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Comparative Effects of Wild Boar (*Sus scrofa*) Rooting on the Chemical Properties of Soils in Natural and Post-Fire Environments of the Edough Forest Massif (Northeastern Algeria)

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Abstract: Wild boars use a wide range of habitats. Their invasive nature is gaining attention due to the complexity of its impact. The goal of this research is to analyze the impact of the wild boar on the chemical properties of soils in a natural and a post-fire forest in the Edough Forest Massif in Algeria. This study compares the impact of wild boar rooting on soil parameters to determine the functional role of the wild boar. The research was conducted during the winter of 2022. The study sites included a natural forest and a post-fire area. Rooting tracks were geolocated and soil samples were collected. The results show significant differences between rooted and control patches in the chemical parameters measured in the two environments. However, in the natural environment, significant differences were only noted for the calcium content and electrical conductivity. But in the post-fire environment, strong significant differences were observed for all measured parameters, suggesting that wild boars do not exert a noticeable soil homogenization effect on the soil properties. This research highlights the importance of understanding and managing the impact of wild boars in natural and post-fire forests on soil formation processes, the diversity of soil properties, and their magnitude.

Keywords: wildlife impact; soil disturbance; soil properties; comparative analyses

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1. Introduction

The wild boar (*Sus scrofa*) is one of the most controversial wild species due to its invasive and prolific nature, ranking among the top 100 worst invasive species responsible for agricultural crop damage and conflicts with humans [1–3]. However, this ecosystem engineer plays a crucial role in its native habitats, including forests: it regulates the density of plant species and disperses fruit seeds through its feces, facilitating the spread of various (including invasive) plant species [4–8]. It contributes to the balance of populations in the trophic chain, particularly for insects and micromammals. It also aids soil aeration and soil organic matter formation [9] while causing physical modifications to the habitat, affecting soil structure and composition [10]. These findings emphasize the importance of developing management and monitoring strategies for wild boar populations to maintain the carrying capacity of forest ecosystems and, consequently, mitigate potential damage in agricultural areas [11], wetlands [12], and urban environments where the species has penetrated.

There is a never-ending debate about the role of the wild boar. Is it a natural effect or is it a damage that we see when we encounter wild boar rooting? Since wild boars have been in the investigated area during the formation of recent soils, one must consider that—in addition to other factors—wild boars played a crucial role in the formation of the soils that we can see today. The question of where the population size should end is a complicated one and is perceived by many interested parties from many points of view: foresters, hunters, wildlife biologists, wildlife managers, rangers or nature conservationists in general, tourists, joggers, walkers, technical sports enthusiasts, parents, etc., all have their own specific view or perception of the same situation [8–12].

Mediterranean forests have faced numerous environmental and anthropogenic pressures, including deforestation, fragmentation, and especially wildfires in recent years, which have had devastating effects on vegetation cover and associated fauna [13–15].

In this study, we investigate the role of the wild boar and its effects on the quality of forest soils. This study was conducted in the Edough Mountain Massif, a region in northeastern Algeria that is part of a regional biodiversity hotspot and is considered an endemism center for many plant species [16]. Like all Mediterranean forests, this area has been exposed to numerous wildfires, the recurrence of which could threaten the integrity of this biodiversity hotspot [17]. Due to climate change, it is predictable that precipitation and temperature will change dramatically in the near future, possibly causing more wildfires. This is why the investigation of the effects of fires with the combination of wild boar rooting on soil parameters can help to find the appropriate number of wild boars (or, more generally speaking, the optimal population size) in these forests.

We hypothesize that soil bioturbation by wild boars has different effects when other factors such as wildfires are prevalent.

The objective of this study is to analyze the impact of wild boar activity on soil chemical parameters in natural forest and post-fire forest environments and to deduce the functional role played by the wild boar in each environment.

2. Materials and Methods

2.1. Short Description of the Studied Areas

This study was carried out on the Edough Peninsula during the winter period of 2022 (from the end of December until the end of February). The Edough Mountain Range is located in the extreme north-east of Algeria, with 35,423 hectares of forest area and 4880 hectares of maritime area, and is limited to the south-east by the Guerbès Senhadja wetland complex, to the south by the Fetzara Lake Basin, to the west by the lower course of Oued El Kébir, and by the Kharraza Plain to the east; to the north, the peninsula is bordered by the Mediterranean Sea [18]. A Mediterranean-type climate and northeast winds prevail in the region. The Edough Massif is populated on its northern slope by forest species. The Edough Massif corresponds to crystalline, eruptive, sedimentary, and metamorphic formations. Lithological analysis reveals a large area occupied by Numidian sandstones and another by gneisses. These siliceous rocks provide an acidic substrate, and the soils resemble brown forest soils (Cambisols and Luvisols) and shallow soils (Leptosols) on steep slopes where water erosion is a natural phenomenon. The combination of humidity and acidity sometimes results in soils with podzolic tendencies, especially those forming on Numidian sandstones [19]. We chose two sites for sampling, mainly based on the significant and regular presence of traces of rooting by the boars: the natural site of Bouzizi and the post-fire site of Aïn Barbar (Figure 1).

