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Study of Soil-Vegetation Relations in the Edough Peninsula (North East of Algeria)

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ABSTRACT

This study aims to determine the relationships likely to exist between the edaphic variables and the abundance of oak species in the Edough forest of the commune of Seraidi (North East of Algeria), a humid bioclimatic stage where rainfall is abundant. In order to characterize the properties of the soils of the Edough forest (Seraidi) and to verify the usefulness of the fractionation of organic matter in a forest ecosystem, we have established a prospecting sampling plan based on a topographic background of the superposition of the different plant groups. In this context, the approach we adopted consisted on three main steps (i) a stratified sampling of the soil, (ii) the determination of the different strata of vegetation, (iii) describing the soil on which these plant formations settle and develop. Our results revealed that the soils of the Edough forest are acidic to very acidic and non-saline. It is also characterized by clayey texture that is not very permeable, with a high rate of organic matter, which controls the buffering capacity of the soil. The characterization of the soils allowed determining three types of plant formations and thus three types of soils where pedogenesis is under direct control of the supply of organic matter. The relationship between the soil and the vegetation in this forest is clearly close. It is mainly controlled by the supply of organic matter, which shows a significant dynamic and evolution. On the other hand, the climatic conditions and the type of plant formations have a capital role in the mineralization of the existing organic matter.

Keywords: forest, organic matter, plant formation, soil, strata.

INTRODUCTION

Forest environment is a clear model of an ecosystem organized in superimposed strata, which allows the maximum use of solar energy and thus a greater diversity of ecological niches (Dajoz, 1985).

Mediterranean forests are one of the global biodiversity hotspots (Myers et al. 2000, Olson and Dinerstein, 2002).

In the Mediterranean basin, the forest area requires a certain ecological and socioeconomic importance (Medail & Quezel, 2003). The current Mediterranean flora is made up of a complex mixture of species of varied and more or less ancient biogeographical origins. It is the result of local differentiations from ancestral species, and multiple migrations of plants, repeated over time. The turbulent geological history of this region and the strong climatic variations that have occurred over the last two million years are both key historical factors in explaining this very heterogeneous biodiversity (Thompson, 2005 in Chouahda, 2016).

The forest is the most widespread environment in the reserves (Hadjdaj, 2017). Like in all the Mediterranean, The algerian forests have significant natural wealth, including proven floristic diversity (Medail & Quezel, 2003). They are essentially irregular light forests composed of stands of deciduous or coniferous trees of all sizes and of all ages with the presence of thick undergrowth composed of a large number of secondary species. This promotes the spread of fires and weakens the average volume yield of woody species (FAO, 1999).

The soil of forest is the outer layer of the earth's crust. It is formed over time under the influence of climate, geology, relief and living beings. Soil is the element that connects the atmosphere (air), the biosphere (living environment of organisms), the hydrosphere (water) and the lithosphere (source rock) (Walser et al., 2021).

The forest soil is a major concern. They present different characteristics to agricultural soils, which require specific approaches to determine their behaviour and their potential evolution (Laissaoui, 2012).

The organic matter is one of the most essential elements in the forest environment. It is all the particulate and molecular organic substances contained in the soil. In other words, it is all the non-living organic constituents. Plant residues become part of the organic matter of the soil when they are mechanically incorporated into it, either by the action of fauna and microfauna or by tillage for cultivated soils (Calvet, 2003).

In a broad sense, soil organic matter includes living biomass and all residual organic material (Ekschmitt et al., 2005). It is the essential substrate for the development of biological life because it is a major source of carbon and energy for microorganisms (Chabalier et al., 2006).

The contribution of exogenous organic matter to the soil in the form of amendments or fertilizers makes it possible to increase and maintain the organic stock of the soil. This restoration of the organic matter content is generally associated with a change in the physicochemical characteristics such as aggregation, reduction in erosion, increase in the cation exchange capacity and the supply of fertilizing elements on one hand and the stimulation of the biological activity on the other (Annabi, 2001).

Another role of the organic matter is to improve the soil structure, especially the soil that is poor in physical-chemical aggregation agents such as clays, iron, aluminium, oxides and hydroxides, and also in the dry environments (Baldock and Nelson, 2000; Franzluebbers et al., 2001).

It increases the cohesion between the mineral particles of the soil through the formation of organo-mineral (clay-humic) complexes and induces hydrophobicity which can increase the resistance of the soil to bursting by wetting (Chenu et al., 2000; Annabi et al., 2007).

According to all these facts, we focused our research on the physicochemical characteristics of the soil of the Edough forest (Seraidi, North East of Algeria), the evolution and dynamics of the existing organic matter and its influence, the modifications of the physical properties of the soils and also the existing relationship between the soil and the vegetation in this forest.

MATERIALS AND METHODS

Study area

The present study was carried out in the municipality of Seraidi (36°54’41 77’’N–7°38’45 68’’E) of Annaba Governorate (northeast of Algeria). This humid area of 13665 ha is situated on

