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CHANGES IN TOTAL NITROGEN CONTENT IN SOILS INFLUENCED BY FOREST FIRES IN BULGARIA

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Abstract

The paper presents results from investigation on total N changes in soils influenced 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 correspondingly situated in the Lower forestry zone (0–700 m a.s.l.) of the Tracian forestry area and the Lower forestry zone (0–600 m a.s.l.) of the Moesian forest area. Soil samples had been taken seven times for ten years in order to investigate the nitrogen content dynamics. The content of total N has been determined using the modified Kjeldal method. A relationship was detected between content of total N and soil type, type and intensity of fires.

Key words: forest fire, forest soils, total N, *Pinus nigra* Arn.

Introduction

Forest fires were very common during the recent decades. They should not be considered separately of the context of global climatic change. According to Kontev (2001), the fire is an environmental factor whose importance has been increased by human activity.

The forest fires cause material damages, environmental changes, air pollution and lead to soil degradation. This problem concerns not only Bulgaria, but also the other Mediterranean countries in EU (Greece, France, Italy, Portugal) and as well as USA and Australia (Tashev and Malinova 1998).

The fire suppression is followed by extensive restoration activities in the affected areas. Young stands that are located in the lower forestry zone have been influenced more frequently. Due to the fact that they are usually situated in remote locations, a lot of financial resources should be spent in order to achieve a recovery of timber production properties of the burned forest soils (Alexandrov et al. 2002).

The content of nitrogen is an important prerequisite for successful development of forest restoration processes and is often a limiting factor for the growth and development of the forest (Velizarova et al. 2002, Bogdanov 2008, Petrova 2009). For this reason, it is necessary to clarify the forest fire influence on the nitrogen content in soils as well as the depth and degree of the changes depending on the type and intensity of fire. This issue is of great scientific and practical interest.

Seilopoulos (2004) established different changes in content of total N and ammonium N (NH_4-N) depending on the value and duration of the maximum temperatures developed at various soil depths during the fire. According to Barnes et al. (1998), much of the nitrogen lost through burning is not in a form available to the plant. The ability of succeeding vegetation and soil bacteria to replace the available nitrogen lost in burning is an important factor determining the effect of fire on site quality. Covington and Sacket (1984, 1992) found a short-term increase in amount of available nitrogen after fire. The studies of Kivekäs (1939), Kutiel and Naveh (1987), Little and Ohmann (1988), Gillon and Rapp (1989) established an increased concentration of ammonium N (NH_4-N) and nitrate N (NO_3-N), and a decreased content of total N after fire. This fact was explained by burning the soil organic matter, in which the nitrogen is a basic component.

The data obtained by other researches on dynamics of nitrogen alterations show a sharp increase of total N immediately after the fire impact and decreasing to the level in unburned control areas two years later (Choromanska and DeLuca 2001, Parker et al. 2001). Kaye and Hart (1998) and Neary et al. (1999) indicated that the increase of total N is due to increase of its nitrate forms and reduction in speed of their immobilization. Some authors (Youngberg and Wollum 1976, Wells et al. 1979, DeLuca 2000, Newland and DeLuca 2000) consider that fire can enhance long-term nitrogen availability in forest ecosystems by favoring populations of nitrogen-fixing plant. Murphy et al. (2006) concluded that the major short-term effects of fire were on leaching whereas the major long-term effect was loss of nitrogen from the forest floor and soil during the fire.

The paper is aimed at establishing the dynamics and degree of total nitrogen changes caused by forest fires and the influence of fire intensity and type on different soils.

Material and Method

The object 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 are located in the Lower forestry zone (0–700 m a.s.l.) of the Tracian forestry area (42° 38’ N, 25° 43’ E). The soils are Cinnamonic forest soils (*Chromic Luvisols*, FAO) influenced by strong crown and strong surface fire affecting thirty years old plantation of Black pine (*Pinus nigra* Arn.). The sample and control plots are situated at 400 m a.s.l., exposition is southwest with slope 10 °.