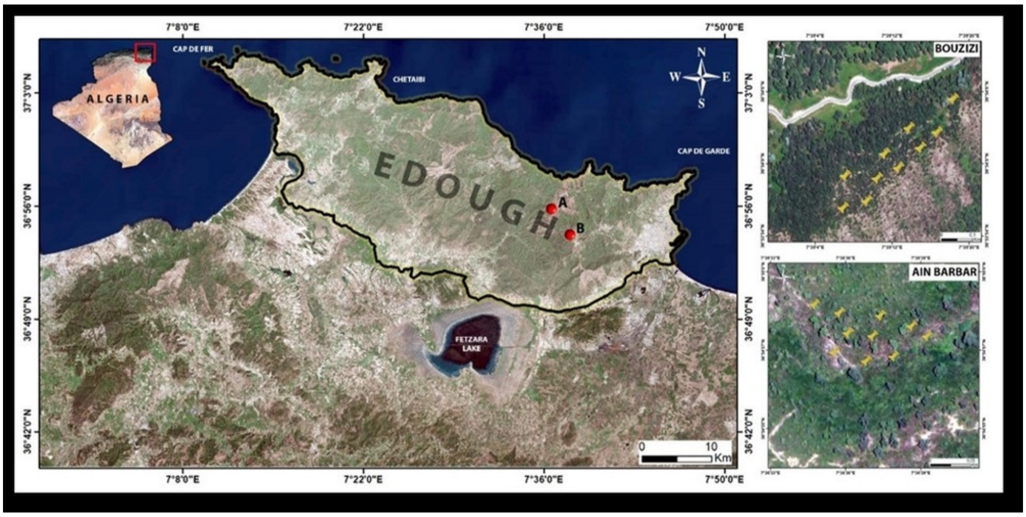

Figure 1. The study area with sampling sites of wild boar rooting in the north-east corner of Algeria (A: Aïn Barbar; B: Bouzizi. Source: Google Earth).

The Bouzizi forest (36°53′59.7″ N–7°39′10.2″ E) is located in Algeria, southeast of the Edough Massif, between 800 and 850 m above sea level. This locality is characterized by cork oak (*Quercus suber* L.) forests and its rich associated floristic procession. The post-fire forest of Aïn Barbar is located near the road (36°55′03.8″ N–7°36′43.0″ E). The area burnt down totally in August 2021. The locality was characterized by the dominance of the cork oak and by the presence of some specimens of the zean oak (*Quercus canariensis*) and maritime pine (*Pinus pinaster*), located at an altitude of 579 m above the Mediterranean Sea (Figure 2).

Figure 2. Photos of the two study sites. (**A**): natural site of Bouzizi, (**B**): post-fire site of Aïn Barbar (on the right) (Photo: Kamelia Benotmane, 5 January 2022).

Figure 2 shows the characteristic differences between the two study sites. The burnt site after 4–5 months shows some regeneration effects, and there are some flowering plants already on the soil surface.

Both sites are characterized by shallow soils. The A horizon is 28–38 cm thick, its color is black, the texture is loamy sand, the lime content is zero, roots are present in the whole depth of the horizon, it is slightly compacted, and the soil moisture was low at the time of the evaluation. Below the A horizon there is the C horizon; its color is yellow, the texture is loamy, the lime content is zero, roots are visible as deep as 72 cm, and it is medium compacted and also dry. Wild boars did not reach the C horizon during their rooting activities.

2.2. Soil Sampling on the Field

Sampling was carried out from the end of December 2021 until the end of February 2022, with two prospecting trips per month, to identify new rooting. The selection and sampling protocol was carried out according to the method of Pitta-Osses et al. (2020) [8]. Only so-called deep rooting was considered during the measurements, meaning that there is a visible/considerable depth (e.g., approximately a minimum of 20 cm) of the inner part of the rooting, and the deep rooting is surrounded by a visible and distinguishable ring formed from the excavated soil material (Figure 3). This deep rooting differs from shallow rooting by its spatial extent; while one deep rooting is approximately typically 1–5 m^2, shallow rooting is typically 5–50 m^2. Each rooting was geolocated by the Map mobile application (Figure 3).

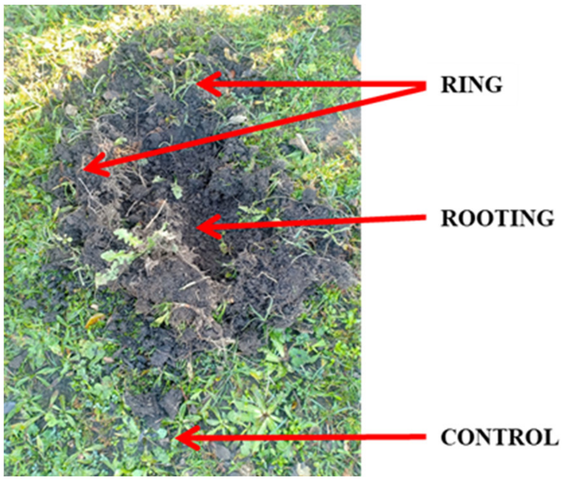

Figure 3. The photo of the rooting where standard measurements were taken in each rooting, ring, and nearby control area (Photo: Benotmane, K., January 2021, Edough).

During the winter period, 10 rooting areas in the natural and 10 rooting areas in the burnt area were sampled from 0 to 20 cm depths. Three samples of 250 g of soil were taken from each rooting: one in the middle of the dug-out depression (rooting), the second from the ring that surrounds the rooting (ring), and the third as a control or outside the rooting (control), which was taken next to the rooting at the intact surface. A total of 60 samples (30 in a natural area and 30 in a burnt area) were collected for analysis.

