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EFFECTS OF LAND USE CHANGES ON THE SOIL PHYSICOCHEMICAL PROPERTIES IN SOUTH-WESTERN ALGERIA

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Abstract

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This study shows the impact of the reforestation program by some tree species (*Pinus halepensis, Cupressus sempervirens* and *Eucalyptus camaldulensis*) on the soil physicochemical parameters in south-western Algeria steppe. The study was realized on soil samples from the Touadjeur site. One hundred soil samples were taken from the field, followed by physicochemical analyses in the laboratory. A comparison of the soil elements between reforested and unreforested sites considered as a control was carried out. The results show that there are differences in the physicochemical parameters of the soil between the reforestation and the non-reforestation ones constituted by a steppe vegetation. The ANOVA one way test shows a highly significant difference change in soil physical parameters, moisture, holding capacity and saturated hydraulic conductivity, but no change in apparent density, actual density and color. Also, from a chemical point of view, the differences concern the organic matter, organic carbon, pH and certain soil contents. The main differences in soil properties between the reforestation sites and the control site, reflect the consequences of forest management adopted by the forest services, most probably the choice of reforestation species.

Key words: steppe, reforestation, soil analyses, desertification, ANOVA, Nâama.

Introduction

The steppe zone is located between the 400 and 100 mm isohyets in northern Algeria, on an area of 20 million ha between the southern limit of the Tellian Atlas and the southern foothills of the Saharan Atlas (Nedjraoui, Bédrani, 2008), characterized by a Mediterranean-type climate, semi-arid to arid, dominated by four main types of plant formations: the grassy steppes based on *Stipa tenacissima* L. and *Lygeum spartum* L., which are rangelands, and Chamaephytic steppes of *Artemisia herba alba* Asso, whose pastoral values are very significant, and *Hamada scoparia* (Pomel) located on the regs. Azonal formations are represented by psammophilous species and halophilous species with good forage values (Nedjraoui, Bédrani,

Abbreviations
V: soil volume; Ps: apparent density; Pp: true density; W weight., K: permeability; OM: organic matter.

2008). The steppe soils are characterized by the presence of calcareous accumulation, the low organic matter content and a high sensitivity to erosion and degradation (Yerou, Benabdeli, 2013). The steppe undergoes a degradation at a rate and intensity that are becoming more and more accentuated, leading to a reduction of biological potential and a rupture of ecological and socio-economic balances (Sitayeb, Belabbes, 2018; Nedjraoui, 2004; Aidoud, Touffet, 1996; Le Houérou, 1985). The steppe zone is particularly exposed to the phenomenon of degradation due to environmental constraints and intense and continuous human pressure (Sitayeb, 2016; Khalid et al., 2015; Aidoud, Touffet, 1996). The restoration of degraded arid and semi-arid lands through the introduction of woody species as a soil protection measure (Castillo et al., 1997), to provide resources, to combat desertification (Reynolds, 2001) and to provide a recreational space (Schiller, 2001). The objective of this study is to identify the main ecological consequences of the introduction of woody species into large monospecific plantations in the arid and semi-arid zones of Algeria. Understanding the ecological consequences of these plantations is a matter of utmost importance to evaluate current and past forest policies, to develop alternative restoration strategies and to predict the long-term consequences of these plantations on ecosystem function and dynamics.

We are interested in the reforestation project that was carried out in 2007 on 400 ha by the use of three forest species (*Pinus halepensis*, *Cupressus sempervirens* and *Eucalyptus camaldulensis)*. To show the impact of land-use change on the modification of the soil physicochemical parameters, more precisely the effect of reforestation practices that lead to change in the soil structure and the modification of the organic contents and mineral elements.

Material and methods

Study area

The study area is part of the high plains of South Oranie, it extends between 32° 08' 45" and 34° 22' 13" north latitude, and 0 °36' 45"is 0 ° 46' 05"of west longitude (UTM WGS 84) ; it belongs to the wilaya of Nâama.

The climatic data for the period 1985–2013 (ONM, 2016) show that the area spreads from the upper arid bioclimatic stage to cool winter. The rainfall pattern is PAEH type (Spring, Autumn, Summer and Winter) and a strong thermal amplitude estimated at 35.1°C is subject to continental influences.

Soils, in general, are shallow (10 to 30 cm), poor in organic matter and consist of limestone or sandstone materials resulting from a source rock alteration (CENEAP, 2009). To study the impact of reforestation on the soil parameters, it is necessary that the only difference between sites is the reforestation species. The primary criteria for a good comparison are then: the homogeneity of the soil and its parent material, the proximity of the sites to each other (Fig. 1), the topography (Mead, Cornforth, 1995). In addition, it is desirable that criteria such as implementation conditions and management (Bonneau, Ranger, 1984), and age (Hughes et al., 1994) be identical for all sites.

Site description

The reforestation site is 20 km north from the wilaya capital. It is located between the national road n°6 and the wilaya road leading to the Touadjeur locality. The site of Touadjeur occupied by a flat plain with an altitude about 1000 m. The reforestation project was carried out to colonize bare lands and treat the silting corridor that threatens the south agglomeration of Mecheria and the Touadjeur locality. It was carried out in 2007 on 400 ha, with 1600 plants/ha of density, three species (*Pinus halepensis*, *Cupressus sempervirens* and *Eucalyptus camaldulensis*) were used. The project was evaluated by the forest services of the wilaya of Nâama at a 70% success rate. No silvicultural practices have been carried out after the planting date.