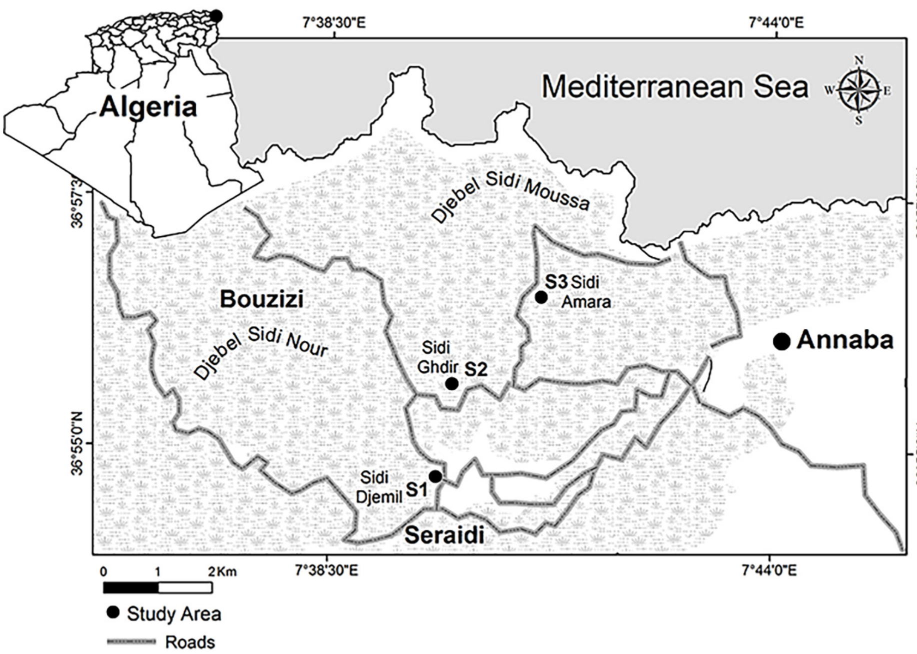

Figure 1. Location of the study and sampling stations

the massif of the Edough on an altitude of 850 m above sea level. It is bordered to the north by the Mediterranean Sea, to the south by the municipality of El Bouni, to the east by the municipality of Annaba and to the west by the municipality of Oued El Aneb (Ghanjati and Benmrabet, 2018).

Sampling

In order to determine the different soil profiles and the type of vegetation characterizing each one, we opted to a stratified sampling strategy (Figure 2).

The samples were conducted on (14 June 2021) at three stations of Seraidi area: (i) Sidi Djelmil (Cork oak forest 36°55’49’’N–7°40’53’’E), (ii) Sidi Ghdir (Mixed forest: zeen oak and cork oak 36°55’31’’N–7°39’’37’’E) and (iii) Sidi Amara (Zeen oak forest 36°54’38’’N–7°39’54’’E).

In order to perform the following physicochemical analyzes, the samples were dried, crushed and sieved to get the fine fraction of the soil (2 mm):

- granulometry → international pipette method (Baize, 2000);
- pH → pH meter (Baise and Girard, 1995);
- electrical conductivity → conductivity meter (Bonneau and Souchier, 1979);
- hygroscopic humidity → oven drying (24h à 105 °C). (Delcour, 1981);
- organic matter → muffle furnace incineration (4h à 450 °C) (Morel, 1986);
- real density → pycnometer (Delcour, 1981).

On the unground fraction of the soil, only one analysis was carried out:

- apparent density → à la paraffine (Baize, 2000).

Fractionation of organic matter (Figure 2). The statistical analyses of the data were performed using R software (R Codes TEAM 2019) version 3.6.2. The results were expressed as means ± standard deviation (m ± sd). The effect of station and depth on soil characteristics was verified by a one-way ANOVA on ranks (Kruskal Wallis test). This test was chosen after checking the normality and the equality of the variances by a Fisher F test. The relationships between the different parameters studied were verified by Spearman’s correlation. The significance level for all tests was set at $p < 0.05$. In addition, the results of the spatio-temporal variations were illustrated by a principal component analysis (PCA) graph. Finally, the similarity between the groups was checked by the ascending hierarchical classification (AHC).

RESULTS AND DISCUSSION

Our results reveled the existence of three oak populations depending on the edaphic characteristics, which differ from one area to another. The cork oak (*Quercus suber*) dominates the lower part of the forest while the zeen oak (*Quercus canariensis*) is mostly in the upper part. On the other hand, a transitional formation (mixed forest) was observed in the intermediate zone.

The variations of the studied parameters are illustrated in Table 1.

Granulometry

The granulometry is used to determine the texture of the soil. According to the U.S.D.A textural triangle (Baize, 2000). Based on the textural triangle of Jamagne, 1967. The granulometry results are shown in Figure 3.

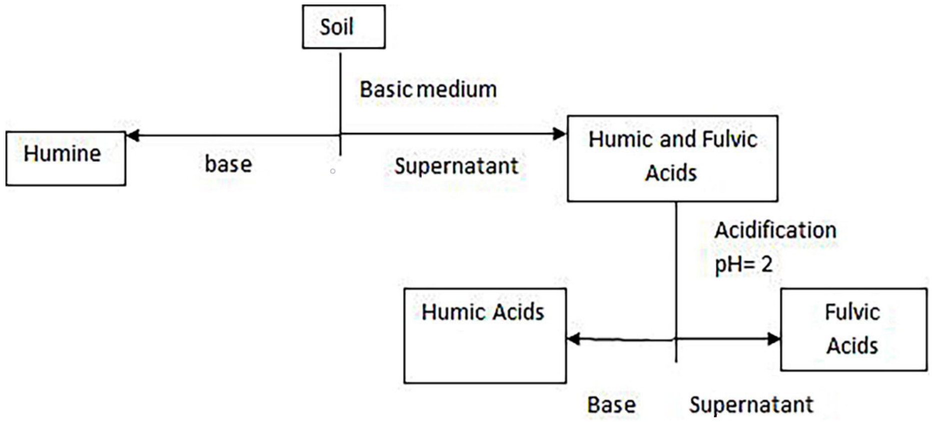

Figure 2. Protocol of the isolation of humic substances, (Duchoufour and Jacquin, 1966)

Table 1. Spatial variations of physico-chemical parameters in the Table 01: Spatial variations of physico-chemical parameters in the three stations (st_1 * cork oak; st_2 * zen oak; st_3 * mixed)

