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FOREST FIRE INFLUENCE ON SOIL TEXTURE IN BURNED FORESTS IN BULGARIA

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Abstract

The paper presents results from investigation on soil texture changes caused by forest fires. Cinnamonic Forest soils (Chromic Luvisols, FAO) and Gray Forest soils (Gray Luvisols, FAO) have been investigated. The sample plots were set up in burned and unburned control areas. They were situated in the Lower forestry zone (0–700 m a.s.l.) of the Tracian forest area and the Lower forestry zone (0–600 m a.s.l.) of the Moesian forest area, respectively. Soil samples have been taken three times in a course of nine years. The fractions of sand, silt and clay have been determined by pipette method. A relationship was established between soil texture and soil type, and the type and intensity of fires.

Key words: forest fire, forest soils, soil texture, *Pinus nigra* Arn.

Introduction

The forest fires are a significant factor of natural forest development. A global tendency of increasing the number, intensity and duration of forest fires has been observed in the recent decades. They should not be considered separately of the context for global climatic changes and human activity.

The forest fires have a devastating impact on forest ecosystems. As a consequence of fires the vegetation, soils, microorganisms and the animal organisms are subjected on degradation. After the fire suppression, it is necessary to apply expensive restoration activities in burned areas. The ecosystem restoration is a continued process that requires comprehensive forestry activity.

Soil properties are strongly dependent on the soil organic matter created by the vegetation. Both components are removed to a variable degree after fire impact. Consequently, fire has the potential to induce major changes in soils. The degree to which soil properties are altered by fire depends on the fire intensity and the amount of burned organic matter (DeBano et al. 1998, Erickson and White 2008, Ubeda et al. 2009). These in turn are influenced by the amount and the distribution of forest combustible materials, their moisture content and the weather conditions (Kimmins 1996).

Soil texture influences soil productivity and forest development. Consequently, it is a basic soil property and an important indicator of soil classification. The soil texture is defined by proportions of sand (63 μm – 2 mm), silt (2–63 μm) and clay (< 2 μm). The sand fraction is composed of rock fragments and primary minerals, especially quartz. Therefore, it is chemically

completely inactive. Sand content directly influences soil porosity and hydraulic properties. The silt fraction is dominated by primary minerals and has, therefore, a low chemical activity. The silt particles slow down the movement of water and air because of filling soil cavities among sand grains. The soil physical and chemical activity depends mainly on clay fraction (Petrova and Bogdanov 2012).

Generally, the sandy soils contain less moisture and nutrient elements in comparison with the loam and clay soils. Thus, coarse sandy soils as a rule favor forest stands composed of species with relatively low requirement for moisture and nutrients, whereas loam and clay soils often are favorable for trees with high moisture and nutrient requirements (Pritchett 1979).

According to Velizarova et al. (2001), the surface fire impact on soil texture has been expressed by a disintegration of coarse fractions and an increase of fine fractions. Burned clay soils with a sand content less than 5 % and clay content more than 55 % have been investigated by Ketterings et al. (2000). They found a sharp increase in the amount of sand and a decrease in silt and clay. Destroying the stands and soil organic matter, the forest fires create conditions for erosion and alteration of soil texture.

The paper aimed at establishing soil texture changes caused by forest fires and the influence of fire intensity and type on different soils.

Material and Methods

The objects of the study were soils influenced by fires in the regions of Stara Zagora and Belogradchik in July 2002. The sample and control plots of 0.1 ha each have been set up in burned and unburned areas in order to investigate the soil properties changes. The plots in Stara Zagora region were located in the Lower forestry zone (0–700 m a.s.l.) of the Tracian forest area. Soils were Cinnamonic Forest soils (Chromic Luvisols, FAO) influenced by strong crown and strong surface fire under thirty-years old plantation of Black pine (*Pinus nigra* Arn.). The sample and control plots were at 400 m above sea level, at southwest exposition with slope 10 °.

