HEIGHT-GROWTH DYNAMICS OF SCOTS PINE (*PINUS SYLVESTRIS* L.) IN BURNED AND CLEARCUT AREAS IN HEMIBOREAL FORESTS, LATVIA

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The aim of this study was to compare medium-term growth dynamics of Scots pine (*Pinus sylvestris* L.) in areas after forest fire and clearcut in different forest types to improve the understanding of post-fire growth of trees in hemiboreal forest zone. The data were collected at four Scots pine dominated forest stands located in northern and central parts of Latvia (56°45′ - 57°40′N; 22°32′-24°98′E) burned or clearcut in 1992, 2004 and 2006; forest types *Vacciniosa, Vacciniosa mel* and *Myrtillosa mel*. In each study site 100m^2 and 25 m^2 circular plots were placed systematically and height increment of Scots pine were measured. The average height of Scots pine at the age of 8 years was 167±54.2 cm *Vacciniosa* and 230±90.3 cm *Myrtillosa mel*. At the age of 10 years 184+71.1 cm *Vacciniosa mel*, and at the age of 22 years 360±214.1 cm *Vacciniosa*. Our results demonstrated that 8 years after the forest fire mean height of Scots pine was significantly lower in burned areas in comparison to clearcut, but there were no significant differences in mean height of trees 10 and 19 years after forest fire. It indicates, that impact of forest fire on tree growth diminishes over time and in forest types on more fertile soil its effect is more limited than on poor soil. Tree height was notably more variable in all the burned areas in comparison to the control areas.

Keywords: forest fire, forest type, height increment.
Parole chiave: incendi boschivi, tipo di foresta, altezza incremento.

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1. Introduction

Latvia is located in hemiboreal forest zone and its forests cover, according to National forest inventory is 52%. During last decade forestland has been expanding gradually due to afforestation of less fertile and abandoned agriculture land. In 2013 forest sector generated around 6% of country's GDP according to Ministry of Agriculture statistics. There are different kinds of natural disturbances in hemiboreal forests, like forest fires, windthrows, insects and disease outbreaks which are essential elements of ecosystem dynamics. In order to improve post-disturbance silviculture practices it is important to understand how to mitigate negative and use positive effects of these disturbances.

Historically forest fires have been a component of the forest ecosystem dynamics, but at least for the last 3 millenniums main cause of them is human activity. Nowadays forest fire occurrence in hemiboreal forest zone in Europe has declined due to the effective forest fire protection systems.

The number of forest fires varies every year. In last 24 years the total forest area burned per year in Latvia vary from 90 ha in year 2012 to 8412 ha in 1992, on average every year in Latvia fire affects 1083 ha of forest land according to Latvian State Forest statistics. In year 2013 93% of all forest fires were human caused. Moreover notably more fires occur around urban areas, for example, 22% of all forest fires in 2013 occurred close to capital city Riga (Leisavnieks, 2013). Similar situation has been observed across northwest Europe: the majority of forest fires is caused by humans and located in vicinity of cities (Hille and den Ouden, 2004). According to the climate-change scenarios, a rise of the mean temperature 2.5 °C in the territory of Latvia until the end of the century is expected, meanwhile the increase of rainfall will be minimal, causing prolonged periods of drought (Aigars *et al*., 2009). This situation will inevitably lead to increase in frequency of years with very high fire risk (calculated based on Nesterov index and Canadian Forest Fire Weather Index) as well as in days per year with very high fire risk. Very high fire risk indicates both high flammability of organic material (litter, duff etc.) as well as high temperatures during the fire, thus increasing fire likelihood of forest fire to initiate as well as its severity. In future in Latvia higher forest fire risk are mainly expected in forest types on poor and dry soils where the dominant tree species mostly is Scots pine. Scots pine is categorized to withstand moderate severity fire (Granströem, 2001). It is important to understand post-disturbance stand development dynamics in order to find most suitable stand regeneration methods in future.

Therefore aim of this study was to compare medium-term growth dynamics of Scots pine (*Pinus sylvestris* L.) in areas after forest fire and clearcut in different forest types.

