Dust career impacts on Pinus halepensis growth

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***Abstract—* Pinus halepensis** *Mill., is a most common tree in the Mediterranean basin. In Tunisia, specifically Kroumirie, it is an excellence species. However, for several years, we assist a continual deterioration of this ecosystem type. Several factors are the origin for this degradation: insects and fungi attack, fire, aging populations, low regeneration and hardening climate. This degradation is further accentuated by installing careers around the pine forest. Our objective in this study was to identify the career dust influence on growth and productivity of Aleppo pine; through dendrochronological approach (tree rings study) and dendrometric approach (measurement of diameter, height and survival rate). Study is accomplished on two populations: a reference site 'Charchara' located away from mining and Oued el maaden site near a gravel extraction career. In addition, physical and chemical parameters are analysed on soil and water samples collected in the two sites. Results showed significant differences of parameters studied between stations both in dendrometric and dendrochronological parameters over time. Second, in physical and chemical parameters, a very high content on metals traces was found on soil and water in Oued el maaden site.*

Keywords— career, growth, Pinus halepensis, productivity.

Résumé - Impact des poussières de carrière sur la croissance de *Pinus halepensis.*

Le pin d'Alep '*Pinus halepensis* Mill' est une essence forestière la plus commune du bassin méditerranéen. En Tunisie, plus précisément en Kroumirie, elle constitue une essence forestière d'excellence. Toutefois, depuis plusieurs années, on assiste à une dégradation continue de ce type d'écosystème. Plusieurs facteurs sont à l'origine de cette dégradation : attaque d'insectes ou de champignons, incendies, vieillissement des peuplements, faible régénération et endurcissement du climat. Cette dégradation serait encore plus accentuée par l'installation de carrières aux alentours de la pinède. Ce travail a donc pour objectif de déceler l'influence de poussière de carrière sur la croissance et la productivité du pin d'Alep ; par le biais de l'approche dendrochronologique (étude des cernes de croissance) et dendrométrique (mesure de diamètre, hauteur et taux de survie). Pour ce faire, deux sites sont choisis : un site dé référence situé loin de la carrière 'Charchara'et un autre au voisinage de la carrière 'Oued el Maaden'. De même, des paramètres physicochimiques ont été mesurés dans des échantillons de sol et d'eau collectés au niveau des deux sites. Les résultats ont montré des variations significatives des paramètres étudiés entre les deux stations aussi bien en hauteur qu'en largeur et aussi au niveau de la croissance radiale au cours du temps. En deuxième lieu, au niveau des paramètres physicochimiques, une teneur très élevée en éléments traces métalliques a été identifiée sous pin d'Alep à Oued el maaden.

Mots clés : Carrière, croissance, *Pinus halepensis*, poussière, productivité.

I. INTRODUCTION

Aleppo pine (*Pinus halepensis* Mill.) is a widely distributed species all around the Mediterranean Basin. It extends from Morocco in the west to Palestine and Jordan in the east, and from France in the north to Tunisia and Algeria in the south (Couhert *et al.*, 1993; Vila, 2008). It prefers regions with a high mean annual temperature and is adapted to prolonged summer droughts (Quezel, 1986). Given its plastic behavior towards climate and soil, the Aleppo pine is the most common tree species in Tunisia with a total area of 296 571 28 ha, representing over 35% of forest land in the country (DGF, 1995). The Kroumirie zone (the North West forest in Tunisia) is characterized by decreasing aridity of the climate from East-South-East to West-North-West. However, the Aleppo pine constitutes an excellence forest essence in this type of ecosystem.

Despite the conservation and protection efforts of this species, mainly used essentially for reforestation, we observe for several years a continual degradation of this essence. Among the degrading factors, the installation of careers near pine forests, accentuates the decrease of growth and the low natural regeneration of the species.

