# The Consequences of the Forest Fire in *Sphagnosa* Forest Site Type Ecosystem

**Olga Miezīte, Aigars Indriksons, Andrejs Dreimanis, Lāsma Freimane**
*Latvia University of Agriculture, Latvia*

**Abstract**

The outstanding and character of forest fires are predicted by the interaction of the meteorological conditions, topography as well the site and forest stand peculiarities. In Latvia since 1990 there have been at an average 850 forest fires every year.

The forest site type *Sphagnosa* is characterising by at least 30 cm thick peat layer and with unfortunate soil moisture and aeration regime. The *Sphagnosa* forests take 1.4% from the total forest area of Latvia. The forest stand is formed by unproductive pine (*Pinus sylvestris* L.) with site index V with some birch admixture. Because of strong suffering during the forest fires, already two or three years after the burning the trees dry up and fall down.

There is a natural regeneration with pubescent birch (*Betula pubescens* Ehrh.) permissible in *Sphagnosa* forest site type, because after the fire there begins the paludification process in the burned area and the birch increases the water transpiration thus improving the growth conditions for the natural regeneration of pine.

The research is carried out in 2010 in the Forestry Rietumvidzeme of the Joint stock company "Latvian state forests". The purpose of research was to evaluate the process of natural regeneration after the subsurface fire in the *Sphagnosa* forest ecosystem 2, 6, 10 and 16 years after the burning by comparing of different areas burned in the past.

Two years after the forest fire all old trees dried up in the burned area. The main tree species of young growth are: birch with 5200±478 trees per hectare, average height 0.29±0.026 m; pine - 800±289 trees per hectare, average height 0.04±0.010 m. The stand composition is 9Birch $_{2\ years}$1Pine $_{1\ year}$ with 6000±558 trees per hectare.

Six years after the forest fire the main tree species are: birch with 5540 trees per hectare, average height 1.15±0.076 m; pine - 2670±249 trees per hectare, average height 0.41±0.031 m and stand composition 7Birch 3Pine $_{6\ years}$. The total number of trees per hectare is 8210±529.

Ten years after the forest fire the main tree species are: pine with 3430±622 trees per hectare, average height 0.93±0.092 m; birch - 2230±211 trees per hectare, average height 1.36±0.069 m. The stand composition is 6Pine 4Birch $_{10\ years}$ with the 5660±614 trees per hectare.

Sixteen years after the forest fire the main tree species in forest stand is pine. The tree stand composition is 8Pine 2Birch $_{16\ years}$ with the total number of 7310±876 trees per hectare, from which 5490±779 trees per hectare are pines with the average height of 1.99±0.142 m. The number of birch is 1830±408 trees per hectare with the average height of 1.96±0.117 m.

There was no significant differences found between the total number of trees in burned areas of different ages in *Sphagnosa* forest site type ($F_{fact.}=0.5283<F_{crit.}=4,7571$, $p=0.6791>p=0.05$). During the inventory in the young growth areas there have been damages found caused by pine bud moth (*Blastesthia turionella* Hb.) in sixteen years old burned area in amount of 3.1% and the damages of pine resin-gall moth (*Petrova resinella* L.) in ten years old burned area in amount of 2.6% and in sixteen years old burned area in amount of 6.3%. There were only the branches and buds of branches damaged.

The fire as a natural disturbance promotes forming of gaps in the layer of tree stand canopies, thus supporting favourable conditions for the natural regeneration of forest. At the age of 16 years the average height of pine and birch is almost similar reaching for pine 1.99±0.142 m and for birch - 1.96±0.117 m.

*Key words: forest fires, Sphagnosa forest site type, forest regeneration, Pinus sylvestris L., Betula pubescens Ehrh.*

## Introduction

The forests are suffering from the different nature disasters for a long time, int. al., from the forest fires (Bušs 1989). The outstanding and character of forest fires are predicted by meteorological condition, topography and site specific. The fire is significant ecological factor. The cause of the outstanding of forest fire in main cases is a conscious or unconscious action of a man (Ткаченко 1955, Liepa et al. 1991). Since 1990 in the Latvia there have been at an average 850 forest fires occurred every year. The highest amount of forest fires has been in 2006, when 1925 fires have been registered and 3370 hectares of the forest burned. In 2002 there were 1742 forest fires with 2364 hectares burned, in 1998 - 356 forest fires with 211 hectares burned, but in 1992 - 1510 forest fires with 8412 hectares burned (the statistical information of State Forest Service). The forest fires are divided in the surface fire, crown fire and subsurface fire. In peatland forests on wet peat soils in dry summers there occurs the subsurface fire (Vanags 1987).