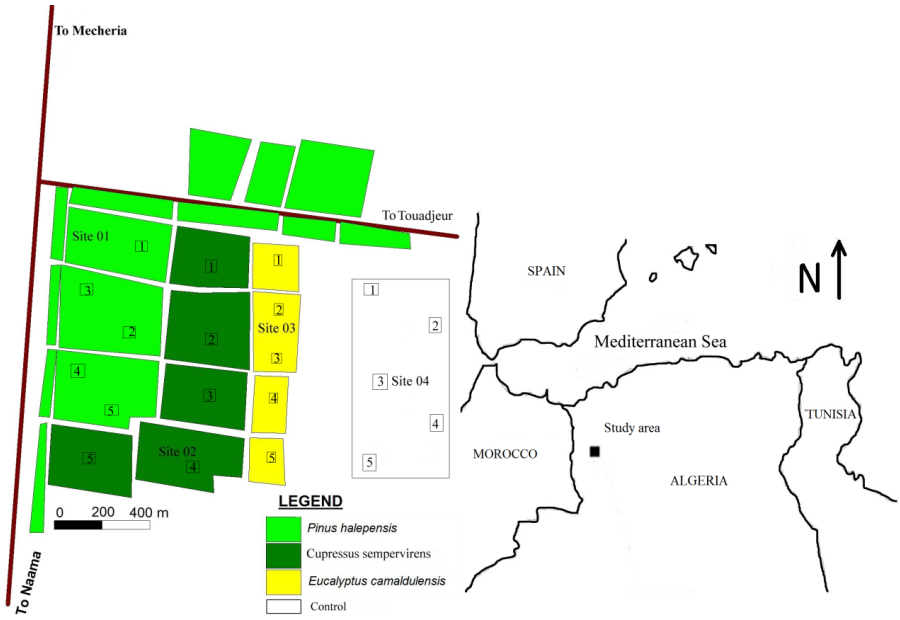


Fig. 1. Situation of study sites.

Sampling

The various methods of soil studying and characterization lead to the topsoil sampling (Pansu et al., 1998). Sampling soil and analyzing it require knowing environmental site context of the site and its occupation (Laperche, Mossman, 2004). The mixed sampling method was used (Gounot, 1969). This strategy begins with stratified sampling consisting of a delineation of four ecologically homogeneous sites (stratification) of the study area (same soil type, similar climatic and topographic conditions) (Fig. 1). Then within the selected sites, we made subjective samples. Three represent the reforestation area and the fourth site in a non-reforestation one. Five plots in each site were chosen, each plot with a surface of 400 m^2. In each plot, five soil samples were randomly carried out in the topsoil (Guénon, 2010). Soils were placed in plastic bags in an unsealed manner to maintain an aerobic state until their transportation to the laboratory. They were then screened at 2 mm to remove undesirable particles (roots, earthworms, etc.) and to obtain a perfectly homogeneous sample, after determining the humidity.

Physical analyses

The method of Mathieu and Pieltain (1998) was used to determine the soil moisture. It is determined after drying 100 gm of soil sample in an oven for 24 hours at 105 °C, and it is calculated by the difference between fresh and dry weight.

Total porosity is determined on the basis of the true density (Pp) and apparent density (Ps) of a soil (Aubert, 1978). The total porosity will be given by:

$$\frac{Pp - Ps}{Pp} \times 100.$$

The Apparent density was determined by the cylinder method (Aubert, 1978). This method involves taking a sample of soil of known volume whose moisture mass will be determined, then the dry mass, and therefore the density. Apparent density "Ps" is then given by:

$$Ps = \frac{\mathrm{Ms}}{\mathrm{V}},$$

where: Ms – soil mass dried at 105 °C (gr),V – Cylinder volume.

To calculate the true density, we adopted the pycnometer method, which is obtained in the following way: To obtain two mass values, m_1: a mass of pycnometer plain of liquid plus the mass of soil; m_2: soil mass plus the mass of liquid completing the pycnometer to the mark. Knowing these two values, we can calculate the difference m = (m_1-m_2), corresponding to the mass of a volume of liquid equal to the volume of soil placed in the pycnometer (Aubert, 1978).

True density "Pp" is then given by:

$$Pp = \frac{Ws}{V},$$

where: Ws – dry soil weight (gr), V – liquid volume remaining in the burette.

The water retention capacity at the field was obtained using the protocol described by Saetre (1998). Thirty grams of fresh soil was weighed in a PVC cylinder (5 cm in diameter, 4 cm in height). Distilled water was then added until the soil was saturated. The cylinder and its contents were placed at 4 °C (12 h) to allow drainage of the gravity water, and then they were weighed. The water content of this saturated sample, referred to as the field capacity, was finally determined by drying the cylinder in the oven (105 °C, 24 h) and subtracting the masses of dry soil and saturated soil (Guénon, 2010).

The soil permeability is the depth of water measured per centimeter that infiltrates the soil per time unit (Mathieu, Pieltain, 1998). The permeability calculation is given by the following formula:

K (cm/h) = 0.857 x h (water).

