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# CHANGES OF GROUND VEGETATION AND TREE-RING GROWTH AFTER SURFACE FIRES IN SCOTS PINE FORESTS

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The influence of low-intensity surface fires were investigated on the development of ground vegetation and tree growth in Scots pine (*Pinus sylvestris*) stands on sandy soils. The study was conducted in eastern part of Lithuania (55$^{o}$35'N, 26$^{o}$07'E). The annual investigations in 1-4-year-old burned sites show that low intensity surface fires mostly affected above-ground part of ground vegetation. Surface fires have destroyed above-ground part of ground vegetation cover, but it began to recover in the subsequent years. Within 3-4 years burned sites have had even higher number of species and ground vegetation coverage than in unburned sites. The pioneer herb species and also dwarf shrubs, mainly *Vaccinium myrtillus*, were spread out. The recovery of moss cover was still non-significant. Investigations show, that low intensity surface fires didn't affect annual radial increment.

Key words: surface forest fire, *Pinus sylvestris*, ground vegetation, dendrochronology, tree growth.

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## INTRODUCTION

Nowadays, forest fires are recognized as important ecological factor affecting vegetation structure and composition, energy fluxes and biogeochemical processes in boreal and hemiboreal forest landscapes (Shugart et al. 1992, Parviainen 1996, Angelstam 1998, Bergeron et al. 2002, Kuuluvainen 2002, Ryan 2002, Wallenius et al. 2007). Modern forest management should consider the impact of fire as the increases in the frequency and intensity of natural and anthropogenic forest fires are expected to occur in the coming decades as a consequence of global climate changes (Päätalo 1998, IPCC 2007, Flannigan 2009).

The effect of the fires on forest ecosystems depends on fire severity and duration (Ice et al. 2004, Certini 2005). Severe crown fires can eliminate above-ground biomass, change successional rates and alter vegetation species composition, belowground physical, chemical and microbial processes.

Surface forest fires mainly affect the species composition of ground vegetation, can promote an herbaceous flora, tree regeneration conditions and short-time increase of plant available nutrients in soil (Parviainen 1996, Granström 2001,Gromtsev 2002, Ryoma and Laaka-Lindberg 2005,Jayen et al. 2006, Marozas et al. 2007, Parro et al. 2009).

Mainly the observations on surface fire impact to vegetation of pine forest ecosystems were presented in European hemiboreal forest zone (Zackrisson 1977, Marozas et al. 2007, Parro et al. 2009). Moreover, there is a lack of long-term investigations on vegetation growth that occur after surface fire.

In Lithuania the annual number of forest fires is about 700 (from 200 to 1600 per year) (LME/SFSS 2010). Total burned forest area ranges from 100 to 700 ha annually with average burned area per one fire of 0.45 ha. Even 84 % of fires emerge in Scots pine forests. The most common are surface fires (97.3 %), while crown fires and underground fires amounts only to 1% and 1.7 %, respectively.

Surface fires only burn the forest community bottom: the forest floor, moss, grass vegetation, undergrowth and underwood. And also burn tree bark and roots of what some of them may result in death or reduced growth of trees (Воронцов 1978).

The aim of this study was to investigate the initial recovery of ground vegetation and tree growth changes in Scots pine forests following the low-intensity surface fires.

## MATERIAL AND METHODS

### 2.1. Study site

The study area is located in eastern part of Lithuania (Zarasai district) (55°35' N, 26°07' E) and it falls in the transitional deciduous coniferous mixed forest hemiboreal zone of Europe (Ahti et al. 1968). The height above sea level is about 150-180 meters. The mean annual temperature ranges from +5.4 to +5.8 °C, with a mean January (coldest month) temperature of -6.4 °C and a mean July (warmest month) temperature of 16.9 °C. Annual mean precipitation is between 600 and 700 mm. Period with permanent snow cover continues from 100 to 110 days (Bukantis 1994). Hilly landscape, sandy soils and pure Scots pine (*Pinus sylvestris*) stands prevail in the forests of investigation area.