The plots in Belogradchik region are located in the Lower forestry zone (0–600 m a.s.l.) of the Moesian forest area. The soils were Gray Forest soils (Gray Luvisols, FAO) influenced by weak surface and strong surface fire under twenty-five years old plantation of Black pine. The altitude was 450 m, at north-northwest exposition, slope 5 °.

The forest fires were classified on the basis of visible impact signs. According to fire intensity they were determined as follows:

– strong crown fire – whole stems were burned and the stand was completely destroyed;

– strong surface fire – the stems were burned to a height of more than 0.5–1 m and the fire impact caused a destruction of the stand;

– weak surface fire – the stems were burned to a height of 0.5–1 m and the fire did not cause a destruction of the stand.

Soil samples have been taken one, four and nine years after the fires in order to investigate the dynamics of soil texture changes caused by fires. Having in mind that the most significant changes of soil properties occur at 10–15 cm depth (Raison et al. 1985, Barnes et al. 1998, Neary

et al. 2008), the samples were taken from the layer 0–15 cm.

The soil texture was determined by pipette method (ISO 11277). It was founded on separation of the mineral part of the soil into various size fractions and determination of the proportion of these fractions. A special attention was paid to the pretreatment of the samples aimed at complete dispersion of the primary particles. Therefore, cementing materials such as organic matter, salts, iron oxides and carbonates were removed.

The fractions of sand (63 μm – 2 mm), silt (2–63 μm) and clay (<2 μm) have been determined. After shaking with a dispersing agent, sand was separated from silt and clay with a 63 μm sieve. The silt and clay fractions were determined by sedimentation.

A textural class of the soils was determined according to U. S. Texture Triangle.

Results and Discussion

The data obtained from soil texture analyses showed that the fire affects mainly the proportion between fractions of sand and silt. The alteration of clay fraction was relatively low.

The results from investigated Cinnamonic Forest soils (Chromic Luvisols, FAO) located in Stara Zagora region are presented in Fig. 1 and Fig. 2. In unburned control area the share of sand fraction was 17 %, the silt is 72 % and the fraction of clay was 11 %. The textural class was silt loam.

In contrast to data obtained from analyzed clay soil by Ketterings et al.

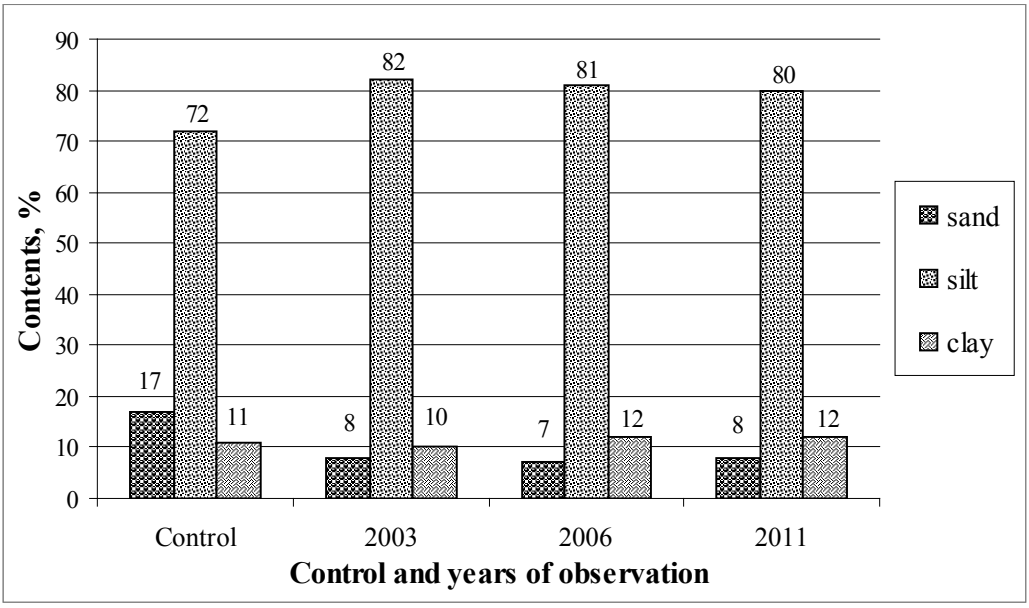

Fig. 1. Soil texture of Cinnamonic Forest soils (Chromic Luvisols, FAO) influenced by strong crown fire in Stara Zagora region – P-1.