The soil color is determined by reference to Munsell code, International normally includes 175 colored cartons or chips (Escadafal et al., 1988). These boxes are systematically grouped according to their Munsell notation on boards assembled in a loose-leaf notebook (Delaunois, 2006).

Chemical analyses

The soil pH was measured on a suspension of soil in distilled water. The measurement was carried out after 2 hours of stabilization at room temperature using a pH meter (HANNA-HI8424). The same operation is carried out for the pH_{kcl} but replacing the distilled water with the (KCl) solution. The electrical conductivity was measured using a conductivity meter (HANNA-HI8733) in slurry of the fine soil in distilled water (Mathieu, Pieltain, 2003). We used the volumetric method, also called the method "Bernard Calcimeter" to calculate total limestone. It was determined by the decomposition with hydrochloric acid (M) of $CaCO_3$ in CO_2, whose volume was determined by the calcimeter Bernard (Aubert, 1978). The total organic carbon was determined by the method of oxidation of the organic matter cold by an excess of potassium dichromate ($K_2Cr_2O_7$) in the presence of concentrated sulfuric acid according to the protocol of Anne described by Aubert (1978).

So, the organic matter is determined by the following formula:

OM% = C% x 1.72,

where: OM% – The percentage of organic matter, C% – The percentage of oxidized carbon.

Chemical elements measured by X-ray fluorescence analysis, this procedure is related to the practical instrumental method of elemental analysis of the soil by fluorescence spectrophotometry. The elements: Si, Al, Fe, Ca, Mg, K expressed in the oxidized forms: SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, K_2O are determined on a solid solution sample.

Statistical analysis

The data collected were subjected to simple descriptive analyzes and one-way analysis of variance (ANOVA), and the Duncan test was used for both analysis of variance and comparison of means. The test was applied at a probability level of (p = 0.05).

Results

The results of comparing the means of the physicochemical parameters of soils between the four sites are shown in Table 1 and 3; the results of Duncan's post hoc test of homogeneous subsets are shown in Table 2 and 4.

T a b l e 1. One-Way ANOVA test of physical parameters.

Parameters	**Sites**				**Signification**
	Pinus	*Cupressus*	*Eucalyptus*	control	
Hu %	2.15	4.50	3.98	3.46	0.000**
Ps (g/cm3)	1.34	1.31	1.32	1.38	0.060
Pp (g/cm3)	2.36	2.34	2.31	2.33	0.859
RC %	35.97	46.19	44.22	45.83	0.036*
Pr (%)	42.72	43.72	42.56	39.72	0.095
Ks (cm/h)	2.20	2.66	2.82	5.74	0.000**
Couleur	R-O	R-O	R-O	R-O	0.919

Notes: Hu – moisture, Ps – apparent density; Pp – true density; RC – retention capacity; Pr – porosity; Ks – permeability; R – red; O – orange; **, * – Significant at 0.01 and 0.05, respectively.

Physical parameters

The hygroscopic humidity (Hu) values show that the site of *Pinus halepensis* represents the lowest average with 2.15% compared to the control site, which represents a high value of 3.47%, whereas the sites of *Eucalyptus* and *Cupressus* represent values high with 3.98 and 4.50%. The retention capacity (RC) analysis represents a mean difference between the *Pinus halepensis* site of 35.97% compared to the other sites that make up a homogeneous group, *Cupressus* 46.19%, control 45.83%, *Eucalyptus* 44.22% (Table 2). The statistical test of soil permeability (Ks) shows a difference in the mean of the two groups – the first constitutes the three reforestation sites with low values compared to the control site, which represents a high value with 5.7 (cm/h), against *Eucalyptus* 2.82 (cm/h), *Cupressus* 2.66 (cm/h), and *Pinus halepensis* 2.2 (cm/h). The Duncan's test on apparent density (Ps), true density (Pp), soil

T a b l e 2. Duncan post hoc test for physical parameters.

Sites	**Physical parameters subset**										
	Hu			**Ps**	**Pp**	**RC**		**Pr**	**Ks (cm/h)**		**Color**
	1	**2**	**3**	**1**	**1**	**1**	**2**	**1**	**1**	**2**	**1**
Pinus	2.15	-	-	1.34	2.36	35.97	-	42.72	2.20	-	2.44
Cupressus	-	-	4.05	1.31	2.34	-	46.19	43.72	2.66	-	2.52
Eucalyptus	-	-	3.98	1.32	2.31	-	44.22	42.56	2.82	-	2.36
control	-	3.46	-	1.38	2.33	-	45.83	39.72	-	5.74	2.52

T a b l e 3. One-Way ANOVA test for chemical characteristics.

Parameter	Sites				Signification
	Pinus	*Cypressus*	*Eucalyptus*	control	
pH_{H2O}	7.60	7.51	7.92	7.87	0.000**
PH_{Kcl}	7.30	6.80	7.10	7.26	0.000**
EC (ms/cm)	6.10	7.04	2.01	2.44	0.000**
$CaCo_3$ (%)	7.98	11.28	9.70	8.30	0.027*
Corg (%)	0.49	0.72	0.84	0.78	0.000**
OM (%)	0.85	1.24	1.45	1.34	0.000**
CaO (%)	22.83	22.25	21.38	21.61	0.487
MgO (%)	0.48	0.40	0.54	0.65	0.000**
AL_2O_3 (%)	9.69	9.05	10.84	11.00	0.000**
SiO_2 (%)	46.57	45.25	45.35	44.23	0.767
K_2O (%)	1.64	1.63	1.70	1.69	0.060
Fe_2O_3 (%)	5.13	5.46	6.34	6.80	0.000**

Notes: EC – electrical conductivity; Corg – organic carbon; OM – organic matter; **, * – Significant at 0.01 and 0.05, respectively.

