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Quality Estimation of the Western Algeria Forest Soils

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ABSTRACT

In recent years, there has been significant regression of the Aleppo pine forest massif in the semi-arid areas of Algeria which is the last barrier against desertification. Several studies on the effects of climate and anthropogenic practices have been undertaken to identify the limiting factors but no study in the region deals with the effects of soil properties. In this work, we studied the quality of soils in a pine forest of Aleppo, Western Algeria by comparing their physico-chemical and biological parameters in order to characterise these soils and to identify the main limiting and degrading factors of their quality. The results of this study showed that the forest soils in this area were alkaline but not salty with a presence of limestone. They had a balanced texture homogeneous moisture with the colour varying from reddish brown to reddish maroon. The C/N ratio was moderately low indicating that these soils release some nitrogen despite being rich in organic matter. Microbial activity in these soils was moderately low as a function of nitrogen availability to ensure good carbon mineralisation. This study has shown that the soils of Aleppo pine forests in semi-arid zones are fragile and generally characterised by heterogeneous properties that are very sensitive to the influence of environmental factors (climate and human). This may result in the deterioration of physico-chemical and biological quality of the soils over a long-term consequently changing them into arid soils.

Keywords: **Soil properties, Aleppo pine, quality, degradation, forest, semi-arid**

INTRODUCTION

The Mediterranean basin is one of the most important hotspots of global biodiversity, given its floristic richness of terrestrial plant communities and its high level of endemism (Médail and Quezel 1999; Myers *et al.* 2000; Médail and Myers 2004). According to Seigue (1985), the Mediterranean forest covers 65 million hectares of which 45 million of forests proper and 19 million hectares of forest formations have become a fragile natural environment disturbed by multiple uses, the origins of which date back to the beginning of the Neolithic period. However, the aggression the Mediterranean forest has undergone

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considerably varied in frequency and intensity over the ages as a function of human demography which has determined regression or progression phases of their surface (Tillier 2011).The issue of degradation of natural resources is still associated with climate, which largely determines the natural characteristics of the environment. Indeed, plants and some soil properties are strongly correlated with the climatic conditions of the area.

Soils are formed over time as the climate and vegetation act on the material of the mother rock. Important aspects of soil formation in an arid climate are significant daily changes in temperature which cause the mechanical or physical decomposition of the rocks, and the sands transported by wind or water erosions (FAO 1992). The knowledge of soil constituents, their composition and their main physico-chemical and biological properties, is in any case a prerequisite for the study of the soil. This fundamental knowledge makes it possible to undertake the study of soil formation processes (pedogenesis process) in relation to environmental conditions, which leads to the classification of world soils and their mapping (Drouet 2010). The objective of this work is to study the physico-chemical and microbiological quality of forest soils dominated by Aleppo pine in a semi-arid zone characterised by strong anthropogenic pressure. This research was carried out at the forest of mountain Sid Ahmed Zeggai located in the Saida region of Western Algerian. This research is the first field study conducted in the area. In the present study, we aim to determine the physico-chemical properties of soils in this area to better characterise them and to build a data bank which will help the managers and the foresters to better manage this very fragile ecosystem.

MATERIALS AND METHODS

The Study Area

The mountain of Sid Ahmed Zeggai located 4.5 km west of Saida (north-west of Algeria) was our study area. The Saida region is called a hybrid territory, neither truly steppe, nor truly Tellian (ANAT 2008). The Sid Ahmed Zeggai mountain is a part of the Saida mountains which are the eastern extension of the denny mountains forming part of the Atlas Tellian as shown in Figure 1. It is characterised by geological formations containing groundwaters and a geomorphological framework characterised by terrain and slopes. The region has fauna and flora specific to the area and its forest encompasses a multitude of landscapes and varied environments, with the Aleppo pine and lentisk as the main tree species present on the mountain of Sid Ahmed Zeggai.