Parametres	Station			Depth		
	St_1	St_2	St_3	0–30 cm	30–60 cm	60–80 cm
Sand	26.67 ± 14.01	40.88 ± 4.26	26.06 ± 13.66	37.83 ± 0.29	33.16 ± 5.55	22.61 ± 19.97
Silt	10.67 ± 3.06	25.97 ± 3.97	31.17 ± 9.70	22.97 ± 13.82	24.17 ± 14.50	20.67 ± 7.02
Clay	62.67 ± 11.59	33.15 ± 7.45	40.94 ± 19.61	39.37 ± 13.58	42.67 ± 15.95	54.72 ± 25.33
pH	6.07 ± 0.29	5.98 ± 0.07	5.48 ± 0.10	6.00 ± 0.40	5.82 ± 0.32	5.71 ± 0.27
EC	0.75 ± 0.23	0.81 ± 0.16	0.59 ± 0.13	0.73 ± 0.26	0.73 ± 0.15	0.69 ± 0.21
H	4.10 ± 1.61	3.77 ± 1.42	4.14 ± 1.62	3.77 ± 1.90	3.55 ± 0.09	4.70 ± 1.62
OM	7.67 ± 2.53	6.34 ± 1.65	7.94 ± 3.98	10.27 ± 2.21	6.65 ± 0.83	5.03 ± 0.20
Poro	16.98 ± 12.11	18.91 ± 12.41	16.98 ± 12.11	20.92 ± 12.82	18.85 ± 0.77	13.11 ± 15.40
L.P.M	22.46 ± 16.04	5.91 ± 6.63	46.49 ± 33.44	44.19 ± 32.92	7.54 ± 5.23	23.15 ± 23.29
FA	19.89 ± 11.15	6.71 ± 4.34	7.86 ± 1.56	4.97 ± 2.88	15.30 ± 10.83	14.19 ± 9.14
H	55.26 ± 4.85	85.04 ± 1.62	42.58 ± 33.10	48.10 ± 36.78	74.21 ± 12.74	60.57 ± 22.81
HA	2.38 ± 0.75	2.33 ± 0.75	3.07 ± 1.91	2.74 ± 2.04	2.96 ± 0.14	2.09 ± 0.69

In all stations, sand particles were equally distributed in the three layers ($p \leq 0.05$) with an average of 37.83 ± 0.19% (st_1), 33.16 ± 5.55% (st_2) and 22.61 ± 19.97% (st_3) (fig. 04). Sand is present with a significant rate in the three study stations which will correct the various harmful effects of this type of texture. It also reduces the risk of compaction and deformation of the structure (Défossez and al., 2004).

In the three stations, the distribution of silt particles did not show any difference between the three layers ($p \leq 0.05$) with an average of 22.97 ± 13.82% (st_1), 24.17 ± 14.50% (st_2) and 20.67 ± 7.02% (st_3)

In all stations, the distribution of clay particles did not vary between the three layers ($p \leq 0.05$) with an average of 39.37 ± 13.58% (st_1), 42.67 ± 15.95% (st_2) and 54.72 ± 25.33% (st_3).

According to the granulometric analyses of the different horizons and according to the textural triangle, we note a clayey texture for the whole length of the profile of station 1, and a clayey-silty surface texture and a sandy bottom texture for station 2, finally for station 3 the granulometric analyses carried out show that each horizon has a different texture to the other; the first surface presents a sandy-silty texture, the second has a clayey-silty texture and the third has a clearly clayey texture.

The particle size of a soil is important, as it has a direct effect on porosity. Fine particles (clay) increase water retention, but decrease aeration (Soltner, 2017). The spatial variations of the physico-chemical parameters are shown in Figure 4.

Hydrogen potential (pH)

It is the measure of the acidity of a suspension of soil in water, with a standardized soil/water ratio (1/5). It also indicates the concentration of "H+" ions present in the water (Morel, 1986). The pH defines the acidity or alkalinity of the soil,

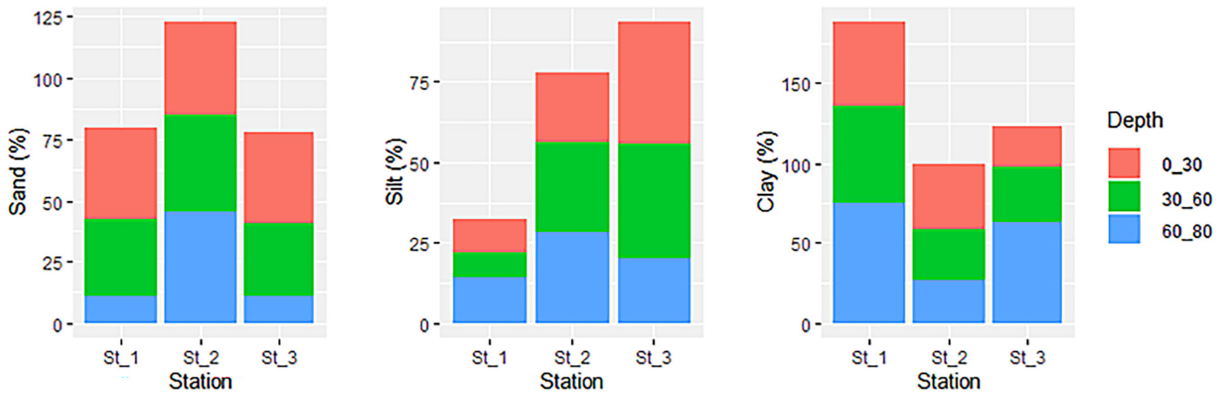

Figure 3. Granulometry results according to depth (cm)

the more H+ ions are retained in the soil particles, the more the soil is acidic (Carrier, 2003).