T a b l e 4. Duncan post hoc test for chemical parameters.

Sites	Chemical parameters subset											
	$CaCo_3$		Fe_2O_3		Al_2O_3		K_2O	CaO	SiO_2	EC		
	1	2	1	2	1	2	1	1	1	1	2	3
Pinus	7.98	-	5.13	-	9.69	-	1.64	22.83	46.57	6.1	-	-
Cypressus	-	11.28	5.46	-	9.05	-	1.63	22.25	45.25	7.04	-	-
Eucalyptus	-	9.70	-	6.34	-	10.84	1.70	21.38	45.35	-	2.01	-
control	8.30	-	-	6.80	-	11.00	1.69	21.61	44.23	-	-	2.44

Sites	Chemical parameters subset													
	OM			pH_{kcl}			pH_{H2O}		MgO			Corg		
	1	2	3	1	2	3	1	2	1	2	3	1	2	3
Pinus	0.85	-	-	-	-	7.30	7.60	-	0.48	0.48	-	0.50	-	-
Cypressus	-	1.24	-	6.80	-	-	7.51	-	0.40	-	-	-	0.72	-
Eucalyptus	-	-	1.45	-	7.10	-	-	7.92	-	0.54	-	-	-	0.84
control	-	1.34	1.34	-	-	7.26	-	7.87	-	-	0.65	-	0.78	-

porosity (Pr) and soil color shows homogeneity of values between the four stations (Table 3), which reflects the lack of reforestation impact with the three species in the change of these parameters.

Chemical parameters

The results arranged in Table 4 show a difference of pH_{H2O} mean between the group formed by the *Cupressus* and *Pinus halepensis* sites and the group consisting of the control and *Eucalyptus* sites. Table 3 and 4 show that Ph_{kcl} results show the difference in mean between the three groups – the first presents *Cupressus* site (6.8), the second group constitutes *Eucalyptus* site, and the last is formed by *Pinus* and control sites with. The electrical conductivity results presented in Table 3 show a significant difference between the resinous species sites (*Pinus halepensis* 6.1 (ms/cm), *Cupressus* 7.04 (ms/cm)) and the control site with a value of 2.44 (ms/cm), which is more or less equal to the value of the *Eucalyptus* site, which has a low electrical conductivity with an average of 2.01 (ms/cm). Duncan's post-hoc comparison of averages between the four sites shows that the *Cupressus* and *Eucalyptus* sites have a high value of Calcium carbonate ($CaCo_3$) against the *Pinus* and control sites (Table 4). The *Pinus halepensis* site has a low value of organic carbon (0.49%) against the control site, *Cupressus* and *Eucalyptus* with 0.78, 0.72 and 0.84%, respectively. The results of organic matter (Table 4) indicate that the average value of *Pinus halepensis* site 0.85% is lower compared to the group constituted by the control, *Cupressus* and *Eucalyptus* sites. The comparison results of the means of soil chemical elements between the four sites studied (Table 3), the modifications are recorded in the following elements: Fe_2O_3: The results (Table 4) show a difference in the mean between *Pinus halepensis* 5.1% and *Cupressus* 5.4%, which have low values against the *Eucalyptus* 6.3% and that of the control 6.8%. Al_2O_3: Values for *Pinus halepensis* and *Cupressus* are low compared to the control and *Eucalyptus* (Table 4). MgO: The reforestation sites have low values against the control 0.65%. The elements (CaO, SiO_2, K_2O) do not present any difference in means between the fourth sites.

Discussion

Rates of soil moisture depletion in the topsoil at the pinus site were significantly lower than at other sites. Given the fact that the land cover ratio was important, according to (Querejeta et al., 2001), plantations of *Pinus halepensis* in semi-arid areas generally show lower soil moisture content with other plant communities. Bellot et al. (1999, 2004) found a negative effect of *P. halepensis* plantations on soil moisture at 0–10 cm, and at 10–30 cm depth, relative to the adjacent shrublands and grasslands in a semiarid catchment in Murcia province (South-East Spain).

The apparent density of the soil globally reflects the state of compaction of the material, and indirectly, the total porosity. When the Apparent density is high, the soil does not contain pores necessary for root growth, water capacities are reduced, and circulation of fluids is slowed down (drainage and gas exchange) (Alongo, Kombele, 2009). The results confirm the explanation of Alongo and Kombele (2009), the apparent density value of the control site is superior to that of the reforested sites, which reflect the influence of soil preparation practices in reforestation sites.

The retention capacity analysis (RC), which is the threshold below which water contained in the soil cannot be drained. RC rate is 36% lower in the *Pinus* site compared to other sites.

Thus, *Cypresus* soil has a high RC value of 46%. Like other physical characteristics, the retention capacity can be influenced by the rate of organic matter (Dutartre et al., 1993; Klute, 1986; Fustec-Mathon et al., 1975). Control, *Cypresus* and *Eucalyptus* sites have a lower land cover ratio and abundant spontaneous vegetation.