The possibility of outstanding and distribution of forest fires depends also on forest peculiarities. The combustibility of forests is impacted of the amount of deadwood. The amount of decedent timber volume in pine forests of *Sphagnosa* type (5.1±0.64 $m^3$ $ha^{-1}$) is one of the lowest (Jansons 2010). Important factors in the spreading process of forest fire are the plants of the ground cover vegetation. In the 1st floor of the ground cover vegetation in *Sphagnosa* forest site type mostly grow the common heather (*Calluna vulgaris* (L.) Hill.), hare's-tail cottongrass (*Eriophorum vaginatum* L.), marsh labrador (*Ledum palustre* L.), bog bilberry (*Vaccinium uliginosum* L.), bog-rosemary (*Andromeda polifolia* L). and others, including the underwood species. The flames can reach the height between 1.0 and 1.5 m. In the 2nd floor of the ground cover vegetation grow the juniper haircap moss (*Polytrichum juniperinum* Hedw.) and different peat moss (*Sphagnum*) species. On the hillocks there grow the big red stem moss (*Pleurozium schreberi* (Brid.) Mill.), wavy broom moss (*Dicranum polysetum* Mich.) and different reindeer lichen's (*Cladina*) species. During the dry weather conditions the ground cover of lichens and mosses starts to burn well and rapidly. The height of flames reaches 0.3 - 0.5 m. The moisture of the burning material is of high importance. The fresh and moist decaying material burns slower if to compare to old and dry material. The decomposition rate of decaying material decreases its combustibility (Ņesterovs 1954, Bušs 1981). The soil, mostly its moisture, radically impacts the outstanding of forest fires. There is less combustibility in forest stands on wet peat and hydro-morph mineral soils. The fires eliminate forest resources, devastate forest ecosystem and do considerable losses for land economy. The fire damages or totally destroys the living trees, shrubs and ground cover vegetation. There is dying the living fauna and the silvicultural activities are disturbed (Vanags

1987, Rivža 2005). There, in the *Sphagnosa* forest site type, the clearcut- and burning areas rapidly become overgrown by heather and often transform to raised bogs (Liepa 2003).

The *Sphagnosa* forest site type is characterising by the peat soil and very unfortunate soil moisture circumstances during the autumn, winter and spring. The *Sphagnosa* site type forests takes 1.4% from the total area of forests in Latvia with the total amount of timber 110 $m^3$ $ha^{-1}$ (Zālītis 2006). The peat consists of the unfertile, strongly acid peat moss with the admixture of residues of pine, cottongrass and shrubs. The thickness of the peat moss layer reaches 20 cm in the soil surface. In the low productive pine (*Pinus sylvestris* L.) stands with site index V, there is some birch admixture usually. The waterlogged peat soils are poorly aerated as in wet so in dry summers. The thickness of the organic soil surface horizons and the peat layer exceeds 30 cm (Bušs 1981). The taproots of pines growing on peat are reduced. The lateral roots are concentrated near to soil surface and therefore are strongly suffering during the fires. Already two or three years after the fire the pines dry up and fall down. There, in the moderate climate zone, the most important pioneer tree species is the birch, which is growing almost in every habitat (Bušs 1989). The pubescent birch (*Betula pubescens* Ehrh.), known also as downy birch, is often considered as a slower growing and not desirable tree species. Naturally, it is growing mostly on the waterlogged, peaty soils. The abundance of birch as an excellent transpirator of water in the stands of conifer tree species is considered as a prerequisite for survivability of the waterlogged forests. There can be found the natural structure of waterlogged forests in the mixed stands of conifers and birch (Zālītis et al. 2003).

The ecological investigations of burned areas are important because of two reasons. One of them is the impact of fire as a stressor on the plants survived after the fire event, as well the natural succession after the fire. The second reason sounds that forest fires are even necessary for the exchange of the nutrients between the soil and living biomass. The tree species have a not overestimated importance for the land economy, giving the timber production and nonwood values. The trees are especially important for the cycles of chemical elements and energy in the biosphere. The forests take less than ¼ of the terrestrial area, but produce more than ½ from the amount of atmospheric oxygen. The forests of the world synthesise ⅔ from the total organic mass produced over terrestrial area. The green plants during the photosynthesis process absorb the solar energy so fulfilling an important cosmic role. No other living organisms have similar height and lifespan as the trees. Therefore, the importance of forest ecosystems increases in the integrated research projects of the biosphere dynamics. In this case the aim of research is to analyse the process of the natural regeneration process of the forest after the subsurface fire in the *Sphagnosa* forest ecosystem in areas burned two, six, ten and sixteen years ago. To accomplish the aim, the following tasks were proposed: 1) to analyse the dynamics of tree number and growth rate; 2) to evaluate the process of the natural regeneration after the forest fire.