2.3. Laboratory Analysis of the Soil Samples

Soil samples were dried at ambient temperatures for about 5 days, crushed and sieved with 2 mm sieves, and then analyzed for different chemical properties: total calcium (Ca mg/L), total magnesium (Mg mg/L), total potassium (K mg/L), and total sodium (Na mg/L) were determined by extraction with buffered ammonium acetate at pH 7.0 before reading with an atomic absorption spectrometer for Ca, Mg, and K and Na with a flame spectrometer [20]. Total nitrogen (N %) was determined by the Kjeldahl method [21] and phosphorus (P mol/L) was measured by colorimetry using the Murphy and Riley methods [22]. Electrical conductivity (EC mS/cm) was measured by a conductivity meter [23]. The equivalent calcium carbonate was determined by the gasometrical method (Bernard's Calcimeter). The pH was determined by using a pH meter (HANNA HI 8520) after mixing soil with distilled water (1:2.5 w/v) [24]. Samples were digested in a mixture (3:1) of Nitric Acid (HNO_3) and Perchloric Acid ($HClO_4$), and the contents of Ca (mg/L), Mg (mg/L), and K (mg/L) were determined using an atomic absorption spectrophotometer (AAS) (Model Analyst 700, Perkin Elmer).

2.4. Applied Statistical Analyses for Evaluation of Soil Data

Statistical analysis of the data was conducted in R (R Development Core Team, 2021) using separate factorial MANOVA tests for the two study sites to depict local differences in soil parameters affected by wild boar rooting. Furthermore, we implemented an additional MANOVA test to verify the effect of fire disturbance, wild boar rooting, and their interaction on soil parameters in general. Pillai's trace was used as a test statistic in all cases. Variables were checked for multicollinearity; neither of them showed high correlation ($r_{max} < 0.65$). Visualizations were created with the *ggplot2* package [25]. We also performed a principal component analysis with the Minitab (version 14) software. The first component included the chemical elements, and the second component represented the different sampled groups (rooting, ring, and control).

3. Results

3.1. Analysis of the Wild Boar's Impact on the Natural Environment (Bouzizi, Algeria)

The results of the MANOVA test performed on soil data collected from the natural environment revealed differences between the characteristic parts of the rootings ($F(16, 42) = 6.08$, $p < 0.001$; Pillai's trace = 1.39). However, the related univariate test revealed that only the calcium content and electrical conductivity (EC) differed between groups (Table 1). This suggests that the rooting activity of wild boars did not cause major changes in the general composition of the soil, except for a few specific elements (calcium: control = 247.8 ± 26.9, ring = 257.9 ± 40.9, rooting = 202.9 ± 41.1 mg/L; EC: control = 0.15 ± 0.02, ring = 0.19 ± 0.03, rooting = 0.18 ± 0.02 mS/cm).

Table 1. Univariate test statistics of separate MANOVA tests performed on soil attribute data. The rooting effect (rooted area, ring, control) was used as an explanatory variable.

	Bouzizi (Rooting)	**Aïn Barbar (Rooting and Fire)**
df	2	2
K	3.08	22.3 ***
Na	0.92	7.27 **
Mg	1.32	11.9 ***
Ca	6.3 **	103.3 ***
P	3.32	45.36 ***
N	0.97	26.5 ***
pH	0.53	24.5 ***
EC	10.9 ***	26.3 ***
Residuals:	*27*	*27*

*** $p < 0.001$; ** $p < 0.01$.

The calcium content was the lowest in the core part of the rooting, while it was nearly similar in samples collected from the redistributed soil (ring) and the control (Figure 4). Additionally, the electrical conductivity was the lowest in samples free from wild boar disturbance (control) and higher in the rooting and the ring, with extremes at both ends of their ranges (Figure 4).

These results indicate that, although the overall impact of wild boars on soil composition in a natural environment is limited, they can nevertheless have significant local effects on certain chemical elements in the soil.