2. Materials and methods

2.1 The study area

The study area is located in northern and central parts of Latvia (56°45´- 57°40´N, 22°32´-24°98´E). The average annual temperature in territory of Latvia is +5.9 °C, on average July is the warmest month with the average temperature is +17.0 °C, the coldest months of the year are January and February with the average temperature from – 4.6 to – 4.7 °C. The mean amount of precipitation annually is 667 mm. The months with the most of precipitation on average 78 mm are July and August. The months with the lowest amount of precipitation on average 33 mm are February and March according to Latvian Environment, Geology and Meteorology Centre statistics**.**

2.2 Data sampling and data analysis

The data were collected in four Scots pine (*Pinus sylvestris* L.) dominated forest stands in summer and autumn in 2014. In all sites has been recorded high severity- stand replacing forest fire, followed by salvage clearcutting. Sites were regenerated by planting in year 1992 (Slitere, *Vacciniosa* forest type), 2004 (Ugale, *Vacciniosa mel*. forest type) and 2006 (Jaunjelgava and Dalbe, *Vacciniosa* and *Myrtillosa mel*. respectively). Clearcut area of the same year and forest type, regenerated by Scots pine, located close to the respective site were chosen as comparison.

At each study site 100 m^2 and 25 m^2 circular plots were placed systematically and height increment of Scots pine, Silver birch (*Bentula pendula* Roth.), Norway spruce (*Picea abies* L.) and Trembling aspen (*Populus tremuloides*) was measured. Student's T-test was used to assess significant differences between areas after forest fire (further in text referred as burned) and control areas.

3. Results

The average height of Scots pine at the age of 8 years was 167±54.2 cm (mean±SD) in *Vacciniosa* forest type and 230.4±90.3 cm in *Myrtillosa mel* forest type. At both sites mean height of Scots pine was significantly higher ($p=0.001$) in the control areas than in the burned areas (Tab. 1). The difference between burned and control areas was from 25 to 36 cm, higher height difference were found in forest type on poorest soil (*Vacciniosa*). At these sites also the Scots pine height increment of the last 3 years demonstrated similar tendency i.e. gradual increase of height difference between burned and control areas (Fig.1. A, B). At age of 10 years in *Vacciniosa mel* forest type no significant ($p>0.1$, $\alpha=0.05$) height differences between control and burned areas was observed, however, it is a results of changes during last years, since at the age 7 years pines were significantly higher in the burned areas than in control (Fig. 1 C).

At the age of 19 years in *Vacciniosa* forest type no significant height differences between burned and control areas ($p=0.76$, $\alpha=0.05$) was observed (Fig. 2). Moreover there was no significant height differences between burned and control areas in the last two years.

Scots pine height was clearly more variable in all the burned areas compared to control areas. At burned areas variation coefficient ranged from 32-59%, but in control areas from 29-50 % respectively (Tab. 2).

The highest Scots pine height variability observed in *Vacciniosa* forest type at age of 19 years in burned area was 59% but in control –50%. The most even distributed height of Scots pine is observed in *Vacciniosa* forest type at age of 8 years in burned areas 32 % but in control areas 29%. Density of Scots pines was notably and significantly higher in burned areas in comparison to clearcuded in both sites in *Vacciniosa* forest type and lower in *Vacciniosa mel.* forest type; density of other tree species (birch, aspen, spruce) was significantly higher in clearcuted sites only in tow oldest areas (Ugale and Slitere). Plot-mean level correlation between density of other tree species and density Scots pine varied widely, but was not significant in any of the sites (Tab. 2).

4. Discussion

Number of studies has analyzed post-fire regeneration and short-term growth trends. For example, positive effect of forest fire on Scots pine regeneration is reported by Hille and den Ouden (2004): they found that Scots pine recruitment in *Oxalio-Myrtillo-Cultopinetum sylvestris* forest sites was more successful and height significantly higher after medium severity fires than after soil scarification in clearcut areas in Germany. Similarly, in Lithuania regeneration of Scots pine in first 4 years after low intensity fire in *Vaccinium* forest type was more successful than in control areas, although height increment wasn't measured in this study (Marozas *et al*., 2007). However, there is very limited number of studies covering medium-term impact of forest fire on tree growth that is the object of our study. Our results demonstrate that after the fire growth of Scots pine is significantly slower at age of 8 years in *Vacciniosa* and *Myrtillosa mel* forest types, but at age of 10 and 19 years no significant mean height differences were observed at burned and clearcut areas in *Vacciniosa mel* and *Vacciniosa* forest types. In Canada study results shows that in black spruce stand height differences between burned and clearcut area disappear at age 50 years on sandy loam soils (Ruel *et al*., 2004). Negative effect of forest fire on tree growth, decreasing over time, is linked to its impact on soil. During high severity forest fire large part of organic matter is consumed, soil characteristics i.e. porosity and structure are degraded (Certini, 2005) and root system and mycorrhizas are damaged (Hille, 2006). Also significant loses from forest floor of K and N have been observed at young stands after forest fire, while no significant loss of soil nutrients were observed after clearcut harvesting (Simard *et al.*, 2001). The higher height difference between burned and control areas was found in *Vacciniosa* forest type at age of 8 years. On average in non-disturbed *Vacciniosa* (poor sandy soil) forest floor humus layer is 5 cm thick, while in *Myrtillosa mel* (sandy loam soil) humus layer is around 20 cm. It could explain the higher absolute and relative tree height differences between burned and clearcut areas observed in Vacciniosa in comparison to