In all stations, pH decreased with soil depth with an average of 6.00 ± 0.40, (st_1), 5.82 ± 0.32 (st_2) and 5.71 ± 0.27 (st_3) but with no significant difference ($p \leq 0.05$).

According to the international standards NF ISO 10390, the environment in the three stations was mostly acid in the topsoil and extremely acid in the deep layers of soil. Indeed, the soil horizons are under the control of several factors such as topographic position, the nature of the source rock and the nature of the plant cover.

Electrical conductivity (EC)

The electrical conductivity is proportional to the quality of the ionizable compounds; it constitutes a good indication of the degree of mineralization of the soil (Duchaufour, 1983). This parameter provides information's on both concentration of electrolytes in the soil solution and soil salinity.

Electrical conductivity increases with depth in station 1 unlike stations 2 and 3 where it decreased with an average of 0.75 ± 0.23, 0.81 ± 0.16 and 0.59 ± 0.13 respectively. However, these variations did not show any significant difference.

The low electrical conductivity values observed in the three stations indicate that the soil of that region is non-saline.

Hygroscopic humidity (H %)

Hygroscopic humidity is the amount of water retained on the outer surface of soil particles and in equilibrium with atmospheric pressure and humidity (Escorihuela, 2006). The water status of the soil reflects both the quantity of water contained in this soil (water content) and the strength of water retention by the soil (matrix potential). The relationship between water content and matrix potential (the retention curve) is characteristic of each soil (Milia, 2011).

The hygroscopic moisture increases with depth in station 1 and 2 unlike station 3 where it decreased with an average of 4.10 ± 1.61 and 3.77 ± 1.42; compared to 4.14 ± 1.62 respectively. However, these variations did not show any significant difference.

Moisture allows the formation of an abundant humus of the moder-mor type (Gounot and Schoenenberger, 1967 in Abdellah, 2015).

Organic matter (OM %)

The organic matter produced by incineration of the soil after passage in a muffle oven at 480 °C for 24 hours, was expressed as a percentage of the dry weight of the earth (Benslama-Zanache, 1998).

The rate of organic matter was determined according as described by Lambert, 1975. The results revealed that the OM decreases significantly (p 0.05) according to the depth in the three stations with an average of 10.27 ± 2.21 (st_1), 6.65 ± 0.83 (st_2) and 5.03 ± 0.20 (st_3).

This decline of OM maybe explained by a strong biological activity on the surface and/or a weak migration of the organic matter towards the deep layers. This highlights the influence of plant cover on the supply of fresh organic matter.

The presence of organic matter promotes biological activity and therefore it acts on the evolution of the texture as well as the structure. (Soltner, 1981), it plays an essential role in the proper functioning of the soil. It helps to ensure its physical, chemical and biological properties. The organic matter promotes the biological activities and thus contributes in the evolution of soil texture (Soltner, 1981). On the other hand, it plays an essential role in the proper functioning of the soil and helps to ensure its physical, chemical and biological properties.

Porosity (Poro %)

The relationship between the apparent density and the real density defines the porosity of the soil. It is defined as the relative volume of the voids present in the rock (dimensionless number) (Saidi, 2010) and it depends on the granulometric composition and the structure of the soils.

Our results showed that the porosity increases according to depth in stations 1 and 2 unlike station 3 where it decreases. The average porosity in each station was 16.98 ± 12.11 and 18.91 ± 12.41 and 16.98 ± 12.11 respectively. This is in line with the result of the textural triangle.

The splitting of the MO

The results of the plitting of the organic matter are illustrated in Figure 5.

The fractionation of OM showed that humins were the most dominant with a heterogeneous distribution between stations and equal distribution between soil layers with an average of 48.10