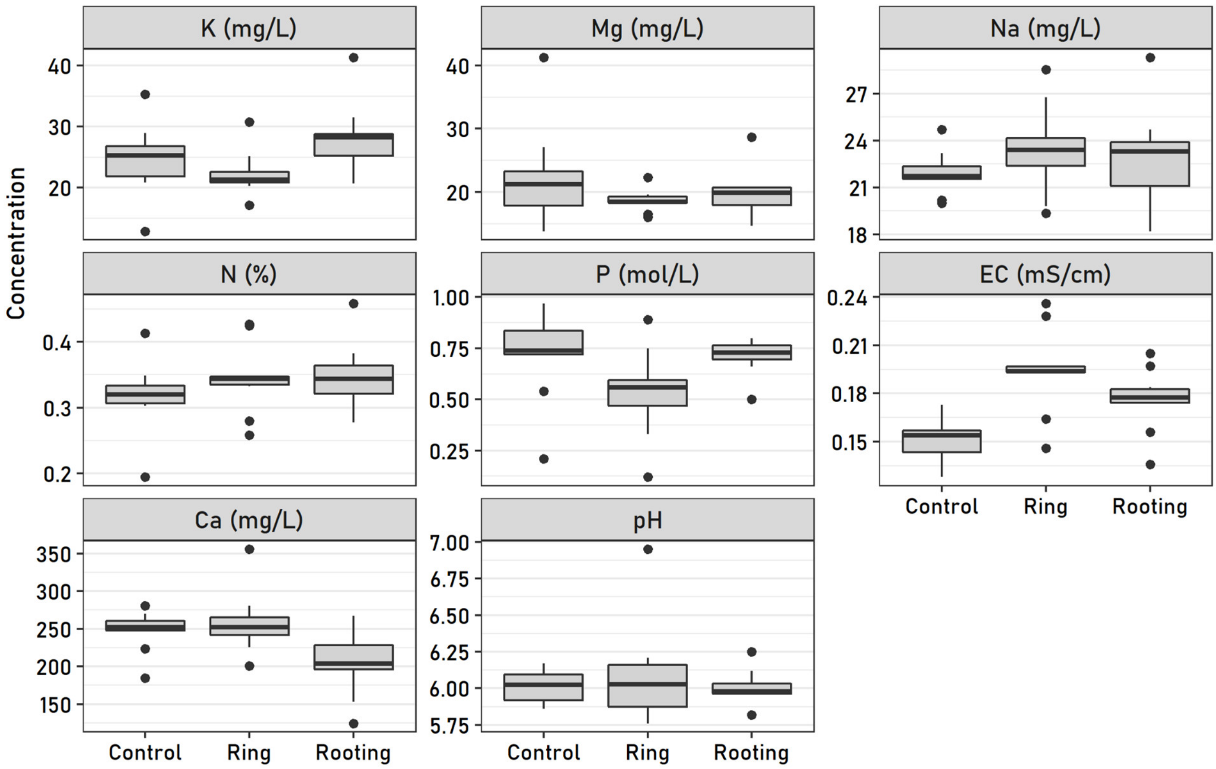

Figure 4. Boxplots showing the distribution of the measured soil parameters originating from Bouzizi, where wild boar rooting but no wildfire occurred. (Boxes show the interquartile range, the black line in the box shows the median value, whiskers show the maximum and minimum values except for outliers, and dots show outlier values.)

3.2. Analysis of the Wild Boar's Impact on the Post-Fire Environment (Aïn Barbar)

The results obtained in the post-fire environment indicate statistically significant differences regarding wild boar rooting ($F(16, 42) = 19.23$, $p < 0.001$; Pillai's trace = 1.76). This was confirmed for all measured soil parameters (Table 1). Contrasts were more pronounced in relation to the control samples. Potassium, sodium, nitrogen, phosphorus, electrical conductivity, calcium, and pH levels were equally the lowest in samples collected from plots free from wild boar disturbance, while in the case of magnesium, we observed quite the opposite (Figure 5).

The variability in parameters among groups was much larger in this post-fire environment than in the first study site where only wild boar disturbance occurred (Table 2).

Table 2. The mean and standard deviation of the measured soil parameters in Aïn Barbar, where wild boar rooting occurred after a wildfire.

	Control	Ring	Rooting
K (mg/L)	13.6 ± 2.2	25.6 ± 4.2	24.3 ± 6
Mg (mg/L)	30.8 ± 5.3	27.5 ± 3.3	22.2 ± 2.9
Na (mg/L)	19.8 ± 1.4	19.2 ± 2	22.7 ± 3
N (%)	0.21 ± 0.04	0.34 ± 0.03	0.32 ± 0.05
P (mol/L)	0.16 ± 0.07	0.62 ± 0.15	0.41 ± 0.1
EC (mS/cm)	0.13 ± 0.02	0.21 ± 0.03	0.19 ± 0.03
Ca (mg/L)	188.7 ± 31	395.8 ± 25	331.7 ± 41
pH	5.9 ± 0.2	6.5 ± 0.1	6.2 ± 0.2

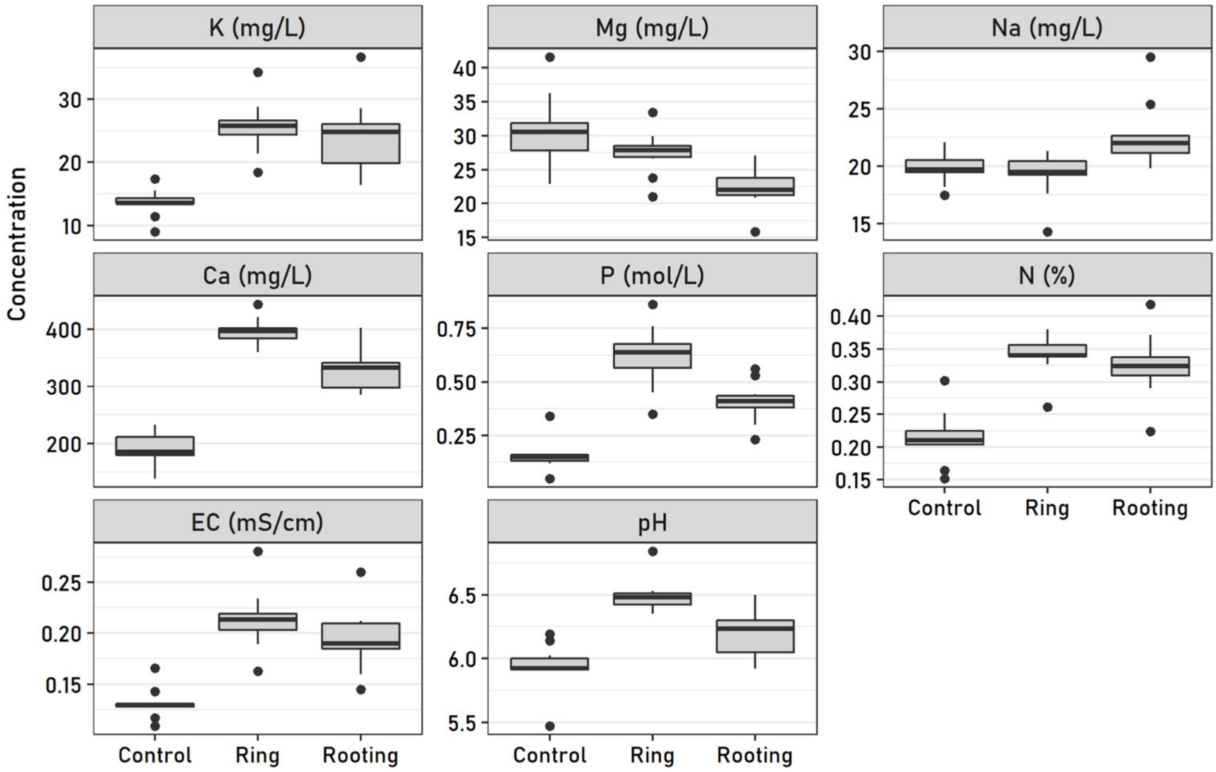

Figure 5. Boxplots showing the distribution of the measured soil parameters originating from Aïn Barbar, where wild boar rooting occurred after a wildfire. (Boxes show the interquartile range, the black line in the box shows the median value, whiskers show the maximum and minimum values except for outliers, and dots show outlier values.)

