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# FOREST VEGETATION ON THE ISLAND OF UPURSALA OF LAKE CIRIŠS, LATVIA

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**Abstract**
Only less than one percent of the territory of Latvia is occupied by broadleaved (trees having relatively wide flat leaves) forests. The aim of the research is to assess forest vegetation in the island of Upursala of Cirišs lake. The data is collected in four forest areas of the island. Totally 12 plots, each with an area of 200 $m^2$ (20 x 20 m) have been created. In each plot, the accounting of growing trees and deadwood is carried out. The vegetation is measured in each forest area - the projective vegetation cover and cover of each plant species by tree, shrub, herb and moss layer are determined. The research founds that the average stock of growing trees on the island of Upursala is 565.8 $m^3$ $ha^{-1}$. The average amount of dead wood is 108 $m^3$ $ha^{-1}$, it consists mainly of fallen deadwood. Totally 45 species are listed in the vegetation plots, of which seven are determinants of European broadleaved forests. The largest number of determinant species of European broadleaved forests have been observed in stands with mixed forests (aspen - small-leaved lime – pedunculate oak, aspen – Scots pine - pedunculate oak and Scots pine – Silver birch – aspen). It can be argued that these stands will become the European broadleaved forests in the future.
**Key words:** lake's island, broadleaved forest, vegetation, dead wood.

## Introduction

Latvia is located in the transition zone between the boreal (northern coniferous forest zone) and nemoral (broad-leaved) forest zone, which is called hemiboreal middle zone (Laiviņš, 2014; Ikauniece, 2017). Old broad-leaved (trees having relatively wide flat leaves) forests in Latvia occupy only 0.04% of the country's territory (Dabas lieguma 'Rušonu...'). Their growing areas are river valleys, slopes of shores and banks of water bodies, lake islands and plains in the areas where broad-leaved forests were spread in ancient period. The geographical location of Latvia and its soils are suitable for broad-leaved forests to be widespread in the country, but due to economic activities, they are rarely found.

During the Atlantic period 6,000 years ago, when the climate became warmer and when the peak of average air temperature was reached throughout the post-glacial period, conditions became more suitable for the growth of broad-leaved species. It was during that time when broad-leaved forests appeared in the territory of Latvia (Suško, 1997; Zunde, 1999). As human economic activities increased, the nemoral broad-leaved forests gradually disappeared (Suško, 1997). By the end of the 18th century almost all oak forests in Latvia had been cut down for obtaining profit or for construction purposes (Zunde, 1999; Priedītis, 1999). With the cessation of agricultural activities, overgrowing of forest lands started. Most often pine and oak started getting established, the advanced growth was overgrown with broad-leaved species, and the vegetation characteristic of the habitat appeared in the ground cover (Brūmelis *et al*., 2011). The climate has changed over the past 2,000 years. It has become 2.5 ˚C cooler and more humid. The soil has become more acidic; consequently, such soil composition is no longer suitable for the growth of broad-leaved forest tree species. This is the reason why fragmented broad-leaved forests are found in Latvia (Dzintare, 2001; Daugaviete, 2017).

European broad-leaved forests are characterized by a deciduous tree climax or completed vegetation. Forest stands, where the proportion of broad-leaved tree species is at least 50% of the total stock, are considered broad-leaved stands (Ek *et al*., 2002). The natural disturbance of broad-leaved forests is their self-removal, caused by falling (under the influence of wind) or death of individual trees. In these places, glades or openings in the canopy are formed (Priedītis, 1999; Ek, Suško, & Auziņš, 2002). New groups of trees emerge in these places, the growth of already existing advanced growth trees increases, and under the influence of light tree crowns begin to spread to the sides, thus occupying the free area.

Broad-leaved forests are characterized by a multi-layer uneven-aged stand, trunks covered with moss and lichens, wood of decayed deciduous trees in various stages of decomposition, trees with hollows made by woodpeckers, rich layer of shrubs and advanced growth of deciduous trees, small amount of spruce admixture and deciduous trees with a diameter of more than 30 cm (Priedītis, 1999). In broad-leaved forests, *Picea abies* (L.) H. Karst., *Populus tremula* L., *Betula pendula* Roth, *Alnus glutinosa* L. and *Alnus incana* L. can be present in the admixture, while *Corylus avellana* L. is most common in the shrub layer (Ek, Suško, & Auziņš, 2002). Herbaceous plants and ferns are most common in the ground cover, while there is a large variety of mosses and lichens on tree trunks and branches (Nikodemus *et al*., 2018). Broad-leaved forests may also contain species typical of boreal forests, such as *Trientalis europaea* L. and *Vaccinium myrtillus* L. The so-called old-growth forest species play an important role in broad-leaved forests, they are characterized by slow spread and low preservation capacity. These species include *Galium odoratum* L. and *Carydalis cava* L. (Hermy & Verheyn, 2007).

