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ORIGINAL ARTICLE

The Effects of Forest Fires on the Chemical Properties of Soils in Northern Iran: A Case Study on *Pinus Taeda* Stands

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ABSTRACT
Fires in northern Iran have been one of the most important factors in the destruction of Pinus Taeda forests as surface fires occur almost every year in the area. This study is designed to analyze the effects of 2008 fires on the chemical characteristics (pH, soil electrical conductivity, phosphorus and absorbent potassium, organic carbon, total nitrogen and cation exchange capacity) of 18 acres of Saravan forest soil, northern Iran, and to compare them to those of the control area (having undergone no fires). After necessary reviews, the burned area was divided into three areas of high, medium and low wildfire burn severity. Then, five samples of soil were randomly collected and transported to the laboratory. The results showed that the fire did not have a significant effect on phosphorus, potassium, and cation exchange capacity at the 95% confidence interval, while it had a significant effect on soil pH, electrical conductivity, organic carbon and total nitrogen at the 95% confidence interval. The fire caused an increase in soil pH and electrical conductivity, and a reduction in organic carbon and total nitrogen. Measured characteristics, except organic carbon, total nitrogen and potassium in the control area were less than the area undergone fire.
Keywords: *fires, northern forests of Iran, Pinus Theda, chemical properties of soils*, Saravan forest

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INTRODUCTION

Forests are one of the most complex ecosystems the components of which are in complete balance. Damaging natural or artificial factors, depending on their type and severity, may lead to the weakening or loss of balance or self-regulation of forests. One environmental factor that can affect forest ecosystems is fire [1]. Fire as a destructive agent may leave short-term and long-term effects on soil physical and chemical properties. Sometimes, fires cause permanent and irreversible changes in the soil. Intense fires, including controlled fires, leave more negative effects on different soil characteristics [2]. Such fires result in the loss of organic matter, destruction of soil structure and porosity, loss of minerals through evaporation and sublimation, soil erosion and leaching [4]. Fire affects the soil pH through base cations [3]. Soil pH results from the total concentration of Mg, Ca, and K elements in the ash [5]. Increased acidity of Na, K, hydroxide and carbonate oxides often disappears during the wet season; however, in comparison, calcite forms may continue for up to 3 years after the fire and retain an Alkaline state for the soil. Fire causes a negligible increase in the acidity of soils containing carbonates [4], and the coefficient of electrical conductivity increases ephemerally and transiently [6, 7]. Over time, the increase of soil nitrogen in burned areas decreases compared to unburned soils because inorganic forms of nitrogen do not remain in soil for long [8]. Fires lead to the destruction of soil horizons. The results of statistical comparison between burned and unburned areas showed that the amount of organic carbon, phosphorus, potassium, calcium and nitrogen decreased in burned soil [9]. Therefore, this study aims to evaluate the impacts of fire with different intensities on soil chemical properties (soil pH, soil electrical conductivity, phosphorus, potassium, organic carbon, total nitrogen and cation exchange capacity) of burned and control (unburned) areas and examine the features that were significantly different between the two regions.

MATERIALS AND METHODS

The study area

The study area is located in northern Iran (Saravan Forest) between 49º 35’ 22” to 49 º 39’ 00” east longitudes and 37º 01’ 47” to 37º 05’ 41” north latitude at the height of 80 to 765 meters above sea level, with the average gradient of 5 to 30 percent and an overall direction toward east. Based on DeMartin Climate Classification, the regional climate falls into the category of very wet climate with cool winters, or temperate climate according to Emberger Classification, with an annual rainfall of 1,366.6 mm. The average annual temperature is 20.6 ° C: the warmest months include July and August with temperatures of 30.1 and 30.3 ° C and the coldest months include January and February with temperatures of -11.2 and -11.1 degrees Celsius respectively. The dominant texture ranges from medium to heavy; the dominant rock type is limestone and shale; soil structure ranges from fine to coarse to multifaceted grains and soil mass falling and sliding have been seen in most areas. 18 acres of this district and its adjacent areas went on intense fire on November 26, 2008 and the fire kept on for four to five days.

Research Methodology

After exploring the forest, an area of 33 acres was selected out of the 50-acres area with its entire surface burned and, for comparison purposes, an unburned surface was selected as the control area, taking into account factors such as slope, direction, altitude and vegetation with identical measures for both areas [10]. The burned area was divided into four areas of high, medium, low and no (=control) wildfire burn severity. In the area with high burn severity, more than 50% of the trees had burn marks and the forest floor vegetation was completely burned and could not be detected. In the area with medium burn severity, from 20 to 50% of the trees had burn marks and the forest floor vegetation could be detected to some extent. In the area with low burn severity, less than 20% of the trees had burn marks and the forest floor vegetation was easy to detect. No burning was witnessed in the control area. Five pieces were randomly sampled form each area and a soil sample was collected from the center of each sample and was transferred to the laboratory in order to measure the following values .

1- Acidity, using a soil: water ratio of 1:2 and an electronic pH meter.

2- Electrical conductivity, using a soil: distilled water ratio of 1:5 and concentrating the mixture, using an EC meter.

3- Carbon and total nitrogen using Carlo, Ebra NAL500 Elemental Analyzer (Milan Italy)

4- Soluble nitrogen (ammonium and nitrate), after concentrating soil samples using a 1:10 ratio of soil and two moles of potassium chloride solution using Auto Analyzer.

5- Available phosphorus, using the Bray-l.

6- Cation exchange capacity of the soil, by concentrating the soil using an ammonium chloride solution and washing it with ethanol, using ICP-AES.

