

Physical and Chemical Properties of the Soils at Burned and Unburned *Pinus brutia* Ten. Forest Sites in the Marmaris Region, Turkey

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Abstract

The aim of this study was to determine the long-term post-fire changes to the physical and chemical properties of the soil in *Pinus brutia* Ten. forests found on ophiolitic rocks in the Marmaris region, southwestern Turkey. Six sites that had burned at different times (3, 6, 8, 9, 16, 26 years ago) and two sites that had not burned for a long time (at least 50 and 100 years) were selected. Three plots 1 ha in size were randomly selected within each site, and three soil samples were collected from randomly selected points within each plot. Soil texture, pH, CaCO₃ content, organic matter content, electrical conductivity, and exchangeable cation concentrations of the soil samples were determined. Soil texture did not vary among the study sites, and percentages of sand, silt, and clay did not differ significantly among the study sites. Organic matter content was significantly higher at unburned sites, but was similar at all the burned sites. There was no significant difference between the three-year-old site and the other sites in terms of exchangeable cation concentrations, electrical conductivity, pH, or amount of CaCO₃. Although there were some slight trends with time since the fire for some of the variables evaluated, soil properties did not change drastically with time, or at least changed without a trend among the study sites. This was attributed both to the importance of studying early post-fire years to detect a change in soil properties, and of site heterogeneity.

INTRODUCTION

Pinus brutia Ten. (Turkish red pine), an important tree for wood production in Turkey, constitutes vast forest areas throughout western and southern

Anatolia. Although these forests have suffered frequent fires, the recovery of vegetation occurs rapidly [1], and several management tools can be used for the regeneration of *P. brutia*, including prescribed fires [2].

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However, the increase in the frequency of fires in the Mediterranean basin in recent years has resulted in soil loss and some regeneration problems in fire-sensitive pine woodlands [3,4]. Therefore, post-fire recruitment of Mediterranean pine species, such as

P. brutia, may depend on the chemical conditions of the soil. Moreover, changes in the chemical and physical properties of the soil after fire may affect even the recovery of fire-tolerant resprouter species [5]. Therefore, it is important to study the soil properties of burned sites in fire-prone areas before management decisions are made [6,7].

There is still shortage of information regarding post-fire changes of soil properties in woodlands dominated by *Pinus brutia* [but see; 8-11] and other pine species [12,13] in Mediterranean Basin. Moreover, the studies mostly interested in short-term changes in soil properties after fire, and long-term changes were rarely focused on [13].

The aim of the present study is to answer the question of how physiochemical properties of the soil in *P. brutia* forests change after fire in long-term. To achieve this aim, soil properties of burned and unburned *P. brutia* stands found on ophiolitic rocks and serpentine soils were investigated by using the synchronic approach (sampling stands with different ages at the same time).

MATERIALS AND METHODS

The study was conducted within an approximately 250 km² area in the Marmaris region, in southwestern Turkey (36° 54' N, 28° 12' E) in the summer of 2005. The study area has a sub-humid Mediterranean climate with dry summers. According to data obtained from the Turkish State Meteorological Service (Marmaris Meteorological Station at 19 m a.s.l.), the mean annual amount of rainfall is 1212 mm and the annual mean temperature is 18.7°C. *Pinus brutia* forests constitute the dominant vegetation cover throughout the study area. The area has suffered many fires over the last 30 years, resulting in a mosaic of post-fire successional stages around the region.

Six sites that had burned at different times (3, 6, 8, 9, 16, 26 years ago) and two sites that had not burned for a long time (at least 50 and 100 years) were selected. All sites were located on ophiolitic rocks which produce serpentine soils [14], and previous dominant cover of the selected burned sites was obtained by *P. brutia* forests. Three plots 1 ha in size were randomly selected within each site, and soil samples were taken from the upper 15 cm of the soil at three randomly selected points within each plot.

Soil texture, pH, CaCO₃ content (%), organic matter content (%), electrical conductivity (EC) (µS/cm), and exchangeable cation (Ca²⁺, Mg²⁺, Na⁺, K⁺) concentrations (ppm) of the soil samples were determined by following the methods described in the soil analysis reference books published by the Turkish Forestry and Agricultural Departments [15,16]. Data were analyzed by one-way analysis of variance (ANOVA) with time since fire as the main factor. Post-hoc comparisons were done using Tukey's HSD test [17]. Data were tested for homoscedasticity and normality before conducting ANOVAs, and, when needed, data transformations were used to obtain the prerequisites of parametric tests [17]. In the case of CaCO₃ content, since the data did not fit the normal probability distribution even after several transformations had been applied, a Kruskal-Wallis test [17] was performed to detect the difference in CaCO₃ percentages among the study sites.

