Impact of risk factor management on the sanitary condition of Norway spruce (*Picea abies* [L.] Karst.) pure stands in Latvia

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ABSTRACT: In management of young forest stands, it is often the case in forestry that several risk factors, biotic, abiotic and anthropogenic ones, have to be dealt with. An anthropogenic factor is of great importance in management of forests, because humans, using ecosystems for their needs, still have to maintain the spatial structure of the forest and prevent the worsening of the health state. Covering all territory of Latvia, empirical material was gathered in 25 pure stands. To find out how neighbouring stands impact the young forest stands of spruce, the location in forest array was detected. In identifying the risk factors, attention should be paid to the shape of compartment and its location in forest array. A correlation between the occurrence and intensity of damage caused by cloven-hoofed game is relevant $r_{fact} = 0.988 > r_{crit} = 0.088$ with 95% probability. Also the occurrence and intensity of *Lophophacidium hyperboreum* Lagerb., and damage by *Heterobasidion spp.* are relevant $r_{fact} = 0.991 > r_{crit} = 0.062$ and $r_{fact} = 0.981 > r_{crit} = 0.088$ with of 95% probability.

Keywords: compartment location; compartment shape; forestry risk factors

Management in young forests has always been an important task for forest owners because forest management is related to tree productivity as well as to the possibility of various risks. Biotic, abiotic and anthropogenic risk factors endanger coppices. The damage caused by the risk factors can be divided into: damage to tree roots, damage to the aboveground part of the tree and damage under the bark or to the wood caused by pests (Miezīte et al. 2013). Every owner is trying to manage their property in a way which limits or fully averts the spread of risk factors which can reduce the productivity of young forest stands. Timely recognition of these risk factors will prevent the deterioration of the sanitary state of young forest stands.

It is certain that pests and tree diseases, cloven-hoofed animals, snow breakage and windfalls can all be the reasons behind tree cutting, loss of growth ability or death in the young forest stands (Monitoring of forest health condition 2013). However, the anthropogenic factor is also of great importance in forest management. Human activity can have both a negative and a positive effect on the productivity of a young forest stand. The productivity can be affected in many ways; however, most often it is done by leaving too many trees per hectare or not performing timely thinning. Sometimes, in the pursuit of profit, one forgets about nature protection and conservation while trying to change the spatial structure of the ecosystem, thus indirectly increasing the amount of damage or the possibility of various risks and worsening the health of the trees in the stand.

The creation of infrastructure objects such as forest roads and forest drainage systems can bring positive or negative changes to the structure of the adjacent stands. Correctly located forest roads and drainage ditches are of crucial importance in forest management. Forest roads can be seen as a kind of ecosystem which is created and maintained by people because, unfortunately, without them no economic activity could be carried out. This ecosystem can affect the adjacent plants and trees (Demir 2007). However, the impact of the infrastructure

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can be positive as well. The spruce productivity near drainage ditches (up to 30 m) in *Myrtillosa mel.* and *Myrtillosa turf. mel.* type forests has been increasing (Zālītis, Lībiete 2005). "Forest structure" usually refers to the way trees are distributed in the forest compartment. The structure is an important feature characterizing the forest ecosystem, and this characterization provides information about the spatial distribution of the trees in the stand. Regardless of the main objectives, it is important to preserve the productivity of future forest stands; therefore a significant process in forest management is the identification of silvicultural risk factors and the possibilities of their reduction and prevention (Kaktiņš, Arhipova 2002).

Therefore an aim has been set to analyze the impact of biotic, abiotic and anthropogenic risk factors on the sanitary state of Norway spruce pure stands. To achieve this aim the following tasks have been set out: (*i*) to analyze the impact of biotic and abiotic risk factors in Norway spruce stands, (*ii*) to analyze the impact of anthropogenic risk factors on the sanitary state of Norway spruce.

