

PHYSICO-CHEMICAL PROPERTIES OF STEPPE SOILS WITH *Hammada scoparia* (Pomel) IN THE NAÂMA REGION (ALGERIA)

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Abstract

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With an average annual rainfall below 150 mm, the steppe with *Hammada scoparia* emerges, constituting the transition between the arid steppes and the Saharan vegetation. The distribution of the vegetation is very irregular, which depends on the nature and structure of the soils. A soil study, based on observations and the sampling of 42 profiles, was carried out within a range of species located in the southern part of Naâma. The principal component analysis enables the identification of relationships between the different soil profiles and the species studied. The results obtained show that the woody steppe with *H. scoparia* occupies habitats characterized by a sandy-loamy to sandy and stony texture on the surface of carbonate crusts, often in the form of slabs with a variable carbonate content of 1.22 to 12.7% in certain types of soil; this element tends to be carried to a depth of 40 to 60 cm. In other types of soil, on the contrary, it remains distributed throughout the entire profile. Colonized soils are generally shallow and poor in organic matter, varying from 2 to 3.65%, with an alkaline pH ranging between 6.7 and 8.8. The measured electrical conductivity varies between 0.1 and 0.7 mS/cm. This variation largely depends on the texture of the soil, the bioclimate and the steppe vegetation. The results obtained enable the valorization of this species, which has a socio-economic and ecological role, as it practically adapts to the different types of soil of the steppe space.

Key words: *Hammada scoparia*, analysis, soil, steppe, Naâma, Algeria.

Introduction

In Algeria, the term ‘steppe’ is adopted to describe the vegetation of arid and Saharan environments from a physiognomic point of view; it is subservient to low and discontinuous vegetation, consisting of herbaceous plants, generally in clumps, and revealing patches of bare soil between them. This vegetation is diversified in its floristic composition and density and plays a fundamental role in the structure and functioning of the ecosystem, of which it constitutes an expression of the biological potential. The steppe domain consists of *Stipa tenacissima*, *Artemisia herba-alba*, *Lygeum spartum*, *Stipagrostis pungens*, *Artemisia campestris* and *Hammada scoparia*, sharing the landscape and ensuring the transition with the Saharan vegetation (Kaabèche, 1990; Aidoud 1996; Benaradj, 2010, 2017; Boucherit, 2018; Benaradj et al., 2021).

Steppe soils are generally shallow and thin. They are characterized by the accumulation of limestone and are generally poor in organic matter and sensitive to erosion and degradation. In the Algerian steppe and the South Oran steppe of Naâma, the soils present a great diversity: poorly developed soils, raw mineral soils, calcimagnetic soils, hydromorphic soils and halomorphic soils (Pouget, 1980; Djebaili et al., 1983; Halitim, 1988; Nedjraoui, Bédrani, 2008; Benaradj, 2009; Moulay et al., 2012; Adjabi et al., 2016; Boucherit, 2018).

The degradation of the steppe environment is accentuated by numerous anthropogenic practices, resulting in the disappearance of palatable plant species and the consequent development of non-palatable species, such as *H. scoparia* and *Thymelaea microphylla*, which are more adapted to new very poor environments (Aidoud, 1994; Boucherit et al., 2017a).

In this context, our work aims to study the physico-chemical parameters of the soils of the steppe with *Hammada scoparia* under an arid climate. According to Pouget (1980) and Halitim (1988), the aridity of the climate reduces the current degree of soil evolution, where more than 95% of soils in arid regions are calcareous, gypseous or salsodic.

Material and methods

Description of the target species

Hammada scoparia Pomel (synonyms: *Haloxylon scoparium* Pomel (1875); *Arthrophytum scoparium* Pomel (1946)) is a Saharo-Mediterranean species; belongs to the Amaranthaceae family and plays an ecological, socio-economic and therapeutic role (Boucherit et al., 2017b). These characteristics of the steppe species in the Naâma region enable them to grow at altitudes rang-

ing from 800 to 1400 m and on average slopes of 20% on stony regs and hamadas, from which the name *Hammada* derived (Fig. 1) (Boucherit et al., 2017c; Boucherit, 2018). *H. scoparia* in the steppe is limited to areas with annual precipitation between 100 and 150 mm, ensuring the transition between, on the one hand, the esparto and white sagebrush steppes, which are vegetation typical of the high steppe plains where the Mediterranean floristic element predominates, and on the other hand, the vegetation of the Sahara characterized by a contracted mode of spatial distribution (Monod, 1957; Maire, 1940).

Study area

Naâma is part of the high southern plains of Oran, extends over an area of 3 million hectares in the southwestern part of the highlands and is occupied by a population along the Oran-Béchar road axis on an area of more than 1 million hectares or 37% of the total area. The climate of the Naâma region is characterized by low and irregular rainfall (200 mm/year) and a fairly long dry period of 6 to 7 months, with low temperatures generally falling below -4°C , indicating that it belongs to the arid bioclimate. The irregularity of precipitation from 1 year to another, combined with prevailing dry winds, causes degradation of the vegetal cover and accelerates the phenomenon of aridization.