Soil permeability is a critical factor in assessing the effectiveness of soil restoration methods, it is expressed by a coefficient characterizing the rate at which water infiltrates into the soil, depending to its moisture status (Bottinelli, 2010; Lipiec et al., 2006). The result shows the negative effect of vegetation on soil permeability. It is mainly controlled by soil macroporosity: size, connectivity and stability of agency gaps between aggregates (Lipiec et al., 2006).

In addition, decaying organic matter and soil microorganisms, particularly fungi, can lead to water repellency (Morales et al., 2010; Lichner et al., 2007; Doerr et al., 2000). Soil acidification due to acid litter decomposition, particularly in plantation conifers, can lead to the collapse of soil aggregates and reduce macroporosity (Chappell, Franks, 1996).

To date, most of the existing studies on hydrology, vegetation-related soil properties, focus on reforestation effects (Bonell et al., 2010; Greenwood, Buttle, 2012) and the comparison of forest soils and degraded pastures or grasslands across watershed studies (Archer et al., 2013; Ghimire et al., 2013). Soil porosity is the first factor of soil fertility. It favors the storage of water for plant and the circulation of air necessary for good functioning of the roots. The color of a soil is a good indicator of the moisture regime of the soil and the state of oxidation of minerals, the soil color of the study stations varies between red and orange, a clear color in 100 samples. The presence of organic matter expresses a dark coloration of the soil (Birot, 1966). The pH is an important parameter that conditions a large number of chemical and microbiological reactions in the soil. The pH_{kcl} corresponds to the hydrogen concentration (H^+) of the soil obtained after the addition of potassium chloride (KCl). KCl has the effect of removing the (H^+) fixed on the Clay-Humic Complex, which makes it possible to determine the total acidity or reserve acidity of the soil. The results show that the pH of soils is more acidic in conifer sites than those under the Eucalyptus cover because of the acidic nature of the main components of conifer leaves and derive from leaves (Laudicina et al., 2012), conifer leaves and litter have lower basal content (Pritchett, Fisher, 1985). The supply of acid pine needles on the forest floor creates extremely acidic bedding that promotes the acidification of the soil (Binkley, Fisher, 2013; Gerrard, 2000; Neal et al., 1992). In all cases, the results show that pH_{H2O} is greater than pH_{kcl}, indicating the presence of negatively charged colloids in soils (Koy Kasongo, 2009). The electrical conductivity of soils (EC) determines their degree of salinity (Hardie, Doyle, 2012).

Soil salinization after afforestation has been reported in several parts of the world for different types of trees (broad-leaved and evergreen, coniferous and broad-leaved) and in a wide range of climates (Nosetto et al., 2007; Jobbágy, Jackson, 2004; Sapanov, 2000; Vertessy et al., 2000; George et al., 1999; Heuperman, 1999). Tree species strongly influence soil salinity, depending on their respective salinity tolerances. Under homogeneous conditions, species with higher salinity tolerances will lead to higher Salinization than less salt-tolerant species. The greater tolerance of *Eucalyptus* could be due to the combination of an effective mechanism of salt exclusion by the roots and a better osmotic adjustment by the synthesis and accumulation of osmolytes (Adams et al., 2005; Niknam, Mccomb, 2000). Others mecha-

nisms, such as salt absorption and excretion by leaf glands, become important in *Tamaris* sp. (Thompson et al., 1969).

According to Pouget (1980), the root system of the perennial steppe vegetation contributes effectively to the limestone dynamics. In the horizons of calcareous accumulation, it shows that the activity of the root system is associated with the presence of a particular type of calcite in very fine crystals, of the order of one micron. But in our case we studied the wooded forest vegetation on steppe, and the level of limestone in soil is due to plowing done in soil preparation before planting, deep plowing can ride the limestone crust into the topsoil.

The result of organic carbon coincides with the findings of (Guo, Gifford, 2002) who found afforestation by *Pinus* (non-leafy species) significantly reduced soil carbon. The organic matter in the Eucalyptus plantation is high compared to the other sites, which confirms the work of Feyisa et al. (2018).

Several studies have found the soil organic matter and the total nitrogen concentration low in the *Pinus halepensis* plantations (Castillo et al., 2002). According to Pouget (1980), there is an influence of the nature of the vegetation cover on the organic matter content and its distribution in the profiles.

Conclusion

The purpose of this study was to evaluate the reforestation effects of species (*Pinus halepensis, Cupressus sempervirens* and *Eucalyptus camaldulensis*) on soil physicochemical properties in the steppe area of the Nâama region. One hundred soil samples were collected at 0–15 cm depth and analyzed at the laboratory. The results suggest that changes have marked many physicochemical soil parameters analyzed in different sites. These changes showed the effect of the introduction of tree species in modifying soil edaphic parameters of a steppe ecosystem. The effect of reforested species is mainly expressed in the upper horizons of the soil. Species such as pine, cypress and eucalyptus cause litter accumulation and acidification of the upper soil layers to not be caused by the steppe vegetation cover native to the area. The choice of a species during an afforestation operation remains partially qualitative with regard to the fragile soils of intermediate fertility. Therefore, it would be useful to gather other data in order to seek to establish a model on which the decision-maker could rely to establish management plans maintaining the sustainability of an ecosystem.