From a climatic point of view, the forest benefits from a semi-arid climate (M = 3°C, P = 344.6 mm) located on the upper floor of the Mediterranean vegetation ($M > 3°C$, $200 < P < 400$ mm). It has a dry period of almost 6 months from May to October and 38 ice days on average per year (ONM 2016).

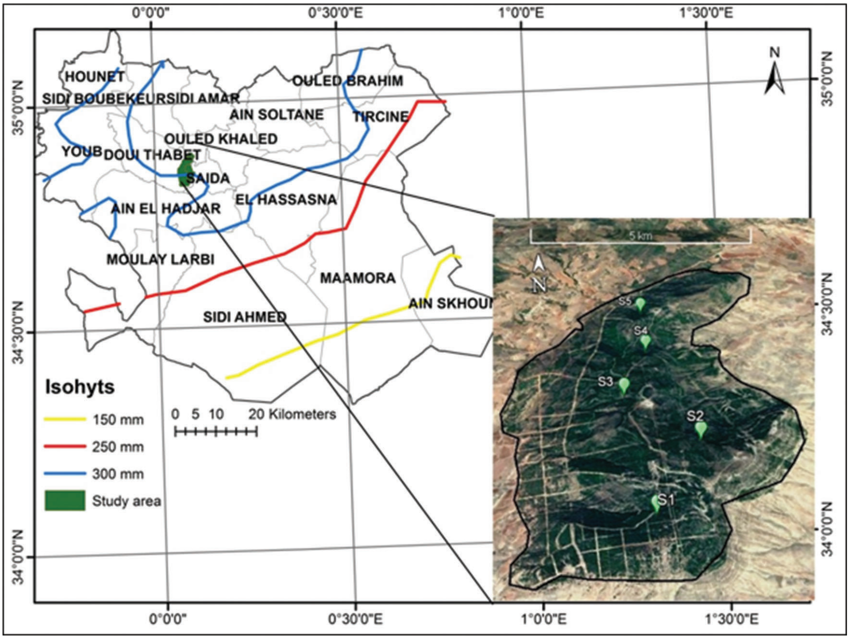

Fig. 1: The study area

Selection of Stations and Sampling

Five sampling stations of 400 m^2 were set up in the study area (Table 1). For each station, five samples of one kilogram soil were randomly collected with a set of 25 soil samples, after the litter was eliminated at a depth of 0 to 20 cm. The composite samples were sieved to 2 mm; the samples were air-dried before subjecting them to physico-chemical analyses, or stored at 4°C pending microbiological assays

Physico-chemical and Biological Analyses

A particle size analysis was carried out using the Robinson pipette method (Aubert 1978). The soil colours were determined by the Munsell Soil Color Chart (Delaunois 2006). Gravimetric water content was determined by subtracting the mass of a sample of dried soil (105°C, 24 h) from that of the fresh sample. The apparent particle density was determined by the method of drying and weighing the cylinders while the actual particle density was determined by the pycnometer method (Aubert 1978). The permeability of a soil was determined by the measurement of water height per centimetre that infiltrated per unit of time in the soil (Mathieu *et al*. 1998). The water retention capacity was measured by weighing a sample saturated with water after decanting for 24 h at 4°C and the soil pH was measured in a soil and distilled water suspension (1:2.5). The measurement was performed after two hours of stabilisation at room temperature using a Métrom pH meter (Herisau, Switzerland). Calcium carbonate ($CaCO_3$) content was determined by decomposition to CO_2 by HCl (Aubert 1978). Total

TABLE 1
Geographic coordinates and characterisation of the study stations

Stations	Altitude (m)	Longitude X	Latitude Y	Exposition	Slope (%)	Vegetation cover (%)
Station 01	1092	34° 52' 13" N	00° 04' 26" E	North	5	70
Station 02	1097	34° 51' 30" N	00° 04' 56" E	South	10	40
Station 03	1146	34° 50' 48" N	00° 04' 40" E	All	0	60
Station 04	1160	34° 50' 11" N	00° 05' 22" E	East	10	60
Station 05	1081	34° 49' 29" N	00° 04' 53" E	North	5	55

nitrogen level was determined by the Kjeldhal method (Aubert 1978). Organic matter content was measured by mass loss of a dry sample during calcination at 550°C for 16 h. Basal respiration and microbial biomass were measured according to the protocol described by Anderson and Domsch (1978).