MATERIAL AND METHODS

Characteristics of the surveyed objects. Empirical material from 2011 and 2012 was obtained while surveying up to 40 year-old Norway spruce young forest stands. The data were collected from 12 pure stands which were surveyed in 2011 in all four regions of Latvia. 50 temporary sample plots were created in these stands. In 2012, 13 pure stands were surveyed from which the empirical material was obtained and 43 temporary sample plots were created. The following biotic damage was discovered in the Norway spruce pure

Table 1. Characterisation of the Norway spruce pure stands surveyed in 2011–2012

Research objects	Coordinates (XY)	Stand composition	Forest site type	$D_{av.}$ (cm)	H_{av} (m)	No. of trees per hectare	Spatial shape
2011							
Šķēde 9/3	424567,5; 6347027,5	$10E_{15}$	*Oxalidosa*	7.2	8.5	3,070	regular
Šķēde 9/14	424443,2; 6346511,6	$10E_{5}$	*Oxalidosa*	2.0	3.1	3,240	regular
Viesīte 294/18	599478.3, 6241660.2	$10E_{6}$	*Hylocomiosa*	1.4	0.9	6,400	not regular
Viesīte 51/25	590339,8, 6251891.1	$10E_{40}$	*Hylocomiosa*	14.6	16.7	5,400	regular
Kalsnava 153/1	614652.5; 6284536.1	$10E_{40}$	*Myrtillosa mel.*	16.8	17.0	1,150	regular
Viesīte 95/28	589197.6; 6249954.6	$10E_{34}$	*Hylocomiosa*	15.9	9.0	6,000	regular
Viesīte 143/27	585145.5; 6246343.0	$10E_{38}$	*Myrtillosa mel.*	15.2	13.7	4,860	regular
Dzelzamurs 293/27	520577,0; 6279421,1	$10E_{28}$	*Hylocomiosa*	11.6	13.6	2,600	regular
Līvbērze 196/24	475208,7; 6283470,6	$10E_{38}$	*Myrtillosa mel.*	14.5	11.7	4,250	not regular
Dagda 128/4	708813,1; 6233142,0	$10E_{32}$	*Hylocomiosa*	11.7	11.5	3,030	not regular
Dzelzamurs 292/24	520559.1; 6279330,6	$10E_{34}$	*Hylocomiosa*	12.6	11.2	6,930	not regular
Jelgava 42/9	484889,8; 6285750,0	$10E_{36}$	*Myrtillosa mel.*	14.5	15.1	5,650	not regular
2012							
Jelgava 34/15	485512.8; 6286449.1	$10E_{10}$	*Myrtillosa mel.*	2.7	3.0	7,700	regular
Jelgava 32/15	484276,9; 6286130,9	$10E_{38}$	*Myrtillosa mel.*	14.8	15.0	2,320	not regular
Jelgava 13/5	484159,7; 6288491,8	$10E_{37}$	*Myrtilloso-sphagnosa*	14.9	15.7	2,320	regular
Rēzekne 60/24	713299.3; 6262257.6	$10E_{12}$	*Hylocomiosa*	4.3	4.2	1,500	not regular
Rēzekne 76/12	708497.1; 6259481.1	$10E_{35}$	*Hylocomiosa*	16.9	15.7	1,200	not regular
Šķēde 30/10	420399.6; 6344767.2	$10E_{24}$	*Oxalidosa*	14.6	15.0	2,600	regular
Šķēde 42/4	417660.3; 6341426.1	$10E_{10}$	*Oxalidosa*	3.0	3.4	1,770	not regular
Šķēde 13/8	417438.2; 6346139.2	$10E_{7}$	*Oxalidosa*	2.3	3.1	2,860	regular
Šķēde 12/11	417224.3; 6346295.9	$10E_{8}$	*Oxalidosa*	2.5	3.0	3,700	regular
Šķēde 72/7	431509,2; 6343564.2	$10E_{8}$	*Oxalidosa*	3.2	3.4	1,960	not regular
Šķēde 7/5	425145.7; 6348065.6	$10E_{10}$	*Oxalidosa*	4.2	4.3	1,800	regular
Šķēde 7/21	424885.5; 6347888.8	$10E_{6}$	*Oxalidosa*	2.0	3.0	4,400	not regular
Šķēde 5/10	423143.1; 6347924.1	$10E_{40}$	*Oxalidosa*	17.4	20.5	1,850	not regular