References

Adams, M.A., Richter, A., Hill, A.K. & Colmer T.D. (2005). Salt tolerance in Eucalyptus spp: identity and response of putative osmolytes. *Plant Cell Environ*., 28(6), 772–787. DOI: 10.1111/j.1365-3040.2005.01328.x.

Aidoud, A. & Touffet J. (1996). La régression de l'alfa (*Stipa tenacissima* L.), graminée pérenne, un indicateur de désertification des steppes algériennes. *Science et Changements Planétaires / Sécheresse*, 7(3), 187–193.

Alongo, S. & Kombele F. (2009). Evolution de la densité apparente et du rapport c/n du sol sous les variétés exotiques et locale de manioc dans les conditions naturelles de kisangani (r.d. Congo). *Annales de l'Institut Facultaires des Sciences Agronomiques de Yangambi*, 1, 197–214.

Archer, N.A.L, Bonell, M., Coles, N.. MacDonald, A.M., Auton, C.A. & Stevenson R. (2013). Soil characteristics and landcover relationships on soil hydraulic conductivity at a hillslope scale: A view towards local flood management. *J. Hydrol*., 497, 208–222. DOI: 10.1016/j.jhydrol.2013.05.043.

Aubert, G. (1978). *Méthodes d'analyses des sols*. Marseille: Centre national de documentation pédagogique, Centre régional de documentation pédagogique.

Bellot, J., Sanchez, J.R., Chirino, E., Hernandez, N., Abdelli, F. & Martinez J.M. (1999). Effect of different vegetation type cover on the soil water balance in semi-arid areas of South Eastern Spain. *Physics and Chemistry of the Earth, Part B*, 24(4), 353–357. DOI: 10.1016/s1464-1909(99)00013-1.

Bellot, J., Maestre, F.T., Chirino, E., Hernández, N. & de Urbina J.O. (2004). Afforestation with *Pinus halepensis* reduces native shrub performance in a Mediterranean semiarid area. *Acta Oecol.*, 25(1–2), 7–15. DOI: 10.1016/j.actao.2003.10.001.

Binkley, D. & Fisher R.F. (2013). *Ecology and management of forest soils*. Oxford: Wiley-Blackwell.

Birot, P. (1966). Les nouvelles classifications des sols d'après P. Duchaufour. *Annales de Géographie*, 75(410), 448–453.

Bonell, M., Purandara, B.K., Basappa, V., Krishnaswamy, J., Acharya, H.A.K., Singh, U.V., Jayakumar, R. & Chappell N. (2010). The impact of forest use and reforestation on soil hydraulic conductivity in the Western Ghats of India: Implications for surface and sub-surface hydrology. *J. Hydrol.*, 391(1–2), 47–62. DOI: 10.1016/j.jhydrol.2010.07.004.

Bonneau, M. & Ranger J. (1984). Effect of an oak forest on a silty acid soil - Changes in humus form and exchangeable cations. In *Proceedings of the ESF workshop* (pp. 249–254), March 1983. Uppsala.

Bottinelli, N. (2010). *Evolution de la structure et de la perméabilité d'un sol en contexte de non labour associé à l'apport d'effluent d'élevage: rôle de l'activité lombricienne.* Doctoral dissertation, Agrocampus-Ecole nationale supérieure d'agronomie de rennes.

Castillo, V., Martinez-Mena, M. & Albaladejo J. (1997). Runoff and soil loss response to vegetation removal in a semiarid environment. *Soil Science Society of America Journal*, 61(4), 1116–1121. DOI: 10.2136/sssaj1997.03615995006100040018x.

Castillo V., González, G., Mosch, W., Navarro-Cano, J., Conesa, C. & López F. (2002). Monitoring and evaluation of forestry restoration and hydrological control works (in Spain). In F. López (ed.), *Seguimiento y evaluación de los efectos sobre el medio natural de la sequía y los procesos erosivos de la Región de Murcia* (pp. 167–231). Murcia: Consejería de Agricultura, Agua y Medio Ambiente de la Región de Murcia.

CENEAP (2009). Etude du plan d'aménagement du territoire de la wilaya de Naama. Phase II : orientations générales, enjeux et schémas prospectifs d'aménagement.

Chappell, N.A. & Franks S.W. (1996). Property distributions and flow structure in the Slapton Wood catchment. *Field Stud.*, 8(4), 559–575.

Delaunois, A. (2006). *Guide simplifié pour la description des sols*. Chambre d'agriculture, TARN. https://www.doc-developpement durable.org/file/Fertilisation-des-Terres-et-des Sols/p%C3%A9dologie/guideSols2006.pdf

Doerr, S.H, Shakesby, R.A. & Walsh R.P.D. (2000). Soil water repellency: its causes, characteristics and hydro-geomorphological significance. *Earth-Science Reviews*, 51(1–4), 33–65. DOI: 10.1016/s0012-8252(00)00011-8.

Dutartre, P., Bartoli, F., Andreux, F., Portal, J.M. & Ange A. (1993). Influence of content and nature of organic matter on the structure of some sandy soils from West Africa. In L. Brussaard & M.J. Kooistra (Eds.), *Soil structure/soil biota interrelationships* (pp. 459–478). Amsterdam: Elsevier. DOI: 10.1016/b978-0-444-81490-6.50037-6.