Then, the data were fed into the computer and a Kolmogrov-Smirnov test was performed using the SPSS software for data distribution normality. If not normal, data were logarithmically transformed. In order to determine the effects of each factor and their interaction between burned and control areas, the multivariate analysis of variance test (ANOVA) was used and in order to compare the areas with different burning severity, the Duncan multiple comparison test was used.

RESULTS

The results of the effects of fire on soil chemical properties are presented in Table 1.

Chemical parameters	Control Area	Area with medium burn severity	Area with medium burn severity	Area with high burn severity
Acidity	** 6.34	** 6.79	** 7.06	** 7.33
Electrical conductivity	**.61	** .63	** .98	** 1.14
Organic carbon	* 4.30	* 3.86	* 3.26	* 2.66
Phosphorus	2.31 n.s	3.13 n.s	.2.83 n.s	2.53 ns
Potassium	144.11 n.s	122.35 n.s	115.10 n.s	107.85 n.s
Total nitrogen	** .27	** .24	** .21	** .17
Cation exchange	6.08 n.s	6.22 n.s	6.20 n.s	6.18 n.s

Table 1: Status of chemical parameters in the study areas

* Significant at the 95% confidence interval

** Significant at the 99 percent confidence interval

n.s not significant

Acidity

Soil pH levels in the control area (=6.34) are less than the burned area. Soil response in the burned area naturally increases with the increase of soil pH levels so that it extends from 6.79 in the area with low burn severity to 7.06 in the area with medium burn severity, and with a dramatic increase, to 7.33 in the area with high burn severity.

Electrical Conductivity

Electrical conductivity of soils in the burned area naturally increases with fire intensity so that it raises from 0.61 in the control area to 0.63 in the area with low burn severity, and then, with the increase of fire, it reaches .89 in the area with medium burn severity and extends to 1.14 ds/m in the area with high burn severity.

Organic Carbon

The effect of fire on the percentage of total carbon decreases with fire intensity so that it reduces from 3.86 in the area with low burn severity to 3.26 in the area with medium burn severity and to 2.66 in the area with high burn severity. The percentage of organic carbon is less in the control area.

Total Nitrogen

The effect of fire on soil total nitrogen in the unburned area is more than that of burned areas so that it reduces from 27% in the control area to 24% in the area with low burn severity. The percentage also decreases with fire intensity. The amount of total nitrogen is 21% in the area with medium burn severity and 17% in the area with high burn severity.

DISCUSSION

Forest fires are usually considered as ecological agents of destruction and reconstruction [4]. The most important effects of fire on soils is the loss of organic matter and an increased risk of erosion in the next step, as well as a significant impact on the regeneration of previous species and on environmental conditions. Many soil physical, chemical, and mineralogical features change as a result of fires [4]. In the study area, the amount of Acidity and Electrical Conductivity increased significantly with fire intensity in four areas of high, medium, low and no (=control) wildfire burn severity. The reason for this can be that because of the burning of litter on the forest floor, large amounts of base cation are released in the soil [11]. This will eventually increase the amounts of soil pH, electrical conductivity and cation exchange capacity. The increase of soil pH could be a result of the formation of oxides, carbonates, sodium hydroxide and potassium released because of litter burning. Increased acidity can be one of the benefits of fire because the increase of soil response (pH), especially in acid soils, increases the ability to absorb essential nutrients [12]. As shown in the results, the percentage of organic carbon decreased significantly in burned areas and this reduction increased with fire severity. The results of this study suggest that soil organic carbon initially increased in the early years of fire; then over a period of time, it decreased significantly with the increase of fire intensity. The long-term lack of enough litter and root debris in soils can reduce the percentage of soil organic carbon over the long run. Also in a study on the effects of forest fires in two areas, Iglesias et al. observed that the amount of organic carbon reduces from 3% in the unburned area to almost 6% in the burned area, while Almendros et al. witnessed no change in the amount of organic carbon. The amount of soil organic carbon had a significant increase a year after the fire compared to the control area (having undergone no fire); however, the amount of increase in the burned area compared to the control area was not significant two years after the fire. The initial increase in carbon may be due to the distillation of carbon into inorganic soil through the organic horizon during the burning as well as the effects of fire on dead plant and microbial tissues [14].One of the key elements required by plants is nitrogen which is widely distributed in nature. Its main source is N2 gas which is not usable by plants: It must be converted to inorganic form so that plants can absorb it. Nitrate is the form which is most easily absorbed by plants [13]. Based on the results of this study, fire had a significant effect on soil total nitrogen percentage. Total nitrogen was higher in burned areas than in unburned areas and decreased significantly with fire intensity in burned areas. The reason can be that inorganic nitrogen significantly reduces after fire due to the absorption of nutrients by plants,microbial immobilization and Nitrification [15]. Like carbon, inorganic nitrogen grows initially in the soil but decreases after a period of time. Given that the annual rainfall in the region is high, it is expected that nitrogen has leached out of topsoil and this has reduced the total nitrogen is in the soil. These results are similar to the findings by Monleon et al. [16]. They also believe that early release of inorganic nitrogen is the cause of ultimate reduction in the total nitrogen. There could be several reasons for the higher amount of nitrogen in the area with lower burn severity. In fact, it is likely that forest ecosystems are able to compensate for the lack of nutrients in the early years of fire by decomposing litter accumulated on the forest floor after the fire or the remaining litter before the fire. Still, another reason can be the low intensity of fires in the region that causes the litter to burn slowly and a steady flame temperature. This causes the flame to remain at a temperature not high enough to cause nutrients, particularly nitrogen, to sublimate.

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