RESULTS AND DISCUSSION

The soils contained very little CaCO₃ (less than 1%), all were slightly acidic, with pH varying between 6.0 and 6.7, and were dominantly loams. Soil texture did not vary among the study sites, and percentages of sand, silt, and clay (39 - 52%, 34 - 45%, and 9 - 20% respectively) did not significantly differ among the

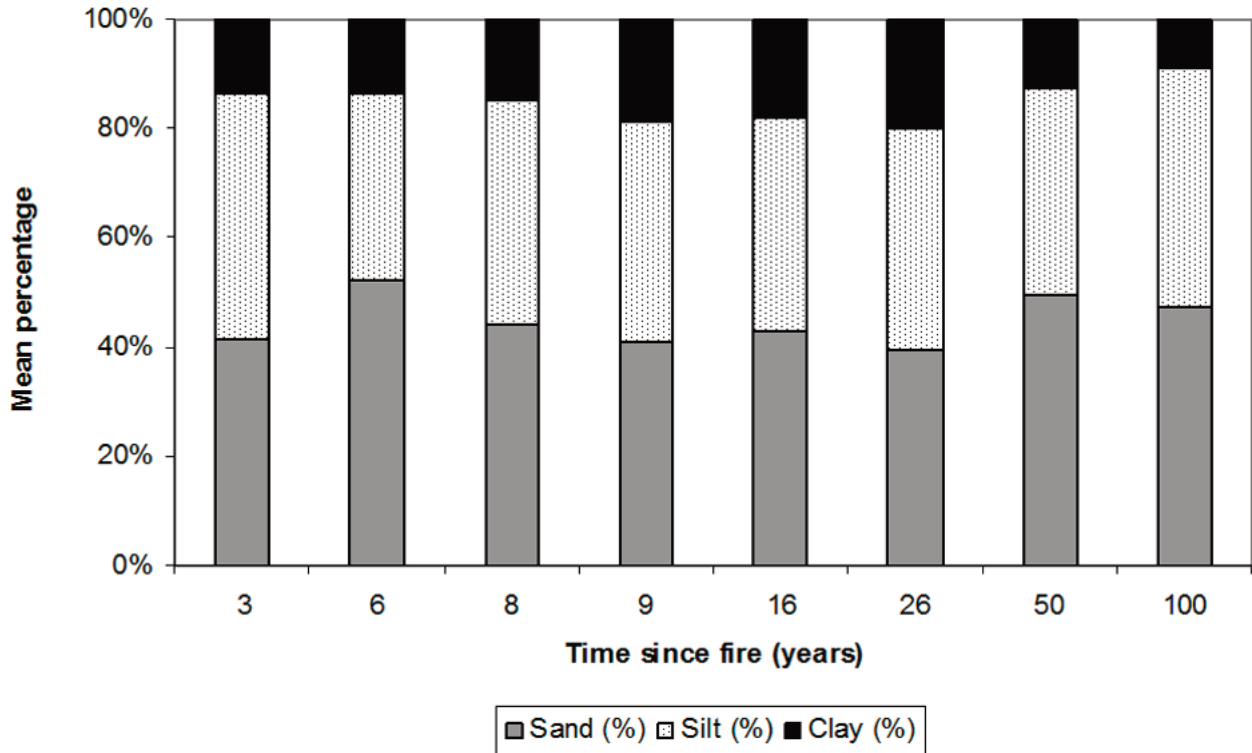


Figure 1. Soil texture properties of study sites representing different times since fire. Values are mean percentages.

study sites except for silt percentage between 3- and 6-years-old sites (Figure 1).

Organic matter content was higher at the long-unburned sites, but was similar among all the burned sites. Mg^{2+} and K^+ concentrations were not significantly different among study sites. Although there were some significant differences among the study sites in Ca^{2+} and Na^+ concentrations, $CaCO_3$ amounts, and pH, these variables did not show any trend with time since the fire (Figure 2). Only EC followed a more-or-less regular increasing trend over time.

Although some slight trends with time since fire were observed for some of the variables evaluated, actually soil properties did not change drastically with time, or at least changed without a trend among the study sites. Our results regarding soil texture were expected since changes in soil texture after fire are negligible except for where soil heating is extreme [18,19]. Much lower $CaCO_3$ levels of soils

in comparison to calcareous Mediterranean forest soils [20,21] are possibly the result of the presence of ophiolitic rocks producing serpentine soils around the region.

Although it was expected a change in the chemical properties of the soil with time since fire, there were not any important change. It is known that post-fire recovery of the chemical properties of soils in *P. brutia* forests generally occurs within the first three post-fire years [8, 9,11]. Organic matter content, pH value, and concentrations of exchangeable cations increases at the first year after fire, but then return their initial (unburned) levels three years after fire [8,9]. Similar conclusions had also been reached by the studies conducted on a *Pinus canariensis* woodland (five years after fire, [13]) and on a *Quercus coccifera* shrubland (one year after fire, [22]). Consequently, chemical properties of the soils of the 3-year-old site in the present study seem to be recovered already when the sampling was performed.