Latvian broad-leaved forests are described as multi-layer stands with a rich shrub layer or advanced growth of deciduous trees, where the ground cover also contains a fallen deadwood layer (Priedītis, 1999; Lārmanis, Priedītis, & Rudzīte, 2000). The different habitat species depend on the structural elements of the different forest habitats (Ek, Suško, & Auziņš, 2002, 2002) - growing trees, standing dead trees, snags, fallen deadwood and old trees of different species (Priedītis, 1999). A large amount of deadwood in different stages of decomposition is characteristic of places with little human influence (Ikauniece, 2013). Broad-leaved forests have the highest availability of deadwood (149.5 m$^3$ ha$^{-1}$). High levels of deadwood are related to the biological age of trees (Liepa, 2021) and the spread of pathogenic organisms (Matisone *et al.*, 2018). Deadwood plays a major role in maintaining diversity, since it provides a habitat for species that cannot exist in another environment, and the diversity of species depends on the stage of wood decomposition.

Oak and lime forests are found in Eastern Latvia and on the largest islands of lakes (Laiviņš, 1986). On the islands of Southern Latgale lakes, the forest stand consists of old *Betula pendula* and *Populus tremula* together with broad-leaved species typical of the habitat – *Quercus robur* L., *Fraxinus excelsior* L. and *Tilia cordata* Mill. The species that characterize old broad-leaved forests do not dominate the first layer, but are present in the admixture of the first layer. In Latvia, more common are forest stands where the dominant tree species are aspen, birch or spruce, but broad-leaved tree species have formed the second layer or advanced growth. Under favorable growing conditions, broad-leaved tree species will be able to take the place of dominant tree species in the future (Ek, Suško, & Auziņš, 2002). Here, the ground cover is dominated by various herbaceous plant species: in spring - *Anemone nemorosa* L., *Asarum europaeum* L., *Galeobdolum luteum* Huds., *Hepatica nobilis* Mill. and *Stellaria holostea* L., in the second half of summer – *Aegopodium podagraria* L. (Dabas lieguma 'Rušonu...', 2017).

It is important to find out in what direction the forests located on the islands of the lakes are developing, because in the future, they will probably be the only places where broad-leaved forests will grow. The aim of the study is to assess the forest vegetation on the island of Upursala of lake Cirišs.

**Materials and Methods**

The research site is the island Upursala of lake Cirišs, which is located in Eastern Latvia. Upursala is located in the protected area of the nature park 'Cirīša ezers' 'Figure 1'. It has been a protected nature monument since 1931 (Dabas parka 'Cirīšu…', 2002).

The island has a peculiar, horseshoe shape, and it is the largest island of this lake. Its area is 18 ha, which is 2.54% of the total area of the lake. There are particularly steep slopes with wet depressions in their lower part. There are several shallow shores around the island. In total, there are four distinct terrain elevations on the island, the highest peak of the island is 160.3 m above sea level. Mainly deciduous forests dominate on the island, but there are also over-moist broad-leaved forests that form in the depressions.

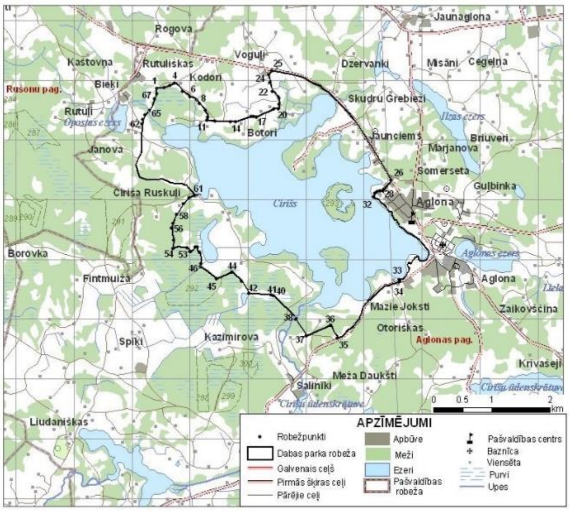


Figure 1. The island of Upursala in lake Cirišs.