Statistical Analysis
The results of analyses of physico-chemical and microbiological properties between the different stations studied were subjected to one-way ANOVA by the Statistica 8.0 software.

RESULTS

Physical Properties
The physical parameters of the soils are recorded in Table 2. On the basis of average particle size composition and according to the texture triangle, the soils of our study area were categorised as sandy-loam. The soil colour generally varied from reddish brown (10R3/3) to reddish black (10R2/1). We noted a moderately low level of soil moisture in the stations ranging from13.29% and 24.12% which was not significant ($p > 0.05$); the S2 station had the lowest percentage of humidity at 13.29%. The experimentation indicates that stations S3, S5, S2 had a higher retention capacity rate (74%, 70%, 69%) per contribution compared to the S1 station with a water storage rate of 60%. The observation that the S4 station had a retention capacity not exceeding 49% was probably due to a significant recovery by the vegetation that used this water. Retention capacity remained moderately significant between study stations ($p < 0.05$). Apparent density was lower than actual density at the five stations and varied from 0.15 g cm^{-3} to 0.25g cm^{-3} while

TABLE 2
Physical properties of soils

Physical properties	Stations					F value and significance
	S1	S2	S3	S4	S5	
Humidity (%)	16.47	13.29	20.90	18.00	24.12	F=2.47 ns
Retention capacity (%)	62.86	73.81	74.91	67.69	77.40	F=4.57**
Permeability (cm.h^{-1})	46.21	50.09	44.21	47.55	50.91	F=11.87***
Porosity (%)	74.30	74.81	81.53	72.61	84.54	F=8.73***
Apparent density (g.cm^{-3})	1.15	1.03	1.03	1.29	0.98	F=3.70*
Real density (g.cm^{-3})	4.53	4.12	4.64	4.87	4.42	F=3.96*

This table records the average values; Physical properties, the *p* value of independent test is presented with its threshold of significance *(*: p*<0.05*; **: p*<0.01*; ***: p*<0.001*;* ns: not significant).

actual density varied from 1.30g cm^{-3} to 2.70g cm^{-3}. Permeability, porosity and real density were found to exhibit a highly significant difference in means ($p>$ 0.001) between the stations. The permeability average ranged from 44.21 cm h^{-1} to 50.91cm h^{-1}. Porosity is an essential concept for all who are concerned with water conservation, the circulation of liquids and gases, and rooting capacity of plants. Table 2 shows that the total porosity varied from one station to another from 12 % to 54 % with Station 4 having the lowest rate of porosity.

Chemical properties

The Soil chemical properties show that the concentrations of organic carbon and total nitrogen varied from one station to another and exhibited a highly significant difference ($p<$ 0.001). However, we recorded average concentrations of significant carbon and total nitrogen in the S5 station (7.19 g kg^{-1}; 0.31 g kg^{-1}) while S2 recorded the lowest carbon and S4 the lowest nitrogen rate (1.33 g.kg-1 and 0.081 g kg^{-1}, respectively). The total nitrogen content was low in all stations compared to the carbon content. The C/N ratio is widely used to classify the evolution and types of organic matter in a soil. It is an indicator of residue degradation in soil and remains moderately significant ($p<$ 0.01) between soils with an average percentage ranging from 16% to 23%. Organic matter averages exhibited a highly significant difference between the stations ($p<$ 0.001) and correlated with carbon averages. Station S5 was richest in organic matter (12.37%) while S4 station had the poorest percentage (2.29%).