The study was carried out in 60-year-old pure Scots pine stands with the undergrowth of Norway spruce (*Picea abies*). All studied stands are growing on nutrient-poor sandy *Arenosols* (forest type - *Vaccinio - myrtillo Pinetum*). In ground vegetation cover prevail: *Vaccinium myrtillus*, *V. vitis-idaea*, *Calluna vulgaris*, *Festuca ovina*, *Linaria vulgaris*, *Luzula pilosa* and *Melampyrum pratense* in the dwarf shrub and herb layer, and *Dicranum polysetum*, *D. scoparium*, *Hylocomium splendens* and *Pleurozium schreberi* in the moss layer. In these stands surface fires occurred at the end of April of 2006 and 2009. Since the fires were of low intensity Scots pine trees were not damaged. Meanwhile Norway spruce undergrowth and shrubs were killed totally and ground vegetation cover had burned. The area of fires was about 60 ha in 2006 and about 5 ha in 2009.

### 2.2. Ground vegetation study

In total 4 permanent transects (20x1 m) with 20 sampling plots (1x1 m) were established for the ground vegetation study in burned site (surface fire occurred in April of 2006) and untouched not-burned site (control) of Scots pine stand. Vegetation studies were conducted annually in June-July of 2006-2009. Each year in transects species composition (species names according to Jankevičienė 1998) and projection cover (in per cent) of shrubs, saplings, dwarf shrubs, herbs and mosses were recorded.

### 2.3. Tree ring study

Wood samples from 15-20 trees of I and II classes according to Kraft's classification were taken in each sample plot at 1.3 m height from root collar by Pressler's borer.

For the preparation of wood samples for annual tree ring measurements dry wood samples were soaked in water 2-4 hours, so that annual rings regain their former width. To make the tree-rings contours more visible, one side of the sample was cut by a special knife.

For annual radial measurement and ring structure assessment were used LINTAB tree ring measurement system and TSAP (Time Series Analysis Presentation) set of programs. TSAP (TSAP by FRANK RINN and SIEGWARD JAKEL, Heilderberg, Germany) software package consist of the annual ring chronology and the radial growth of trees used for synchronization, the global practice of the dendrochronological research-based methods (Eckstein 1989).

**2.4. Data statistical analyses**

Because vegetation data were not normally distributed, we used nonparametric Mann-Whitney test to test differences in species number, vegetation projection cover between burned and untouched control sites. The non-parametric Wilcoxon test was used to test differences among pairs of data set in different years. Statistical analyses were conducted using the software STATISTICA 8.0.

## RESULTS AND DISCUSSION

**3.1. Changes in ground vegetation**

In total 28 different species were found during 4 years period in ground vegetation cover of burned and control sites of Scots pine stands. Average species number per 1 m$^2$ significantly ($p<0.05$) decreased in the first year after the low intensity surface fire (Fig. 1). In the subsequent years average species number slightly increased, and in the fourth year after surface fire it was even higher than that in non-burned control site of pine stand. That species number increases was contributed mainly by spread out of pioneer early succesional herb species (*Calamagrostis epigejos, Equisetum hyemale, Pteridium aquilinum, Rubus idaeus, R. saxatilis, Scorzonera humilis, Solidago virgaurea, Ceratodon purpureus, Polytrichum juniperinum*).

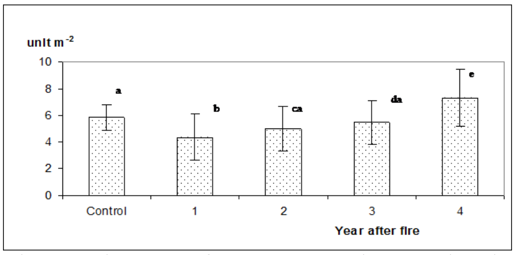


Fig. 1. Changes of average species number in ground vegetation cover of burned and control sites in Scots pine stands. Values are given as mean ± SD. Different letters indicate a statistically significant difference ($p< 0.05$).

Obtained data are confirmed by other authors. The same decline in the number of species immediately after the fire and the following increase after a few years was reported (Nuzzo 1996; Parro et al. 2009).

In the cover of ground vegetation of Scots pine stand prevailed herbaceous, moss and dwarf species (Table 1). Only 2 species of shrubs (*Frangula alnus* and *Sorbus aucuparia*) and 2 species of saplings (*Quercus robur* and *Picea abies*) occurred seldom before the fire. Besides, only *F. alnus* was found in the burned site.

In total 9 herbaceous and dwarf shrub species occurred in ground vegetation cover before the fire (Table 1). Meanwhile, in the burned site the number of these species increased and comprised 15 species. Among mentioned plants dwarf shrubs as *Vaccinium myrtillus* and *V. vitis-idaea* were the most abundant in the control site. These dwarf shrubs were declined by surface fire, however were recovered, especially *V. myrtillus*, during 3-4 years.