Human activities such as mining, industry, agriculture, waste treatment, and transportation release substantial amounts of trace elements into the environment (Nriagu and Pacyna, 1988; Nriagu, 1990a). Increasing anthropogenic influences on the environment, especially dust careers, have caused negative changes in natural ecosystems; decreased biodiversity, simplified structure, and lowered productivity (Shparyk Y.S., and Parpan V.I., 2004). These degradation processes can be seen especially in forest ecosystems. Deterioration of forest health has been a major concern of the word community for the past 20-30 years (Royal Ministry for Foreign Affairs, 1971; UN/ECE, 1979; Smith, 1981). Dust carriers affect organisms within forest ecosystems, and inhibit decomposition of organic matter on forest floors, which disrupts nutrient cycles (Cotrufo *et al.*, 1995). Anthropogenic elements deposited to forest soils accumulate in the surface layers of the soil (Corwin et al., 1999; Hou *et al.*, 2005a; Ruan *et al.*, 2008)., and are usually immobilized there for a long time (e.g. Friedland and Johnson, 1985; Hawkins *et al.*, 1995).

In particular, smelting, incineration, and transportation release pollutants into the atmosphere. Transportation emits trace elements from fuel combustion (Huang *et al.*, 1994; Wang *et al.*, 2003). Thus, the air around career is rich in trace elements (Mizohata *et al.*, 2000). The fine particulate matter like An, As, Sb and Pb is suspende in air for several weeks and is often transported over large distances. The particulate matter is eventually deposited to soil either directly or via deposition onto vegetation (Takamatsu *et al.*, 2000; Sakata *et al.*, 2006). Therefore, pollution of soil and water by trace elements progresses gradually, even in montane forests far from urban areas.

Although there are no rules or guidelines on montane soil pollution in Tunisia especially in Kroumirie. It is important to analyze current levels of anthropogenic elements in montane forest and to determine potential effects of this pollution. However, such studies have rarely been carried out in Kroumirie and the large-scale impact of dust careers in forest ecosystems is not so evident. The aim of the studies presented here was to identify the impact of dust career emissions on the Aleppo pine forest. Two populations were targeted, the first is located in front of a career and the second has served as a control population.

II. MATERIALS AND METHODS

2.1. Study area

Our study area was located in the Kroumirie zone (the north west of Tunisia) belonging to the Beja governorate characterized by a subhumid climate with mild winters and moderate hot summer. Two natural Aleppo pine populations are chosen: : a reference site 'Charchara' (latitude 36°52'34,10''N, longitude 9012'05,31"E, altitude 349m) located away from mining and Oued el maaden site (latitude 36°54'05,82"N, longitude 9°06'44,86"E, altitude 189m) near a career (Fig. 1). Sites are circular with an area of 500m², that a circle of 12.5m of radius. To note that Oued el maaden population is in front of a career exploited for lead extraction Pb since the 1960 and actually for a gravel extraction since the 1980 (Fig. 2).

FIG. 1. MAP SHOWING SAMPLING LOCATIONS OF ALEPPO PINE POPULATIONS. ★: CHARCHARA ; ●: OUED EL MAADEN.

FIG. 2. OUED EL MAADEN CAREER.

2.2. Data sampling and chronology construction

Biometric parameters

Biometric measurements were taken from all representative trees of each population (60 in Oued el maaden and 54 in Charchara). These parameters correspond to the total height of trees and the diameter growth at 1.30 m from the trunk base.

Soil and water sampling

A soil profile was selected to be the most representative of each station. A large pit has been dug. Then, each soil horizon was refreshed by removing the soil which was in contact with the tools. A maximum of three representative horizons were sampled down the profile. Thereafter, water samples were collected from the existing sources in each site.

Only the fine fraction (< 2mm) of representative samples from soil was chosen to be analyzed. To ensure the representativeness of the sample fraction to be analyzed, each soil sample was carefully separated into four equivalent subsamples. Then, two opposite subsamples were mixed and separated again into four subsamples. This procedure was repeated three times. Finally, the final representative subsample was carefully crushed in an agate mortar.

The main soil parameters (granulometry, pH, organic matter content OM, phosphorus extracted P2O5, content of metal traces ETM) have been analyzed at the INRGREF laboratory of soil Sciences following classical methods (Ponette et al., 1997).