The island has a typical continental climate. The average air temperature in January is -7.5 ˚C, while in July it ranges from +16.5 ˚C to +17.4 ˚C, the frost-free period is 140-155 days a year. The amount of precipitation reaches 550-650 mm per year. The eastern part of the island is covered by secondary aspen forests and the western part by pine forests. The habitat mosaic of Upursala is determined by the distinct micro terrain, which rises up to 20 m above the lake level in the southern part. 264 plant species have been found on the island (Dabas parka 'Cirīšu ...', 2002).

Three sample plots were established in each of the four forest compartments. The size of each plot is 20 x 20 m (400 m$^2$). In each sample plot, all growing and dead trees (fallen deadwood, standing dead trees and snags) starting with a diameter of 6 cm were measured and the tree species were determined. The stage of decomposition of fallen deadwood was also determined, taking into account the condition of the bark of the fallen deadwood, texture, shape, wood colour and the presence of branches according to the methodology developed by Hunter (1990).

In one sample plot of each forest compartment, an inventory of vascular plant species was carried out by vegetation (trees, shrubs, herbaceous plants and mosses) layers: the total projective cover (%) of each vegetation layer, as well as the projective cover of each individual species (Mueller-Dombois & Ellenberg, 1974).

Microsoft Office Excel programme was used for calculations. The calculations of the indicators of the tree stand structural elements were done using generally accepted formulas in forestry (Liepa, 1996; Dreimanis, 2016).

Univariate analysis of variance was performed to determine the strength of the relationship between the characteristics. The Shapiro-Wilk test (Shapiro & Walk, 1965) was initially used to compare the diameters of the growing trees, in order to find out whether the data obtained correspond to the normal distribution. For further data processing, a non-parametric data processing method was used - the Kruskal-Wallis test (Kruskal & Wallis, 1952).

According to the Raunkiaer formula, an occurrence coefficient was calculated for each species of vascular plants, which reflects the frequency of the species representation in the sample plots (Markov, 1965). The occurrence coefficient determines the constancy index. It was also determined for the species by referencing the number of the plots where the species was found against the total number of sample plots: I (< 21 %), II (21 – 40 %), III (41 – 60 %), IV (61 – 80 %) and V (81 – 100 %) (Mueller-Dombois & Ellenberg, 1974).

The Shannon-Wiener diversity index was calculated to determine the relative abundance (uniformity) of the listed species.

## Results and Discussion

In *Populus tremula-Tilia cordata-Quercus robur* forest stand (PTQ), the total standing volume is 555 $m^3$ $ha^{-1}$, of which 4.7% (25 $m^3$ $ha^{-1}$) is the volume of the second layer of the tree stand 'Figure 2'. The age of the forest stand is 83 years. The average diameter of trees in the forest stand is 29.7 cm. The diameter of the trees varies the most from 20 - 38.7 cm, which is smaller than the average in Latvia (49.3 cm) (Nacionālais meža monitorings (National Forest Monitoring), 2022). The average height of trees is 24 m although the National Forest Monitoring data indicate that in the stands where the dominant tree species is aspen and the age of the stand is 81-90 years, the average height of trees is 34.2 m. The trees of largest dimensions in the forest stand are small-leaved lime and common oak. The total number of trees per hectare is 583. By performing the univariate analysis of variance, it was found that the total standing volume of trees growing in the stand differs significantly at different classes of diameter F = 7.5167 > Fcrit = 2.6022 (p-value 0.0004 < 0.05). This indicates that in the future there could be more deadwood and more openings in this stand, as currently there is a small number of small dimension trees.

*Populus tremula-Pinus sylvestris-Quercus robur* stand (PPQ) has the highest total standing volume – 668 $m^3$ $ha^{-1}$ 'Figure 2'. According to forest taxation data, the age of the forest stand is 98 years. The diameter of the average tree in the forest stand is 38.5 cm. The diameter of trees varies the most from 31.8 - 45.1 cm. The trees of largest dimensions are Scots pine and aspen. The average height of the trees is 26 m. The diameter and height of the average tree in the forest stand, compared to the information provided by the National Forest Monitoring are smaller, but the diameters of individual Scots pine trees are even twice as large (64-86 cm) compared to the average diameters in Latvia. The total number of trees per hectare is 383, of which 78% (300 trees) are trees of the first layer. By performing the univariate analysis of variance, it was found that the total standing volume of the trees growing in the stand does not differ significantly at different diameter class values F = 0.0729 < Fcrit = 19.4457 (p-value 0.9998 > 0.05).

