

EFFECT OF FIRE ON SOIL PHYSICAL AND BIOLOGICAL CHARACTERISTICS IN NORTHERN FORESTS OF IRAN

Saeedeh ESKANDARI^{1*}, Samane ESKANDARI²

¹ Forest Research Division, Research Institute of Forests and Rangelands, Agricultural Research, Education and Extension Organization (AREEO), Tehran, Iran

² Department of Soil Science, Faculty of Agriculture, Isfahan University of Technology, Isfahan, Iran

Abstract

This study was performed to investigate fire effects on some soil physical characteristics and biological characteristics in Northern forests of Iran. The soil physical characteristics included soil moisture and soil particles. The biologic characteristics included leaf litter moisture and depth, forest ground cover and fallen trees. For this purpose, 70 samples of soil and leaf litter were collected in the burned and unburned areas. The sampling method was based on random-selecting method. The soil moisture and leaf litter moisture of samples were obtained by weighing the humid and dry samples in Soil Science Laboratory. Soil particles size was measured by hydrometer method in Soil Science Laboratory. For data analysis, the mean comparison test of two statistical societies was used because data include two groups (burned area and unburned area). Thus, Independent-Sample T test was applied to investigate the significant difference of soil and biologic characteristics in the burned and unburned areas. Results showed that there was a significant relation between mean of soil moisture, clay, silt and sand percent, leaf litter moisture, leaf litter depth and ground cover in the burned and unburned areas; while there was not a significant relation between fallen trees in the burned and unburned areas in this study.

Keywords: Fire; Leaf litter; Soil moisture; Soil particles; Fallen trees; Forest ground cover

Introduction

Fire is one of the most important causes of forest destruction in the world [1] which its effect on forest ecosystems is different regarding to fire type, extent and intensity. Fire has the direct and non-direct effects on forest soil characteristics. The direct effects of fire on soil include burning and decomposing the leaf litter, increasing the available mineral material, increasing the pH reaction, increasing the soil temperature and decreasing the soil moisture [2]; while the non-direct effects of fire on soil include increasing or decreasing microorganisms, fauna and flora and also site quality and productivity [3, 4]. Most of the fire effects on soil and biologic characteristics of the forests are due to decrease the organic matter in the soil surface [5]. Fire may change the physical properties of the soil such as structure, moisture and water holding capacity [6].

Many studies have been performed about fire effects on soil and biologic characteristics of the forests in the world. *A.F.J. Martínez and A.D.E. Pereira* [7] concluded that fire significantly decreases the water penetration to the soil. *D.G. Neary et al.* [8] investigated the fire effects on forest floor properties and concluded that the produced heat by fire is caused all direct changes in the forest soil characteristics. In addition, the direct effects of fire on soil are

* Corresponding author: saeede.scandari@yahoo.com

the quick decomposition of leaf litter and change of soil temperature and moisture conditions [2]. *F. Moreira et al.* [9] investigated the effects of the prescribed fires on the vegetation structure of Northern forests of Portugal. Results of their research showed that the herbaceous species are usually established in the burned areas in the first three years after fire. *C.C. Rhoades et al.* [10] investigated the effects of burning the trees on the physical, chemical and biological characteristics of the soil in Oak forests of Central Missouri in comparison with the surrounding grassland. The results showed that fire alters the soil structure and permeability of the water to the soil. *K.S. Are et al.* [11] investigated the fire effects on soil quality and concluded that there are some changes in soil particles size after fire occurrence.

Many studies have also been done about effects of fire on the soil and ecologic properties of the forests in Iran. *A. Banj Shafiei* [12] investigated the fire effects on ecologic characteristics of Chelir forests of Golband area in Northern Iran. Results showed that the herbaceous cover percent of many species in the burned area is more than other areas. *R. Molavi et al.* [13] investigated the fire effects on physical and chemical characteristics of soil surface. Results showed that the clay particles have been decreased and the sand particles and pH of soil have been increased in the burned area because of the high temperature created by fire. *A. Salehi et al.* [14] studied the soil properties in *Pinus taeda* plantation of Siahkal forests in five years after fire. Results showed that clay and sand particles had significant differences in the burned and unburned areas. *M. Bakhshandeh Savadroodbari and M.R. Marvie Mohadjer* [15] investigated the herbaceous cover changes after fire in Dinekooh of Noshahr area. Results showed that the proper condition for establishing the herbaceous cover has been provided after fire occurrence. Thus, herbaceous cover has been increased in the burned area. *J. J. Heidary et al.* [16] investigated the impact of fire on soil physical properties in semi-steppe rangelands of Karsanak region of Chaharmahal and Bakhtiari province in Iran. Results showed that in the first year after fire, clay percent has been decreased and sand percent has been creased in the burned area in comparison of unburned area.