Sampling methods

The soil study provides a description of the soils based on observations and sampling done on 42 soil pits within the range of the steppe where *H. scoparia* is located in the southern part of Naâma (Table 1). Different geographical points (GPS, Global Po-

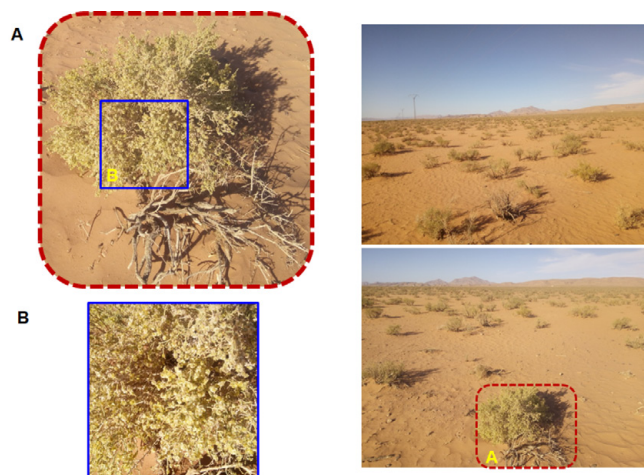


Fig. 1. Group of *Hammada scoparia* in the Naâma region (Western Algeria).

sitioning System) were taken with the aim of characterizing the location of the profiles and developing a distribution map (Fig. 2). To obtain the representativeness of the selected stations, we used a random sampling method.

Physical analysis

Particle size: The analysis of the particle size was carried out using the Robinson pipette method on soil sieved to 2 mm. It first

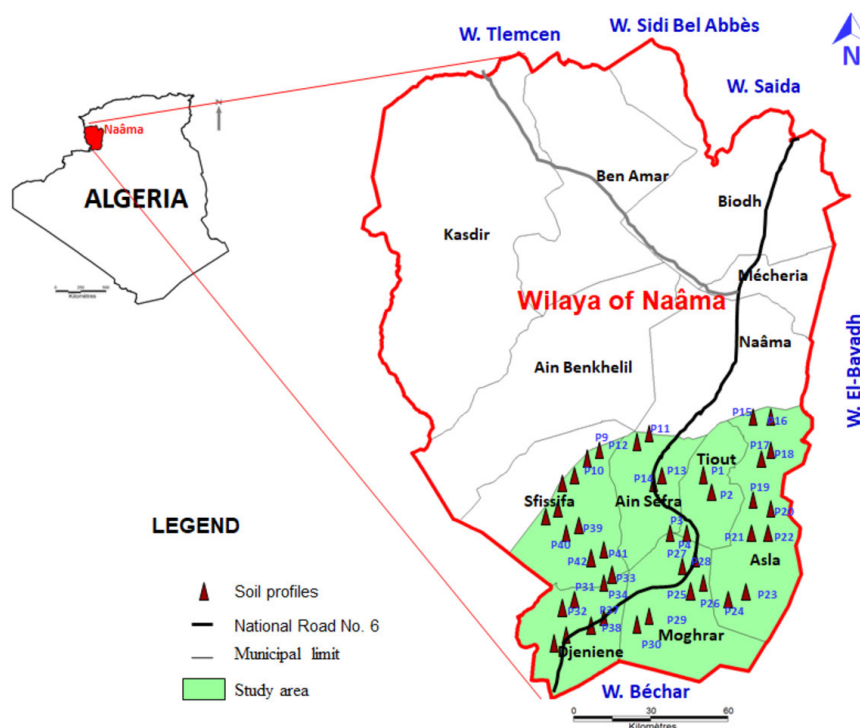


Fig. 2. Presentation of the study area and location of soil profiles (Boucherit, 2018).

Table 1. Geographical location of soil profiles in the study area.