Escadafal, R., Girard, M.C. & Courault D. (1988). La couleur des sols: appréciation, mesure et relations avec les propriétés spectrales. *Agronomie*, 8(2), 147–154.

Feyisa, D., Kissi, E. & Kebebew Z. (2018). Rethinking *Eucalyptus globulus* Labill. based land use systems in smallholder farmers livelihoods: A case of Kolobo Watershed, West Shewa, Ethiopia. *Ekológia (Bratislava)*, 37(1), 57–68. DOI: 10.2478/eko-2018-0006.

Fustec-Mathon, E., Righi, D. & Jambu P. (1975). Influence des bitumes extraits de podzols humiques hydromorphes des Landes du Médoc sur la microflore tellurique. *Revue d'Écologie et de Biologie du Sol*, 12, 393–404.

George, R.J., Nulsen, R.A., Ferdowsian, R. & Raper G.P. (1999). Interactions between trees and groundwaters in recharge and discharge areas - A survey of Western Australian sites. *Agric. Water Manag.*, 39 (2–3), 91–113. DOI: 10.1016/S0378-3774(98)00073-0.

Gerrard, J. (2000). *Fundamentals of soils (Routledge fundamentals of physical geography).* London: Routledge.

Ghimire, C.P., Brujinzeel, L.A., Bonell, M., Coles, N., Lubczynski, M.W. & Gilmour D.A. (2013). The effects of sustained forest use on hillslope soil hydraulic conductivity in the Middle Mountains of Central Nepal. *Ecohydrol. Hydrobiol.*, 7(2), 478–495. DOI: 10.1002/eco.1367.

Gounot, M. (1969). *Méthodes d'étude quantitative de la végétation*. Paris: Massonet Cie.

Greenwood, W.J. & Buttle J.M. (2012). Effects of reforestation on near-surface saturated hydraulic conductivity in a managed forest landscape, southern Ontario, Canada. *Ecohydrol. Hydrobiol.*, 7(1), 45–55. DOI:10.1002/eco.1320

Guénon, R. (2010). *Vulnérabilité des sols méditerranéens aux incendies récurrents et restauration de leurs qualités chimiques et microbiologiques par l'apport de composts*. Doctoral dissertation, Université Paul Cézanne-Aix-Marseille III.

Guo, L.B. & Gifford R.M. (2002). Soil carbon stocks and land use change: a meta analysis. *Global Change Biology*, 8(4), 345–360. DOI: 10.1046/j.1354-1013.2002.00486.x.

Hardie, M. & Doyle R. (2012). Measuring soil salinity. In S. Shabala & T. Cuin (Eds.), *Plant salt tolerance* (pp. 415–425). Totowa: Humana Press. DOI: 10.1007/978-1-61779-986-0_28.

Heuperman, A. (1999). Hydraulic gradient reversal by trees in shallow water table areas and repercussions for the sustainability of tree-growing systems. *Agric. Water Manag.*, 39(2–3), 153–167. DOI: 10.1016/s0378-3774(98)00076-6.

Hughes, S., Norris, D.A., Stevens, P.A., Reynolds, B., Williams, T.G. & Woods C. (1994). Effects of forest age on surface drainage water and soil solution aluminium chemistry in stagnopodzols in Wales. *Water Air Soil Pollut.*, 77(1–2), 115–139.

Jobbágy, E.G. & Jackson R.B. (2004). Groundwater use and salinization with grassland afforestation. *Global Change Biology*, 10(8), 1299–1312. DOI: 10.1111/j.1365-2486.2004.00806.x.

Khalid, F., Benabdeli, K. & Mosli B. (2015). Impact de la mise en défens sur la lutte contre la désertification dans les parcours steppiques: cas de la région de Naâma (sud-ouest algérien). *Revue d'Écologie*, 70(1), 16–31.

Klute, A. (1986). Water retention: laboratory methods. In A. Klute (Ed.), *Methods of soil analysis: Part 1. Physical and mineralogical methods* (pp. 635–662). American Society of Agronomy, Inc. Soil Science Society of America, Inc. DOI: 10.2136/sssabookser5.1.2ed.c26.

Koy Kasongo, R. (2009). *Amélioration de la qualité des sols sableux du plateau des Batéké (RD Congo) par application des matéreils géologiques et des déchets organiques industriels locaux*. Doctoral dissertation, Ghent University.

Laperche, V. & Mossman E.J. (2004). *Protocole d'échantillonnage des sols urbains pollués par du plomb*. Editions BRGMP/RP.

Laudicina, V.A., De Pasquale, C., Conte, P., Badalucco, L., Alonzo, G. & Palazzolo E. (2012). Effects of afforestation with four unmixed plant species on the soil–water interactions in a semiarid Mediterranean region (Sicily, Italy). *Journal of Soils and Sediments,* 12(8), 1222–1230. DOI: 10.1007/s11368-012-0522-0.

Le Houérou, H.N. (1985). *La régénération des steppes algériennes*. Rapport de mission, de consultation et d'évaluation. Ministère de l'agriculture, Alger.

Lichner, L., Orfánus, T., Nováková, K., Šír, M. & Tesař M. (2007). The impact of vegetation on hydraulic conductivity of sandy soil. *Soil and Water Research*, 2, 59–66.