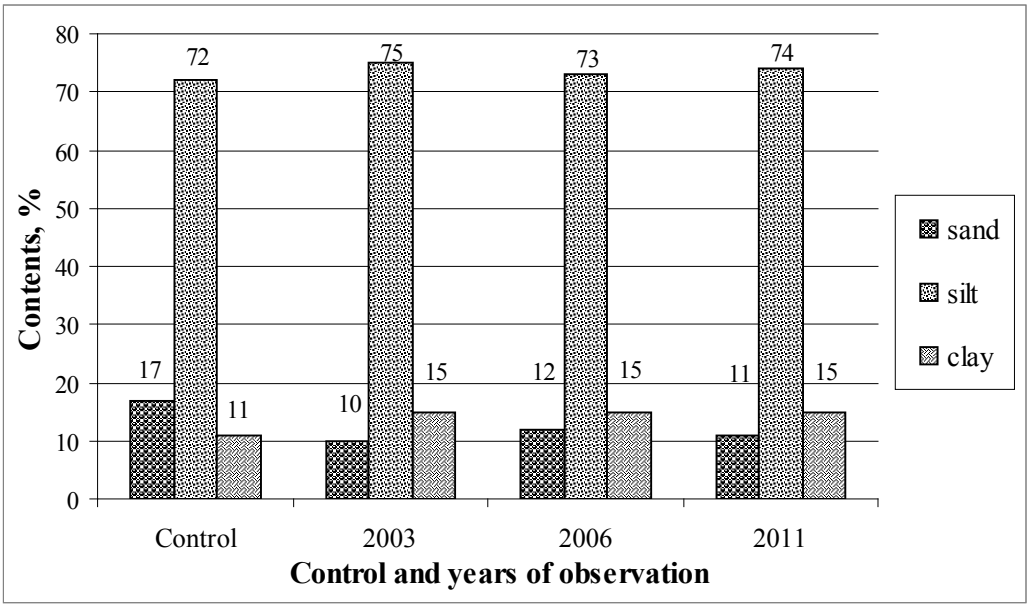

Fig. 2. Soil texture of Cinnamonic Forest soils (Chromic Luvisols, FAO) influenced by strong surface fire in Stara Zagora region – P-2.

(2000), a sharp decrease in the amount of sand and an increase in silt one year after the fires were recorded. This might be a consequence of the fire influence which causes decomposition of sand grains and leads to increase of silt fraction (Ulery and Graham 1993). In the case of strong crown fire (P-1) more significant alteration was established (Fig. 1). This is in conformity with a higher volume of burned biomass. The share of sand decreased from 17 % to 8 % and the silt increased from 72 % to 82 %. The content of clay was reduced by 1 % compared to control plot. The soil has changed over to textural class silt. In the case of strong surface fire (P-2) the biggest change of the amount of clay fraction was recorded (Fig. 2). Its share increased from 11 % to 15 %. This fact is indicative for the importance of the combustible materials distribution that generally determines the characteristics of fire effect. The share of sand decreased to 10 % and the silt increased to 75 %. The textural class was not altered.

Four years after the fire, in Cinnamonic Forest soils influenced by strong crown fire (P-1) an increase in clay by 2 % was recorded. Both the sand and the silt slightly decreased by 1 %. The textural class was again a silt loam. In the soil influenced by strong surface fire (P-2) the share of clay did not change. The sand increased and the silt decreased by 2 %.

It was found that the differences between burned and unburned areas in the Stara Zagora region were kept nine years after the fire. In the case of strong crown fire (P-1) more enduring alteration regarding contents of sand and silt was

established. They differed from control plot by 8–9 %. The clay slightly increased by 1 % compared to unburned soil. Regarding change of the clay content, the most enduring alteration was established in the Cinnamonic Forest soil influenced by strong surface fire (P-2). The share of clay continued to be 4 % more than in unburned control area nine years after the fire impact. The differences in contents of sand and silt between burned and unburned soil were 6 % and 2 %, respectively.