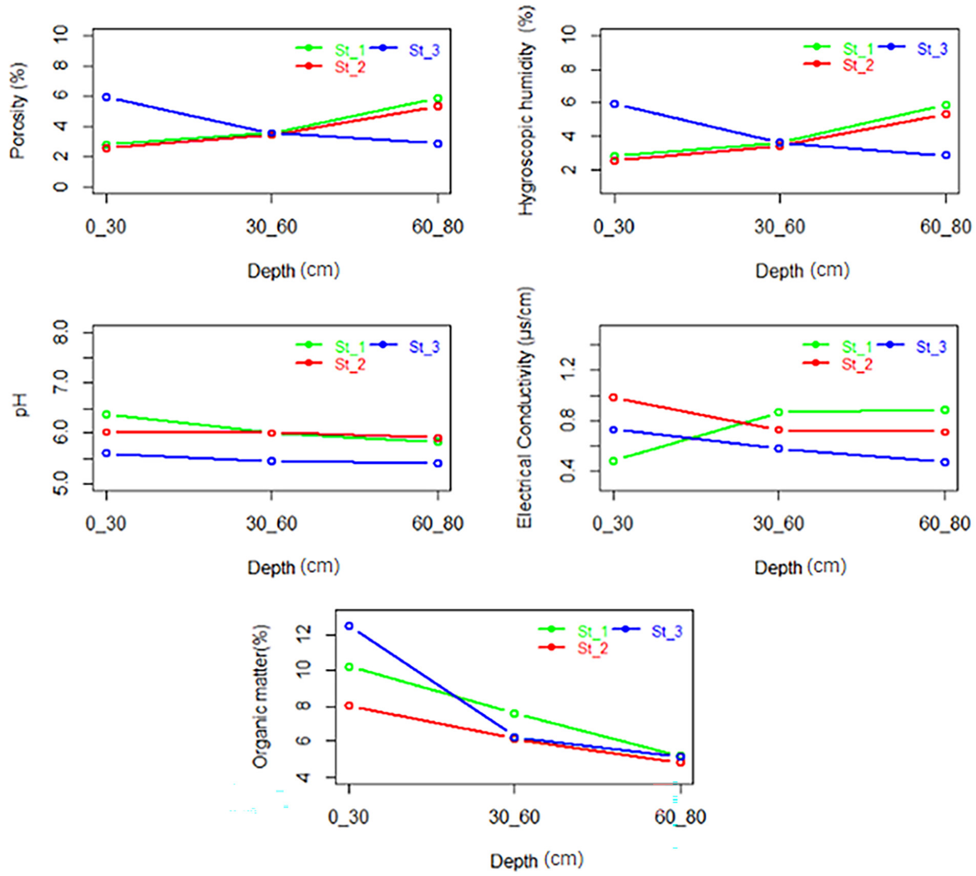

Figure 4. Spatial variations of the physicochemical parameters in the 3 study stations as a function of depth (Depth in cm)

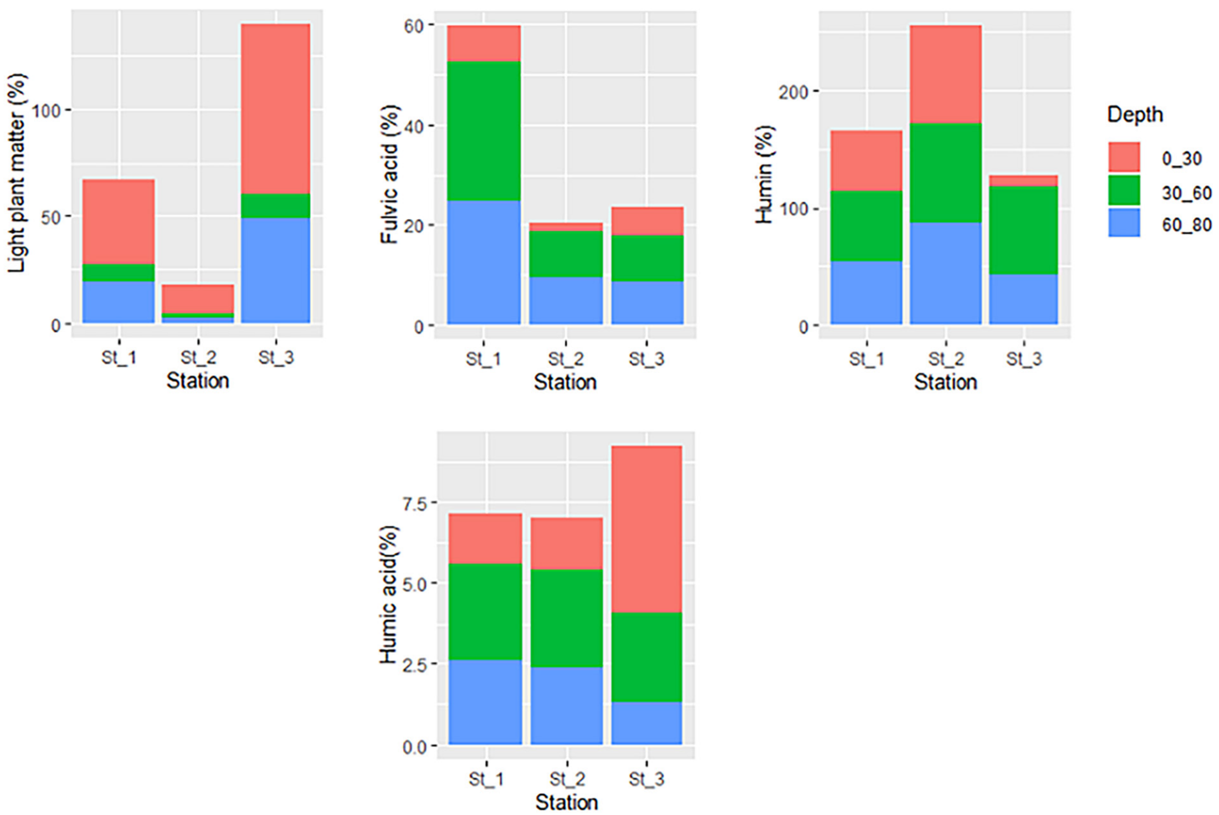

Figure 5. Spatial distribution of the different fractions of organic matter in the three study stations according to depth

± 36.78% (st_1), 74.21 ± 12.74% (st_2) and 60.57 ± 22.81% (st_3). This reflects the strong stabilization of the organic matter in the area.

In the three stations, light plant matter was mostly present in the topsoil with an average of 44.19 ± 32.9% while the lowest amounts were in the middle layers with 7.54 ± 5.23%. The LPM was negatively correlated to the humins (p 0.005; r = -0.74) (Figure 7 and 8).

In the three stations, the level of fluvic acid was more considerable in lowest layers (15.30 ± 10.83%; 14.19 ± 9.14%) than in the topsoil›s 4.97 ± 2.88%. This indicates a slow transformation of the organic matter which is soluble in water and in acidic media.

Humic acids are the condensed and polymerized fraction of organic acids. They were barely present in the three stations with an average of 2.74 ± 2.04% (st_1), 2.96 ± 0.14% (st_2) and 2.09 ± 0.69% (st_3).

The ANOVA results showed that there was no significant difference between the parameters studied in the 3 study stations except for organic matter (OM) which varied significantly (p ≤0.05) in depth function (Table 2).