No. of stations	Locality	Municipality	No. of profile	No. of horizons	Depth (cm)	Geographical coordinates		
						X	Y	Z (m)
Station 1	Zaboudja	Tiout	P1	3	20	32°47'51,74"N	000°19'45,16"O	1060
			P2	4	32	32°47'42,39"N	000°19'50,52"O	1100
Station 2	Sam 1	Tiout	P3	2	10	32°39'03,5"N	000°20'05,5"O	986
			P4	3	26	32°44'06,4"N	000°14'02,2"O	970
Station 3	Sam 2	Tiout	P5	2	22.5	32°43'44,6"N	000°14'20,9"O	1089
			P6	3	54	32°44'06,69"N	000°13'53,80"O	1117
Station 4	Benhanjir 1	Ain Séfra	P7	3	45.5	32°41'38,3"N	000°47'01,6"O	1178
			P8	3	52	32°43'08,25"N	000°40'27,50"O	1110
Station 5	Benhanjir 2	Sfissifa	P9	3	26	32°43'32,3"N	000°39'08,3"O	1123
			P10	3	45	32°42'24,19"N	000°42'27,41"O	1156
Station 6	Tirkount	Ain Séfra	P11	3	51	32°49'08,7"N	000°36'32,2"O	1178
			P12	2	16	32°49'10,2"N	000°36'23,3"O	1192
Station 7	Bouarfa	Ain Séfra	P13	5	87	32°54'13,41"N	000°35'23,84"O	1217
			P14	3	92	32°53'57,83"N	000°35'17,88"O	1220
Station 8	Hassilabied	Asla	P15	4	48	32°59'05,5"N	000°08'43,2"O	1124
			P16	3	26.5	32°55'29,5"N	000°08'40,0"O	1119
Station 9	Lamouahi	Asla	P17	3	24	33°01'47,6"N	000°09'19,7"O	1133
			P18	3	31.5	33°01'49,5"N	000°09'21,0"O	1132
Station 10	Rejima	Asla	P19	4	47	32°52'31,8"N	000°12'49,6"O	1136
			P20	3	67	32°53'35,1"N	000°11'44,0"O	1113
Station 11	Ouarka 1	Asla	P21	2	6.5	32°50'06,5"N	000°14'19,6"O	1163
			P22	3	40,5	32°50'26,8"N	000°15'12,7"O	1122
Station 12	Ouarka 2	Asla	P23	4	59	32°48'16,90"N	000°14'18,79"O	1167
		Asla	P24	5	92	32°48'08,39"N	000°14'08,39"O	1158
Station 13	Moghrar Tahtani	Moghrar	P25	3	52	32°31'51,9"N	000°29'43,4"O	899
			P26	4	40	32°31'05,5"N	000°29'02,2"O	865
Station 14	Hadjaj	Moghrar	P27	2	24	32°43'38,5"N	000°25'13,3"O	1021
			P28	3	42	32°43'34,8"N	000°25'10,0"O	1016
Station 15	Hadjaj 2	Moghrar	P29	3	26	32°35'45,06"N	000°25'57,64"O	924
			P30	4	40	32°35'49,32"N	000°26'08,32"O	932
Station 16	Djeniene 1	Djeniene	P31	3	45	32°21'56,3"N	000°50'04,4"O	983
			P32	3	80	32°21'54,55"N	000°50'25,68"O	978
Station 17	Djeniene 2	Djeniene	P33	4	50.1	32°26'12,1"N	000°45'46,2"O	1045
			P34	2	75	32°25'50,75"N	000°46'08,94"O	1040
Station 18	Djeniene 3	Djeniene	P35	4	51	32°29'05,0"N	000°41'43,1"O	1026
			P36	3	34	32°31'04,4"N	0°28'55,3"O	1031
Station 19	Chekika	Djeniene	P37	3	27	32°19'24,60"N	000°48'19,76"O	1020
			P38	3	18	32°19'52,01"N	000°47'55,48"O	1033
Station 20	Founassa	Sfissifa	P39	3	26	32°28'44,8"N	000°46'51,7"O	1127
			P40	3	30	32°28'39,44"N	000°46'38,67"O	1220
Station 21	Oued Yak-hou	Sfissifa	P41	2	21	32°31'08,9"N	000°45'21,3"O	1278
			P42	3	37	32°38'10,0"N	000°50'29,1"O	1206

consists of destroying the organic matter with hydrogen peroxide (H_2O_2) and dispersing the clay with sodium hexametaphosphate. The texture of the soil is then determined by the different percentages (%) of soil particles (clay, silt and sand) by separating the particle size fractions: coarse silt (20–50 μm) and fine silt (2–20 μm); clays (0–2 μm); fine sands (50–200 μm) and coarse sands (200–2000 μm).

Chemical analysis

- pH: The measurement of pH was performed on soil sieved to 2 mm and in a soil/water ratio of 1/5 using a pH meter.
- Electrical conductivity (EC): EC was measured using the conductivity meter with the soil/water ratio of 1/5, which is expressed in $\mu S/cm$.