The results from investigated Gray Forest soils (Gray Luvisols, FAO) located in Belogradchik region are presented in Fig. 3 and Fig. 4. In unburned control area the share of sand fraction was 42 %, the silt – 51 % and the fraction of clay was 7 %. The textural class was a silt loam.

A sharp decrease in sand and corresponding increase in silt was established one year after the fire. The amount of clay changed little. The alteration was more significant in the case of strong surface fire (P-4), which is characterized by a higher intensity corresponding to a higher volume of burned biomass. The sand decreased from 42 % to 20 % and the silt increased from 51 % to 71 %. The clay increased by 2 % compared to control plot (Fig. 4). In the case of weak surface fire (P-3) the share of sand decreased to 24 % and the share of silt increased to 69 %. The content of clay was the same as in the unburned area – 7 % (Fig. 3). The textural class was a silt loam in both cases of fire and has not changed during the whole period of investigation. Four years after the weak surface fire (P-3) the sand decreased

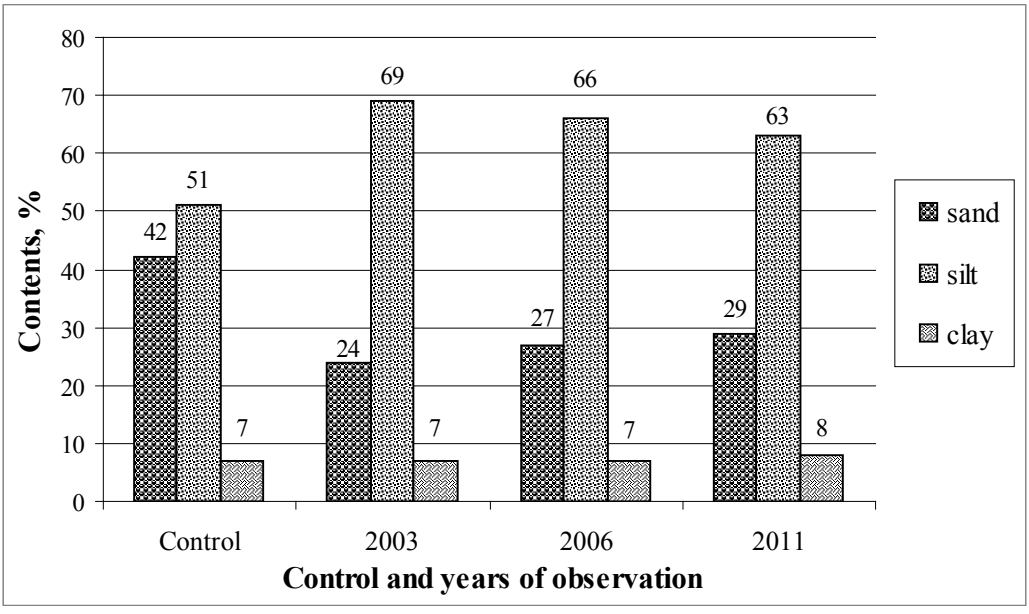

Fig. 3. Soil texture of Gray Forest soils (Gray Luvisols, FAO) influenced by weak surface fire in Belogradchik region – P-3.