E – *Picea abies* (L.) Karst., number – stand structure and age, $D_{av.}$ – average tree diameter, $H_{av.}$ – average tree height

Table 2. Evaluation of damage caused by biotic and abiotic factors in degrees

Damage evaluation	Damage degree
Trees without indications of weakening or growth disturbances	0
Economically insignificant damage or faults (few broken branches, small stem damage)	1
Economically significant damage (trees with one or smaller stem injury)	2
Highly damaged (damage to the tree top, its premature dieback; withered, broken top; the tree stem is bent and cannot take a vertical position; a tree with damage to one or more stems; visible resin galls on all the length of the tree stem)	3
Trees died in the current year (needles and leaves are yellow and brown)	4
Dead trees	5

stands: damage caused by spruce aphid *Elatobium abietinum*, large pine weevil *Hylobius abietis* L., six-spined spruce bark beetle *Pityogenes chalcographus* L., eastern spruce gall aphid *Sacchiphantes abietis* L., spruce bud scale *Physokermes piceae* Shrnk., spruce bud moth *Zeiraphera ratzeburgiana* Sax., little spruce sawfly *Pristiphora abietina* Crist., spruce needle rust *Chrysomyxa abietis* (Wallr.) Ung., spruce snow blight *Lophophacidium hyperboreum* Lagerb., *Heterobasidion annosum* (Fr.) Bref. root rot and cloven-hoofed animals; as well as the following abiotic damage: windthrow, windfall, snow crush, snow breakage and snow falls. The parameters characterizing the pure stands surveyed in 2011 and 2012 can be seen in Table 1.

Field research. The area of forest compartment is the most important factor in choosing the number of sample plots. Rectangular sample plots on diagonals or transects at equal distances have been created only in dense stands and comprise the entire area of the forest compartment. All sample plots have been chosen according to the systematic principle and most of them are round. The area of sample plots was chosen according to the average tree height in the stand. In stands where the average tree height is up to 12.0 m, 50 m^2 sample plots with a radius of 3.99 m have been created (rectangular plots 10.0 × 5.0 m); in stands where H ≥ 12.0 m, 200 m^2 sample plots with a radius of 7.98 m have been created (Law of Forests 2013). The stands have been sorted in groups according to the average tree height ≤ 2.5; 2.6–4.0; 4 < (Ruba et al. 2013).

The stem diameter of each tree listed on the temporary sample plot has been measured at 1.3 m above the root collar to the nearest 1 mm. Tools necessary for the work – regular calliper gauge or electronic sliding calliper. A VERTEX measuring instrument was used to measure the height of 20–30 trees (to the nearest 0.1 m). The coordinates of each young forest stand have been determined using the GPS device LKS-92 and transforming the geographical coordinates into XY system coordinates (Rūba 2012). All the discovered damage has been divided into six damage levels (Table 2).

Methods of data processing. To determine the number of trees per hectare the following formula was used (1):

$$N = \frac{N_p \times 1{,}000}{L} \quad (1)$$

where:

N – number of trees per hectare according to the measured sample plot data (indd·ha^{-1}),

N_p – number of trees on the measured sample plot,

L – area of the measured sample plot (m^2).

Damage incidence proportion was calculated using the following formula (2):

$$P = \frac{n \times 100}{N} \quad (2)$$

where:

P – damage incidence proportion (%),

n – number of damaged trees (indd·ha^{-1}),

N – total number of trees counted (indd·ha^{-1}).

Damage impact intensity was calculated using the following formula (3):

$$P = \frac{\Sigma n_i b_i \times 100}{N \times k} \quad (3)$$

where:

R – damage impact intensity (%),

n_i – number of damaged trees (indd·ha^{-1}),

b_i – level of damage (degrees),

N – total number of trees counted (indd·ha^{-1}),

k – highest level of damage (degrees) (Miezīte et al. 2013; Ruba et al. 2013).