For water samples, they were taken from the main sources at each site (watercourse in Charchara, river and watercourse in Oued el maaden). The analyses conducted aim to characterize the pH, electric conductivity e.c., suspended matter content MES and metal traces ETM parameters.

Dendrochronological approch

Tree-ring width has long been used to reconstruct historical trends in tree vigor and has been shown to be responsive to various environmental factors (Fritts, 1976; Biondi, 1993). Tree rings, if validated as an environmental archive for pollution, would provide a convenient, geographically widespread archive for studying the temporal and spatial distribution of atmospheric pollutants. More recently, metal element concentrations in tree rings have been used as biomonitors of chemical parameters in the environment, including soil solution, chemistry and atmospheric pollution (Padilla and Anderson, 2002; Poszwa et al., 2004).

In our study, dendrochronology is used to determine the impact of dust carrer in growth of Aleppo pine population. We selected six individuals per population and collected cores with a Pressler borer at two levels of each tree (at 0.30m and at 1.30 m from the trunk base). The selected trees are settled in homogeneous stands, with dominant status, healthy, without significant deformation and are not subject to specific microclimatic conditions. After drying and polishing cores, in order to ensure the absence of anatomic abnormalities and to assign for each identifies the exact vintage of its formation, the tree-ring series were interdated (Fritts, 1976). For each population, the crossdating was achieved by seeking to identify the same ring sequences between the two cores of the same tree and between trees from the same plot. The cross dating being made, the thickness of the rings was measured with an accuracy of 1/1000 mm using the measuring table (LINTAB 5; Rinntech, Heidelberg, Germany), a stereoscope (MZ 6; Leica, Wetzlar, Germany) and the TSAP Win Scientific 4.63 soft-ware (Rinntech, 2009). The crossdating was checked visually by comparing the curves of the interannual variation of the rings thickness (Munaut, 1978). Then, to reduce longterm variations related to biological factors (geometric effect, age of individuals, changes in habitat), the sets of raw data were standardized which reduces the fluctuations of low and medium frequencies and lead to compare representative chronologies of each individual (Fritts, 1976). For this, a low-pass filter (window: 20 years) was used.

2.3. Statistical analyses

The relationships between dendrometric parameters (DBH, H) were described using the software STATITCF (ver.F). The measures were the object of an analysis of the variance to one factor following the case, significance levels were established at $P<0.05$. It was completed by a multiple comparison of the averages by the test of Newman-Keuls test (at 5%) according Dagnelie (1986). The graphical exits are realized with the software Exel 2000.

III. RESULTS

A regional climatic analysis was established for 2014. Data taken from button pile located near the two populations studied (Fig. 3).

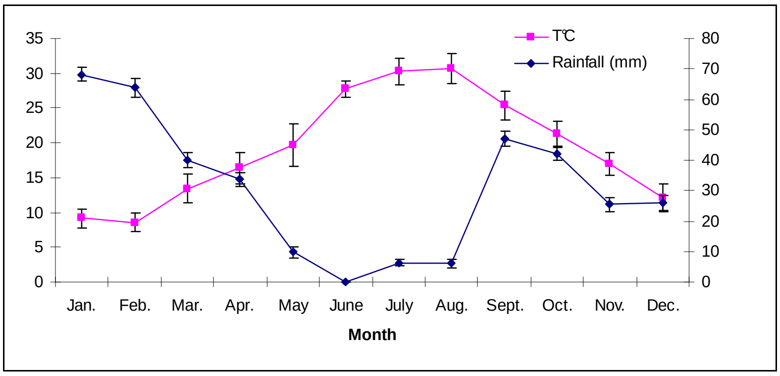

FIG. 3. AVERAGE MONTHLY TEMPERATURE AND RAINFULL AT THE BEJA GOVERNORATE.

Overall growth parameters

Overall growth differed significantly between the two sites (Fig. 4). On average, the trees in Charchara were about 17.75 ± 1.26 m and 39.83 ± 3.00 cm thicker in DBH. However, those of Oued el maaden were respectively 14.08 ± 1.00 m and 26.41 ± 0.8 cm.