**Research methods**

The research is carried out in the Forestry Rietumvidzeme of the Joint stock company "Latvian state forests". In the Region Limbaži and the Region Cēsis, where there is the highest amount of precipitation, the snow cover remains longer and the spring entries later. The precipitation in the forests of the region has a slightly acid pH. The research data have been collected about the regeneration process in four forest stands of *Sphagnosa* type burned two, six, ten and sixteen years ago respectively. The first forest stand takes 0.6 hectares and is located in the Nature Reserve "Ziemeļu purvi" in the area of North Vidzeme Biosphere Reserve (co-ordinates x, y: 556639.3, 6427536.8). The area is supervised by Forestry Mazsalaca of the Ziemeļvidzeme Forest District of the State Forest Service. This forest stand has burned in the summer of 1992. The total area burned is about 80 hectares. The second forest stand takes 1.1 hectares and is located in Forestry Katvari of Riga region Forest District (co-ordinates x, y: 534466.2, 6394417.0). The forest fire has been there in the summer of 1998, taking 79 hectares in total. The third forest stand with the area of 2.2 hectares is located in Forestry Mazsalaca (co-ordinates x, y: 568346.1, 6415981.3), being burned in the summer of 2002. The total area burned is 15 hectares. The fourth forest stand with the area of 0.7 hectares is located in Forestry Katvari (co-ordinates x, y: 536413.8, 6394385.3) and burned in summer of 2006. The total area burned is 12 hectares.

There were sample plots with the size of 25 $m^2$ (10 x 2.5 m) established for the estimation of the height and the number of trees. The sample plots were placed on the longest diagonal of the forest stand area. In the first stand researched there were 7 plots, in the second – 7 plots, in the third – 15 plots and in fourth stand – 7 plots established. For the control of the current location in the certain forest stand, a GPS (Global positioning system) receiver was used. In total, there were 36 plots established, where the trees were counted for each species. For the each species there was the height for 30 trees measured by tape with precision of 0.01 m. The trees placed more than 50 cm distant each from the other were counted for each species. The health condition of the trees was evaluated visually, using the characteristics of insects and diseases by different authors (Amann 1965, Millar 1975, Plīse 2007, Jansons et al. 2008).

According to data of the inventory, the number of trees (N, trees per hectare) was calculated for each species by equation 1:

$$N = \frac{\sum_{i=1}^{i} \frac{n_i \cdot 10000}{L}}{i}, \quad (1)$$

where $n_i$ - the number of trees according to inventory data of i-th sample plot;

$L$ - the area of sample plot, $m^2$;

$i$ - the number of plots established in the forest stand, pieces.

Summing the number of trees of both tree species on a hectare, there is the total number of trees (trees per hectare) on the hectare achieved. The average tree height of forest stand ($H_{average}$, m) for each species was calculated by equation 2:

$$H_{average} = \frac{H_1 + H_2 + ... + H_i}{i}, \quad (2)$$

where $H_1$, $H_2$...$H_i$ - tree height, m.

In the research, there is the growth course of the natural regeneration of pine and pubescent birch compared after the subsurface fires in the *Sphagnosa* forest site type, comparing the number and height of trees.

There has been the Pearson correlation analysis and the variance analysis used for the evaluation of the natural regeneration of pubescent birch and pine in *Sphagnosa* forest site type 2, 6, 10 and 16 years after the fire. The arithmetical mean and standard error of mean ($\bar{x} \pm s_{\bar{x}}$) has been calculated with MS EXCEL program by confidence level of 95 % (Arhipova & Bāliņa 2003).

## Results and discussion

### The dynamics of tree number and growth course

The fire is wide scale disturbance, simultaneously creating considerable changes in the whole forest stand area (Bušs 1989). Two years after the fire the trees in the burned area have dried out and a part of them are torn up by the roots. It corresponds to previously performed researches that the probability of the loss of the uncovered burned roots during the four next years is 100%, independent from the tree dimensions (Никитин & Рубцов 1986, Donis 2010). According to measurements it can be concluded that in *Sphagnosa* forest site type two years after the fire there takes place the natural regeneration by pubescent birch (*Betula pubescens* Ehrh.), which reaches the height of 29±0.026 cm and the tree number of 5200±478 per hectare. After the devastating impact of fire, there, in the forest stand area, changes regime of light, moisture and temperature. In the result of fire there appear the preferences for species with fast growth course – pioneer species, which are very important for growth course of the natural regeneration of forest (Bušs 1989). In this case such species is the pubescent birch. Between the birches there grows also 3 – 5 cm long seedlings of the pine (*Pinus sylvestris* L.) with the average height of 0.04±0.010 cm and the number of trees 800±289 per hectare (Figure 1). The spreading of the pine seeds is irregular, which is confirmed by fact that in the 3 plots from the seven the seedlings were not present. The forest stand composition is $9Birch_{2\ years}$ $1Pine_{1\ year}$ with the total number of trees 6000±558 per hectare. In the moment of measurement there were no damages found made by insects and diseases.