The forest type has been determined by vegetation and soil in pure stands: *Hylocomiosa* – sod-podzolic rich soil in the sand, loam, sandy loam, podzols, humus horizons are highly visible and detritus layer is up to 5 cm, vegetation found in more than 120 vascular plants, mosses and lichens; *Oxalidosa* – podzols or sod-podzolic rich soil in the sand, loam, sandy loam, humus horizons are highly visible and rapidly degradable, detritus layer is up to 5 cm, vegetation found in more than 180 vascular plants, mosses and lichens; *Myrtillosa mel.* – acidic soil, uncommonly deep podzolic, well-decomposed humus is up to 20 cm, vegetation found in more than 110 plant species; *Myrtilloso-sphagnosa* – thick sandy peat or coarse humus, medium rich mineral soil, detritus layer is up 10–30 cm, vegetation found in more than 100 plant species.

The location within the forest massif has been determined in order to ascertain what effect the adjacent stands have on the status of the Norway spruce young forest stands. The form of forest compartments (regular or irregular) has been determined using the State Forest Service's (SFS) geographical information system (GIS) maps ArcGIS 9.1, 9.2 and 9.3 (Digital forest map, 2007) (ESRI, Redmont, USA). Irregular forest plots were naturally formed, but regular ones were transformed by humans into triangular or rectangular forest plots.

A regression equation has been used to characterize the incidence and intensity of the management risk factors; the importance of the regression coefficients. The second task was to analyze eight Norway spruce pure stands where damage caused by cloven-hoofed animals was found out, 10 stands with needle fall damage and seven stands with root rot damage. For determination of the root rot *Heterobasidion annosum* (Fr.) Bref. all trees on the sample plot were cored at the root collar with Pressler drill to pith. On some trees fruiting bodies were noted on the roots located above the ground. In the stands where the average tree diameter was smaller than 6 cm in order to check the occurrence of root rot, one of the trees which grew close to each other (less than 50 cm) was cut. Spruce snow blight damage was determined by characteristic features – brown spots on infected needles; as the disease develops, needles are turning red-brown, later tan-grey and fall off (Annila et al. 2006). The methodology used in this study was verified and used in previous publications.

RESULTS AND DISCUSSION

Impact of biotic and abiotic risk factors on young pure stands of Norway spruce

Firstly, a study must be performed concerning the economically most significant risk factors endangering pure stands of Norway spruce (*Picea abies* [L.] Karst). In the examined Norway spruce pure stands, the most urgent is currently damage caused by biotic risk factors – even-toed ungulates (artiodactyls) – and illnesses – spruce snow blight (*Lophophacidium hyperboreum* Lagerb.) and root rot (*Heterobasidion annosum* [Fr. Bref.]). The damage caused by artiodactyls frequently occurs in pure stands and can lead to extensive losses for forest managers. Red deer may cause damage by fraying and rubbing on the bark up to 1.8 m but roe deer by fraying up to 1.2 m (Gill 1992), deer browsing tree plants can kill them or reduce their growth (Curtis 2002). Damage caused by artiodactyls was found in 16 young stands in various types of forest growth conditions: *Hylocomiosa* (Dm), *Oxalidosa* (Vr), *Myrtillosa mel.* (As) (occurrence of damage 0.8–49.0%, intensity – 0.2–20.2%); however, the study covered analyses of damage in *Oxalidosa* only because it represents the largest number of growth condition types in this forest.

Upon examining the impact of damage by artiodactyls, the damage observed in some stands has not deteriorated the sanitary condition, because it does not interfere with the growth of trees if up to 50% of lateral shoots are destroyed. Whereas the most significant damage by artiodactyls has been found in 7 and 24 years old pure stands of *Picea abies* with the average tree height and standard deviation of 3.11 ± 0.22 and 15.0 ± 0.37 m (Fig. 1) and are to be included in the third height group (see the Methods). The bigger the average height of trees, the more significant is the bark damage in the stand, which is repeatedly confirmed by the results of the previous study (Ruba et al. 2012a).

A correlation between the occurrence and intensity of damage caused by cloven-hoofed game is relevant r_{fact}= 0.988 > r_{crit}= 0.088 with 95% probability (Fig. 2).