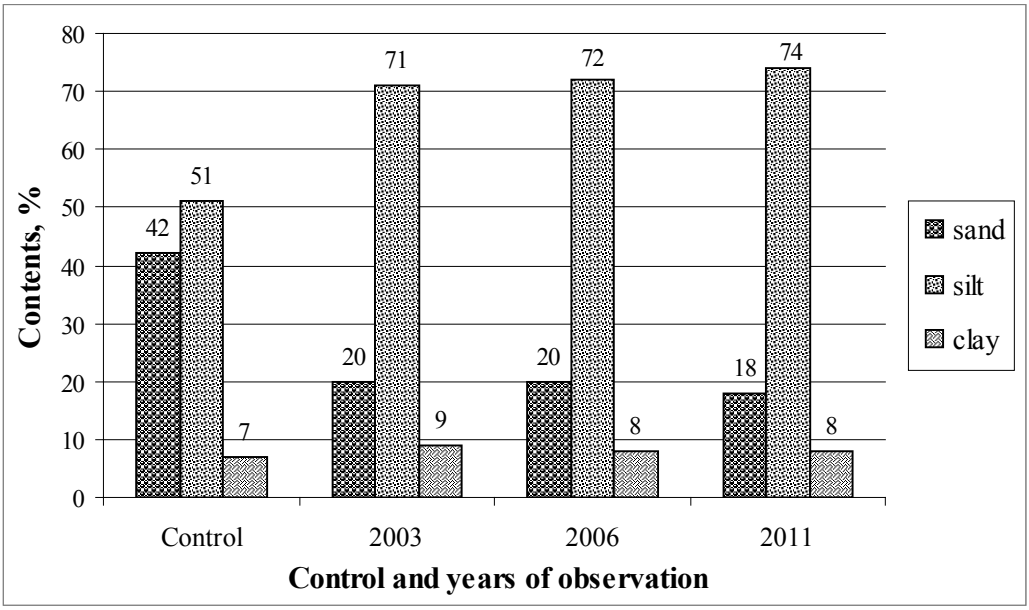

Fig. 4. Soil texture of Gray Forest soils (Gray Luvisols, FAO) influenced by strong surface fire in Belogradchik region – P-4.

and the silt increased by 3 %. The share of clay did not alter. Essential alterations have not been established in the soil influenced by strong surface fire (P-4). The share of sand did not change. The silt content increased and the clay decreased by 1 %.

A slow tendency of restoration, regarding the proportion of sand and silt, was observed in the case of weak surface fire (P-3) nine years after its impact. The differences between burned and unburned soils were reduced to 12–13 %. The share of clay, in both cases of fire, was 1% higher than in control plot.

It was found that the alterations in proportion of sand and silt increased nine years after the strong surface fire (P-4). The differences between burned and unburned control areas amounted to 23–24 %. It was due to a higher volume of burned biomass and more significant changes of vegetation. In the case of strong surface fire (P-4) the stand has been destroyed and replaced by herbaceous and bush species.

The results showed that the forest fire causes more significant changes of sand and silt in Gray Forest soils (Gray Luvisols, FAO) located in Belogradchik region compared to Cinnamonic Forest soils (Chomic Luvisols, FAO) located in Stara Zagora region, independent of fire intensity. That is in conformity with more significant alterations in chemical properties of researched Gray Forest soils, which contain lesser amount of nutrients (Bogdanov 2010). The share of clay has changed more in Cinnamonic Forest soils, which contain a larger proportion of this fraction.

Although the low chemical activity of silt fraction, when its share was dominant,

it had ability to determine the deep alteration in chemical properties due to a sharp change in its content.

Conclusions

The forest fire caused soil texture changes of burned Cinnamonic Forest soils (Chomic Luvisols, FAO) and Gray Forest soils (Gray Luvisols, FAO), which were expressed in change of proportion mainly between fractions of sand and silt. The clay fraction was altered to relatively lesser extent.

The soil textural class is an important factor which defines the character of the alterations. In the studied silt loam soils the part of sand strongly decreased, while the part of silt increased.

The soil type, type and intensity of the fires exerted significant influence on alternations of soil texture changes of studied soils. The share of clay changed to a higher degree in Cinnamonic Forest soils (Chomic Luvisols, FAO) containing higher amount of clay. The sand and silt were altered more in Gray Forest soils (Gray Luvisols, FAO) characterized by lesser amount of nutrients. A sharp change of silt fraction, which has a low chemical activity, might cause significant changes of chemical properties of soils dominated by silt.

The distribution of forest combustible materials could influence soil texture changes. More significant alterations have been observed in sand and clay in the case of crown fire, and the surface fire affected to a higher extent the clay content.

The larger volume of burned biomass and the deep changes of vegetation determine more significant and long lasting alterations in soil texture in the cases of more intensive fires.

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