Lipiec, J., Kus, J., Slowinska-Jurkiewicz, A. & Nosalewicz A. (2006). Soil porosity and water infiltration as influenced by tillage methods. *Soil Tillage Res.*, 89(2), 210–220. DOI: 10.1016/j.still.2005.07.012.

Mathieu, C. & Pieltain F. (1998). *Analyse physique des sols*. Méthodes choisies, TEC et DOC. Paris: Lavoisier.

Mead, D.J. & Cornforth I.S. (Eds.) (1995). *Proceedings of the trees and soil workshop*. Canterbury: Lincoln University Press.

Morales, V.L., Parlange, J.Y. & Steenhuis T.S. (2010). Are preferential flow paths perpetuated by microbial activity in the soil matrix? A review. *J. Hydrol.*, 393(1–2), 29–36. DOI: 10.1016/j.jhydrol.2009.12.048.

Neal, C., Reynolds, B., Smith, C. J., Hill, S., Neal, M., Conway, T., Ryland, G.P., Jeffrey, H., Robson, A.J. & Fisher R. (1992). The impact of conifer harvesting on stream water pH, alkalinity and aluminium concentrations for the British uplands: an example for an acidic and acid sensitive catchment in mid-Wales. *Sci. Total Environ.*, 126(1–2), 75–87. DOI: 10.1016/0048-9697(92)90485-b.

Nedjraoui, D. (2004). Evaluation des ressources pastorales des régions steppiques algériennes et définition des indicateurs de dégradation. *Cahiers Options Méditerranéennes*, 62, 239–243.

Nedjraoui, D. & Bédrani S. (2008). La désertification dans les steppes algériennes: causes, impacts et actions de lutte. *Vertigo*, 8(1). DOI: 10.4000/vertigo.5375.

Niknam, S.R. & Mccomb J. (2000). Salt tolerance screening of selected Australian woody species — a review. *For. Ecol. Manag.*, 139(1–3), 1–19. DOI: 10.1016/s0378-1127(99)00334-5.

Nosetto, M.D., Jobbágy, E.G., Toth, T. & Di Bella C.M. (2007). The effects of tree establishment on water and salt dynamics in naturally salt-affected grasslands. *Oecologia*, 152(4), 695–705. DOI: 10.1007/s00442-007-0694-2.

ONM (2016). Office national météorologique, données climatiques de la Wilaya de Nâama.

Pansu, M., Gautheyrou, J. & Loyer J.Y. (1998). *L'analyse du sol:* échantillonnage*, instrumentation et contrôle*. Paris: Masson.

Pouget, M. (1980). *Les relations sol-végétation dans les steppes Sud-Algéroises*. Paris: ORSTOM.

Pritchett, W.L. & Fisher R.F. (1985). *Properties and management of forest soils*. New York: John Wiley and Sons Ltd.

Querejeta, J.I., Roldán, A., Albaladejo, J. & Castillo V. (2001). Soil water availability improved by site preparation in a Pinus halepensis afforestation under semiarid climate. *For. Ecol. Manag.*, 149(1–3), 115–128. DOI: 10.1016/s0378-1127(00)00549-1.

Reynolds, J.F. (2001). Desertification. In S.A. Levin (Ed.), *Encyclopedia of biodiversity* (pp. 61–78).Vol. 2. London: Academic Press.

Saetre, P. (1998). Decomposition, microbial community structure, and earthworm effects along a birch–spruce soil gradient. *Ecology*, 79(3), 834–846. DOI : 10.1890/0012-9658(1998)079[0834:DMCSAE]2.0.CO;2.

Sapanov, M.K. (2000). Water uptake by trees on different soils in the Northern Caspian region. *Pochvovedenie,* 11, 1318–1327.

Schiller, G. (2001). Biometeorology and recreation in east Mediterranean forests. *Landsc. Urban Plann.*, 57(1), 1–12. DOI: 10.1016/S0169-2046(01)00182-7.

SiTayeb, T. (2016). Impact of climate change and anthropogenic activities in the dynamics of land cover in Mediterranean Steppe West Algeria. In L. Ouwehand (Ed.), *Living planet symposium* (p. 157). Praha.

SiTayeb, T., & Belabbes, I. (2018). Landscape change in the steppe of Algeria South-West using remote sensing. *Annals of Valahia University of Targoviste, Geographical Series*, 18(1), 41–52. DOI: 10.2478/avutgs-2018-0005.

Thomson, W.W., Berry, W. L. & Liu L.L. (1969). Localization and secretion of salt by the salt glands of Tamarix aphylla. *Proc. Natl. Acad. Sci. USA*, 63(2), 310–317. DOI : 10.1073/pnas.63.2.310.

Vertessy, R.A., Connell, L.D., Morris, J.D. Silberstein, R.P., Heuperman, A., Feikema, P.M., Mann, L., Komarzynski, M., Collopy, J. & Stackpole D. (2000). *Sustainable hardwood production in shallow watertable areas*. Water and Salinity Issues in Agroforestry No. 6. Kingston: Rural Industries Research and Development Corporation.

Yerou, H. & Benabdeli K. (2013). Rôle des types d'élevage dans la dégradation des formations steppiques dans la région de Naâma (Algérie sud-occidentale). *Revue d'Écologie*, 68, 157–165. http://hdl.handle.net/2042/55962.