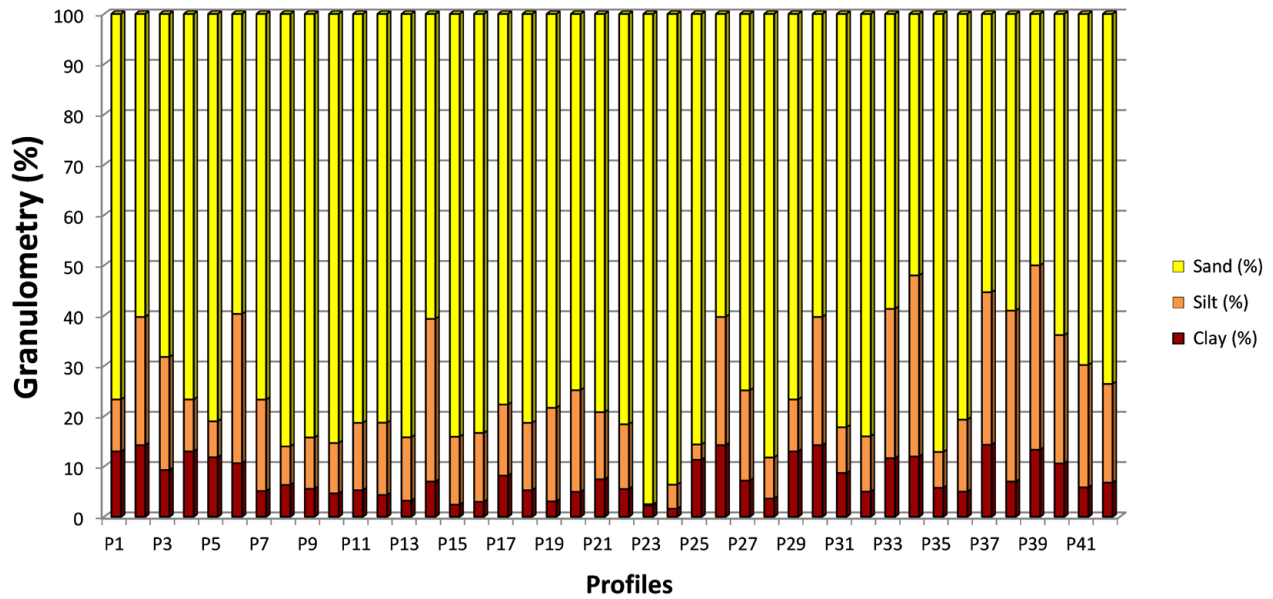


Fig. 3. Granulometric composition of different profiles in the study area.

- Organic matter: The content of organic matter was measured from the content of organic carbon by the method of Ane by applying the following formula: $MO\% = C \times 1.72$ (Mathieu, 2003).
- Total carbonate ($CaCO_3$): The total carbonate was measured by the volumetric method using Bernard calcimeter by decomposing calcium carbonate with hydrochloric acid and measuring the volume of CO_2 released.

Data processing

The statistical processing of soil parameters was carried out by a principal component analysis (PCA) using XLstat (v 2017) and Statistica software to better understand the relationship between soil and groups of *H. scoparia*. This was conducted using a correlation matrix based on 42 soil profiles and 7 parameters measured: Depth (cm), grain size (clay (%), silt (%) and sand (%)), pH, $CaCO_3$ (%), EC ($\mu S/cm$), organic matter (%) and organic carbon (%).

Results and discussion

Physical analysis (particle size)

The soils of the Naâma region belong to the steppe category, and they generally do not exceed 1 m in depth. In the analyzed profiles (Fig. 3), we noticed a clear predominance of the sandy and loamy texture, which appears in all the study stations. The clay texture is poorly represented and varies from 1.5 to 14% in all profiles.

According to the textural diagram (Fig. 4), the different study stations are distributed among the four most dominant soil classes: sandy, sandy-loamy and loamy. In the study area, there are two dominant textures: sandy-loamy (LS) and a coarse sandy texture in most profiles due to silting. Le Houérou et al. (1977)

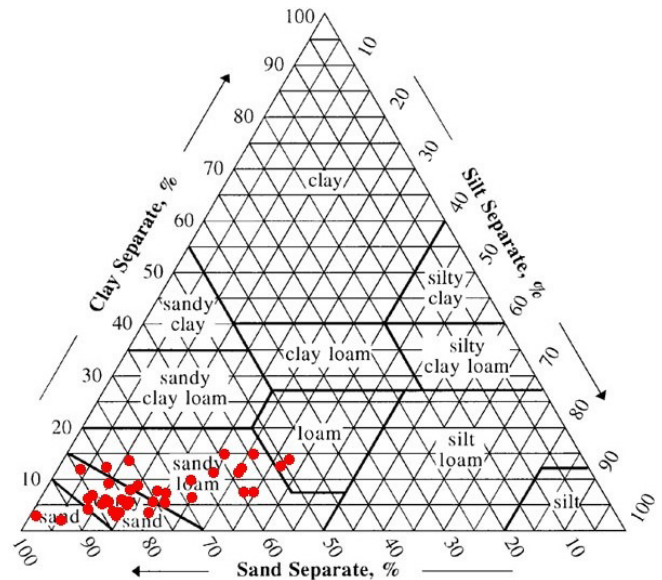


Fig. 4. Textural diagram of soil profiles (according to the USDA, 1975).

indicate that steppes with *H. scoparia* become very frequent and often dominate on more or less loamy soils. These give rise to thin surface films of chlorides, gypsum or carbonates (Aubert, 1962).

Chemical analysis

pH

The results depicted in Figure 5 show that the pH values are similar across different stations. All the samples analyzed are alkaline, with pH values generally falling between 6.7 and 8.6.