The plots in Belogradchik region are located in the Lower forestry zone (0–600 m a.s.l.) of the Moesian forestry area (43° 70’ N, 22° 68’ E). The soils are 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 is 450 m a.s.l., exposition is north-northwest, slope 5 °.

The forest fires were classified in present paper on basis of visible impact signs. According to fire intensity they were determined as follow:

– 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 immediately after the fire, 45 days, one, two, three, four and nine years later in order to investigate the dynamics of changes in total N content. Having in mind that the most significant changes of soil properties happen in the 10–15 cm depth (Raison et al. 1985, Barnes et al. 1998, Neary et al. 2008), the samples have been taken from the layers 0–5 cm and 5–15 cm.

The content of total N was determined using the modified Kjeldal method. The average content of total N has been calculated in order to establish the degree of the changes. The results were processed by statistical program Statistica 6. The arithmetical means (M) and standard deviations (SD) have been calculated. The alterations between burned and unburned control areas were analyzed in percentage terms.

Results and Discussion

The nitrogen forms most commonly assimilated by plants were the ammonium and nitrate ions. Their content was highly variable during the vegetation season. It depended on conditions of ammonification and nitrification, as well as their assimilation by the plants. Therefore, the determination of changes in available nitrogen content was difficult to achieve (Donov 1993). Therefore, the present work deals with changes in content of total N.

The dynamics of changes in total N content in Cinnamonic forest soils is presented in Table 1 and Figure 1 and 2. The data obtained showed a lack of lasting trend in the alterations during the first two years of the researched period. In the upper (0–5 cm) layer of the soil influenced by strong crown fire (P-1), an increase of total N by 29 % immediately after the fire impact was established and by 46 % 45 days later. One year after the fire there was a decrease by 24 % as compared to control plot (P-3).

The content of total N in lower (5–15 cm) layer decreased by 20 % immediately after the strong crown fire (P-1) and by 11 % 45 days later. An increase by 31 % compared to control plot (P-3) was observed one year after the fire.

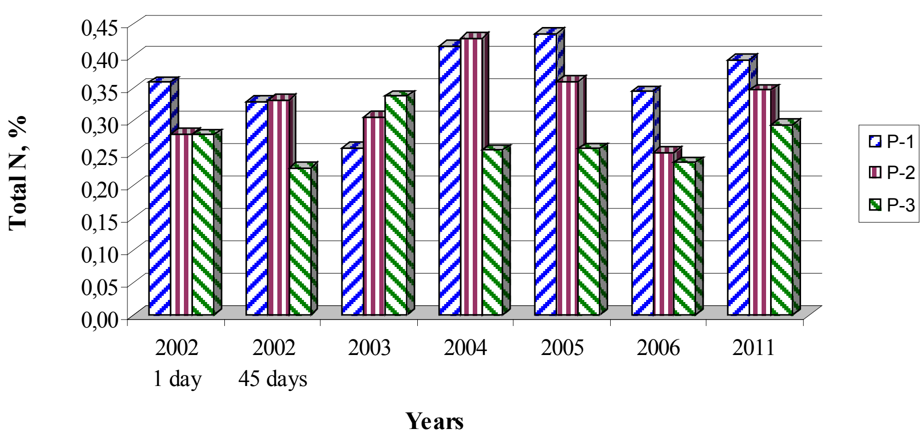

Fig. 1. Dynamics of total N content for depth 0–5 cm in Cinnamonic forest soils (*Chromic Luvisols*, FAO).