The spruce snow blight *Lophophacidium hyperboreum* Lagerb. is a fungal disease that spreads in spruce stands where the snow cover remains intact over protracted time periods. This damage is typical of forest stands in Finland. Local weather in Latvia during the

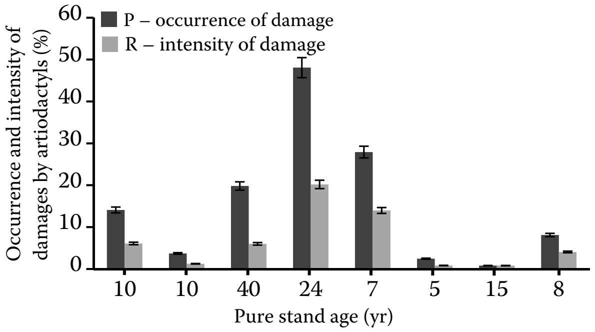

Fig. 1. Occurrence and intensity of damage caused by artiodactyls depending on the *Oxalidosa* forest type and stand age

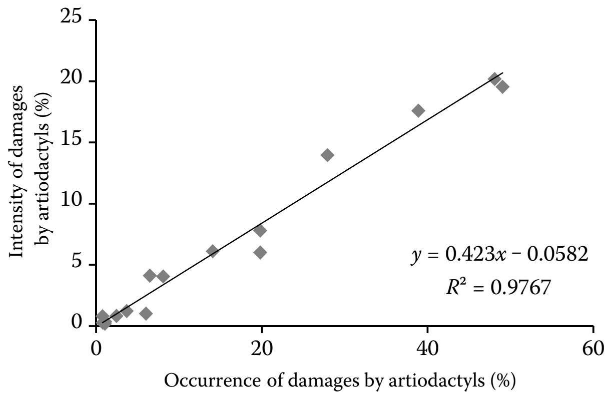

Fig. 2. Correlation between the occurrence and intensity of damage caused by cloven-hoofed game

winter 2010/2011 was very specific with untypically thick snow cover and freezing rain, which initiated the expansion of fungi causing snow blight in spruce stands in Latvia. Needles which are under the snow cover for too a long time are attacked by fungi – they change their colour from green to yellow, grey and fall off at the end (Annila et al. 2006). Despite the loss of needles in pure stands, the snow blight damage is not significant (Sevcenko, Ciljurik 1986). Damage due to snow blight has been assessed in 25 young stands and the impact of damage due to the infection has been detected in 11 pure stands of Norway spruce (occurrence between 1.2 and 76.5%, intensity – 0.2 to 18.8%). As shown in Fig. 2, the most significant damage was observed in *Myrtillosa mel.* forest growth type of 10 and 36 years old spruce stands with the average tree height of 15.1 ± 0.65 and 3.03 ± 0.19 m, as well as in *Hylocomiosa* with the average tree height of 9.1 ± 0.95 and 11.7 ± 0.28 m, which can be included in the third height group (see the Methods).

When determining during the study the correlation between the forest type $P = 0.288 > \alpha = 0.05$ and the occurrence and intensity of damage $P = 0.337 > \alpha = 0.05$, the regression equation that most effectively describes the dispersion along the regression curve $y = 0.2308x - 0.2406$ shows that the factor is significant because $r_{fact} = 0.991 > r_{crit} = 0.062$, $\alpha = 0.05$.

Upon continuing the inspection with the aim to determine the sanitary condition, during the study the root rot was found to be one of the most destructive diseases that damage trees. The root disease *Heterobasidion annosum* (Fr.) Bref., the Armillaria root rot caused by *Armillaria spp*., and the bleeding Stereum *Stereum sanguinolentum*, causing red heart rot, are the most widespread diseases in the forests of Latvia (Gaitnieks et al. 2010). European forests are suffering a great economic loss from this disease impacts (Woodword et al. 1998; Asiegbu et al. 2005; Oliva, Stenlid 2011). Healthy trees most frequently get infected during thinning, when the rot from the infected roots spreads to the stem, i.e. the tree infection is closely associated with forest management activities (Redfern, Stenlid 1998). In some trees, it is observed at a height of even 10 m, thereby damaging the most valuable part of the spruce stem (Gaitnieks 2010), causing a reduction of periodic increment (Bendz-Hellgren, Stenlid 1995), mortality (Bendz-Hellgren et al. 1998) and storm damage in young forest stands (Oliva et al. 2008).