Table 2. Results of the ANOVA testing the station and depth effects on the variation of the parameters studied

Variables	Factors			
	Station (df=2)		Depth (df=2)	
	P value	Observation	*P* value	Observation
Sa	0.192	ns	0.668	ns
Si	0.061	ns	0.875	ns
Cl	0.176	ns	0.561	ns
Por	0.735	ns	0.663	ns
H	0.706	ns	0.668	ns
pHw	0.066	ns	0.392	ns
EC	0.352	ns	0.864	ns
OM	0.732	ns	0.027	*
LPM	0.148	ns	0.148	ns
FA	0.393	ns	0.066	ns
H.OM	0.061	ns	0.491	ns
HA	0.956	ns	0.252	ns
NB: * ($p \leq 0.05$), ** ($p \leq 0.01$), *** ($p \leq 0.001$), ns ($p > 0.05$)				

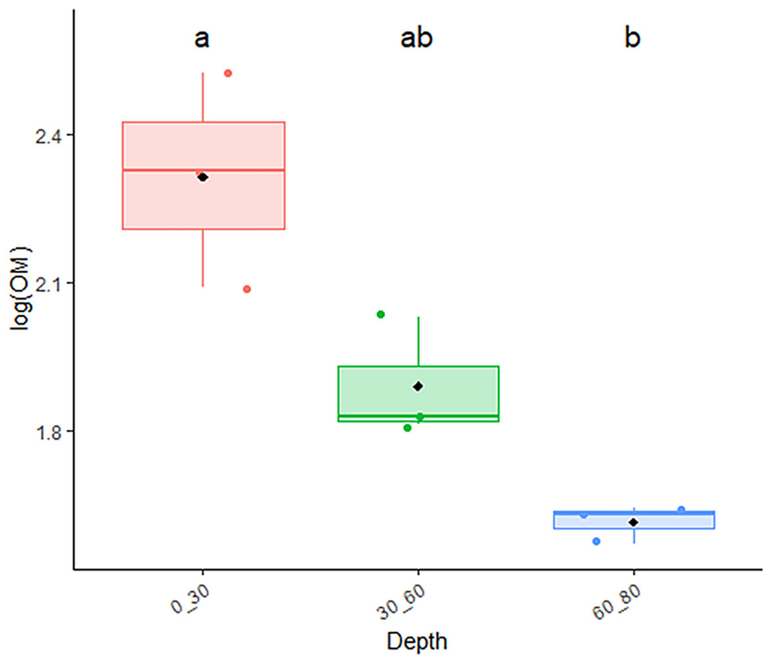

Figure 6. Variation of organic matter according to depth

The results of Dunn's test for the homogeneous groups showed that the organic matter (OM) is mostly present in the topsoil layer of 0–30 cm (Figure 6).

Spearman's correlation

The correlation test showed the existence of four highly significant associations between variables:

- a negative correlation between the sand and clay highly significant (r = -0.75; $p \leq 0.01$);
- a positive correlation between the porosity and sand very highly significant (r = 0.82; $p \leq 0.001$);
- a negatively correlation between the porosity and clay highly significant (r = -0.68; ($p \leq 0.01$);
- a negative correlation between humins and light organic matter very highly significant (r = -0.74; $p \leq 0.001$) (Figure 7 and Table 3).

Principal component analysis (PCA)

The spatial overlap of all studied parameters was expressed through a Principal Components

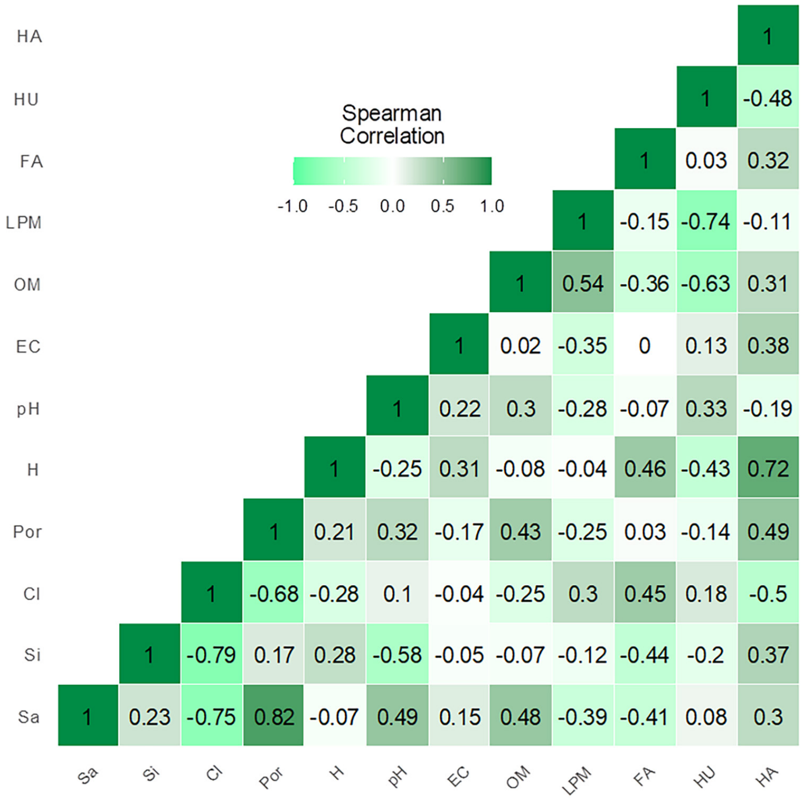

Figure 7. Spearman correlation results

Table 3. Degrees of significance of the spearman correlations (P value)