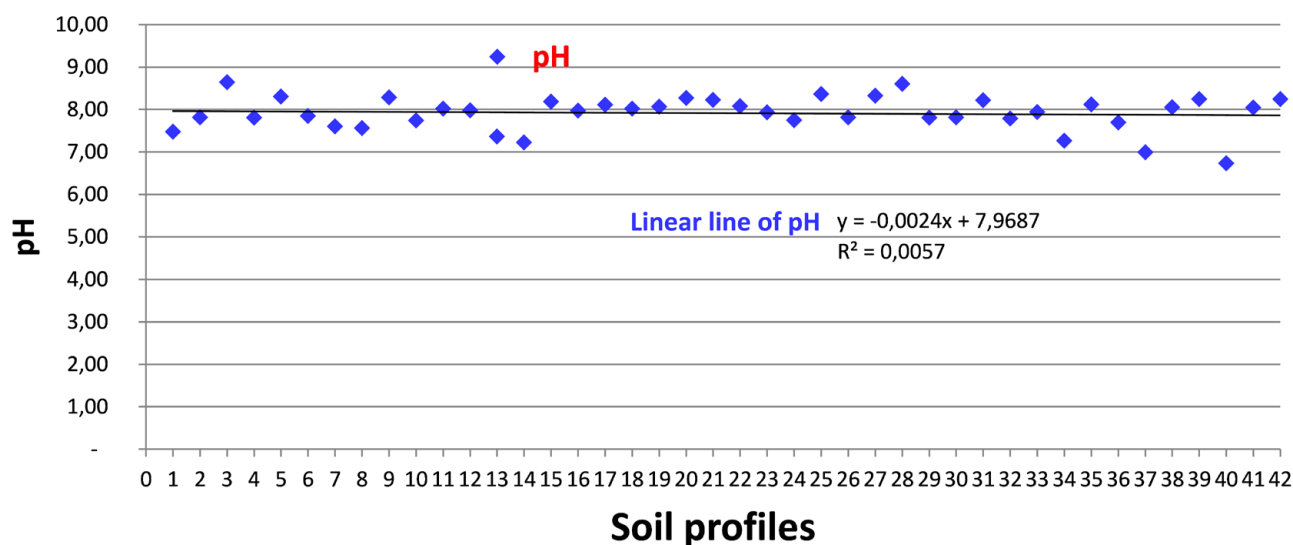


Fig. 5. pH values of different profiles in the study area.

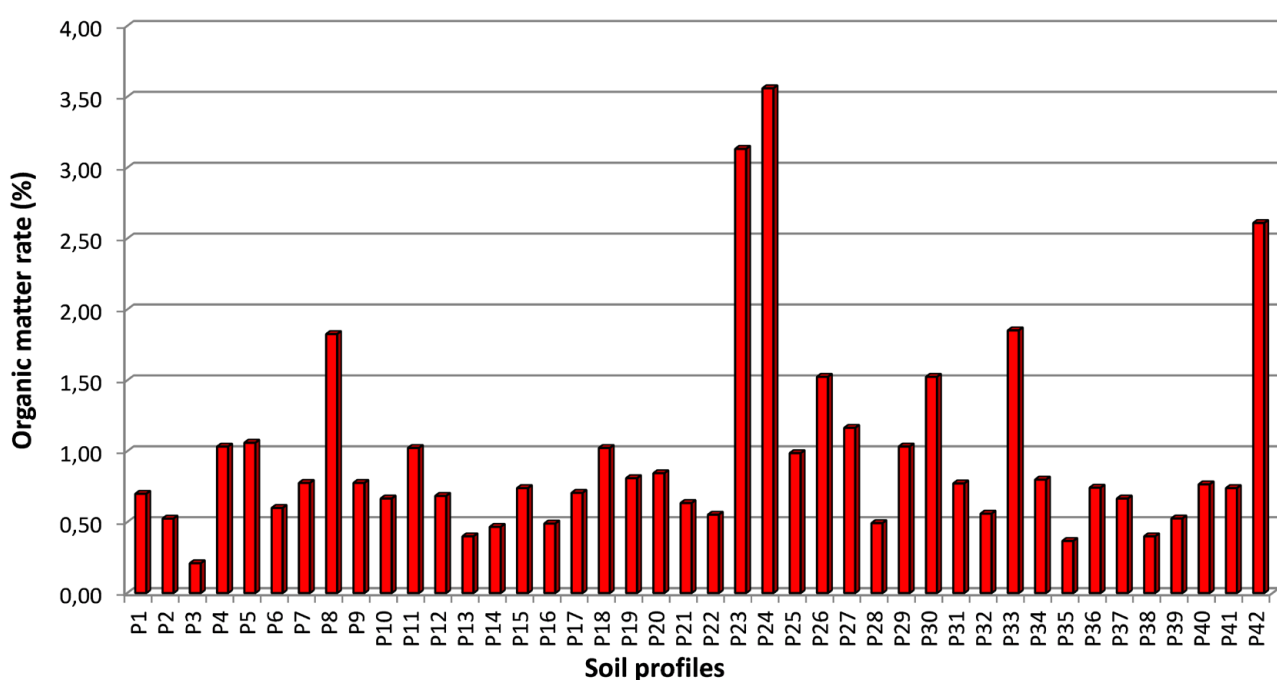


Fig. 6. Organic matter content in different profiles.

Electrical conductivity

The EC measured in the laboratory for all the profiles shows very low values, oscillating between 0.1 and 0.7 mS/cm, which justifies an unsalted to slightly saline soil.

Organic material

The results obtained show that the content of organic matter is very low for all the profiles. According to Figure 6, four profiles

have an average organic matter content ranging from 2 to 3.65%. This variation largely depends on the soil texture of the bioclimate and the steppe vegetation. According to Pouget (1980), the aridity of the climate and the degradation of the plant cover are two determining parameters of the low rate of organic matter.

Carbonate content (CaCO₃)

The soils of the study area show variable calcium carbonate contents, varying the recorded percentage between 1.22 and 12.71%

Table 2. Eigenvalues and variability.

	F1	F2	F3	F4	F5	F6
Own value	3.3279	2.3993	1.6617	1.1994	1.0022	0.5725
Variability (%)	30.2537	21.8117	15.1060	10.9040	9.1110	5.2049
Cumulative (%)	30.2537	52.0655	67.1715	78.0755	87.1865	92.3914

(Fig. 7). The limestone content increases with depth, showing limestone accumulations in the form of encrustation.