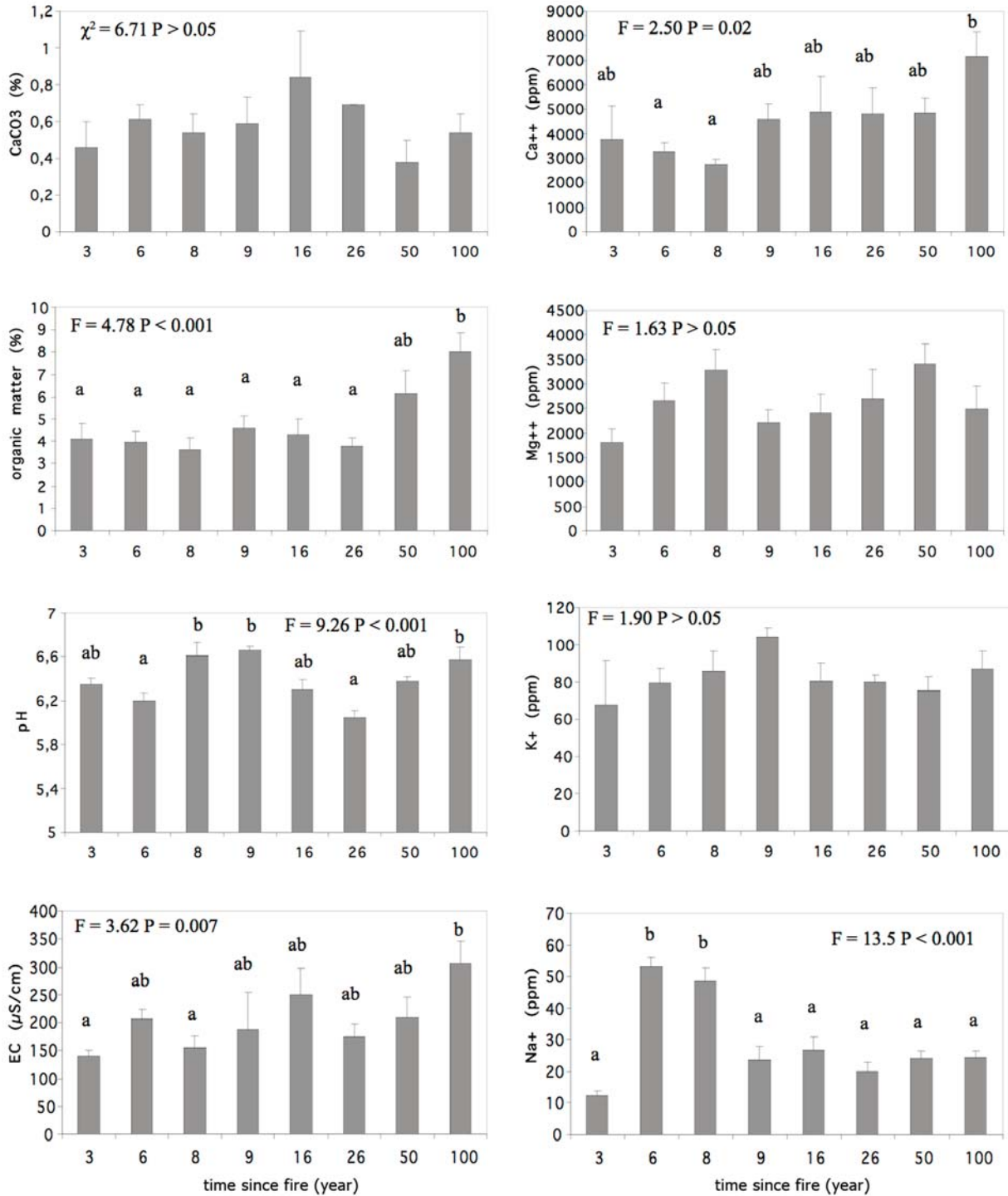


Figure 2. Soil chemical properties of study sites representing different times since fire. Values are means, and the error bars are \pm S.E. of the mean. Different letters on the bars indicate significant differences among the study sites at $P = 0.05$ level.

In a similar study conducted within a limited area of burned *P. brutia* stands in Marmaris region [10] showed such a relationship between soil chemical properties and time since fire. In comparison to that study, however, the present study gives a more comprehensive approach by extending the studied

area to the landscape scale. As a result, increasing of site heterogeneity may explain the difference of the main results between the present study and those of previous one conducted in the same region [10]. Indeed, in general terms, changes in soil properties depend on the land-use history of the

burned sites [23], the severity and frequency of fires, and post-fire climatic conditions [24]. Moreover, soil temperatures during a fire affect the composition and spatial pattern of soil properties in different ways [19,25]. Therefore, the spatial pattern of fire severity is responsible for the site heterogeneity in post-fire environments [26].

CONCLUSIONS

In conclusion, we failed to find any significant trend of change in soil chemical properties through a chronosequence of time since fire in *P. brutia* forests of Marmaris region. It is apparent that studying early post-fire years (in the case of *P. brutia* forests the first three years after fire) is crucial to detect such changes in soil chemical properties. Moreover, site heterogeneity appears to be an important factor possibly responsible for the variability observed in some soil properties among the study sites. More studies are still needed to understand how landscape heterogeneity affects the patterns of recovery of soil chemical properties in Mediterranean Basin.

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