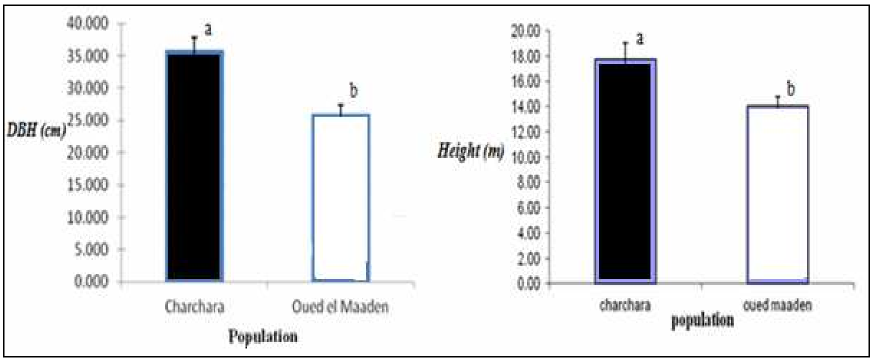

FIG. 4. OVERALL GROWTH PARAMETERS OF THE TWO POPULATIONS; GIVEN ARE MEAN VALUES ± STANDARD DEVIATION FOR EACH POPULATION. RESULTS OF THE NEWMAN-KEULS TEST CALCULATED FOR THE TWO SITES ARE INDICATED BY LETTERS.

Soil and water analyses

The texture of the soils is presented in Fig. 5. Results reveal highly significant values in clay (32.17% ± 5.29) and silt (49.86% ± 3.59) in the Oued el Maaden station. These proportions decreases in Charchara station (22.33% ± 0.83 of clay and 45.17% ± 2.3 of silt).

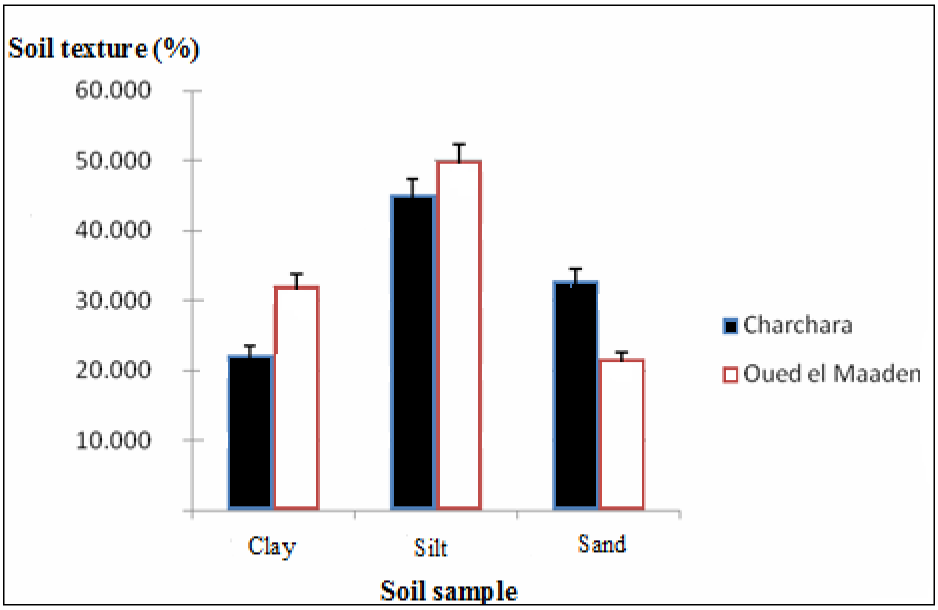

FIG. 5. SOIL TEXTURE OF THE TWO POPULATIONS. RESULTS INDICATE THE AVERAGE VALUE OF THE THREE HORIZONS FOR EACH SOIL SAMPLE (FINE FRACTION < 2 MM).