Myrtillosa mel.: effect of forest fire on thinner humus layer could be more degrading and soil nutrient leakage is more intense from sandy soils than from sandy loam soils. In *Vacciniosa mel* forest type with relative thick humus layer (20 cm on average) all organic material may not be consumed also during high intensity forest fire and could therefore explain, why no significant height differences are observed for Scots pine at the age of 10 years between burned and clearcut areas in this forest type. Negative effect of forest fire on soil (total mass of organic carbon, extractable Ca, P and pH), lasting longer than the age of trees of in our study (for 21 years) was found in boreal forest zone (Simard *et al*., 2001). Sooner disappearing impact of forest fire in our study could be explained by differences of climatic conditions (as the nutrient cycling and accumulation of organic matter is faster in hemiboreal or nemoral, than in boreal zone) or forest type. Scots pine and other tree species density in our study varied significantly between treatments and sites; moreover we did not find significant correlation between Scots pine density and other tree species densities. Tree densities at commercial stands are mainly influenced by timing and intensity of thinning (not known in our study sites) therefore we cannot attribute observed differences to influence of forest fire. Stand-development following fire disturbance primarily depends on the fire severity and the scale of damage to the ecosystem (Hille, 2006). Scots pine height variation was higher at burned sites compared to control areas. Similar results have been observed by Taylor *et al*. (2013) in boreal forests and these differences can be explained by different spatial heterogeneity of forest fire severity which is affected by stand composition and fuel load (Kafka *et al*., 2001) weather conditions and topography (Taylor *et al*., 2013).

This heterogeneity affects humidity, soil moisture and temperature, crucial for early development stages of trees (Hille and den Ouden, 2004) as well as nutrient availability, important to boost tree growth. Patches of lower fore intensity might even have had a positive influence on availability of soil minerals and eliminate plant competition (Certini, 2005), therefore boosting growth of particular trees.

Therefore further studies shall include soil- analysis to improve the understanding of the causes of observed Scots pine height differences and cover higher number of sites and sample plots to address the impact of heterogenity and better reveal the medium-term impact of forest fire.

Acknowledgements

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Table 1. Tree height in stands after forest fire and clearcut.

Site *Forest type*	*Treatment*	*Mean height of Scots pine (cm)*	*SD (cm)*	*Mean height of birch, aspen, spruce tree species (cm)*	*SD (cm)*
Jaunjelgava *Vacciniosa*	Burned	167	54.2	147	83.3
	Control	202	57.9	165	151.6
Dalbe *Myrtillosa mel*	Burned	230	90.3	146	64.2
	Control	254	85.9	125	52.1
Ugale *Vacciniosa mel*	Burned	184	71.1	78	44.8
	Control	192	69.4	117	64.9
Slitere *Vacciniosa*	Burned	360	214.1	75	53.8
	Control	356	179.1	119	71.9

SD - standard deviation
*differences between burned and clearcuted sites statistically significant

Table 2. Variation of Scots pine height at burned and control sites.

Sites	*Treatment*	*Coefficient of variation*	*Scots pine ha^{-1}*	*Birch, aspen, spruce trees ha^{-1}*	*Correlation*
Jaunjelgava *Vacciniosa*	Burned	32%	2829*	2800	0.10
	Control	29%	3815	5070	0.21
Dalbe *Myrtillosa mel*	Burned	39%	3174	3076	-0.06
	Control	34%	2995	2633	-0.16
Ugale *Vacciniosa mel*	Burned	39%	2820*	565*	-0.34
	Control	36%	2008	3602	-0.29
Slitere *Vacciniosa*	Burned	59%	1918*	1362*	0.09
	Control	50%	4457	6811	0.64

Correlation-plot mean correlation between density of Scots pine and density of other tree species

