques to improve soil fertility.

Change of soil chemical parameters according to the technique applied

The soil analysis carried out revealed contrasting values between different techniques applied (Table 5). The pH showed approximately similar values and they are basic. These values are consistents with Tir who concluded that the pH is moderately alkaline throughout the soil of arid regions, where the dissolution of carbonate geological formations ($CaCO_3$) is manifested according to Boutelli [78,79]. However, the difference in pH is not significant between the two sampling periods for all techniques. It might be due to the duration between these two samples (two years) which was not sufficient to have a change in the soil pH. According to several authors, it turns out that the pH remains relatively unchanged over the years. This is due to the buffering capacity which is stronger in soils contains a high level of organic matter [80]. However, following Omeiri, the organic matter supply decreases the pH [81]. In turn, Heydari confirmed that the pH was affected only by climatic conditions and not by the type of technique [82]. On the other hand, Shanmugam and Kingery detected in their study the effect of soil nutrients on pH and the effect of the latter on plant diversity [83]. They found that this diversity decreases with the increase in pH. According to Jendoubi manure has increased the electrical conductivity because of the liberation of ions [5]. Also, the mineralization of organic matter (manure, mulch, litter) provides variable amounts of chemical elements [84] generating the increase in soil salinity. In addition, watering led to the leaching of ions by water, which reflects the low salinity in these plots. The assimilation of phosphorus in the soil depends on several factors [85,86]. Although phosphorus can be present in significant quantities in soils, it is not permanently in an available form [66]. According to Davet, organic matter makes the phosphorus more bio-available and subsequently it is assimilated by the roots of plants [87]. That operation generate a decrease in phosphorus concentrations. Kumar has reported that the augmentation of carboxylic acids of the organic matter support the phosphorus assimilation [88]. Another study, which was completed by Lemming, focused on the nature of the organic amendment and its effect on residual phosphorus [89]. They concluded that the availability of phosphorus after the application of the amendment by composted household waste on the ground is significantly lower than that of phosphorus provided by the amendment by sewage sludge and livestock manure. Therefore, the availability of phosphorus is related to its level in the soil and the nature of the amendment. However, once the phosphorus has released in the available form, it is immobilized by calcium carbonates [90]. The decompacting technique with watering was significantly effective for phosphorus assimilation. Water has increased the solubility of this ion and has led to greater bio-availability for plants [91]. In reality, organic matter is largely responsible for the biological life of a soil [5]. According to the same author, it improves its chemical fertility (nutrients), physical (cohesion) and biological (stimulation of biological activity). This organic matter values has experienced an increase following the application of all techniques (especially decompacting with manure) which informs us about the chemical fertility of our soil. Following Murray, the treatment of the soil with a fertilizer (nitrogen (N) with lime) increased the biomass of the plants by improving the living conditions around the roots, so the absorption was optimal [92]. These results confirmed the work of Hart and August, who concluded that the content of the microbial biomass of the soil, first 20 cm from the surface, was greater than 70% after two years of addition of Nitrogen (N) fertilizers [93].

With the contribution of litter mainly by sowing, the amount of organic matter increased, as concluded by Benzina and Ben Hadj and Tir [78,94]. Thus, the addition of manure stimulates the activity of soil biomass in quantity and quality [84]. In turn, Bolinder confirmed that the renewal of organic reserves in soils could be implemented by harvest residues [95]. However, the beneficial effect of organic matter on the total stability of the soil is well known [74]. Thus and according to the same author, it is clear that the improvement of soil properties is an effective tool to combat desertification (mainly with manure and mulching).

Effect of tillage on the floristic and pedological parameters

Although several authors have proven that the covering of vegetation has a positive effect on the properties of the soil, it has been demonstrated in this study that the opposite is also possible. Because, plots where there is a significant improvement in chemical fertility of the soils (mainly by manure), there is an increase in floristic diversity, and consequently the decrease in the surface of the bare ground. Here, we can note the particular effect of the decompacting with watering technique on the rate of available phosphorus of the soil. Meanwhile, watering had the less important positive effect, comparing it to other biological methods. It can be explained by the water deficit of the study region (the average annual cumulative rainfall is 148.69 mm for the period 1996-2017) which could not be rewarded by simple watering. For the control plot, he experienced a slight improvement in the parameters that is not comparable to the improvement generated by the techniques of tillage. In addition, it was also revealed the particular effect of the decompacting with mulching technique and the decompacting with sowing technique in the increase of the litter rate. The technique of decompaction with manure had important effects on the level of organic matter. These two later techniques are the most effective in stimulating the development of a good plant cover and therefore floristic diversity. The decompacting all alone had the least important effect for all the techniques applied (Tables 4 and 5). In summary, to improve the condition of the soil surface and subsequently the floristic diversity, there are two complementary approaches, the first, according to Roose called mechanical, consists in working the soil superficially (decompacting) by breaking the bare silty crust in order to improve the infiltration of water and consequently the development of a plant cover [73]. However, this is not enough all alone for having an optimum development of plant communities. It is recommended according to the same author to accomplish it by another biological approach consist in adding, for example: seedlings, manure, water or mulching to the soil [96-100].

CONCLUSION

From the results obtained, we can discern the positive impact of the grazing exclosure for the restoration of degraded courses. Also, it is clear that the state of the soil plays a major role. The elimination of anthropogenic disturbances by the grazing exclosures with simple tillage techniques allowed to the courses to be reconstituted even if the protection period was short (2 years). The application of these techniques has generated significant positive changes in the floristic diversity and the elements of the soil surface while the percentage of bare ground has decreased. For the chemical parameters of the soil, the electrical conductivity and the organic matter have displayed values that are more important after the application of techniques than before. The available phosphorus is lower while the pH remains almost unchanged. Manure has improved the chemical fertility of the soil and consequently the biological diversity. Nevertheless, to remedy the excessive accumulation of salts, especially in plots amended with manure, it is strongly recommended to study the dose effect of these treatments. The presence of mulching protects the soil from the destruction of the macro-structure and maintains the right conditions for the acceleration of organic matter mineralization. In addition, although water is a limiting factor in these steppe zones, the addition of this element had a positive effect on the dynamics of this ecosystem. However, the watering technique was the least effective biological method because of the very severe arid conditions (lack of rainfall) that persist in these areas. Nevertheless, the decompacting all alone did not have a great influence compared to the techniques applied. Finally, taking into account these results, it turns out that the rehabilitation of degraded environments by the grazing exclosures but with tillage techniques are effective techniques in a short time and easier to generalize in steppe zones even if the degradation of the environment has reached an irreversible stage. However, to achieve the objectives, these restoration techniques require a fine study of the duration of protection of theses plots and the adhesion of the populations, in particular the breeders. Therefore, it is appropriate to take into account the problems of these populations, particularly to set up a participatory approach that values the land and the work of the peasants.

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