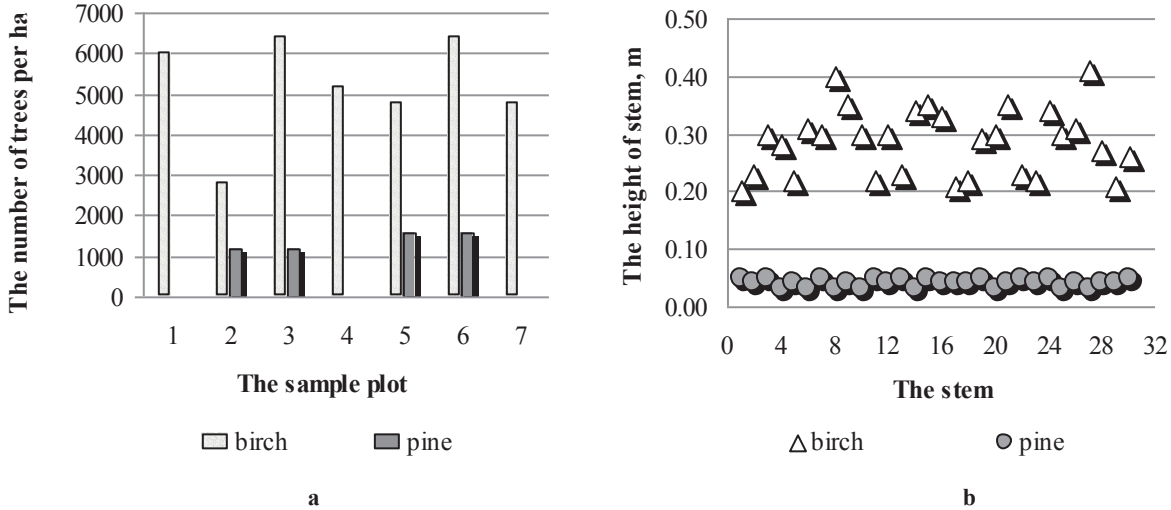


Figure 1. **The natural regeneration two years after the fire in *Sphagnosa* forest site type**: a – the number of trees per hectare, according to the inventory data of i-th sample plot, trees per hectare; b – the height of trees measured, m.

There, in the forest stand, six years after the fire, the pubescent birch reaches the average height of 1.15±0.076 m with the number of trees of 5540±378 per hectare. Correspondingly, the average height of pine is 0.41±0.031 m and the number of trees - 2670±249 per hectare (Figure 2). The number of pubescent birch trees per hectare is two times higher as for pine in the area six years after the forest fire. However, the average height of trees is 2.8 times lesser. The forest stand composition is $7Birch\ 3Pine_{\ 6\ years}$ with the number of trees 8210±529 per hectare. There were no damages found made by insects and diseases.