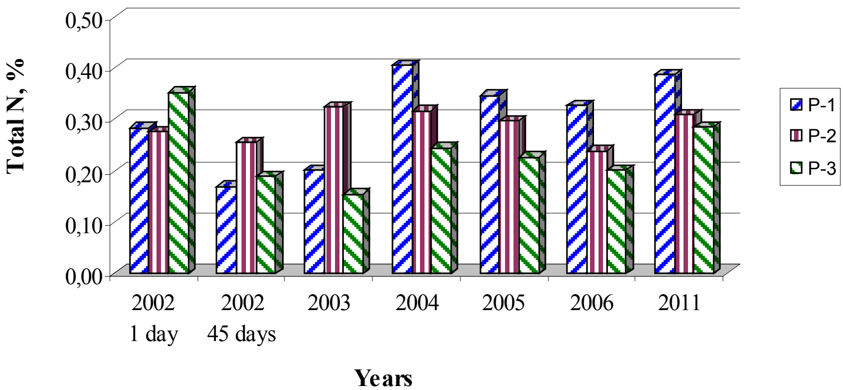

Fig. 2. Dynamics in total N content for depth 5–15 cm in Cinnamonic forest soils (*Chromic Luvisols*, FAO).

The results of investigated Cinnamonic forest soils influenced by strong surface fire (P-2) were also contradictory during the initial period of the study. Essential alterations have not been established in the 0–5 cm depth immediately after the fire. An increase by 47 % was found 45 days after the fire and a decrease by 10 % one year later compared to control plot (P-3). In the lower (5–15 cm) layer following initial reduction of 22 % it was recorded an increase by 35 % 45 days after the fire impact and by 110 % one year later.

After the second year of the period of study, the content of total N in burned area was higher than the unburned control area in both cases of fire impact. In the layer 0–5 cm the differences between area influenced by strong crown fire (P-1) and unburned control area (P-3) were 62 % in 2004, 69 % in 2005 and 47 % in 2006. For the depth 5–15 cm the increase was 66 %, 53 % and 63 %, respectively.

In the case of strong surface fire (P-2) the increase in both layers was 68 % and 30 % in 2004 and 41 % and 31 % in 2005, respectively. Four years after the fire the differences between burned and unburned areas were reduced to 6 % in layer 0–5 cm and to 19 % in layer 5–15 cm. The initial increase of total N can be due to the conversion of organic N released from burned plants to NH_4-N (DeBano et al. 1998, Raison 1979, Seilopoulos 2004).

Table 1. Dynamics in total N content in Cinnamonic forest soils (*Chromic Luvisols*, FAO) compared to control plot (±%)

Object	Depth, cm	1 day 2002	45 days 2002	1 year 2003	2 years 2004	3 years 2005	4 years 2006	9 years 2011
P-1	0–5 5–15	+29 –20	+46 –11	–24 +31	+62 +66	+69 +53	+47 +63	+34 +35
P-2	0–5 5–15	0 –22	+47 +35	–10 +110	+68 +30	+41 +31	+6 +19	+18 +8

The higher total nitrogen content of burned Cinnamonic forest soils was kept to the end of the period of study. In the case of strong crown fire (P-1) the increase in both layers was 34–35 % as compared to the control plot (P-3). In the case of strong surface fire (P-2) the differences between burned and unburned areas were lower – 18 % in layer 0–5 cm and 8 % in layer 5–15 cm.

The results of the study on Cinnamonic forest soils show that the strong crown fire (P-1) causes more significant and long lasting alterations in total N content as compared to the changes caused by strong surface fire (P-2). It might be explained by higher severity of the fire corresponding to a higher volume of burned biomass.

The dynamics of total N content in Gray forest soils is presented in Table 2 and Figure 3 and 4. In contrast to data obtained from analyzed Cinnamonic forest soils, different results were established in investigated Gray forest soils located in Belograd-