The soil samples showed pH values which oscillate between 7.05 and 7.85 in different horizons to both profiles of the two populations (Table. 1). The average content of organic matter O.M and phosphorus extracted P2O5 in Charchara soil samples were respectively 4.5 (%) ± 1.5 and 116.87 (ppm) ± 24.18. In Oued el maaden, the O.M content was 4.4 (%) ± 0.3 and the P2O5 was 44.21 (ppm) ± 15.23.

TABLE 1
THE MAIN PARAMETERS ANALYSED OF THE SOIL SAMPLES IN THE TWO POPULATIONS.

Populations	pH	Organic matter content O.M (%)	P2O5
Charchara	7.05	4.5 ± 1.5	116.87 ± 24.18
Oued el maaden	7.87	4.4 ± 0.3	44.21 ± 15.23

Table 2 shows the soil content of metal traces ETM in the two population profiles studied. In all horizons, the abundance order of metal trace content in soil samples is: Pb > Zn > Cd (Table. 2). This abundance was the same on the two sites. The highest values were 256.15 for Pb, 7.95 for Cd at depth-1 (0-10 cm) and 133.15 at depth-2 (10-30 cm) in Oued em maden. There were highly significative average contents of Pb, Zn and Cd in Oued el maaden site (195.48 ± 3.20, 87.24 ± 6.74, 4.61 ± 3.48) compared to Charchara site (81.67 ± 3.44, 37.15 ± 5.24, 2.96 ± 0.33).

TABLE 2
CONTENT AND DISTRIBUTION OF METAL TRACE ELEMENTS IN THE SELECTED SAMPLES (FRACTION < 2 MM).

Station	Depth (cm)	Trace elements		
		Pb	Zn	Cd
Charchara	0 - 10	29.9	25.45	3.7
	10 - 25	218.2	52.6	1.09
	25 - 50	39.2	37.15	3.25
	50 - 80	39.4	33.4	3.8
Oued el maaden	0 - 10	**256.15**	49.47	**7.95**
	10 - 30	248.2	**133.05**	3.15
	30 - 70	82.1	79.21	2.75

For water analyses, there were no significant differences for pH values and electric conductivity 'e.c' between the two sites (Table .3). However, about the pollution level, the suspended matters content 'MES' and the metal traces parameters 'ETM' were highly significant in Oued el maaden compared to Charchara (Table .3).

TABLE 3
THE RELATING PARAMETERS TO THE WATER QUALITY IN THE TWO SITES.

Chronologies

The trees age averages are 29.6 years in Oued el maaden and 36 years in Charchara. The general appearance of chronologies averages by sector (Figure. 6) reveals a rather irregular radial growth in the area of Oued el maaden. Charchara sector presented, at an equal cambial age, growth average significantly higher than Oued el maaden.