The stations represented in Figure 8 show that all the soil pits were conducted from April to May 2017. These profiles made it possible to measure the thickness of the different horizons and to refine the description of the soils. Therefore, the soil characteristics of these stations were extrapolated to neighboring sites.

From the PCA on axis 1, we notice that the stations of Ouarka and Benhenjir (P23, P24 and P8) are strongly linked to organic matter and carbon (Fig. 7). The effect of organic matter on physical properties can manifest itself by improving the structural stability regardless of the type of soil (Henin et al., 1969; Sidi, 1987; Kouakou, 1998; Abiven, 2004; Goma-fortin, 2009; Merrouki et al., 2011; Boucherit, 2018). In the steppe environment, the level of organic matter varies from the upper horizon (deposition of animal waste) to the lower horizon (the presence of root systems and debris and litter) (Table 2.).

Exudation and in-situ mineralization within the soil profile of part of the root phytomass form the dominant resource of organic input (Bourahla, 2017; Benaradj, 2017). The organic fraction is very low, and it is generally less than 1% and does not allow good aggregation. These skeletal soils are very infertile, and their water retention is very low, about 8% by the volume of available water (Daoud, Halitim, 1994). According to Djebaili (1983), steppe soils are characterized by the presence of limestone accumulation, low organic matter content and high sensitivity to erosion and degradation.

The Tirkount, Hassi-Labied and Lamouahi stations (P15, P11 and P18) are the richest in sand, and this could be due to the geological nature and the prevailing winds, which invade the region (Fig. 9). Ozenda (1982) indicates that the composition of plant groups is essentially influenced by the nature of the substrate, and we can cite the physical characteristics of the soil, resulting in the connection between certain plants and a given type of texture or structure (Fig. 10).

Axis 2 explains 21.81% of the information. This axis is strongly positively correlated to EC, carbon, MO and CaCO_3 and negatively to pH. This axis can be qualified as the conductivity-pH axis. On axis 2, the stations in the southern regions are characterized by basic pH, sometimes close to neutrality. These high pHs are an unfavorable factor for the mobility of many trace elements, which have a major physiological role in plants (Rognon, 1996). The conductivity remains low on all the stations, but it becomes more or less important with the depth of the profile.

The organic matter content is low on the majority of the profiles, with the exception of the two stations of Asla and Sfisifa, where this is higher than 3% because the repeated passage of livestock enriches these soils with humus (Boucherit, 2018; Benaradj et al., 2020). Indeed, the increase in the quantity of organic matter in the first centimeters in uncultivated soil facilitates water

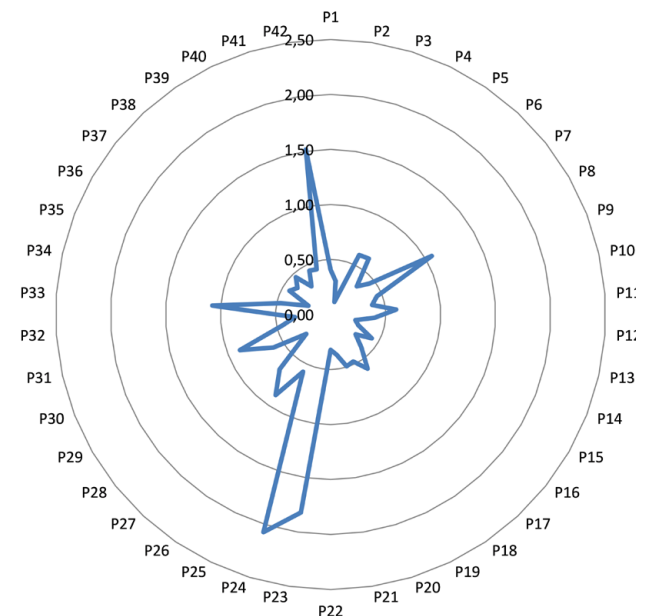


Fig. 7. Variation in the content of limestone in different profiles of the study area.

infiltration (Findeling et al., 2003). Djebaili (1984) and Pouget (1980) indicate that the average organic matter is 1 to 2% for steppe soils. Axis 3 (Fig. 11) explains 15.1% of the correlations; it is mainly positively correlated to clay and negatively correlated to altitude. On this axis, the Djeniene and Moghrar stations (P26, P30 and P33) are the richest in clay, while the Benhenjir, Tirkount and Djeniene stations (P10, P13 and P32) are characterized by a high altitude.