3.3. Comparative Analysis of the Wild Boar's Impact between the Natural Environment (Bouzizi) and the Post-Fire Environment (Aïn Barbar)

The final MANOVA test on the joint dataset of the two study sites verified our hypothesis that soil bioturbation by wild boar has different effects when other factors such as wildfires are prevalent. The soil parameters were statistically different between the study sites, rooting effect groups, and with the combined impact of wild boar and fire disturbance (Table 3).

Table 3. Multivariate test statistics of MANOVA performed on soil attributes data. The study sites (Aïn Barbar and Bouzizi), the groups of the rooting effect (rooted area, ring, control) and their interaction were used as explanatory variables.

	df	**Pillai's Trace**	**F**
Study site	1	0.85	29.37 ***
Rooting	2	1.38	11.65 ***
Study site × Rooting	2	1.17	7.35 ***

*** $p < 0.001$.

Almost every parameter was significantly different among groups of the studied factors (Table 4), but we need to note that the confirmed significant effects for rooting alone come from the effect of merging the datasets of the two areas and were largely affected by the significant differences observed in the Aïn Barbar area (see Table 1).

Table 4. Univariate test statistics performed on soil attribute data. The study sites (Aïn Barbar and Bouzizi), the groups of the rooting effect (rooted area, ring, control), and their interaction were used as explanatory variables.

	Study Site	Rooting	Study Site × Rooting
df	*1*	*2*	*2*
K	9.3 **	11.2 ***	11.1 ***
Na	12.7 ***	3.5 *	3.8 *
Mg	30.9 ***	7.4 **	3.3
Ca	58.5 ***	48.3 ***	50.5 ***
P	45.3 ***	5.5 **	23.9 ***
N	12.7 ***	15.9 ***	6.2 **
pH	12.8 ***	11.8 **	7.4 **
EC	0.9	36.6 ***	4.4 *
Residuals: 54			

*** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$.

On the other hand, significant interactions of the site and rooting indicate that wild boar rootings could have various effects on soil properties depending on the presence/absence of fire disturbance. In the case of potassium, its concentration was different between sites without rooting (control: Bouzizi = 24.6 ± 5.8 vs. Aïn Barbar = 13.6 ± 2.2 mg/L), but wild boar rooting induced the convergence of these tendencies (Figure 6). In contrast, sodium levels were the most different in the redistributed soil (ring) between the natural environment and the post-fire site (ring: Bouzizi = 23.5 ± 2.8 vs. Aïn Barbar = 19.2 ± 2 mg/L), and its levels were more similar even in the rooting or in the control samples.

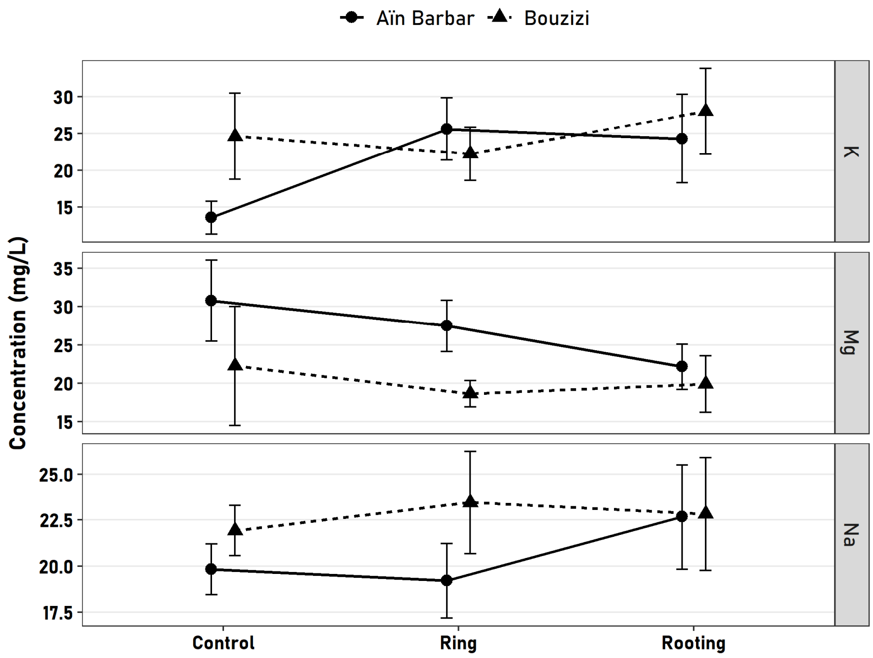

Figure 6. Interaction plots of rooting and site effects on potassium, magnesium, and sodium content of the soil. The solid line with black points indicates data collected from Aïn Barbar, the dotted line with black triangles indicates data collected from Bouzizi.

The same converging tendencies can be observed in total nitrogen and phosphorus (Figure 7), where the redistributed soil (ring) showed very similar levels (nitrogen: Bouzizi = 0.34 ± 0.05 vs. Aïn Barbar = 0.34 ± 0.03%; phosphorus: Bouzizi = 0.53 ± 0.21 vs. Aïn Barbar = 0.62 ± 0.15 mol/L), while calcium levels tend to separate in rooted patches between the two sites, as noted in the case of phosphorus.