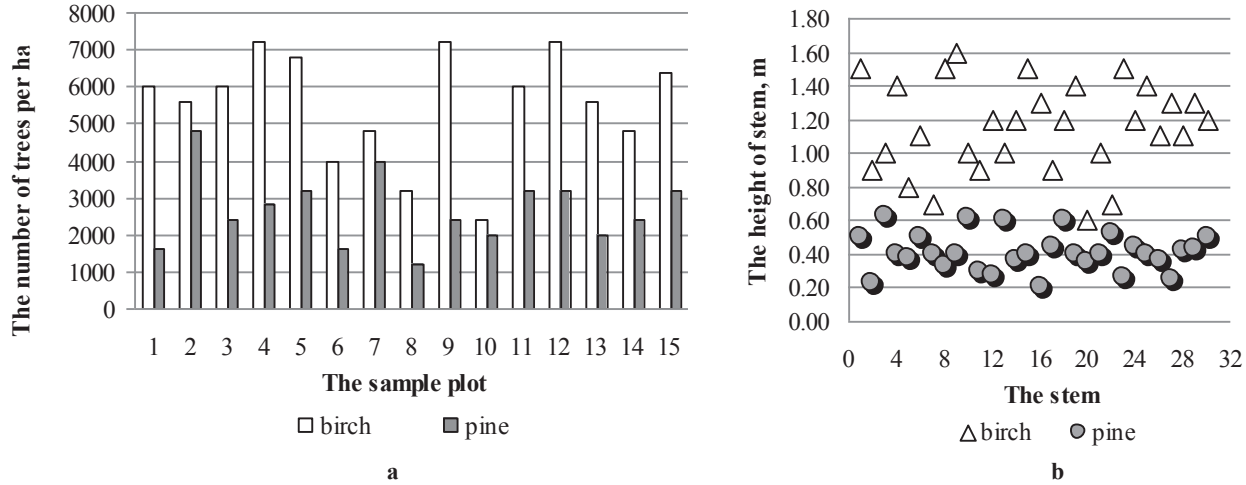


Figure 2. **The natural regeneration six years after the fire in *Sphagnosa* forest site type:** a – the number of trees per hectare, according to the inventory data of i-th sample plot, trees per hectare; b – the height of trees measured, m.

Ten years after the fire, the birch has reached the average height of 1.36±0.069 m and the number of trees was 2230±211 per hectare. In its turn, the average height of pine was 0.93±0.092 m and the number of trees was 3430±622 per hectare (Figure 3). In the area of natural regeneration, the number of pubescent birch on a hectare decreases in relation to the number of pine. However, the average height for pine is of 0.43 m less than those for pubescent birch. The forest stand composition is $6P4B_{10}$ with the total number of trees of 5660±613 per hectare. Evaluating the vitality condition of trees visually, there were non significant (2.6%) damages of pine resin-gall moth (*Petrova resinella* L.) found. The damages caused by diseases were not found.

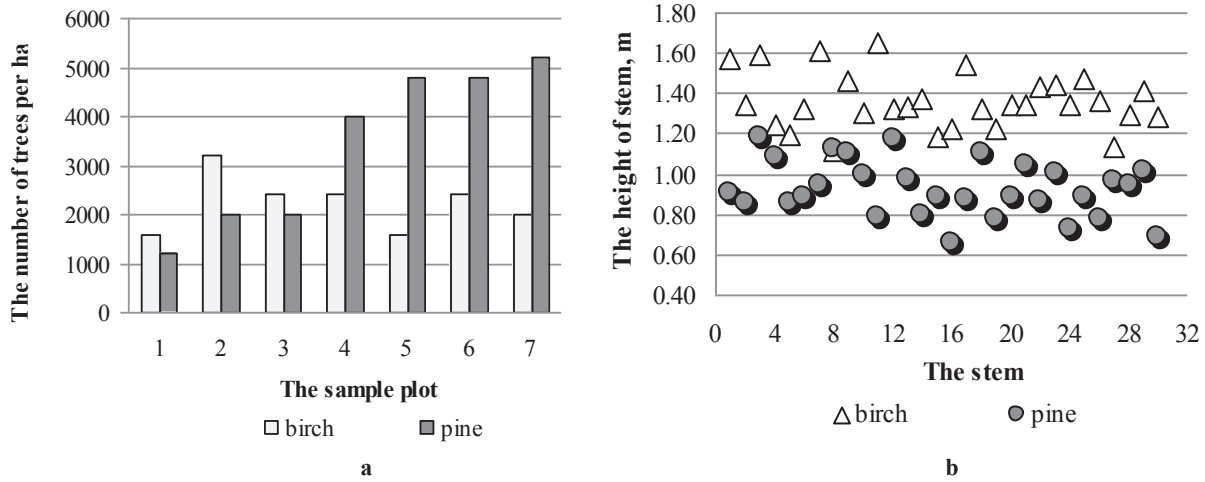


Figure 3. **The natural regeneration ten years after the fire in *Sphagnosa* forest site type:** a – the number of trees per hectare, according to the inventory data of i-th sample plot, trees per hectare; b – the height of trees measured, m.

In the forest stand of *Sphagnosa* forest site type, sixteen years after the forest fire the pubescent birch has reached average height of 1.96±0.117 m and the number of trees of 1830±408 per hectare. In its turn, the average height of pine was 1.99±0.142 m with the number of trees of 5490±779 per hectare (Figure 4). The composition of forest stand is $8P2B_{16}$ with the total number of trees of 7320±876 per hectare (Figure 4).