Axis 3 presents the relationship between the groups of *H. scoparia* and the environmental variables, especially altitudinal and textural. Indeed, the variance 15.1 explained by these two axes (1 and 3) shows that it is positively correlated to sand (%) and depth and negatively correlated to altitude, organic matter and pH. According to Aidoud et al. (2006), *H. scoparia* thrives in soil with a sandy-loamy texture. On the other hand, the morphology of the study stations is marked by wind processes, at least in two different ways. The sandy veils are particularly extensive, and all the intergrades with accumulations in the form of dune fields are present: microdunes, sandy mounds fixed by vegetation (nebkas) and scattered dunes, which explain this proportion of sand present in the samples (Escadafal, 1989). On the physiognomic and floristic levels, Djebaili (1978) defines the variation in the floristic composition of the group according to the nature of the lithological substrate. When it develops on heavily sandy erosional

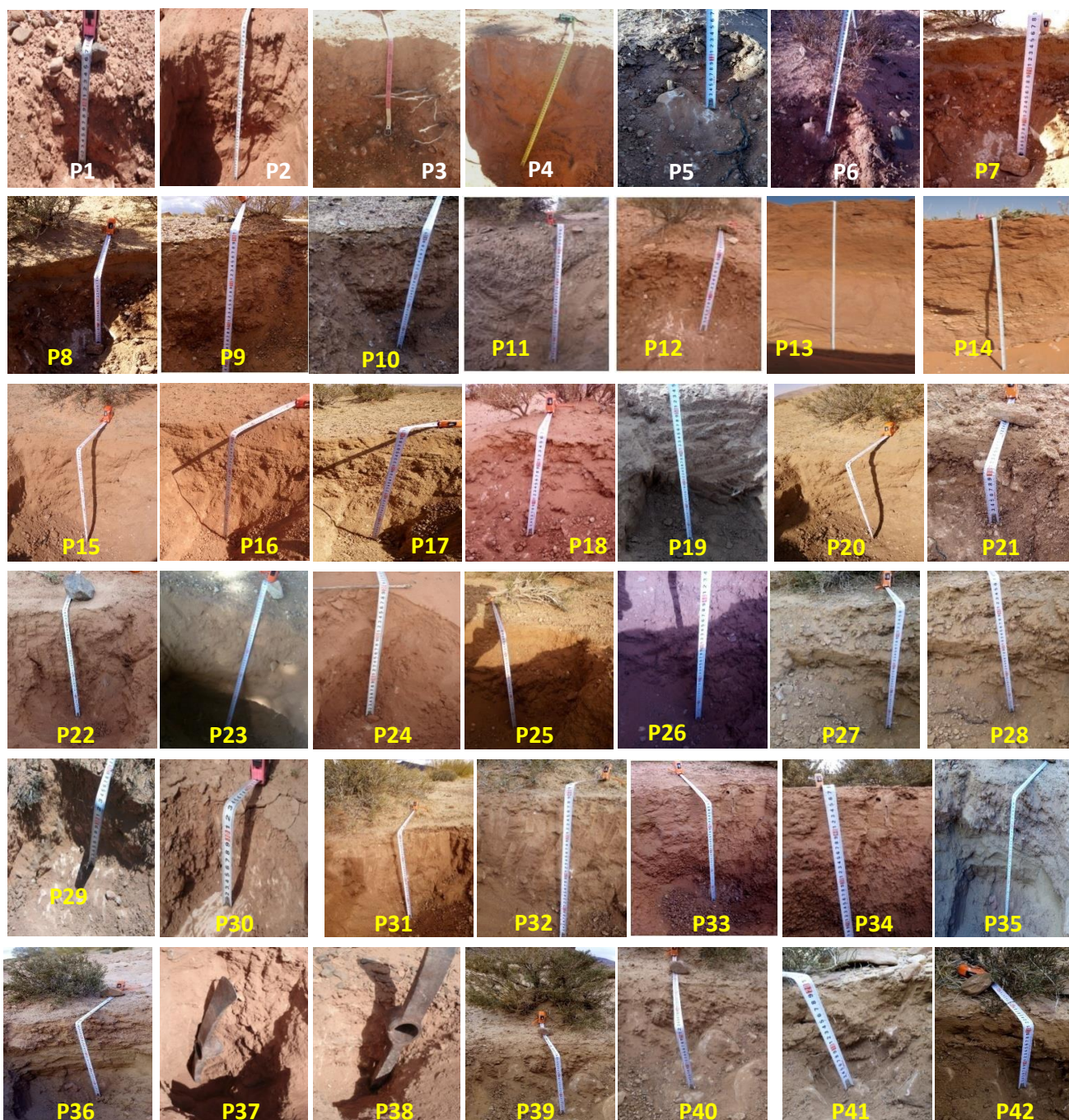


Fig. 8. Presentation of soil profiles in the study area.

glacis, this group forms facies with psammophyte species, such as *Retama raetam* and *Thymelaea microphylla*.

The pedoclimatic conditions of arid regions indicate that the flora can be subdivided into three types, including psammophytes (*Stipagrostis pungens*, *Ephedra alata*, *Retama sphaerocarpa*, *Caligonum comosum*, *Cutandia dichotoma*, *Genista saharae*, *Schismus barbatus*, *Echinops spinosus* and *Bromus rubens*), hydrophytes (*Nerium oleander* and *Pistacia atlantica*) and xerophytes (*Astragalus armatus*, *Atractylis serratuloides* and *Stipa tenacissima*) (Quézel, Santa, 1963). According to

Ozenda (1983) and Lacoste and Salanon (2001), the distribution of the different species in groups essentially depends on the availability of water and consequently on the characteristics of the soil and the topography. In the study area, psammophytes are characteristics of more or less fixed Saharan environments, subservient to sands, sandy veils and dunes. They are essentially dominated by *Koelpinia linearis*, *Hammada schmittiana*, *Marrubium desertii*, *Cutandia dichotoma*, *Ifloga spicata*, *Linaria aegyptica*, *Asphodelus tenuifolius* and *Malcolmia aegyptiaca*. All the horizons are also marked by the presence of carbonates,