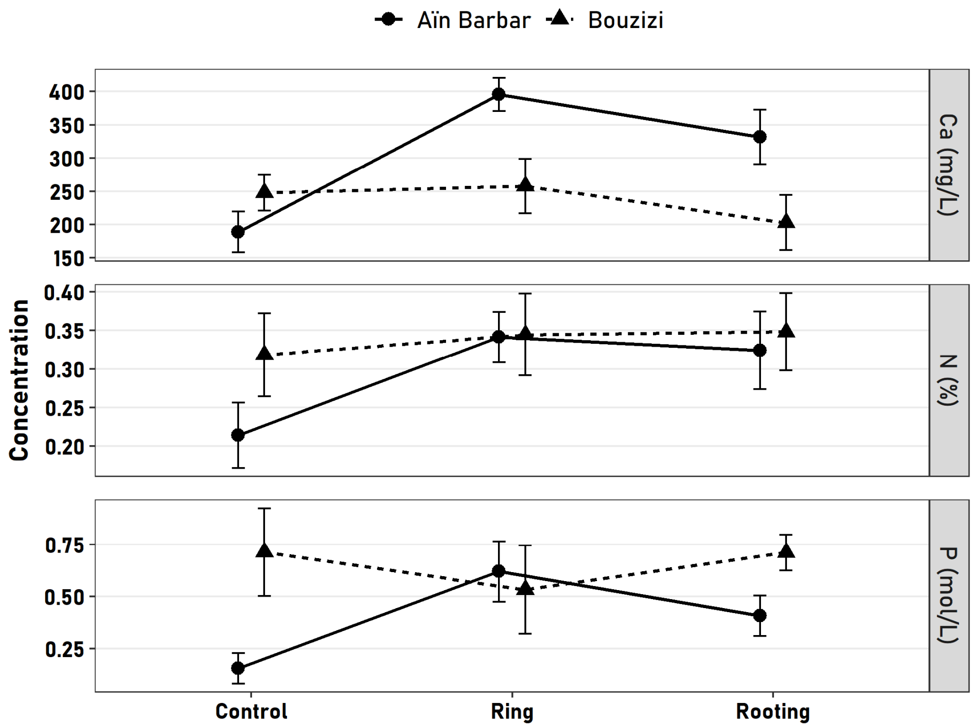

Figure 7. Interaction plots of rooting and site effects on calcium, total nitrogen, and phosphorus content of the soil. The solid line with black points indicates data collected from Aïn Barbar, the dotted line with black triangles indicates data collected from Bouzizi.

Electrical conductivity values were similar between sites; only rooting affected them significantly (Table 4). The variability was not impressive considering the pH of the samples, but still reached a significant difference between sites and among rootings, where the differences were the highest in the redistributed soil (ring: Bouzizi = 6.1 ± 0.3 vs. Aïn Barbar = 6.5 ± 0.1) (Figure 8).

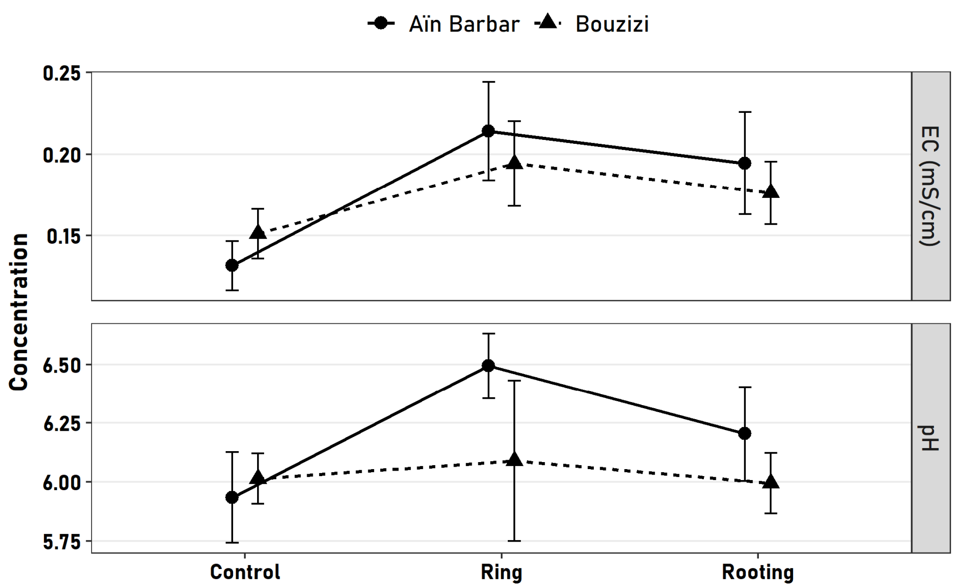

Figure 8. Interaction plots of rooting and site effects on electric conductivity and pH of the soil. The solid line with black points indicates data collected from Aïn Barbar, the dotted line with black triangles indicates data collected from Bouzizi.

3.4. Principal Component Analysis on Soil Parameters of the Two Study Sites

We conducted a principal component analysis (PCA) by correlating all the chemical parameters of the soil in two types of environments (Figures 9 and 10).