Root rot damage was found out in 8 pure stands of spruces. The most significant root rot damage was observed in young stands of 36 and 38 years old spruces with the average tree height of 15.1 ± 0.65 and 15.0 ± 0.61 m, as well as in *Hylocomiosa* – in young stands of 34 years old trees with the average height of 9.1 ± 0.95 and 11.2 ± 0.68 m.

In such cases, when the factors of root rot impact rates are high, trees profusely discharge resin, the stem becomes thicker at the bottom part, and therefore the wood material loses quality (Woodward et al. 1998). However, the sanitary condition is considerably better in *Oxalidosa* and *Myrtillosa mel.* in young stands of 38 and 40 years old *Picea abies* with the average tree height of 13.7 ± 0.61 and 20.5 ± 0.62 m (Fig. 3). The regression equation that

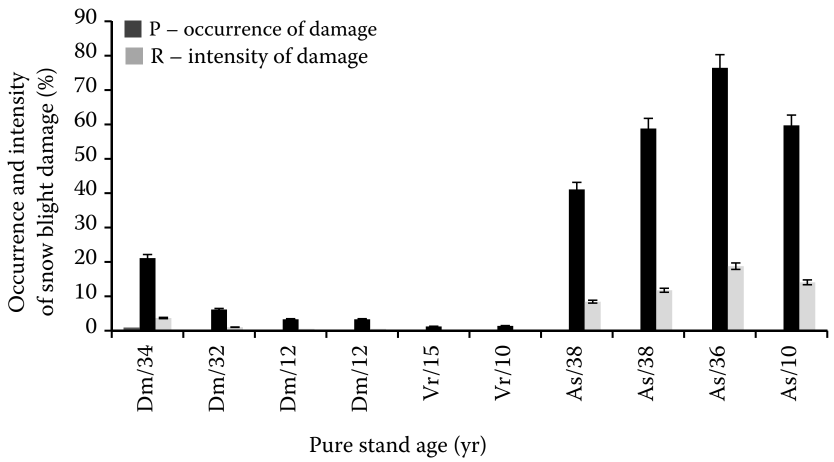

Fig. 3. Occurrence and intensity of snow blight damage depending on the forest type

Dm – *Hylocomiosa;* Vr – *Oxalidosa;* As – *Myrtillosa mel.*

most effectively describes the dispersion along the regression curve $y = 0.4446x - 0.3176$ shows that the factor is significant because $r_{fact} = 0.981 > r_{crit} = 0.088$, $\alpha = 0.05$.

Insects are an integral part of forests affecting the health condition of young stands. In pure stands of Norway spruce, damage caused by a number of insect species has been found: eastern spruce gall aphid *Sacchiphantes abietis* L., spruce aphid *Elatobium abietinum* (Walker), large pine weevil *Hylobius abietis* L., spruce sawflies *Pristiphora abietina* Crist., bark beetles *Pityogenes chalcographus* L. and *Ips typographus* L., spruce bud moth *Zeiraphera ratzeburgiana* Sax., little spruce sawfly *Pristiphora abietina* Christ.**,** however, as shown by the high indicators of damage occurrence and intensity, the spruce bud scale *Physokermes piceae* Shrnk. causes the greatest damage, revealed in 4 pure stands: Viesīte 51/25 (occurrence – 17.3%, intensity – 13.0%), Līvbērze 196/24 (occurrence – 83.5%, intensity – 12.5%), Dzelzamurs 292/24 (occurrence – 88.5%, intensity – 22.3%), Jelgava 42/9 (occurrence – 68.2%, intensity – 15.3%). Normally, it spreads in young spruce stands of up to 10 years old and damages tree growth, nevertheless, damage has been found in young stands of various ages. Like aphids, this insect has a twofold impact on trees, namely, direct and indirect one. Its direct impact is effectuated through sucking the phloem sap, whereas the indirect impact is leaving the waste which serves as a food source for the saprophytic fungus *Apiosporum pinophilum* Fuckel., thereby slowing down the tree growth, the photosynthesis process, as well as transpiration (Miezīte et al. 2013).