	Sa	Si	Cl	Por	H	pHw	EC	OM	LPM	FA	H.1	HA
Sa	-	0.3660	0.0104	0.0013	0.9658	0.1684	0.8551	0.7476	0.2839	0.6828	0.2220	0.5292
Si	0.3660	-	0.0096	0.3871	0.3660	0.3085	0.8305	0.8647	0.9661	0.3085	0.7324	0.1875
Cl	0.0104	0.0096	-	0.0122	0.4720	0.8984	0.8979	0.5457	0.5755	0.4064	0.4328	0.1544
Por	0.0013	0.3871	0.0122	-	0.5537	0.3871	0.5312	0.5554	0.5554	0.8460	0.5554	0.4267
H	0.9658	0.3660	0.4720	0.5537	-	0.1684	0.6816	0.7476	0.8810	0.2418	0.6828	0.0704
pHw	0.1684	0.3085	0.8984	0.3871	0.1684	-	0.3537	0.3085	0.3807	0.7650	0.3317	0.8312
EC	0.8551	0.8305	0.8979	0.5312	0.6816	0.3537	-	0.5890	0.5440	0.7313	0.4720	0.2950
OM	0.7476	0.8647	0.5457	0.5554	0.7476	0.3085	0.5890	-	0.2646	0.1116	0.2440	0.4328
LPM	0.2839	0.9661	0.5755	0.5554	0.8810	0.3807	0.5440	0.2646	-	0.1116	0.0005	0.4879
FA	0.6828	0.3085	0.4064	0.8460	0.2418	0.7650	0.7313	0.1116	0.1116	-	0.4064	0.5165
H.1	0.2220	0.7324	0.4328	0.5554	0.6828	0.3317	0.4720	0.2440	0.0005	0.4064	-	0.8647
HA	0.5292	0.1875	0.1544	0.4267	0.0704	0.8312	0.2950	0.4328	0.4879	0.5165	0.8647	-

Analysis (PCA) as depicted in Figure 8. Axis 1 expresses (33.2%) of the total variance, axis 2 expresses (23.8%) of the variance and axis 3 expresses (16%).

Station effect

Station 1 is mainly characterized by a high content of clay (Cl) and fulvic acid (Fa). Station 2 is mainly characterized by a high rate of sand (Sa) and humins (H) and low rates of light plant matter (LPM) and clay (Cl). Station 3 is mainly characterized by a high rate of light plant matter (LPM) and a low electrical conductivity (EC) and low rate of humins (Hu).

Depth effect

The topsoil layers (0–30 cm) were characterized by a high rate of humins. The intermediate layers (30–60 cm) were characterized by a considerable level of huminsand low levels of light vegetable matter (LPM) and fulvic acid (FA). The deep layers (60–80 cm) were characterized by high clay content and low sand content and thus by low porosity.

Hierarchical ascending classification (AHC)

The results of Hierarchical Ascending Classification are shown in the truncated dendrogram (Fig. 9). According to the dendrogram, we distinguished 4 soil profiles in the studied area:

- group 1 – a soil characterized by the properties of the surface layer (0–30 cm) of station 3;
- group 2 – a soil characterized by the properties of the 3 layers (0–80 cm) of station 2 and the intermediate layer (30–60 cm) of station 3;