*Pinus sylvestris-Betula pendula-Populus tremula* stand (PBP) has the lowest total standing volume. It is 427 $m^3$ $ha^{-1}$ in the first layer and 15 $m^3$ $ha^{-1}$ in the second layer of the forest stand 'Figure 2'. The age of the forest stand is 113 years. The average tree diameter is 31 cm, and the average tree height is 25.4 m. The National Forest Monitoring data indicate that in forest stands aged 111-120 years, where the dominant tree species is Scots pine, the average tree diameter in Latvia is 30.19 cm, height - 22.78 m. The average dimension values of this stand are the closest to what they are on the Latvian scale. Trees with a diameter of 21 - 39.7 cm are most represented, but there are also trees of larger dimensions. The total number of trees per hectare is 442. By performing the univariate analysis of variance, it was found that the standing volume in the stand does not differ significantly at different diameter class values F = 2.4248 < Fcrit = 2.5068 (p-value 0.056 > 0.05). This indicates an even distribution of the standing volume of the trees growing trees in the forest stand.

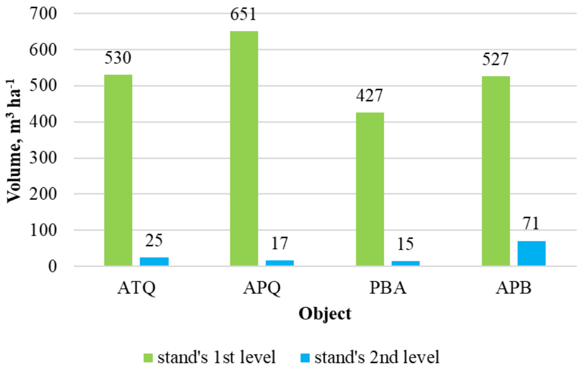


Figure 2. The distribution of standing volume per forest stands.

Abbreviations:
ATQ *Populus tremula-Tilia cordata-Quercus robur,*
APQ *Populus tremula-Pinus sylvestris-Quercus robur,*
PBA *Pinus sylvestris-Betula pendula-Populus tremula,*
APB *Populus tremula-Pinus sylvestris-Betula pendula.*

The total standing volume of *Populus tremula-Pinus sylvestris-Betula pendula* (PPB) is 598 $m^3$ $ha^{-1}$ with the largest standing volume of the second floor - 71 $m^3$ $ha^1$, accounting for 12% of the total standing volume 'Figure 2'. According to forest taxation data, the age of the forest stand is 93 years. The average tree diameter of this forest stand is 34.6 cm and the average tree height is 24 m. Here, too, the average indicators are lower than those indicated in the National Forest Monitoring, the average diameter and height of this forest stand are also less than the average diameter (52.76 cm) and height (33.04 m) of aspen (91-100 years old) in Latvia. The diameters of the trees vary mainly from 19.9 - 44.4 cm. The number of trees per hectare is 408, of which 65% are trees of the first layer.

The number of trees is one of the factors affecting tree diameter (Zeide, 2002; Castedo *et al*., 2005). The greater the number of trees per hectare, the smaller the diameter of the average tree. By performing the univariate analysis of variance, it was found that the standing volume of the trees growing in the stand at different diameter class values does not differ significantly F = 0.6923 < Fcrit = 2.8120 (p-value 0.757 > 0.05).