Investigation of fire effects on soil characteristics of forests is an important subject because soil is bed of growth and regeneration of the forests [17]. Fire effects on physical, chemical, biological and microbiological properties of soil have been studied for several years [2, 18]; but most of these studies have been performed in the Mediterranean areas or Boreal forests. There are no many studies about fire effects on soil characteristics in the temperate forests [17]. In addition, most of previous studies have been done to investigate the fire effects on soil chemical properties not soil physical properties [19]. Therefore, the aim of this study is investigation of fire effects on some soil physical characteristics and biological characteristics in District Three of Naka-Zalemroud (DTNZ) forests in Northern Iran.

Material and methods

Study area

DTNZ forest has been located between 36° 30' to 36° 40' N latitude and 53° 15' to 53° 26' E longitude in South of Neka and Behshahr counties of Mazandaran Province in Northern Iran. It covers an area of 153.07 km² and it is bounded by Neka-Behshahr road in the North, Chakhani and Souterabad in the East, Zarandin Khoramchamaz in the South and Ablou in the West. Minimum and maximum altitudes from sea level are 90 and 820 meters respectively. DTNZ forests have 103.4km forest roads, 27 km rural roads and 21 km asphalt roads (Fig. 1).

Forests of study area have uneven-aged and mixture structure. Plant species include tree species (*Fagus orientalis*, *Carpinus betulus*, *Quercus castaneifolia*, *Alnus subcordata*, *Parrotia persica*, *Zelcova carpinifolia*, *Acer sp.*, etc.), shrub species (*Buxus hyrcanus*, *Mespilus germanica*, *Crataegus pentagyna*, *Prunus caspica*, etc.) and herb species (*Asperula odorata*, *Ruscus hyrcanus*, *Siclaman sp.*, *Carex sp.*, *Rubus sp.*, etc.) (Mazandaran Natural Resources

Administration (MNRA), 2014) [20]. A wide area of these forests has been burned by wildfires in the recent years [21].

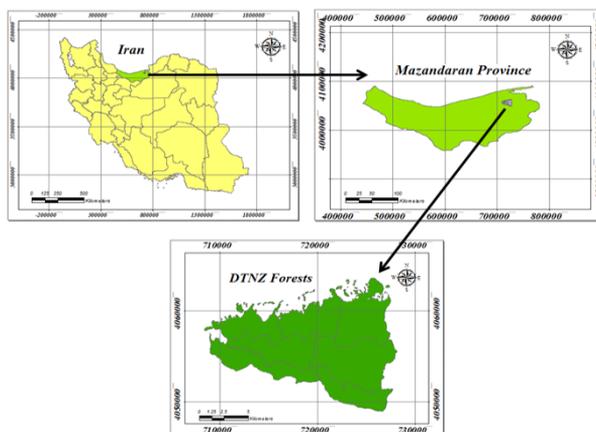


Fig. 1. Study area map

Research method

Data collection

DTNZ forest was selected to investigate the fire effects on soil and biologic characteristics in this research. A wildland fire was occurred in Seri Five of these forests in 2013 which was continued for one month (Mazandaran Natural Resources Administration (MNRA), 2014) [20]. The control area (unburned area) was the Seri Three of these forests which was not affected by fire (Fig. 2a). The burned area was the Seri Five of these forests which was burned by fire in 2013 (Fig. 2b). Data were collected in the burned and unburned areas one year after fire occurrence.



Fig. 2. Unburned area (a) and Burned area (b)

Soil characteristics included soil moisture and soil particles percent (sand, silt and clay) and biologic characteristics included leaf litter moisture and leaf litter depth, forest ground cover and fallen trees. Sampling of soil (in 10cm depth) and leaf litter was done by random-selecting method in the burned and unburned (control) areas.

For this purpose, 70 samples of soil and leaf litter were taken in the burned and unburned (control) areas (35 samples in each area). Location of the sampling points was randomly selected regarding to expert opinion in the burned and unburned (control) areas. In each sampling point, leaf litter depth was measured at the center and four corners of a square

plot (1×1 m) which its center was accordant to the sampling point (Fig. 3a). The mean value of leaf litter depth measurements (Five measurements) was used as the final value of leaf litter depth in each sampling point. Leaf litter samples were also collected at the center and four corners of the same square plot (1×1 m²) using a metal frame (20×20 cm) (Fig. 3b). The mean value of leaf litter moisture measurements (Five measurements) was used as the final value of leaf litter moisture in each sampling point. In addition, the soil samples were collected at the center and four corners of the same square plot (1×1 m) using a metal cylinder (10 cm height and 8 cm diameter) (Fig. 3a and b).