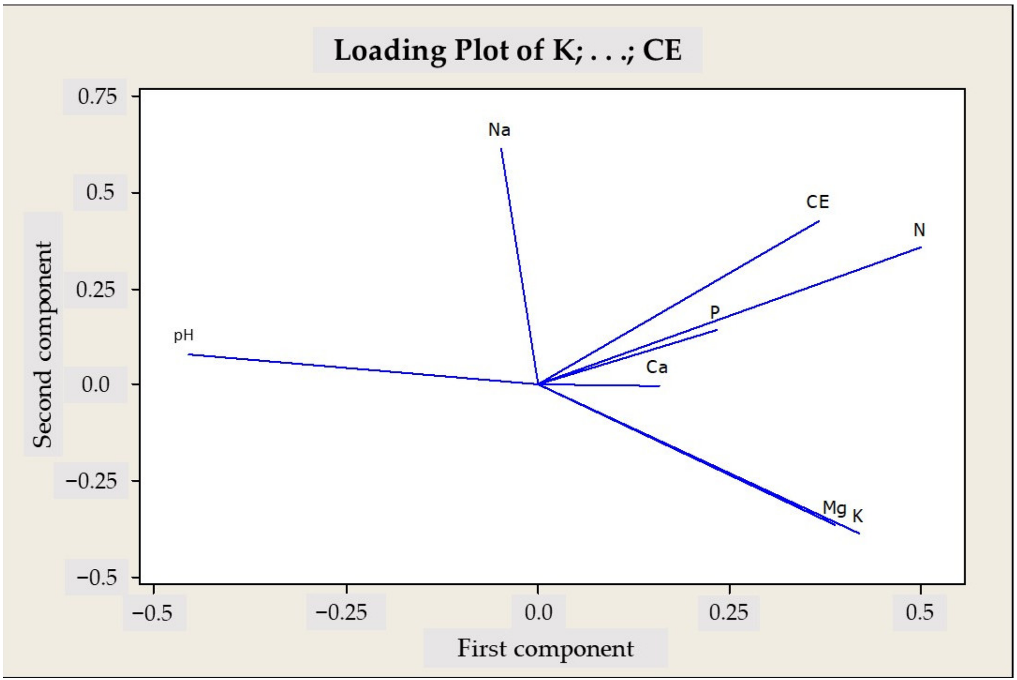

Figure 9. Principal component analysis of the measured parameters of the soil in the natural forest of Bouzizi, Algeria. First component: the chemical elements; second component: rooting, ring, and control.

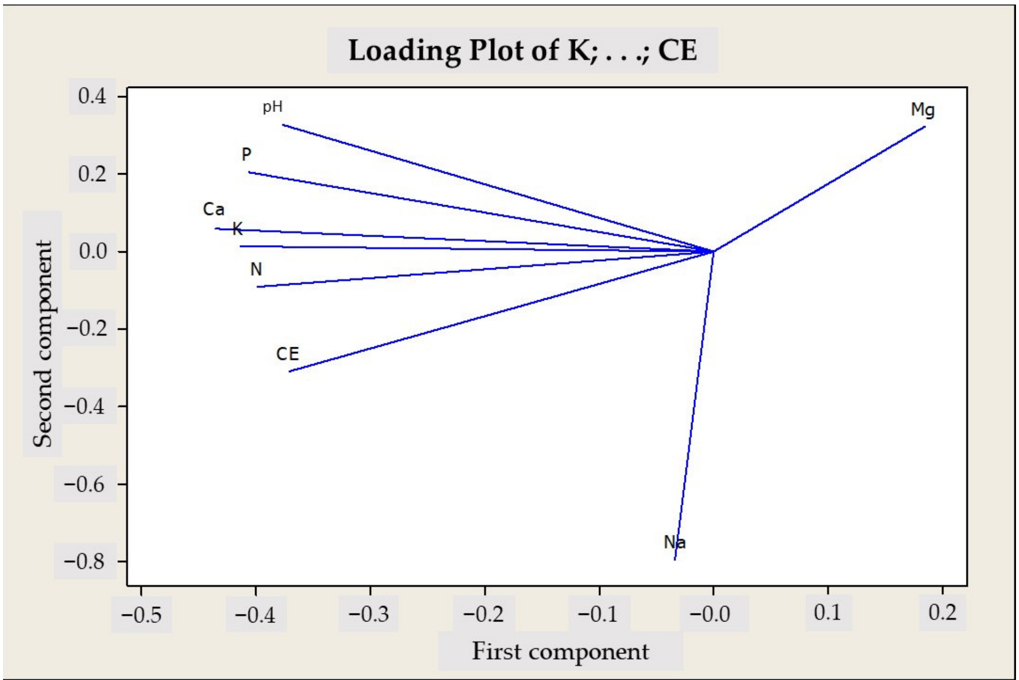

Figure 10. Principal component analysis of the measured parameters of the soil in the post-fire forest of Aïn Barbar, Algeria. First component: the chemical elements; second component: rooting, ring, and control.

This analysis revealed the following findings:

- In the natural environment, pH, Na, and Mg and K appear to behave separately from the other parameters.
- In the post-fire environment, pH has a positive correlation with P, Ca, and K.
- Magnesium (Mg) is negatively correlated with the other parameters in the post-fire environment.
- Magnesium (Mg) and potassium (K) are strongly positively correlated in the natural environment, whereas Mg tends to be negatively correlated with other components in the post-fire environment (just as well as sodium).
- In both environments, sodium (Na) exhibits a negative correlation with the other parameters.