As the soil pH varied from 7.67 to 8.91, the results confirmed that the soil in all the stations were alkaline. The electrical conductivity varied from 0.37dS m^{-1}, and 0.55 dS m^{-1}, and based on these results, all stations are characterised by unsalted soil (Aubert 1978). The stations studied exhibited a variable limestone rate with a small difference ($p<$ 0.05). Station S5 had the maximum value with

39.26%, with Station 4 having the minimum limestone rate at 19.99% as shown in Table 3.

TABLE 3
Chemical properties of soils

Chemical properties	Stations					F value and significance
	S1	S2	S3	S4	S5	
Carbon ($g.kg^{-1}$)	3.31	5.60	3.80	1.33	7.19	F=378.82***
Nitrogen ($g.kg^{-1}$)	0.18	0.27	0.22	0.081	0.31	F=50.36***
C/N ration	18.30	20.90	17.06	16.45	23.54	F=5.98**
Organic matter (%)	5.70	9.64	6.54	3.29	12.37	F=382.40***
pH	7.67	8.76	7.73	8.21	7.93	F=108.53***
Conductivity ($dS.m^{-1}$)	0.45	0.55	0.52	0.37	0.47	F=8.66***
Total limestone (%)	27.40	27.03	21.48	19.99	39.26	F=4.18*

This table records the average values; for chemical properties, the *p* value of independent test is presented with its threshold of significance (*: $p<0.05$; **: $p<0.01$; ***: $p<0.001$; ns: not significant).

Biological Properties

The averages of the soil microbial parameters are recorded in Figure 2. The statistical data show that the biomass is homogeneous throughout the study area and is not significantly different ($p > 0.05$). Station S5 had the highest microbial biomass (50.25 µgC-CO_2 g^{-1}) while Station S2 had the lowest microbial biomass with an average of 22.65 µgC-CO_2 g^{-1}.

Basal respiration averages were low compared to microbial biomass in all stations. The lowest value was recorded in station S3 (2.06 µg C-CO_2 $h^{-1}.g^{-1}$) and the maximum for station S1 (4.13µg C-CO_2 $h^{-1}.g^{-1}$). The statistical results showed a small significant difference between the stations ($p<0.05$). A moderately significant difference was measured between stations for metabolic quotient (qCO_2) ($p< 0.01$).

DISCUSSION

Soils are a major component of forest ecosystems with their qualities being closely dependent on vegetation, climate and human action. In this context, it is important to be able to monitor soil quality in the short and medium terms (INRA 2006). However, it is quite widely accepted that there is no single, universal indicator of the quality of a forest floor (Fox 2000). The degradation of soil resources results from the synergistic effects of climate, the aggressiveness of certain natural conditions, and above all human activities carried out on generally fragile and infertile soils. All agricultural, forestry and pastoral activities must contribute to