Herabaceous species of *Calluna vulgaris, Luzula pilosa* and *Polygonatum odoratum* were found only in the control site and still did not occur in 4-year-old fire site (Table 1). In opposite, *Rubus saxatilis, Scorzonera humilis, Calamagrostis epigejos, Pteridium aquilinum, Trientalis europaea, Peucedanum oreoselinum, Solidago virgaurea, Equisetum hyemale, Rubus idaeus* occurred only in the burned site.

Table 1. Changes of average projection cover (%) of shrubs, herbaceous, dwarf shrub, herbaceous and moss species in burned and control areas

| Name of species | Control | Year after fire | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| **Shrubs** | | | | | |
| *Frangula alnus* | + | + | + | - | + |
| *Sorbus aucuparia* | + | - | - | - | - |
| **Saplings** | | | | | |
| *Quercus robur* | + | - | - | - | - |
| *Picea abies* | + | - | - | - | - |
| **Herbs and dwarf shrubs** | | | | | |
| *Calamagrostis arundinacea* | 0.1 | 0.1 | 0.2 | 0.3 | 0.2 |
| *Calamagrostis epigejos* | - | + | 0.1 | 0.1 | + |
| *Calluna vulgaris* | 0.3 | - | - | - | - |
| *Convallaria majalis* | 0.6 | + | 2.6 | 1.9 | 1.8 |
| *Equisetum hyemale* | - | + | + | + | + |
| *Festuca ovina* | + | + | + | 0.3 | 0.5 |
| *Luzula pilosa* | 0.2 | - | - | - | - |
| *Melampyrum pratense* | 0.2 | - | + | 0.9 | 1.0 |
| *Peucedanum oreoselinum* | - | + | 0.1 | + | - |
| *Polygonatum odoratum* | + | - | - | - | - |
| *Pteridium aquilinum* | - | 0.9 | 1.5 | 4.2 | 4.5 |
| *Rubus idaeus* | - | - | - | - | 0.1 |
| *Rubus saxatilis* | - | 0.8 | 2.8 | 2.8 | 2.6 |
| *Scorzonera humilis* | - | + | 0.2 | 0.3 | 0.2 |
| *Solidago virgaurea* | - | + | + | - | - |
| *Trientalis europaea* | - | 0.1 | 1.2 | + | + |
| *Vaccinium myrtillus* | 17.5 | 2.7 | 23.2 | 50.4 | 47.6 |
| *Vaccinium vitis-idaea* | 13.4 | 0.4 | 2.0 | 3.9 | 4.4 |
| **Mosses** | | | | | |
| *Dicranum polysetum* | - | - | - | - | + |
| *Dicranum scoparium* | - | - | - | - | + |
| *Hylocomium splendens* | 35.7 | - | - | - | - |
| *Pleurozium schreberi* | 60.5 | - | - | - | + |
| *Ceratodon purpureus* | - | - | - | - | 0.8 |
| *Polytrichum juniperinum* | - | - | - | | + |

The reduction of average projection cover of herbaceous and dwarf shrub species due to surface fire was observed only during the first year. Projection cover recovered in the second year after the surface fire. Moreover, in the third year projection cover of herbaceous and dwarf shrub species was even higher than that in the control site (Fig. 2). Such increase was mainly because in burned sites the coverage of *V. myrtillus* (near 50%) almost by 3 folds exceeded the coverage of this dwarf shrub in Scots pine stand before the fire.

Only 2 moss species, *Pleurozium schereberi* and *Hylocomium splendens*, occurred but comprised almost 90 % of ground vegetation cover before the fire in observed Scots pine stand (Table 1). The decline of these mosses was still in fact total in the 4 year after the fire. Instead of mentioned mosses, 4 new moss species (*Dicranum polysetum, D. scoparium, Ceratodon purpureus, Polytrichum juniperinum*) occurred in the burned sites. However, average projection cover of the mosses was still very law (comprised only 1-2%) in 4-year-old fire sites.