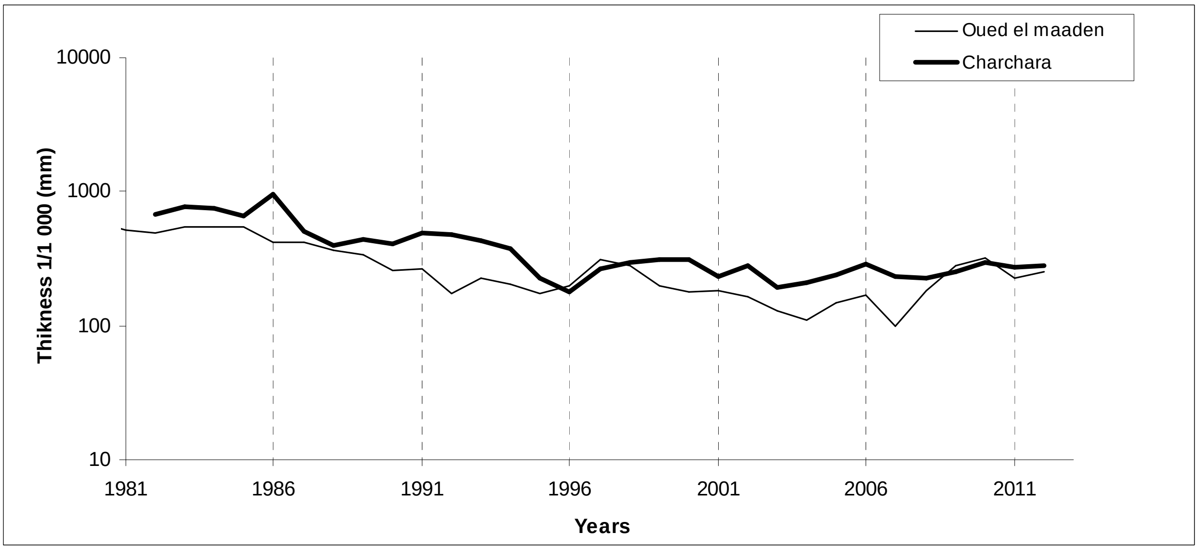

FIGURE 6. MASTER CHRONOLOGIES BY SITE OF PINUS HALEPENSIS POPULATION. THICKNESS OF RAW CIRCLES 1/1000 MM.

Looking at the normalized curves, we noted the disappearance of any age tendency and the geometrical effect, as well as the attenuation of peaks or the depressions of growth (Figure. 7). We observed that trees from Charchara react stronger than from Oued el maaden of 1981 to 2013 to the local conditions.

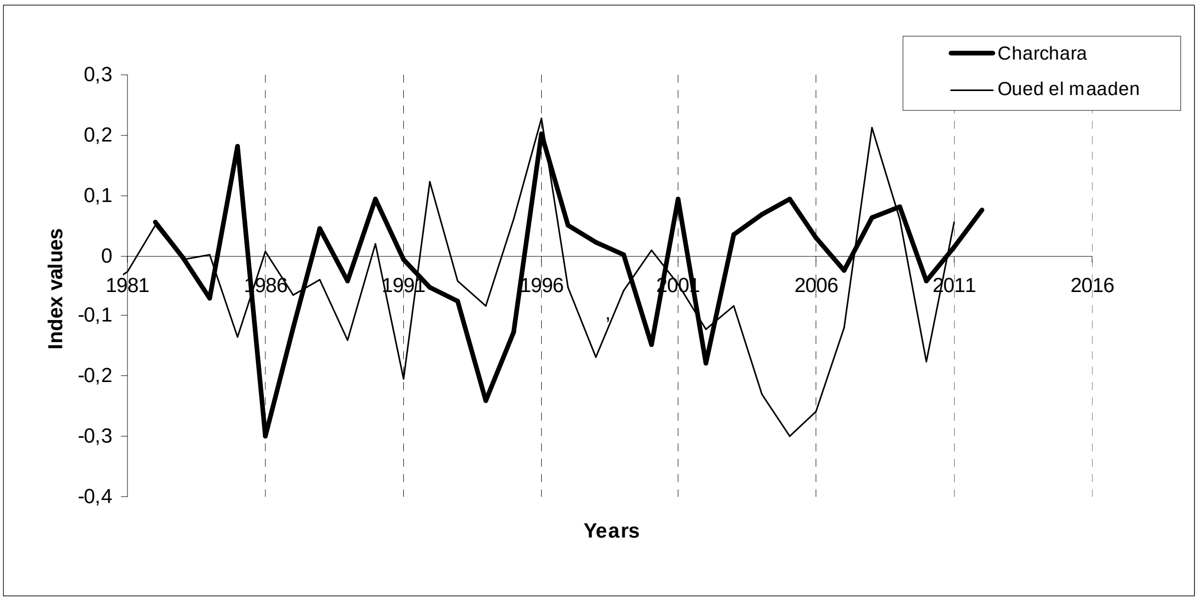

FIGURE 7. NORMALIZED CHRONOLOGIES OF PINUS HALEPENSIS.

IV. DISCUSSION

The impact of heavy metal pollution on ecosystems due to anthropogenic activities like smelting or mining activities has been frequently investigated (Adriano, 1986; Chuan *et al.,* 1996; Cambier, 1997; Dijkstra, 1998; Sheppard *et al.,* 2000). The atmospheric pollutants have affected forests and soils during the last century. Particulary, long range atmospheric transport of heavy metals can lead to pollutant deposition even in supposedly pristine areas (De Vries *et al.,* 2002). This study highlights the impact of dust career emissions on the growth and productivity of Aleppo pine forest.