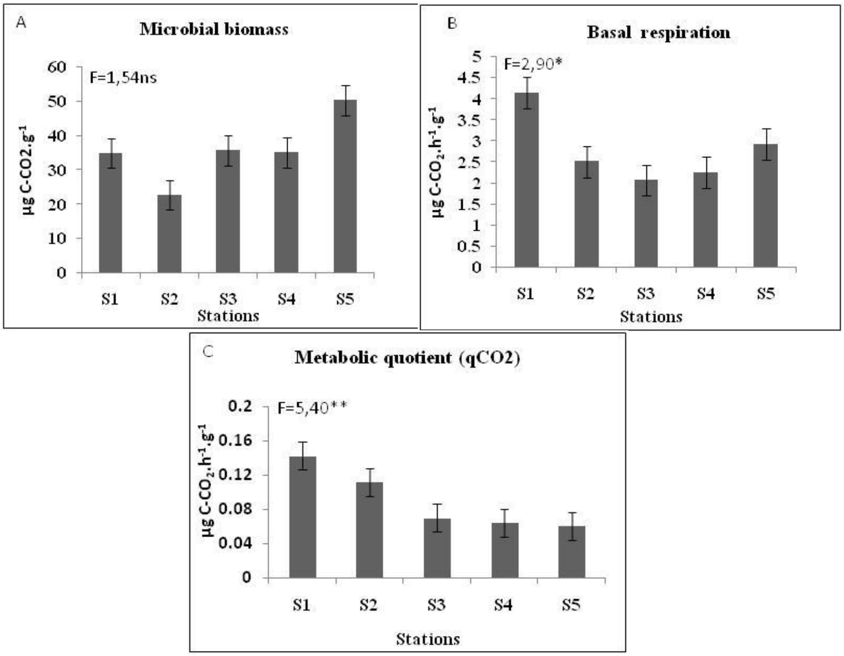

Fig. 2: Microbiological properties of soil (A. Microbial biomass; B. Basal respiration; C. Metabolic quotient (qCO_2) (: $p < 0.05$; * *: $p < 0.01$; * * *: $p < 0.001$; ns: not significant).*

the maintenance of this natural capital, to the improvement of its productivity and to the preservation of the environment (AEE 2014).

The results show that the soils of the different stations have a sandy-loam texture. The soils have a red colour due to the oxidation of iron which is present in large amounts in these soils while the brown and maroon colours are due to brunification (formation of iron hydroxide) (Birot 1966; Delaunois 2006). Humidity is moderately low due to high evaporation and evapotranspiration and irregular precipitation. Borsali (2013) shows that the gravimetric water content of soils depends primarily on the climatic conditions (temperatures and precipitation) preceding sampling and that this decrease in water content could be a consequence of the impacts of the past events of forest fire on some physico-chemical properties of soils and on vegetation.

Soils have a good capacity for water retention due to the presence of organic matter (Borsali 2013; Zouidi and Borsali 2017). Several authors have shown that the retention capacity decreases if the organic matter is destroyed by fire, which induces a decrease in the aggregate stability leading to a reduction in the soil capacity to conserve water (Rigolot 1992; Borsali *et al*. 2012). The soils have good porosity due to the presence of sand which has high infiltration and percolation rates. The size and number of pores are closely dependent on texture (balanced texture) and soil structure which also influence its permeability. The finer the soil texture, the lower the permeability (FAO 1985). The soil in the study area is well structured and fine with good (wide pores); its apparent density will be low compared to that of the same compact soil (Laborier 1994). The degradation of the physical properties of a soil can lead to a significant reduction of its chemical and biological qualities.

Soil quality assessment is based on chemical properties (Singer and Ewing 2011). The results of the chemical properties show that the soils of the pinewoods at Saida exhibit highly significant variation in organic carbon richness and organic matter. This difference is explained by the rate of plant recovery which differs from one station to another and which ensures the production of litter (the fall of plants, mainly the needles of Aleppo pine). Nitrogen is low relative to carbon in the stations, which induced a C/N ratio that varied from ($15<C/N<20$). This is a sign that required nitrogen cover to allow good decomposition of the carbonaceous material is found in all stations except for station S5 where the ratio $C/N > 20$, indicating a significant carbon rate but not enough nitrogen to allow for carbon decomposition. Soils at the level of our forest are generally alkaline (pH 7.5 – 8.5). The presence of carbonates strongly influences soil reaction, with carbonate soils distinguished by a pH that is higher than 7 (Drouet 2010). Based on the salinity scale (Aubert 1978), the conductivity of the soils studied in our area shows that they are classified in the category of non-saline soils. This is due to a low level of mineral salts and also because the fragmented chemical elements have been leached by the rains and transported by erosion (Aubry 2007). Determination of total limestone shows that the soils in the study area are moderately calcareous except for the S5 station, which has a highly calcareous soil. According to (Nieder and Benbi 2008), carbon in the soil occurs largely in carbonaceous minerals such as calcium carbonate ($CaCO_3$) that develops on calcareous parent materials and in arid or a semi-arid climate. The chemical properties of a soil condition its biological quality. Any disturbance of these properties (natural or anthropogenic) can lead to a reduction in the biological quality of a soil and consequently induce a malfunction of the terrestrial ecosystem (Gros 2002).