4. Discussion

Rooting is a trophic behavior of wild boars in the forest environment that results in soil renewal, leading to its aeration, as well as improved oxygen penetration and the mixing of nutrients and organic matter [26,27]. Several studies have highlighted numerous positive effects of this species, which exerts a natural plowing effect on the soil [6,8,28]. These studies have rehabilitated the functional role of the wild boar, which appears to be ecologically beneficial for both fauna and flora, and especially for the soils of the environments they colonize [29]. The rooting effect is particularly crucial for improving physical characteristics, as it even contributes to slowing down the erosion process by creating depressions to halt water runoff [8]. These benefits can be advantageous for other ecologically important animal groups, such as amphibians, earthworms, and insects, many of which rely on consistently moist soils for feeding and breeding, and for which the use of these rootings and depressions in the soil caused by ungulates has been reported [8,30]. This soil humidification action also allows for better growth of organisms that colonize the soil (soil microfauna and macrofauna) [30]. Our results are consistent in some cases with existing studies, as we observed a modification of the analyzed chemical parameters between the rooting, ring, and control zones. In the same study area, Benotmane et al. [31] found no statistically significant differences in soil chemical parameters in the natural forest environment, except for organic matter. Other studies, such as Singer et al. [32], have observed that disturbed soils had lower concentrations of certain elements, such as Ca, P, Mg, Mn, Zn, Cu, H, and N, as well as reduced cation exchange capacity. Siemann et al. [33] noted an increase in the nitrogen mineralization rates in rooted plots in deciduous pine forests in the United States. The work by Bruinderink and Hazebroek [34] and Mohr et al. [35] found no effect of rooting on characteristics such as soil horizon depth, soil pH, organic matter, and nitrogen content. A more recent study showed that some values do not illustrate significant differences but suggest that wild boars engage in a natural plowing action by mixing litter with the upper mineral horizons of the soil, resulting in a more homogeneous distribution of nutrients [36–39].

The results obtained in the post-fire environment, a few months after the fire, highlight significant differences between the values of the chemical parameters in the three analyzed zones (rooting, control, and ring). In the literature, it is well established that wildfires have an impact on the chemical properties of soils, especially in Mediterranean ecosystems [40–42]. Many studies indicate a substantial increase in nutrients immediately after a fire event [41,43–46], caused by the combustion of vegetation and debris, which significantly affects their availability. Our study supports these findings, as we observed very high concentrations of K, Na, Mg, Ca, P, N, pH, and EC in the examined soils. The PCA analysis reveals two distinct configurations that suggest that, unlike in the natural environment, wild boars do not exert a noticeable soil homogenization effect in the post-fire forest. Few studies have assessed the effects of fires on herbivore diversity profiles, establishing a connection between fire occurrence gradients, climate, soil fertility, and the alpha and beta diversity profiles of ungulates [47–49]. The recent works of Lewis et al. [50] showed that fire severity and wild and domestic ungulate herbivory can strongly influence the long-term (10 years post fire) regeneration and recruitment of plant species over varying durations.

Similar disturbances occur in soils when other natural phenomena happen. In the Tatra Mountain, windfall caused losses of all measured nutrients (Ca, Mg, K, Fe, Al, ammonium-N, nitrate-N, S) except P [51]. These nutrient leaching were due to the strongly acid soils (pH 3.0–4.5). The examined area of Algeria did not have this very low pH so the results are not comparable.

Regardless of the lack of data, mainly concerning the joint impact of forest fires and wild boar rooting, we tried to build some foundation on the findings of the recent research, and taking into account the complexity of the soil, some statistical data could establish some of our further discussion in this manner. For example, not strictly speaking but searching for solutions, our results might help to evaluate the magnitude of wild boar impacts by taking the following findings into account:

(a) The statistical tests confirmed differences in soil parameters between sites, rooting effects, and the interaction of the two. This suggests that each site has its own specific soil system that can react differently to biotic and abiotic disturbances like wild boar rooting or wildfires. Since we lack soil data of the pre-fire status from Aïn Barbar, we cannot depict the extent of how significant the impact of wildfire could be on the alteration of soil attributes. If we can consider the two sites rather similar in their pedological attributes, then forest fires did exert a notable impact on soil life and its parameters (Table 4). For example, phosphorus levels were statistically different between sites as well: this can be the result of receiving extra phosphorus from the ashes after the forest fire.

(b) While forest fires can highly affect topsoil layers, bioturbations by wild boars could reach deeper in the soil, homogenizing layers and nutrients or creating much larger disparities in nutrient levels. We found examples for both cases (Table 1), but it seems that bioturbation's effects were more prevalent in the post-fire environment.

(c) This twofold effect of wild boar rooting was also confirmed when the interacting terms of fire and rooting were tested (Figures 6–8). The redistributed soil showed especially high variability in this context: some soil parameter levels converged (N, P, K), while others tended to separate here (Na, Ca, pH).

As soils are very complex and very diverse, these considerations might help in the further evaluation of the effect of wild boar rooting, especially on areas after forest fires, as there is very little information available from the literature. The size of the deep rooting is obviously an important influencing factor on water retention, missing the less permeable ash layer and thus helping the infiltration of rainwater into the soil, which can also prevent soil, nutrient, and water runoff, reducing the effect of soil water erosion as described by Pitta-Osses et al. [8].

5. Conclusions

The comparison of the rooting, ring, and control areas of wild boar rooting at two Algerian sites proved that wild boar have more significant effects on the soil parameters (K, Na, Mg, Ca, P, N, pH, EC) in natural environments than after a recent forest fire.

Based on the literature review, we can also conclude that the Algerian natural (non-disturbed = non burnt) site is similar to those natural forest areas described in numerous studies from the wild boar rooting point of view (with lots of non-significant effects).

The last conclusion is that more research is needed on the analysis of the effects of wild boar rooting in areas after forest fires, by regular and progressive monitoring of edaphic parameter characterization, over long periods (up to 10 years post fire). This can help us to assess when the wild boar's action becomes beneficial for forest regeneration, and to deduce the processes influenced by the rootings after forest fires.

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