Soil analyses showed a highly clay content in Oued el maaden than charchara site (Figure. 5). In fact, clays, with their physico-chemical properties, play a very important role in the availability of heavy metals. Indeed, heavy metals can be absorbed and immobilized by clay minerals (Li, 2000). The clay proportion has a great importance for metal behaviour in the different soils and plays a major role in the physico-chemical processes and to metal retention in soils (Hernandez *el al.,* 2003).

The average contents of organic matter O.M under *Pinus halepensis* was ± the same in both sites (Table. 1). This result refutes correlations of this parameter with the average tree height and diameter growth. The relationships between organic matter content and heavy metals found in our soil samples are weak. Harter (1983) and McBride et al. (1997) suggest that the absence of correlation between total soil organic matter content and heavy metal absorption can be attributed to the fact that the reactive fraction of the organic matter could not be assessed in the relationship. It is possible that decreased tree growth resulted from Pb-induced changes in the soil (Selonen *et al.,* 2014) and concomitant changes in soil processes. It is also possible that Pb impared tree growth by damaging tree roots and root-associating mycorrhizal fungi (Malkonen *et al.,* 1999; Hartley-Whitaker *et al.,* 2000; Kukkola *et al.,* 2000; Menon *et al.,* 2007; Sousa *et al.,* 2014).

For evaluation of environmental pollution potential effects, content of metal trace ETM were selected as a basic indicator of anthropogenic influence. Table 2 shows the distribution of Pb, Zn and Cd concentrations in the forest soils of the two Aleppo pine populations studied. It is evident that there is a general regularity in this respect: minimum concentrations are occurring in Charchara soil, while the maximum concentrations are in the career areas of the Oued el maaden region.

Human activities contribute largely to the pollution of Environmental matrices by Pb. This was confirmed in the low Pb traces found in the soil samples from the Charchara station (located at a distance of 15 km to the career). Indeed, this soil has been contaminated by dusts from the mine (Sirven, 2006). Soil Pb contamination is thus rather the result of many years of deposition enriched in transboundary leaded particles of local or regional industrial sources. The soil surface reflects several years of atmospheric deposition. This study highlights that atmospheric pollution inputs have impacted the soils in forest areas, and that soil surface accumulates heavy metals in areas where pollutant inputs are significant but also in more remote areas. Likewise, for water analyses, traces of pollution were highly significant in Oued el maaden site; despite the low concentrations compared in the soil (Table .3).

Tree radial-growth models are valuable for simulating the impacts of environmental conditions changes on the future growth of forest species (Jorge *et al.,* 2012). Wood anatomical features in tree rings have been interpreted as indicators of environmental change (Briffa *et al.,* 2003). In the present study, dendrochronological techniques have been applied to estimate the effects of career pollution on two Tunisian Aleppo pine populations growing under different conditions. Since both sites are in the same climatic, altitudinal and soil conditions (in the Beja region), the difference in radial growth is attributed to the presence of the career. Charchara sector presented a growth average significantly higher than Oued el maaden (Figure 6 and 7). This dendrochronological investigation has demonstrated that the growth dynamics of Aleppo pine forests are affected by a complexity of environmental factors, which mostly involve atmospheric polluants (Battipaglia *et al.,* 2007). Our study shows that not only the climatic factors are critically important for the growth of trees, but also, Human activities such as mining.

V. CONCLUSION

The reaction of forests to activities such as human activities gains more and more importance under future. We found considerable differences in overall growth yield of the two sites. Furthermore our findings suggest that the response of trees depends on the local conditions. We showed that atmospheric pollutants induced changes in the soil, water resources and growth of pine trees. In addition, our findings suggest that some crucial functions such as decomposition of organic matter and primary production strongly depend on the contamination history of the site. The Aleppo pine growth is sensitive to environmental changes and can provide clear evidences of pollution impacts on this ecosystem.

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