The largest total volume of deadwood is in the *Populus tremula-Tilia cordata-Quercus robur* stand – 137.5 $m^3$ $ha^{-1}$, of which 35 $m^3$ $ha^{-1}$ are fallen deadwood, 53 $m^3$ $ha^{-1}$ snags and 49.5 $m^3$ $ha^{-1}$ standing dead trees 'Figure 3'. The volume of deadwood in the *Populus tremula-Pinus sylvestris-Quercus robur* stand is 117.1 $m^3$ $ha^{-1}$ (Fig.3.). In both stands, the volume of deadwood consists mainly of *Populus tremula*, damaged by the windbreak. The smallest volume of deadwood is in the *Populus tremula-Pinus sylvestris-Betula pendula* stand – 74 $m^3$ $ha^{-1}$ 'Figure 3'. This site also has the smallest average volume of standing dead trees – 0.7 $m^3$ $ha^{-1}$. The average amount of deadwood volume in the *Pinus sylvestris-Betula pendula - Populus tremula* stand is 100.2 $m^3$ $ha^{-1}$ 'Figure 3'. Compared to the data provided by the National Forest Monitoring, the average volume of deadwood is much larger - in the stands where the dominant tree species is aspen aged from 81 to 90 years, the average amount of deadwood is 96.15 $m^3$ $ha^{-1}$. In 2022, the average amount of deadwood in Latvia was 20.57 ± 0.86 $m^3$ $ha^{-1}$ (Treimane, 2023). In all sites, the volume of deadwood is sufficient to maintain species biodiversity. The recommended volume of deadwood in broad-leaved forests is 30-50 $m^3$ $ha^{-1}$ (Müller & Bütler, 2010), but in broad-leaved forests that have developed naturally, it usually exceeds 100 $m^3$ $ha^{-1}$ (Bobiec, 2002). Deadwood is a habitat for many plant and animal species, and it maintains and increases biodiversity (Müller & Bütler, 2010). The diversity of species is greater in places where the deadwood dimensions are larger (Kruys, Jonsson, & Ståhl, 2002; Stokland & Larsson, 2011; Stockland *et al*., 2012). By carrying out bivariate variance analysis, it was found that there are no significant differences between the total volume of deadwood F = 0.6103 < Fcrit = 4.7571 (p-value 0.6325 > 0.05), and there are also no significant differences between the sites F = 0, 0228 < Fcrit = 5.1432 (p-value 0.9775 > 0.05).

All objects are dominated by fallen deadwood of the III and II stages of decomposition (proportion of 19-31% and 49%, respectively). This indicates gradual dying of the forest stand in a short period of time. It has been proven that the highest number of epiphyte species is on the fallen deadwood in its first three stages of decomposition (Donis, 2020). As the stage of deadwood decomposition changes, species diversity also changes (Stokland, 2001). Studies in Sweden prove that on the deadwood larger than 20 cm there are more than 50% of species, and on the deadwood with a diameter more than 40 cm – 15% of species. Smaller dimension deadwood is important for wood fungi and mosses (Dahlberg, Stokland, 2004; Jonsson *et al*., 2005). Carrying out univariate analysis of variance, it was concluded that there is no significant difference in the volume of deadwood in different stages of decomposition F = 5.1826 < Fcrit = 23.0555 (p-value 0.007 < 0.05).

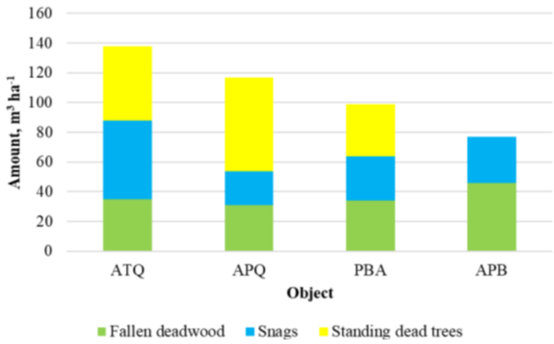


Figure 3. The distribution of dead wood in forests stands.

Abbreviations:
ATQ *Populus tremula-Tilia cordata-Quercus robur,*
APQ *Populus tremula-Pinus sylvestris-Quercus robur,*
PBA *Pinus sylvestris-Betula pendula-Populus tremula,*
APB *Populus tremula-Pinus sylvestris-Betula pendula.*

The largest number of plant species is found in the *Populus tremula-Pinus sylvestris-Betula pendula* stand - 28 species in total. In the stand of *Populus tremula-Tilia cordata-Quercus robur* and *Populus tremula-Pinus sylvestris-Quercus robur* - 22 and 21 species, respectively. The smallest number of species (20) was listed in the *Pinus sylvestris-Betula pendula - Populus tremula* stand. The diversity of herbaceous plant species is affected by the lack of light, as the projective cover of the tree layer in all the sites is over 50%. Common oak, which is one of the indicator species of broad-leaved forests, was listed in all the sites. In oak and lime forests on dry mineral soils, there are on average 31.3 species per 400 $m^2$ (Priedītis, 1999). The highest diversity index H' = 0.37 was calculated in the stand of *Populus tremula-Pinus sylvestris-Betula pendula*, which is explained by the largest number of occurring species. In the remaining forest stands, the diversity index ranges from 0.32 to 0.34. The diversity index in all four sites is equivalent, since the number of listed species is similar in all forest stands.