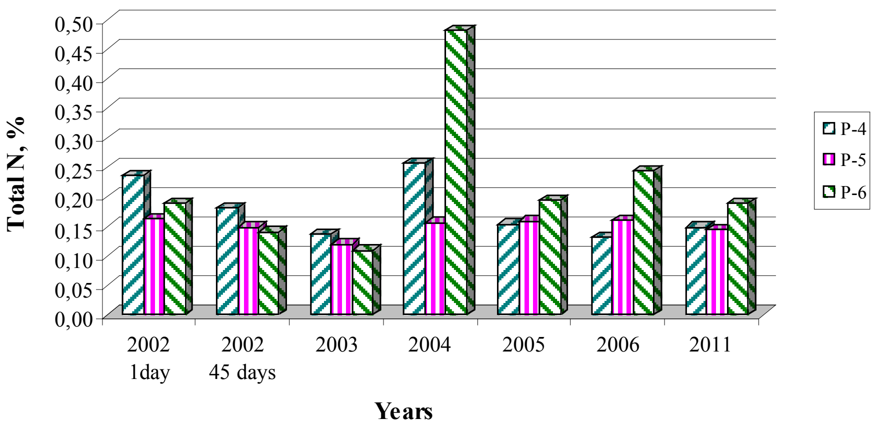

Fig. 3. Dynamics in total N content for depth 0–5 cm in Gray forest soils (*Gray Luvisols*, FAO).

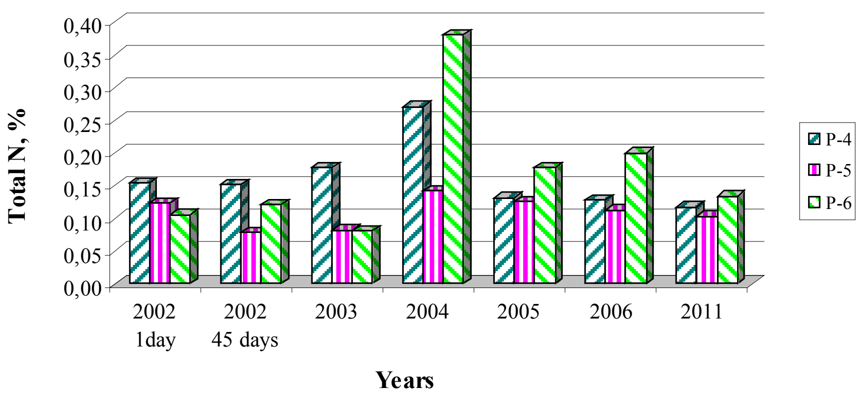

Fig. 4. Dynamics in total N content for depth 5–15 cm in Gray forest soils (*Gray Luvisols*, FAO).

Table 2. Dynamics in total N content in Gray forest soils (*Gray Luvisols*, FAO) compared to control plot (±%).

Object	Depth, cm	1 day 2002	45 days 2002	1 year 2003	2 years 2004	3 years 2005	4 years 2006	9 years 2011
P-4	0–5	+26	+29	+25	–47	–21	–46	–22
	5–15	+45	+25	+120	–29	–25	–36	–13
P-5	0–5	–14	+6	+9	–68	–19	–34	–24
	5–15	+16	–35	+1	–63	–28	–47	–23

chik region. Two years after the fire, in both cases of fire impact was found a decrease in content of total N compared to unburned control area. This lasted to the end of the period of study.

The amount of total N in the Gray forest soils influenced by weak surface fire (P-4) was higher as compared to control plot (P-6) during the first two years after the fire impact. The increase was 25–29 % for depth 0–5 cm and 25–120 % for depth 5–15 cm. After the second year the content of total N in burned area was lower than that in the unburned control area. The differences in upper (0–5 cm) layer were 47 % in 2004, 21 % in 2005 and 46 % in 2006. In layer 5–15 cm the decrease was 29 %, 25 % and 36 %, respectively.

The results obtained on Gray forest soils influenced by strong surface fire (P-5) were contradictory during the first two years of the investigation. After the second year the content of total N in burned area was lower than that in the unburned control area (P-6). For depth 0–5 cm the decrease was 68 % in 2004, 19 % in 2005 and 34 % in 2006. The differences for depth 5–15 cm were 63 %, 28 % and 47 %, respectively.

It was found that the differences between burned and unburned Gray forest soils located in Belogradchik region lasted nine years after the fire. In the case of weak surface fire (P-4) was established a decrease by 22 % in layer 0–5 cm and by 13 % in layer 5–15 cm. In the case of strong surface fire (P-5) the decrease in both layers was 23–24 %.