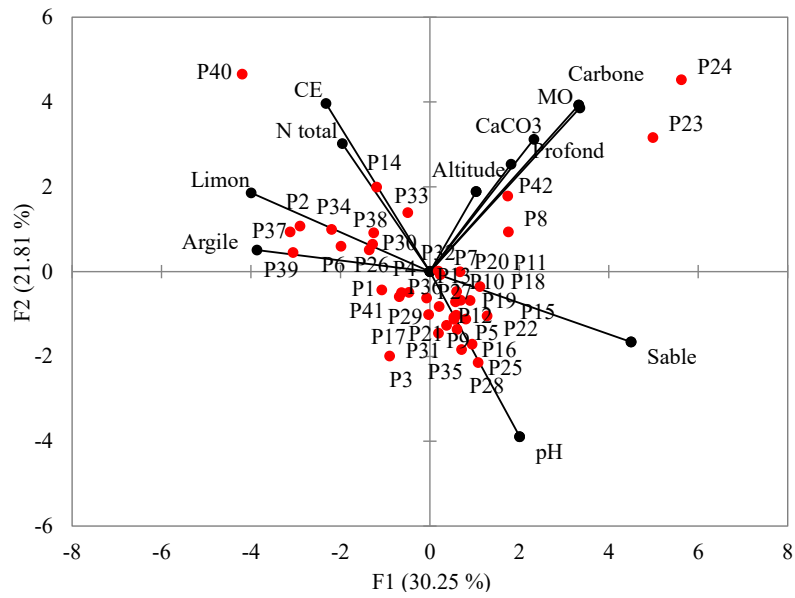


Fig. 9. Projection of stations on plan 1/2.



Fig. 10. Sand invasion in the area with *Hammada scoparia*.

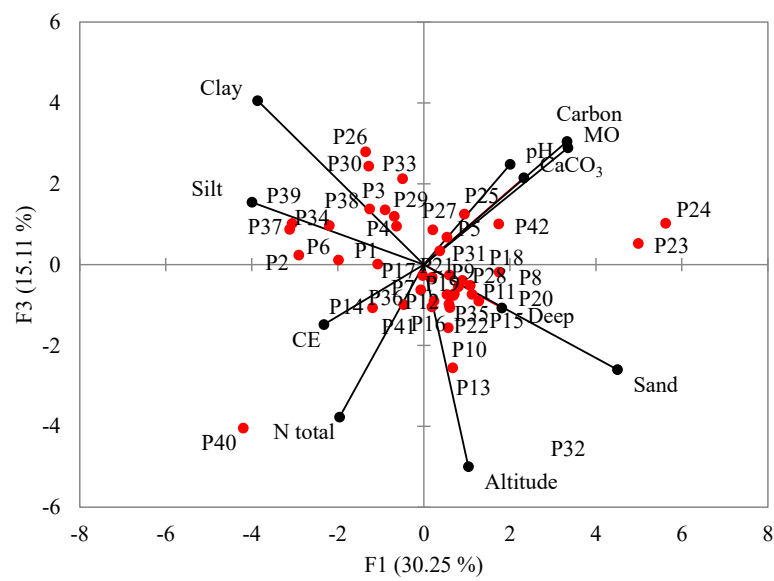


Fig. 11. Projection of stations on plan 1/3.

resulting in a generalized effervescence, strong to very strong, and a pH that is always basic, varying from 6.8 to 8.7. Calcareous and gypsum accumulations are abundant, particularly in the deep horizons. Le Houérou et al. (1977) and Pouget (1980) indicate the presence of gypsophyte species in the steppe at *Hammada scoparia*. This situation is analogous to that of Mediterranean ecosystems (Le Houérou, 1980, 1995; Quézel, 2000; Quézel, Médail, 2003; Benabadi et al., 2009; Benaradj et al., 2017).

According to Kellogg (1938), steppe-type soils, those corresponding to the most arid regions, are called sub-desert gray soils and sub-desert red soils. These soils are characterized by the presence of limestone accumulation, low organic matter content and high sensitivity to wind erosion, often water erosion and degradation (Djebaili, 1983).

Conclusion

The distribution of the vegetation is very irregular and is closely linked to all the physico-chemical characteristics of the soil. On the other hand, steppe soils are skeletal, that is to say poor and fragile because of the scarcity of humus and their very shallow depth. It appears from the analyses carried out that the distribution of *H. scoparia* is closely linked to altitude, soil structure and conductivity. Soil samples taken from different stations at an altitude ranging from 900 to 1100 m generally show a sandy to sandy-loamy texture, often very gravelly, with an alkaline pH between 6.7 and 8.8. Another element whose evolution is fundamental in the soils of semi-arid regions is limestone. A variable limestone rate of 1.22 to 12.7% is recorded in certain types of soil; this element tends to be carried to a depth of 40 to 60 cm. In other soil types, on the contrary, it remains distributed throughout the entire profile. The measured EC varies between 0.1 and 0.7 mS/cm, revealing unsalted soils in all the study stations. The steppe in *H. scoparia* develops on stony regs and hamadas, from which the name *Hammada* derived.

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