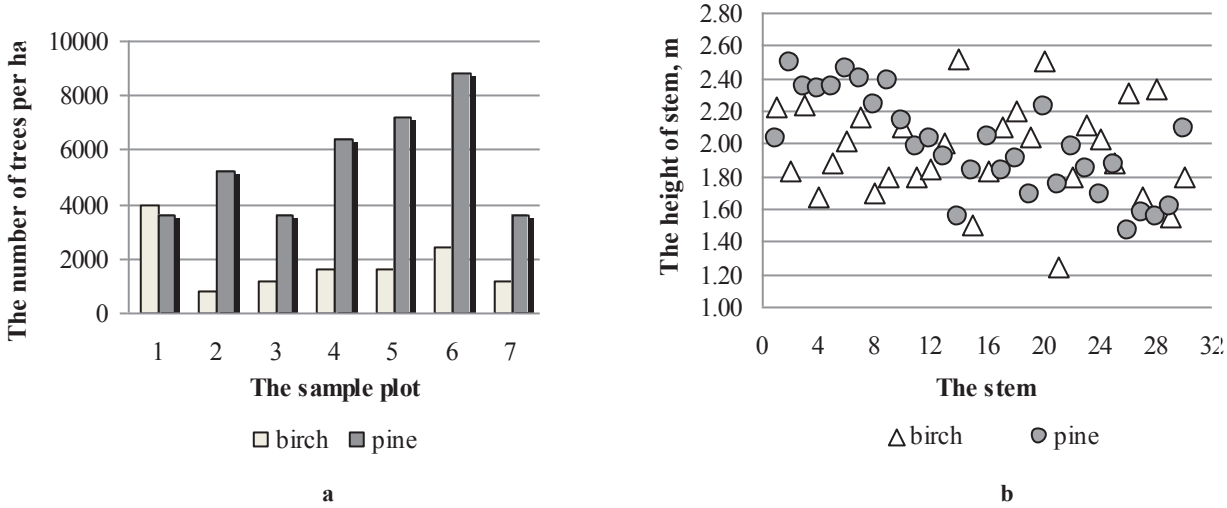


Figure 4. **The natural regeneration sixteen years after the fire in *Sphagnosa* forest site type**: a – the number of trees per hectare, according to the inventory data of i-th sample plot, trees per hectare; b – the height of trees measured, m.

It means, that sixteen years after the forest fire in the area of natural regeneration the number of pine overtakes those of pubescent birch in 3 times and the average height of pine is 0.03 m higher than those for birch. Evaluating the vitality condition of trees visually, there were some damages of pine bud moth (*Blastesthia turionella* Hb.) (3.1%) and of pine resin-gall moth (*Petrova resinella* L.) (6.3%) found. These damages are not significant for a young growth, because only the branches and buds of branches are damaged.

**Evaluation of the process of the natural regeneration after the fire in the *Sphagnosa* forest site type**

K.Bušs (1989) suggests, that in the forests, reached the climax stage, almost all nutrients of plants are bounded in living biomass or in humus. Only a small part of nutrients are circulating between the soil and living organisms. During the forest fire there is being destroyed the O horizon of the soil, the soil acidity decreases, as well the several chemical compounds releases, which turns to forms available for the plants. In this case, the forest fire acts as an enabling factor, helping release the nutrients bounded in humus. In the cases – two and six years after the fire in *Sphagnosa* forest site type, there mostly the natural regeneration with pubescent birch proceeded (Figure 5). The pubescent birch protects the burned area from the paludification, as from 1 kg of the birch leafs, there, during the growing season (May-October), evaporates 400 l of water (Zālītis et al. 2003), thus promoting also the growing of pine. The natural regeneration in *Sphagnosa* forest site type is successful (Figure 5). The Regulations Nr. 1453 of the Cabinet of Ministers of the Republic of Latvia prescribes, that there, in the *Sphagnosa* forest site type, the regeneration with pine and birch is permissible with the term of not more than 10 years after the cut or impact of other factors. The maximal number of young trees in *Sphagnosa* forest site type is not limited. However, in spite of Regulations, I.Liepa (2003) indicates, that the target species in *Sphagnosa* forest site type is pine.

The measurements of the number (Figure 5a) and the height (Figure 5b) of trees, showed in diagram, suggest that after the fire, the regeneration of pine proceeds very dynamically. If in the first two years after the fire there are only 800±289 pine seedlings per hectare, then after the sixteen years - 5490±779 pine trees per hectare with the average height of trees of 1.99±0.142 m. The good growth and big number of birch trees was monitored in the areas burned two and six years before. The number of birch trees in natural way, without any silvicultural activity of man, reduces from the 5200±478 trees per hectare till the 1830±408 trees per hectare and the average height of trees reaches 1.96±0.117 m.