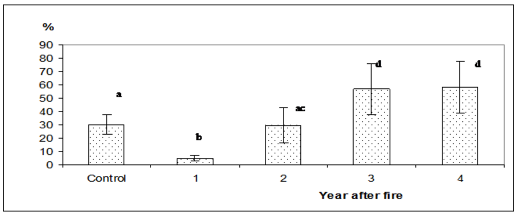


Fig. 2. Changes of average projection cover (%) of herb and dwarf shrub layer in burned and control areas. Values are given as mean ±SD. Different letters indicate a significant differences ($p< 0.05$).

Surface forest fires had considerable effect on ground vegetation coverage. Fire destroyed above-ground part of vegetation, but the herbs and, especially, dwarf shrubs quite rapidly recovered within 3-4 years. The recovery of moss layer is much slower and it takes more than 10 years (Marozas et al. 2007, Parro et al. 2009). Skre (Skre et al. 1998) found that the biomass of *Calluna vulgaris*, *Polytrichum*. *Deschampsia flexuosa* and *Pteridium aquilinum* increased after the fire in pine forests of western Norway while regrowth of *Vaccinium myrtillus* and *V. vitis-idaea* was slower. Other investigations also suggested (Ryoma and Laaka-Lindberg 2005) that *Ceratodon*, *Funaria*, *Pohlia nutans*, *Polytricum* spp. appears quickly after the fire in boreal forests. Investigation of post fire recovery of species in Scots pine forest in the central part of the Kola Peninsula (Gorshkov and Bakkal 1996) showed that the herb and dwarf shrub layers recovered within 5-15 years after the fire while the mosses recovered within 90-140 years after the fire.

### 3.2. The changes of average tree radial growth

Tree of burned and control pine stands were growing rapidly at young age (Fig. 3). Average annual radial growth in burned stand at the 1950-1970 period varied from 1.62 mm to 5.03 mm, in control stand – from 1.78 mm to 4.01 mm. At older age of radial growth of trees has slowed. At the 1970-1990 period in burned stand the average annual radial growth varied from 1.14 to 2.15 mm, and in control stand – from 1.11 to 2.22 mm. The smallest increment of trees in burned stand

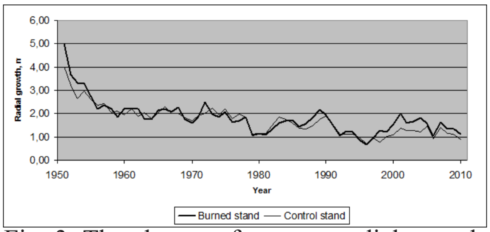


Fig. 3. The change of average radial growth of Scots pine in burned and control stands.

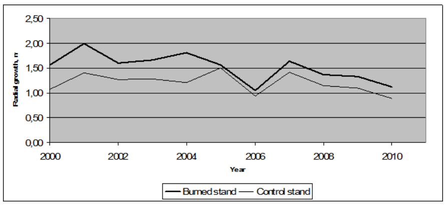


Fig. 4. The change of average radial growth of Scots pine in burned and control stands.

was 0.69 mm, and in control stand – 0.71 mm. The average annual growth of the entire growth period (60 years) in burned stand was 1.83 mm and 1.71 mm in the control stand.

In 1951, 1966, 1972-1975, 1990, 2001, 2004 years records of annual maxima of the radial growth of pine trees coincided with favourable climatic conditions for growth in diameter, whereas those characterized by periods of optimum growing season temperatures and adequate rainfall (Bukantis 1998).

In 1956, 1963, 1969, 1970, 1979, 1987, 1996 years recods decreased radial growth of trees. Reduced growth of pine trees was due to extreme winter temperatures and summer drought (Bukantis 1998).

Surface fire occurred in 2006 year in mid-spring time. At fire time the pine stand was 56 years old. Radial growth of trees in burned and control stands is shown in Figure 4.

First year after the fire noticeable increase of radial growth and decrease in radial growth 2-3 years after a fire could be related with the other factor because the increase of radial growth in control stand was detected.

## CONCLUSIONS

Surface fires have destroyed above-ground part of ground vegetation in V*accinio-myrtillo Pinetum* forests. Nevertheless, ground vegetation began to recover in the subsequent years. Within 3-4 years after the fires the burned sites have had even higher number of species and ground vegetation coverage than in unburned sites. The pioneer herb species and also dwarf shrubs, mainly *Vaccinium myrtillus,* were spread out. The recovery of moss cover was still non-significant.

The radial growth of tree has not changed after low intensity surface fire. Scots pine trees are a fire-tolerant species and can survive low severity surface fires.

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