It was found in the inspected pure stands that the impact of abiotic risk factors was not significant, because the factors of prevalence of snow crush and snow breakage are low (3.3–4.9%), whereas the prevalence of abiotic factors such as windbreaks, windfalls, snow flurries in the forests of Latvia is even less frequent, which indicates that forest stands have suffered to a minor extent and the sanitary condition is satisfactory.

Impact of anthropogenic risk factors on the sanitary condition of Norway spruce

It is indisputable that it is impossible to avoid the impact of biotic and abiotic risk factors in young stands, however, their impact can be reduced by implementing forest management planning. It is necessary in order to avoid a reduction of the forest value through regular utilisation and to increase the stock by properly performed tending (Dubrovskis 2001). Proper tending is closely linked to the sanitary condition of young stands (Lazdiņš 2008), as well as to the resistance of trees against windfalls, snow break and to the spread of various insects and diseases in the forest (Zviedris 1960). Certainly, by interfering with the natural processes, the humans disturb the natural forest structure by their activities and affect the forest scenery (Bells, Nikodemus 2000), however it is impossible to tend a high-quality and highly productive forest without them. A forest that grows naturally, without tending, free of any human interference, features low productivity and poor quality wood. When performing an analysis of pure stand management to determine the positive or negative impact of anthropogenic risk factors on the sanitary condition of spruce young stands, forest compartments were divided into artificially formed, regular ones, and into natural, irregularly shaped compartments, and a study was conducted of the impact of the situation of stands in the woodland and of the surrounding infrastructure on the sanitary condition of stands.

Upon evaluation of the situation of young stands in the woodland and the surrounding infrastructure objects, it was found out that the most significant damage caused by artiodactyls was observed in the pure stand Šķēde 5/10 with the natural, irregular compartment shape (occurrence – 19.8%, intensity – 6.0%). The high values can be explained by the fact that the stand is situated on well-drained mineral soils – in *Oxalidosa* forest growth type, which features a rich food source base for forest animals and they can easily enter the tended pure stand with glades on both sides, middle-aged pine dominated stand to the south and a road to the west, with the number of trees per ha 1,850, corresponding to legal requirements (Regulations for forest restoration, afforestation and plantation forests 2012). In the twenty-four years old pure stand of Šķēde 30/10, the damage by artiodactyls is even greater (occurrence – 48.1%, intensity – 20.2%). This stand is situated in *Oxalidosa* forest growth type with 2,600 trees per hectare, artificially created, with the regular compartment shape, enclosed from four sides by young stands of various three species having regular compartment shapes. The number of trees after tending does not comply with legal requirements, according to which the number of trees in a young spruce stand must be 2,000 trees per hectare (Regulations for forest restoration, afforestation and plantation forests 2012). Several authors have concluded that if the tree height is taller and thinning is performed, the damage caused by artiodactyls increases (Birģelis et al. 1998), which was confirmed in this study, because thinning had been performed in both stands showing high damage values, and the average tree height reached 20.5 ± 0.62 and 15.0 ± 0.37 m. As it was proved in the previous study the stands that are situated between two young stands suffer the most significant damage (Rūba 2012), which was confirmed also during this study. No data can be found in literature regarding the impact of compartment shapes on the sanitary condition; however, the results of this study present evidence that damage is more severe in artificially created regularly shaped compartments (Ruba 2013).