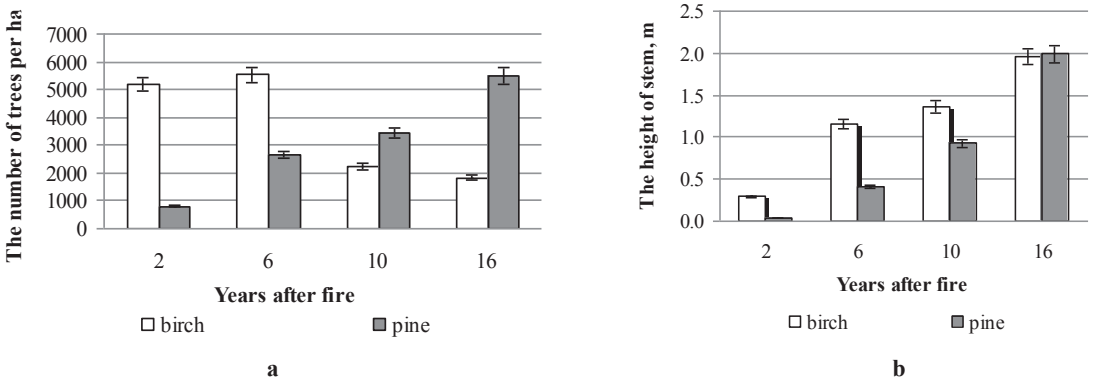


Figure 5. **The natural regeneration in *Sphagnosa* forest site type:** a – the number of trees per hectare; b – the height of trees measured, m.

There exist no significant differences between the total number of trees in the burned areas of different age in *Sphagnosa* forest site type ($F=0.528<F_{crit.}=4,757$, $p=0.679>p=0.05$). In its turn, there is close positive correlation ($r=0.99$, $p<0.05$) between the age of burned area and the number of pine trees established.

The natural regeneration, taking in to account the number of trees, is successful and the young growths correspond to the criteria of a regenerated area. There have been only non significant damages of insects and diseases impacting the vitality condition of trees found.

## Conclusions

In spite of the fact, that the forest fire destroys the forest resources, makes big damages to the forest biocenosis, brings the considerable losses to the national economy and pollutes the atmosphere, the forest fires have also a positive impact. There is being promoted the exchange of nutrients between the soil and living biomass. There proceeds the natural succession of the vegetation. After the forest fires, there, in *Sphagnosa* forest site type, as a pioneer species spreads the pubescent birch (*Betula pubescens* Ehrh.). The birch provides the transpiration process, which avoids the paludification of the burned area. Under the birches, there sows also the pine (*Pinus sylvestris* L.), which certain time jogs along with the pubescent birch. Because of nutrient pure peat soil and of waterlogged conditions, there, at the age of sixteen years, the growth of birch begins to drop behind of pine and the area is taken by pine.

The natural regeneration with the pubescent birch proceeds evenly in the area. The number of naturally regenerated birch trees in the forest stands with different age in all sample plots was between 1422 and 5918 trees per hectare. The natural regeneration of pine is more unevenly. The pine trees are abundant in 83.3% of the sample plots. The number of naturally regenerated pine seedlings in the area, two years after the fire, not exceeded 1089 trees per hectare. The natural regeneration with the pubescent birch proceeds numerically more successful. The numerical prevalence of pine has been found in one research object – in the sixteen years old burned area, where the number of pine trees in all sample plots exceeds 3500 trees per hectare. There is no significant differences between the total number of trees in the burned areas with different age in the *Sphagnosa* forest site type ($F=0.528<F_{crit.}=4.757$, $p=0.679>p=0.05$).

Two, six, ten and sixteen years after the forest fires in *Sphagnosa* forest site type, the forest regeneration initially proceeds with the pubescent birch, later also with the pine. Because of insufficient amount of nutrients and, also, because of waterlogged conditions, the birch, reaching the height of 1.96 m begins to drop behind the pine in growing, as well there decreases the number of birch trees in forest stand. The pine becomes the dominant tree species in the *Sphagnosa* forest site type.

Evaluating the vitality condition of trees, there were some damages of pine bud moth (*Blastesthia turionella* Hb.) sixteen years after the forest fire found in amount of 3.1%. The damages of pine resin-gall moth (*Petrova resinella* L.) ten years after the forest fire were in amount of 2.6%, but sixteen years after the forest fire – in amount of 6.3%. These damages are not significant for a young growth, because only the branches and buds of branches are damaged.

**Acknowledgments.** This research is financed through the European Regional Development Fund project "*Decision support system for sustainable forest managemen*t" (No.2010/0208/2DP/2.1.1.0/10/APIA/VIAA/146).