The soil and leaf litter samples were transferred to the Soil Science Laboratory after sampling. Moisture of the soil and leaf litter samples were obtained by putting the samples in the laboratory oven (For 24 hours at 105°C) and by measuring the humid and dry weights of the samples. Soil particles size was measured using hydrometer method in Soil Science Laboratory. This method quantitatively determines the physical proportions of three sizes of primary soil particles as determined by their settling rates in an aqueous solution using a hydrometer. Proportions are represented by stated class sizes: sand ranging from 50 - $2000 \mu\text{m}$; silt ranging from 0.2 - $50 \mu\text{m}$ and clay $< 2.0 \mu\text{m}$ and those stated by the USDA Soil Survey and Canadian Soil Survey Committee. Settling rates of primary particles are based on the principle of sedimentation as described by Stokes' Law and measured using a hydrometer [22].

Finally the mean value of leaf litter depth, leaf litter moisture, soil moisture and soil particles percent of five samples in each sampling point, was considered as the final value of these factors in each sampling point (70 sampling points in the burned and unburned area). The forest ground cover was also investigated in the same square plot (1×1 m). The fallen trees were counted in a circle with a 10 m radius from the center of sampling point.

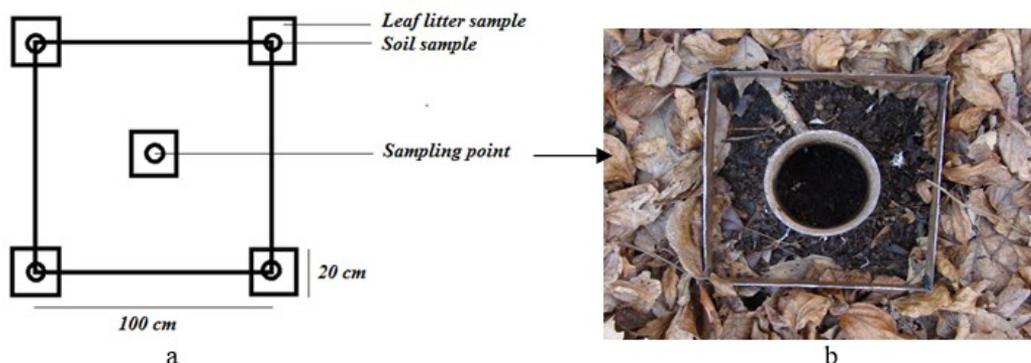


Fig. 3. Sampling pattern of soil and leaf litter (a) and Sampling point (b)

Data analysis

The normal distribution of data was investigated by Kolmogorov-Smirnov test. Results showed that distribution of all data followed a normal distribution. The mean comparison test of two statistical societies was used to analyze the data, because the data included two groups (the burned area and unburned area). Thus, Independent-Sample T test was applied to investigate the significant difference of soil and biologic characteristics in the burned and unburned areas because data in two groups (the burned area and unburned area) were independent [22]. All data analysis was performed in by SPSS IBM ver. 22.

Results

In this study, the fire effects on some soil and biologic characteristics of Northern forests of Iran were investigated. The soil characteristics included soil moisture and soil particles. The biologic characteristics included leaf litter moisture and depth, forest ground

cover and fallen trees. The data were collected in the burned and unburned (control) areas. Results demonstrated that clay and silt percent, soil moisture, leaf litter moisture and leaf litter depth have been decreased in the burned area. On the other hand sand percent and forest ground cover have been increased in the burned area. Finally the fallen trees have not significantly changed in the burned areas (Fig. 4).

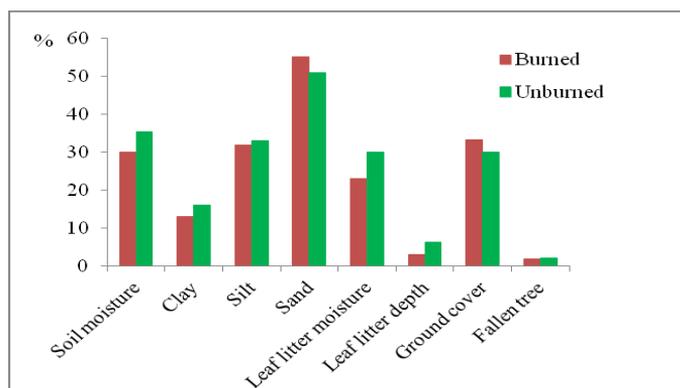


Fig. 4. Physical soil characteristics and biologic characteristics in the burned and unburned areas

In current study, Independent-Sample T test was applied to investigate the significant difference of soil and biologic characteristics in the burned and unburned areas. Results showed that there was a significant relation between mean of soil moisture, clay, silt and sand percent, leaf litter moisture, leaf litter depth and forest ground cover in the burned and unburned areas; while, there was not a significant relation between fallen trees in the burned and unburned areas (Table 1).