Projective cover of the tree layer in all sites exceeds 50%. The smallest projective cover of the tree layer is in the *Populus tremula-Pinus sylvestris-Quercus robur* stand (55%), because relatively large openings have been formed in it due to the death of a large amount of *Populus tremula*. The largest projective cover of the tree layer is in the *Populus tremula-Tilia cordata-Quercus robur* stand (87%), most of it is aspen (45%). Projective cover of shrubs varies from 37% to 95%. The largest projective cover of the shrub layer is in the *Pinus sylvestris-Betula pendula - Populus tremula* stand. It consists mainly of *Corylus avellana* L. – 50%. In other remaining sites, the projective cover of the shrub layer is similar - about 40%. It is slightly larger than that which is typical of oak and lime forests (Priedītis, 1999). The smallest projective cover of the herbaceous plant layer is in the *Pinus sylvestris-Betula pendula - Populus tremula* stand. It is affected by the thick projective cover of the shrub layer, which shades the herbaceous plants growing in the forest stand. The projective cover of herbaceous plant vegetation in the *Populus tremula-Pinus sylvestris-Betula pendula* stand is 99%, which exceeds the canopy of the herbaceous vegetation layer characteristic of boreal coniferous forests (Priedītis, 1999). *Vaccinium myrtillus* L. (23%) and *Vaccinium vitis-idaea* L. (20%) make up the most of it.

*Tilia cordata* is a species typical of broad-leaved forests, while *Populus tremula* is more common in boreal forests, but it can also be a transitional species from boreal to broad-leaved forests or vice versa. Overall, the projective cover of the species characteristic of broad-leaved forests is 43%. Since in none of the forest stands the total standing volume of broad-leaved tree species of at least 50% is not reached, currently they cannot be defined as broad-leaved forests. *Corylus avellana* and *Lonicera xylosteum* L. are listed among the shrub species characteristic of broad-leaved forests (Priedītis, 1999). Shrub layer species characteristic of broad-leaved forests make up 20% of the projective cover. The herbaceous plant layer is dominated by *Aegopodium podagraria* L. (33%), which is characteristic of fertile deciduous forests (Priedītis, 2014). Unfortunately, the study lacks early summer data.

## Conclusions

1. *Populus tremula* L. and *Pinus sylvestris* L. make up the largest proportion of the total standing volume of growing trees in the forest stands of the island of Upursala of lake Ciriš. Their average volume is 330.7 $m^3$ $ha^{-1}$ and 155.2 $m^3$ $ha^{-1}$, respectively.
2. The standing volume of growing trees at different diameter classes differs significantly in the aspen-small-leaved lime-common oak stand. No significant differences were found in the other stands.
3. The volume of deadwood in the forest stands of the island of Upursala of lake Cirišs varies from 74 $m^3$ $ha^{-1}$ - 137.5 $m^3$ $ha^{-1}$. In the forest stands where the proportion of aspen is higher, the largest volume of deadwood was also found. The average proportion of fallen deadwood is 35% (37.9 $m^3$ $ha^{-1}$), snags – 32% (34.3 $m^3$ $ha^{-1}$) and standing dead trees – 33% (35 $m^3$ $ha^{-1}$).
4. The volume of deadwood does not differ significantly between the sites and there are no significant differences within one site either.
5. Overall, all five stages of fallen deadwood decomposition have been found in the forest stands of the island of Upursala of Lake Cirišs. The highest proportion of the fallen deadwood is in stage III and stage II of decomposition, which indicates a uniform death of trees in a short period of time.
6. In all the research sites, the composition of vascular plant species indicates a development in the direction of European broad-leaved forests. The largest number of forest indicator species of European broad-leaved forests (seven species) has been listed in the *Populus tremula-Tilia cordata-Quercus robur* stand.
7. Intensive dying of aspen is taking place in all forest stands, thus giving the opportunity for new species to develop.

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