**References**

1. Amann G. 1965. Kerfe des Waldes (The beetles of the forest). München, Neumann Verlag, 189-190. (In German).
2. Arhipova I., Bāliņa S. 2003. Statistika ekonomikā. Risinājumi ar SPSS un Mikrosoft Excel (Statistics in economics. Solutions with SPSS and Microsoft Excel). Datorzinību centrs, Rīga, 53-54, 197-206, 221-229. (In Latvian).
3. Bušs K. 1981. Meža ekoloģija un tipoloģija (The forest ecology and typology). Rīga, Zinātne, 39 – 40. (In Latvian).
4. Bušs K. 1989. Meža ekosistēmas (The forest ecosystems). Rīga, Zvaigzne, 21-25. (In Latvian).
5. Donis J. 2010. Klimata izmaiņu radītie meža audzēšanas riski un to samazināšanas iespējas (The hazards in forest growing caused by climate changes and the possibilities to reduce them). No: Jansons Ā. Meža apsaimniekošanas klimata izmaiņas kontekstā. 18-20 lpp. (In Latvian).
6. Jansons A. 2010. Latvijas priežu meža atmirums atšķirīgos meža augšanas apstākļos (The decay of pine forests in different forest site types in Latvia). LLU Raksti 25(320), 40; 36-43. (In Latvian).
7. Jansons Ā., Neimane U., Baumanis I. 2008. Parastās priedes skujbires rezistence un tās paaugstināšanas iespējas (Needlecast resistance of Scots pine and possibilities of it's improvement). LVMI Silava, Mežzinātne, 7-8. (In Latvian).
8. Liepa I. 2003. Purvājs (Sphagnosa forest site type). No grām.: J. Broka vadībā autoru kolektīvs. Meža enciklopēdija. Rīga, Apgāds Zelta grauds, 266-267. (In Latvian).
9. Liepa I., Mauriņš A., Vimba E. 1991. Ekoloģija un dabas aizsardzība (Ecology and nature protection). Rīga, Zvaigzne, 65-67. (In Latvian).
10. Millar C. 1975. Report on 5th European Colloquium for Forest Pathologists Lophodermium in pines. European journal of forest pathology, 5(6), pp. 383-384.
11. Ņesterovs V. 1954. Vispārīgā mežkopība (Common forestry). Rīga, LVI, 546 – 547. (In Latvian).
12. Plīse H. 2007. Latvijas kokaugu kaitēkļi. Rokasgrāmata (The pests of woody plants in Latvia. Handbook). Ozolnieki, SIA Latvijas Lauku konsultāciju un izglītības centrs, 38-53, 172-205. (In Latvian).
13. Rivža P. 2005. Riski lauksaimniecībā un privātajā mežsaimniecībā. Monogrāfija (The hazards in agriculture and private forestry. Monography). LLU, RTU DITF, 657 lpp. (In Latvian).
14. Ткаченко М. Е. 1955. Общее лесоводство (Common forestry). Москва, ГОСЛЕСБУМИЗДАТ, с. 559-561. (In Russian).
15. Vanags J. 1987. Aizsardzība un apsardzība (Forest protection). No grām.: Bušs M., Vanags J. Latvijas meži. Rīga, Avots, 128-129. (In Latvian).
16. Zālītis P. 2006. Mežkopības priekšnosacījumi (The preconditions of forestry). LVMI Silava, et cetera SIA, 47. – 52. lpp. (In Latvian).

17. Zālītis P., Dreimanis A., Daugaviete M. 2003. Bērza audžu kopšana (The cultivation of the birch stands). Rīga, A/S Latvijas Finieris, 2003. 51.lpp. (In Latvian).
18. Никитин Ю. А., Рубцов В. Ф. 1986. Предупреждение и тушение пожаров в лесах и на торфяниках (The warning and extinguishing of fires in forests and peatlands). Москва, РОССЕЛЬХОЗИЗДАТ, с. 21-22. (In Russian).

---

**Olga MIEZĪTE**, Latvia University of Agriculture, Forest Faculty, Department of Silviculture, Meza fakultate. Address: Akademijas iela 11, Jelgava, LV-3001; telephone and fax number: +371 63021619; e-mail: olga.miezite@llu.lv.

**Aigars INDRIKSONS**, Latvia University of Agriculture, Forest Faculty, Department of Silviculture. Address: Meza fakultate, Akademijas iela 11, Jelgava, LV-3001; telephone and fax number: +371 63021619; e-mail: aigars.indriksons@llu.lv.

**Andrejs DREIMANIS**, Latvia University of Agriculture, Forest Faculty, Department of Silviculture. Address: Meza fakultate, Akademijas iela 11, Jelgava, LV-3001; telephone and fax number: +371 63021619; e-mail: andrejs.dreimanis@llu.lv.

**Lāsma FREIMANE**, Latvia University of Agriculture, Forest Faculty, Department of Silviculture. Address: Meza fakultate, Akademijas iela 11, Jelgava, LV-3001; telephone and fax number: +371 63021619; e-mail: lasma_freimane@inbox.lv.