Table 1. Independent T test for soil and biologic characteristics in burned and unburned areas (Mean \pm SE)

Soil and biologic characteristics	Burned area	Unburned area	Sig.
Soil moisture (%)	30.01 \pm 0.92	35.48 \pm 0.55	0.000**
Clay (%)	13.04 \pm 0.20	16.04 \pm 0.30	0.000**
Silt (%)	31.85 \pm 0.42	33.04 \pm 0.27	0.000**
Sand (%)	55.11 \pm 0.60	50.92 \pm 0.52	0.000**
Leaf litter moisture (%)	22.95 \pm 0.55	30.03 \pm 0.33	0.000**
Leaf litter depth (cm)	2.93 \pm 0.43	6.26 \pm 0.34	0.000**
Forest ground cover (%)	33.39 \pm 0.56	30.04 \pm 0.33	0.000**
Number of fallen trees	1.91 \pm 0.74	2.02 \pm 0.78	0.53 ^{ns}

** Significant in 99% confidence level

ns: No Significant

Discussion

This study was done to investigate the fire effects on some soil and biologic characteristics of DTNZ forests in Northern Iran.

About soil physical characteristics, the results of this research showed that the soil moisture in the burned area was significantly less than unburned area which is accordant to results of *M.V. Alauzis et al.* [24]. Results of *M.H. Hodjati et al.* [5] study also showed that the soil moisture content in the burned area is less than unburned area. *D.G. Neary et al.*, [8] stated that the produced heat by fire is caused all direct changes in the forest soil characteristics. On the other hand, fire causes the soil dryness because of reduction of water permeability in the soil and reduction of the soil organic matter [25]. *A.F.J. Martinez and A.D.E. Pereira* [7] in their

study also concluded that the fire reduces the permeability of water in the soil, thus it reduces the amount of soil moisture.

Results of this research also showed that clay and silt particles have significantly been decreased in the burned area. On the other hand, the sand particles percent has significantly been increased in the burned area. The results of another research also showed that the clay particles have significantly been decreased and the sand particles have significantly been increased in the burned area [14]. Results of *H. Rouhani et al.* [6] and *J. Heidary et al.* [16] studies also showed that the sand particles have been increased and the clay particles have been decreased in the burned area which are accordant to the results of current research. The clay soils have more potential to hold water than sandy soils, thus decrease in clay particles and increase in sand particles in the burned area can be an important factor to reduce the water holding capacity in the burned area.

About biological factors, leaf litter depth and leaf litter moisture also showed a significant difference in the burned area and unburned area; as the values of these factors in the burned area was significantly less than unburned area. The reason is loss of leaf litter and humus layer in the burned area which is also an important factor for reducing of soil moisture. Destruction of vegetation cover and humus layer of forest floor decreases the water storage capacity of the soil and leaf litter. The direct effects of fire on forest floor and soil are the rapid burning and decomposition of leaf litter and change of soil temperature and moisture conditions [2].

The results of this study also showed that the forest ground cover in the burned area was significantly more than unburned area. The results of *M. Bakhshandeh Savadroodbari and M.R. Marvie Mohadjer* [15] also showed that the fire changes the forest herbaceous cover by changing some characteristics such as increasing the soil chemical reaction. Results of another study also showed that the herbaceous cover percent of many species in the burned area was more than other areas [12]. In addition, results of another research also showed that some herbaceous species had more density in the burned area than other areas [26]. The herbaceous species are usually established in the burned areas in the first years after fire which is usually occurred in the first three years after fire [9].

On the other hand, the results of current research showed that there was not a significant difference between the number of fallen trees in the burned and unburned areas. This result can indicate that fire has not had an important role in felling the trees in the study area. Thus trees in the study area may be fallen by other reasons (Pests, extreme wind, etc.). Thus, fire has not seriously threatened the stand trees in the study area.

Conclusion

The final results of this study showed that fire has had many impacts on soil physical and biological characteristics of temperate forests in Northern Iran. The results of this research proved that fire has decreased the soil and leaf litter moisture. Furthermore, fire has decreased clay and silt percent and has increased sand percent in the soil of study area. Therefore, fire has decreased the water maintenance capacity in the soil which is an important threat for fauna, flora and microorganism life in the study area, because life of many animals and plants is dependent to environment moisture. In addition, fire has decreased the leaf litter depth which hardens the life conditions for many microorganisms. On the other hand, fire has significantly increased the herbaceous species in the forest floor which is a positive point for life conditions of fauna and flora. Considering these important results, a comprehensive plan for monitoring and managing the future fires in the study area is very important.

Finally, it is suggested that the difference between other characteristics such as pH, electrical conductivity (EC), elements of soil, as well as regeneration situation, organic matter and microorganisms of the soil in the burned and unburned areas would be investigated in the

future studies. In addition, it is suggested that the future studies will be done in the different slopes, aspects and elevations for more exact investigation of fire effects on soil and biologic characteristics in the forest areas.

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