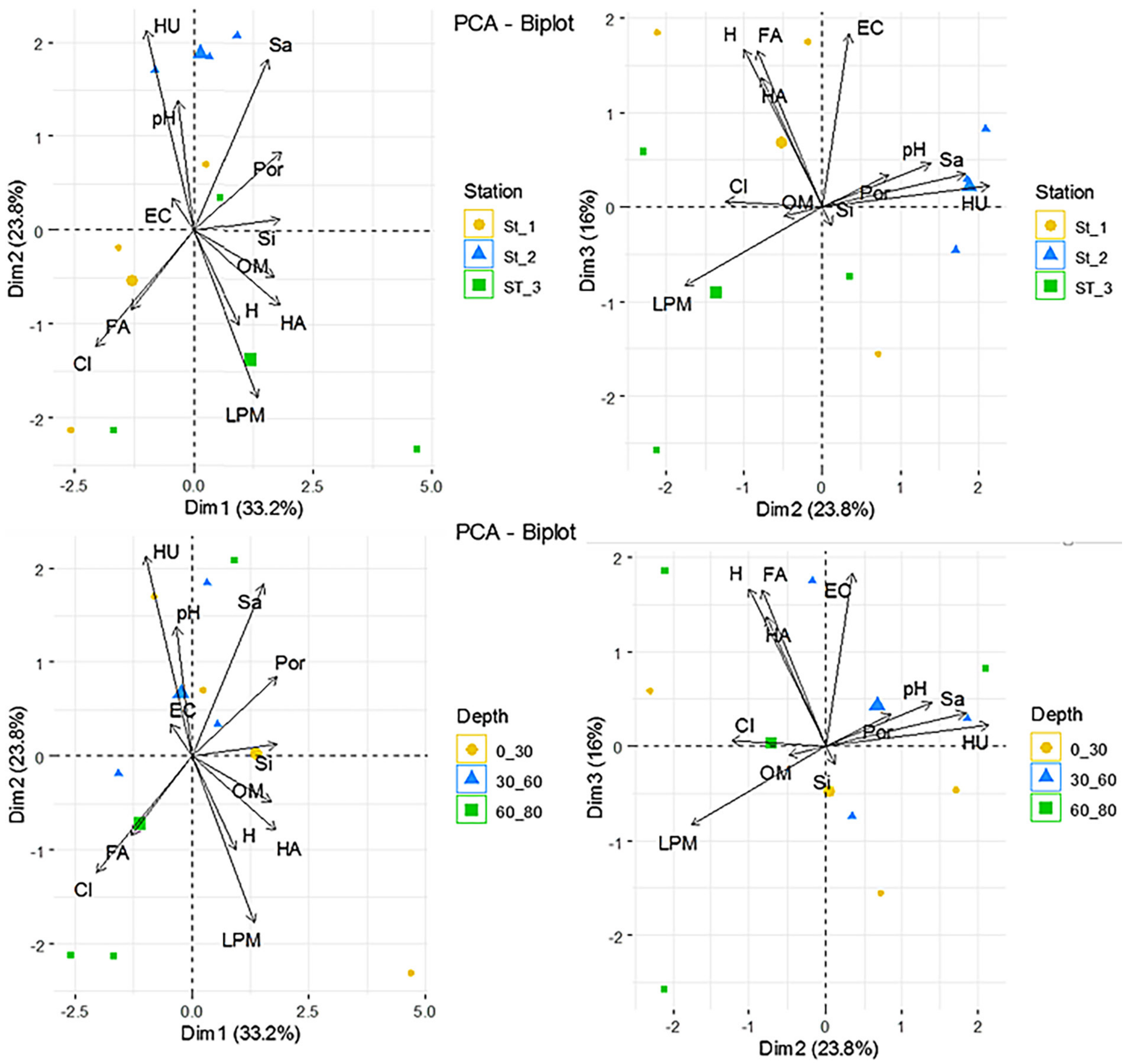

Figure 8. Principal component analysis based on the spatial variation

- group 3 – a soil characterized by the properties of the last 2 layers (30–80 cm) of station 1;
- group 4 – a soil characterized by the properties of the surface layer of station 1 (0–30 cm) and the deep layer of station 3 (60–80 cm).

CONCLUSION

This study revealed the existence of three types of forest in the Edough mountain of Seraidi (North-eastern of Algeria), characterized each by specific environmental conditions. The first forest is a low maquis of cork oak with specific vegetation mostly damaged due to fire. The second one is a dense forest of zenn oak with a specific floristic procession. The third is a mixed forest (cork oak with zeen oak) in transition area between the two others.

The morpho-analytical results of the soils showed a physical homogeneity in all the stations, with a clayey texture (clayey to clayey-loamy). As our study demonstrated, the presence of clay directly influences soil porosity and moisture.

The chemical analysis showed that the soil in Seraidi forest is an acid to very acid medium with low conductivity and high rates of organic matter that exceeds 4%. This explains the richness of the Edough forest in organic matter. The latter plays an important role in the overall functioning of forest ecosystems, and particularly on biological activity and on the various reactions of the adsorbent complex. Furthermore, the organic matter was very saturated due to the presence of a high quantity of ions resulting from the alteration of the source rock, and allowing the installation of a rich and diversified plant cover. This plant cover controls the evolution of the soil by a significant and permanent supply of litter.

This study revealed the existence of a great diversity of soils in the region of Seraidi, such as: little evolved soils under cork oak forest; forest brown soils under zeen oak forest and eroded brown soils under mixed forest.

The fertility of soil is considerably correlated to the production of plant biomass, which plays a determining role in the morphological differentiation of the soil.

Therefore, it is imperative to protect this rich forest against degradation caused by human activities such as fires, deforestation and overgrazing. It is also recommended to carry out a regular check, at least once a year, to preserve this ecosystem.

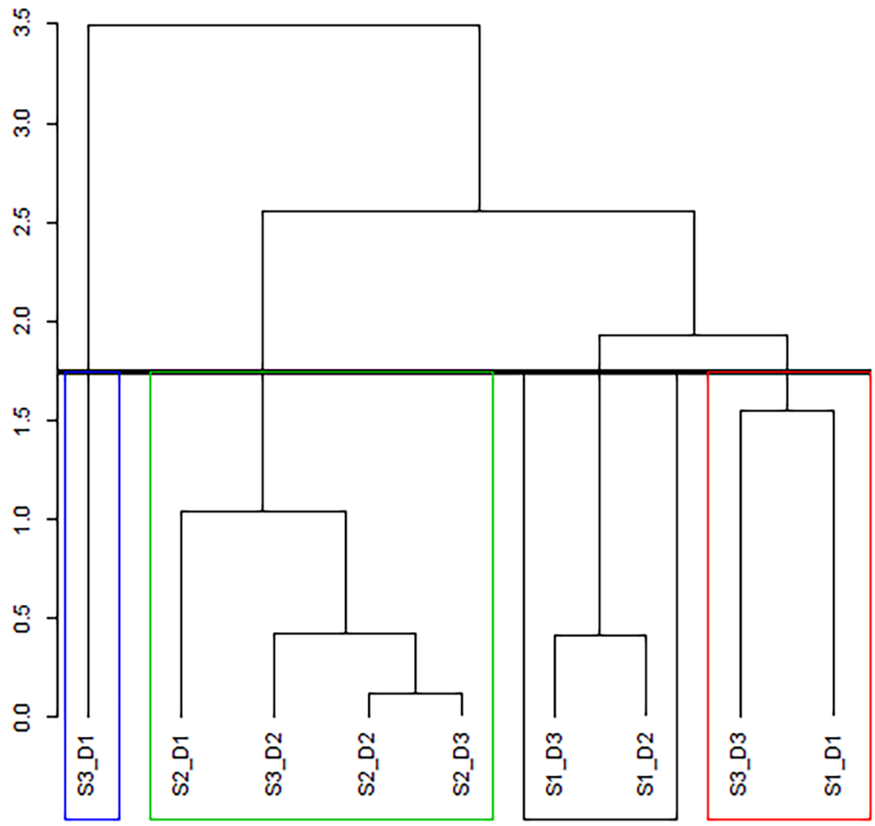

Figure 9. Dendrogram classifying groups (soil profiles) according to edaphic quality (parameters studied)

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