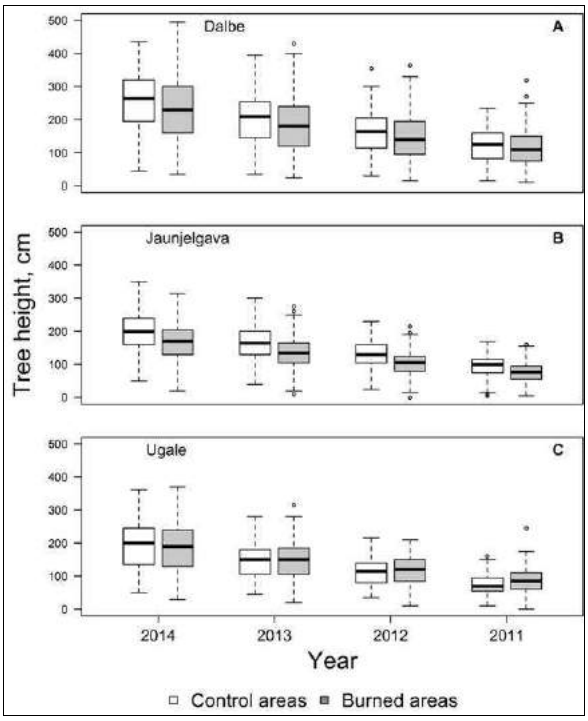

Figure 1. Average height of Scots pine at the age of 5 to 8 years in *Myrtillosa mel* (A) and *Vacciniosa* (B) forest type and at age of 7 to 10 years in *Vacciniosa mel* (C) forest type.

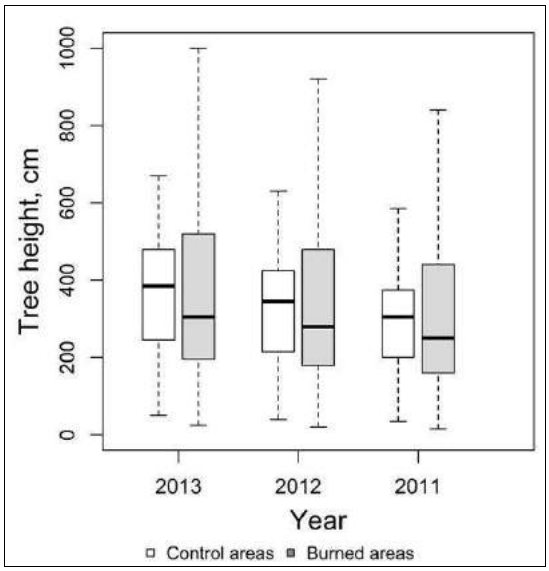

Figure 2. Average height of Scots pine at the age of 17 to 19 years in *Vacciniosa* forest type.

RIASSUNTO

La dinamica della crescita in altezza del pino silvestre (*Pinus sylvestris* L.) nelle aree bruciate e in quelle disboscate a taglio raso delle foreste emiboreali, Lettonia

L'obiettivo di questo studio era quello di comparare la dinamica di rigenerazione e crescita di lungo periodo del pino silvestre (*Pinus sylvestris* L.) nelle aree bruciate e in quelle disboscate a taglio raso per migliorare la comprensione delle conseguenze a lungo termine dell'incendio boschivo nella zona delle foreste emiboreali.

I dati sono stati raccolti in quattro soprassuoli forestali dominati da pino silvestre situati nelle parti settentrionali e centrali della Lettonia (56°45′ - 57°40′N; 22°32′-24°98′E), bruciati o disboscati a taglio raso nel 1992, 2004 e 2006; tipi forestali: *Vacciniosa, Vacciniosa mel* e *Myrtillosa mel*.

In ogni area di studio sono stati localizzati in modo sistematico i plot circolari di 100 m^2 e di 25 m^2 ed è

stata misurata la crescita in altezza del pino silvestre. Il test T è stato usato per stimare differenze significative tra le aree bruciate e quelle di controllo. L'altezza media del pino silvestre all'età di 8 anni era 167±54.2 cm (media ± DS) – *Vacciniosa* e 230±90.3 cm – *Myrtillosa mel*. All'età di 10 anni: 184+71.1 cm – *Vacciniosa mel*, e all'età di 22 anni: 360±214.1 cm – *Vacciniosa*. I nostri risultati hanno dimostrato che 8 anni dopo l'incendio boschivo l'altezza media del pino silvestre era significativamente più bassa nelle aree bruciate rispetto a quelle disboscate a taglio raso. Comunque 10 e 19 anni dopo l'incendio boschivo non abbiamo constatato differenze significative dell'altezza media del pino silvestre tra le aree bruciate e quelle di controllo. Ciò potrebbe indicare che l'importanza delle conseguenze dell'incendio col passare del tempo sta cambiando. Inoltre l'altezza dell'albero era notevolmente più variabile in tutte le aree bruciate che nelle aree di controllo.

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