The average content of total N is indicative about the degree of the alterations and is presented in Table 3 and Table 4. The data obtained from studied Cinnamonic forest soils and Gray forest soils are contradictory, which is determined by the different dynamics of the changes.

The average content of total N in burned Cinnamonic forest soils was higher compared to unburned control plot in both cases of fire impact. The biggest change was recorded in the soil influenced by strong crown fire (P-1), which is characterized by a higher intensity corresponding to a higher volume of burned biomass. An increase by 41 % for depth 0–5 cm and by 34 % for depth 5–15 cm was established. In Cinnamonic forest soils influenced by strong surface fire (P-2) the increase was reduced to 25 % in layer 0–5 cm and 33 % in layer 5–15 cm. The standard deviations were between 0.02 and 0.07 (Table 3).

Essential alterations have not been established in Gray forest soils influenced by weak surface fire (P-4). The differences between burned and unburned areas amounted 2–7 % (Table 4).

A significant change in comparison with control plot (P-6) in Gray forest soils influenced by strong surface fire (P-5). The average total N content decreased by 18 %

for depth 0–5 cm and by 26 % for depth 5–15 cm. That is in conformity with a higher intensity of the fire corresponding to a higher volume of burned biomass and more significant changes of vegetation. In the case of strong surface fire (P-5) the stand was completely destroyed. The standard deviations were between 0.01 and 0.05 (Table 4).

The decrease in total N in Gray forest soils might be explained by lower intensity of the fires. According to Wells (1971) and Viro (1974), total N is highly correlated with organic matter and, when the forest floor burned, nitrogen decreased in relation to the severity of the fire. On the other hand, the forest fires increase the soil temperature that activates the development of soil microorganisms. This in turn could lead to a reduction in total N and an immobilization in both ammonium N (NH_4-N) and nitrate N (NO_3-N).

Table 3. Average content of total N in Cinnamonic forest soils (*Chromic Luvisols*, FAO)

Object	Depth, cm	M, %	SD	VS control, ±%
P-1	0–5	0.363	±0.04	+41
	5–15	0.289	±0.07	+34
P-2	0–5	0.320	±0.04	+25
	5–15	0.286	±0.03	+33
P-3 control	0–5	0.257	±0.02	-
	5–15	0.215	±0.02	-

Table 4. Average content of total N in Gray forest soils (*Gray Luvisols*, FAO)

Object	Depth, cm	M, %	SD	VS control, ±%
P-4	0–5	0.177	± 0.05	–7
	5–15	0.154	± 0.02	+2
P-5	0–5	0.156	± 0.01	–18
	5–15	0.111	± 0.02	–26
P-6 control	0–5	0.191	± 0.04	-
	5–15	0.151	± 0.04	-

Conclusion

The forest fire causes different changes in investigated soils. The alterations depend on the soil type and the type of fire, which is defined by fire intensity and distribution of forest combustible materials.

The total N increased in affected Cinnamonic forest soils (*Chromic Luvisols*, FAO) that contain larger amount of nitrogen. The increase is correlated with a higher volume of burned organic matter. It is due to a higher intensity of the fires and leads to the release of larger amount of nitrogen.

The total N is decreased in burned Gray forest soils (*Gray Luvisols*, FAO) that are characterized by less amount of nitrogen and nutrients. The decrease is in conformity with a lower volume of burned biomass. Similarly, the increase of soil temperature after the fire activates the development of soil microorganisms and nitrification. This might be a prerequisite for reduction in content of total N.

The larger volume of burned biomass and the deep changes of vegetation determine more significant and long lasting alterations in content of total N. Therefore, it is an important indicator that has ability to characterize the forest fire impact on the forest soils.

The changes lasted until the end of the researched period in the cases of strong fires. The results obtained nine years after the fire impact confirm the generally accepted opinion that the fire might cause long lasting alterations in soil properties and forest development depending on its severity.

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