During this research the snow blight damage, which usually occurs in 1–3 years old spruce pure stands (Sevcenko, Ciljurik 1986), was detected at the objects – Jelgava 42/9 and Jelgava 34/15 on drained soils – in *Myrtillosa mel.* (occurrence – 76.5% and 59.7%, respectively, whereas the intensity was 18.8% and 18.1%). The pure stand Jelgava 42/9, which has a natural irregular compartment shape, is surrounded by a young pine stand to the north and a compartment ride to the east; whereas the other two sides are abutting maturing pine stands. The high damage intensity indicators can be explained by the fact that during tending the number of trees left per hectare, i.e. 5,650, was too high, which led to the proliferation of *Physokermes piceae* Shrnk. and to the spread of *Heterobasidion annosum* (Fr.) Bref. in this stand. The second object Jelgava 34/15 has an artificially created regular compartment shape, surrounded by a young pine stand to the north, a middle-aged pine stand to the south, and infrastructural objects – a road and a ditch – to the other two sides. In this stand, thinning has not been performed yet, however, the number of trees per hectare is too high reaching 7,700 trees. This object is affected by the spread of spruce aphids, spruce bud moths, as well as snow blight, which, once again, proves the notions described in the literature, namely, that due to the excessive number of trees in a stand, the trees lose resistance against attacks of insects and diseases (Zviedris 1960). On the other hand, the least severe snow blight damage was found in 15 years old Šķēde 9/14 stand and 10 years old pure spruce stand Šķēde 42/4, in *Oxalidosa* forest growth type, with occurrence of 1.2% and 1.4% and intensity of 0.2%. The artificially created regular compartment shape and the location between three mixed stands, as well as the proximity of the road to the first object did not have any adverse impact on the sanitary condition. The number of trees left after thinning of the 5 years old stand exceeds the number stipulated by law (Regulations for forest restoration, afforestation and plantation forests 2012) and reaches 3,240 trees per hectare with the average tree height of 3.1 m ± 0.14. Upon evaluation of the impact of forest management risk factors in the pure stand Šķēde 42/4, it was found that the number of trees left per hectare after thinning in the ten years old pure stand was 1,770 with the average tree height of 3.4 ± 0.15 m exceeding the average height of trees in the aforementioned 15 years old pure stand of spruce (3.4 m). This indicates the fact that by observation of regulatory requirements (Regulations for forest restoration, afforestation and plantation forests 2012) it is possible to reduce the competition between trees striving for growth resources, thereby fostering the wood boost (Plauborg 2004).

Upon performing then inspection and registration of young stands, root rot was found out in those stands which are surrounded by at least two maturing or middle-aged stands. The disease endangers young Norway spruce stands and is observed in 8 young stands (occurrence between 0.9 and 39.8%, intensity – 0.3–17.2%). In the pure stand Jelgava 32/15, featuring an irregularly shaped compartment, the damage caused by the root rot is most significant (occurrence – 39.8 %, intensity – 17.2%). The high occurrence and intensity indicators can be explained by the proximity of infrastructure objects, as forest roads are situated to the south and west of the stand. Whereas the least significant rate of root rot damage is observed in stands of *Myrtillosa mel.* forest growth type and surrounded on two sides by two compartment rides and maturing spruce stand.

Upon evaluating the impact of the anthropogenic factor on the health condition of young stands, it can be stated that damage caused to trees in young stands by human activity (broken tree tops, broken off branches) does not contribute to any major distress, whereas inadequate thinning and leaving too many trees per hectare leads to deterioration of the sanitary condition, thereby contributing to risks of proliferation of insects and diseases in the stand (Lazdiņš 2008). The positive impact of the tending regime is manifested as an improvement in the sanitary condition of stands, increase of the stand resistance against abiotic and biotic risk factors, and enhanced wood quality (Bells, Nikodemus 2000). Forest roads and other infrastructure objects affecting the water regime can be regarded as endangering factors (Kabucis 2001). During the research we have come to the conclusion that human actions in the forest influence the sanitary condition of mixed stands. A significant difference was found in the occurrence and intensity of damage caused by biotic factors between forest stands with regular (human made) and irregular (natural) shape, $P = 0.0338 < \alpha = 0.05$. When the trees reach the felling age in these compartments, efforts must be made to maintain irregularly shaped compartments in order to avoid a complete transformation of the spatial structure of forest scenery (Bells, Nikodemus 2000).

CONCLUSIONS

The most important biotic risk factors endangering the sanitary condition in Latvian forests include artiodactyls, snow blight, and root rot.

A significant difference was found in the occurrence and intensity of damage caused by biotic factors between forest stands with regular (human made) and irregular (natural) shape, $P = 0.0338 < \alpha = 0.05$.

Upon evaluating the impact of the anthropogenic factor in the damaged pure stands, deterioration of the sanitary condition was observed in cases of inadequately performed thinning, contributing to risks of spread of insects and diseases in the stand.

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