Soil microbial activity is largely controlled by the physical and chemical conditions prevailing in these soils (Doran and Linn 1994). At the level of our study area, the rate of microbial biomass is homogeneous in all stations. This homogeneity depends in the first place on water content that is similar in all the stations and also on the pH, limestone, salinity, texture and temperature that does not change much between the study sites, as reported by several authors (Lavelle and Spain 2001; Salducci 2007; Briat and Job 2017). Soil microbial activity is largely controlled by management practices such as tillage (Doran and Linn 1994) and in parallel, biological fertility influences the physical state of the soil, the amount of organic matter, and the availability of nutrients. Our results show a weakly significant difference in basal breathing between stations ($p< 0.05$) although microbial biomass is homogeneous, and this is probably due to dormancy of certain bacteria under the influence of soil-climatic conditions.

Microbial activity is mainly dependent on soil conditions (aeration, moisture, porosity, microbial life). The activation of microbial life requires the presence of easily degradable organic matter that will serve as food. It is the interactions between the different soil properties that give it its ability to feed the plant in the long term (Huber and Schaub 2011). Return dynamics are therefore highly variable and depend on the amount of resources available, the adaptation of communities, and the stressful climatic conditions that may limit microbial recolonisation (Borsali 2013), including decreased water content and an increase in recalcitrant carbon levels for microbial biodegradation (Borsali *et al.* 2012). The metabolic quotient (qCO_2) indicates a low efficacy of microbial activities that use available soil carbon for biosynthesis; this can be explained by the variation in daily and seasonal temperatures in semi-arid areas, and by the age and types of microbial communities in this area that can affect energy efficiency (Anderson and Domsch 1978; 1986).

During this experiment a large number of physical, chemical and microbiological parameters were studied in order to best identify the quality of the soils subjected to different stresses. Field observations have highlighted that different microbial responses and physico-chemical characteristics related to local environmental stresses (drought, heat wave, salinity etc.) which are either internal or external factors to the ecosystem can affect the forest traits (growth, reproduction, longevity, etc.) and the behaviour of organisms. All these factors affect all levels of ecological organisation (individuals, populations, communities and processes) (Barrett *et al.* 1976). The stress imposed on an active system develops an adaptive or attenuation response which intensity depends on the state of the system (stability and vulnerability). Smithers and Smit (1997) indicated that in the case of a natural stimulus such as the climate, adaptation differs according to frequency, duration, suddenness and amplitude of the phenomena (Guénon *et al*. 2011).

CONCLUSION

The study showed the existence of a semi-arid bioclimatic stage imprint on the physico-chemical and biological properties of forest soils at different spatial scales by integrating the specific stress effect into a semi-arid environment such as climate, terrain and vegetation. To our knowledge, there is no data on soil characteristics in the semi-arid area of western Algeria. These soils generally have a balanced texture favorable to the life of the roots and micro-organisms because it has good aeration, drainage, water retention and nutrient status. This study shows that variation for many distinct parameters (texture, actual and apparent density, holding capacity, moisture, bacterial biomass and basal respiration) among the soils is very minimal. A small difference exists for the organic matter decomposition rate as a result of the difference in the slope and recovery rate. The C/N ratio indicates moderately low biological activity in the soils due to the presence of low nitrogen which does not support the decomposition of the highly carbonaceous material. Soils in this region are alkaline but not salty and contain a significant amount of limestone resulting from the weathering of calcimagnesic parent materials which contains high amounts of limestone. Soil microbial properties show only a significant presence of microbial biomass due to the high temperature and low humidity of this area.

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