FORESTS´ FUTURE 2022

Consequences of Bark Beetle Calamity in Central Europe

Book of Abstracts

Forestry and
Game Management
Research Institute

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FORESTS´ FUTURE 2022

Consequences of Bark Beetle Calamity in Central Europe

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Ladies and gentlemen, dear participants,

as you may know the first Forests´ Future conference was planned in 2020 when we faced the peak of bark beetle calamity not only in the Czech Republic but in broader Central European region. Due to the Covid-19 pandemic the meeting had been cancelled and we only had a chance to discuss this hot issue on-line in March 2021. Today, after two years these, I´m really delighted that we could meet face to face here in Jihlava which is the centre of the Vysočina region, currently most affected by the calamity.

What has changed recently? The bark beetle calamity is slowly on the decline due to favourable weather course during last two vegetation seasons, partly due to protective measures and – we have to admit – partly due to disappearing of mature Norway spruce forests in some regions. The situation, nevertheless, is serious with calamity felling still significantly higher than any time before 2018.

As you will experience during the excursion, the calamity has changed the landscape in many affected areas. We are aware of potential environmental and ecological risk connected with large clear-cuts and loss of forest cover and we focus on its monitoring and evaluating. We, however, don´t speak about deforestation. The land is registered as forest and should be reforested – according to the law as well as according to the feeling of forest owners and general public. We will make a huge effort to renew stable ecosystems capable of facing future challenges on such large areas. I personally hope that your conference will help to mark the road to the prosperous future of forests and wish you inspiring and fruitful meeting.

Zdeněk Nekula
Minister of Agriculture of the Czech Republic

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Session 1: The calamity – has it already passed?

Bark Beetle Outbreaks in Slovakia

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The area of Norway spruce forests in Slovakia is approximately 460 thousand hectares, covering 22.5 % of forests. Pines, mostly Scotch pine and Black pine, cover 7 % of the total forest area. Norway spruce is the most attacked tree species by bark beetles – 98 %. Other tree species' attacks are rarely recorded – 1 % of pines and 1 % of other tree species. Approximately 98 % of bark beetle damages on Norway spruce are caused by *Ips typographus*, and 2 % by *Ips duplicatus and Pityogenes chalcographus*.

There are two major factors affecting bark beetle outbreaks in Slovakia. First are wind disturbances (central mountains), and second is drought in interaction with Honey fungus (*Armillaria* spp.) located in the northwest part of Slovakia (sandstone mountains). The last bark beetle outbreaks in Slovakia were triggered by large wind storms from 2004 and 2014 and drought periods. Another important factor was implementing a law on" Nature protection" that forbids windthrow removal and salvage logging of infested trees in areas with a higher level of protection. As a result, uncleared windthrow areas in protected localities initiated bark beetle outbreaks throughout Slovakia.

The last two bark beetle gradations from 2006–2013 and 2015–2021 were historically the largest and of similar progress. They started after the significant wind calamities in 2004 and 2014. The culmination of both gradations occurred four years after their beginning, and the gradations lasted 7–8 years. The first year after the culmination was followed by a slight decline of approximately 10 %. In the second year a significant decline of 35–45 %.

During the first gradation, in 2011, when a significant drop was recorded, the temperature was +1.3 °C above average in the growing season (compared to the long-term average). However, precipitation was below normal (-69 mm to the long-term average). In 2020, when the most significant decline in the second gradation was recorded, the temperature was +0.8 °C above the long-term average and precipitation +15 mm above the long-term. Although the weather in the vegetation season significantly affects gradations, it is only one of several factors contributing to a significant decline in the population of bark beetles.

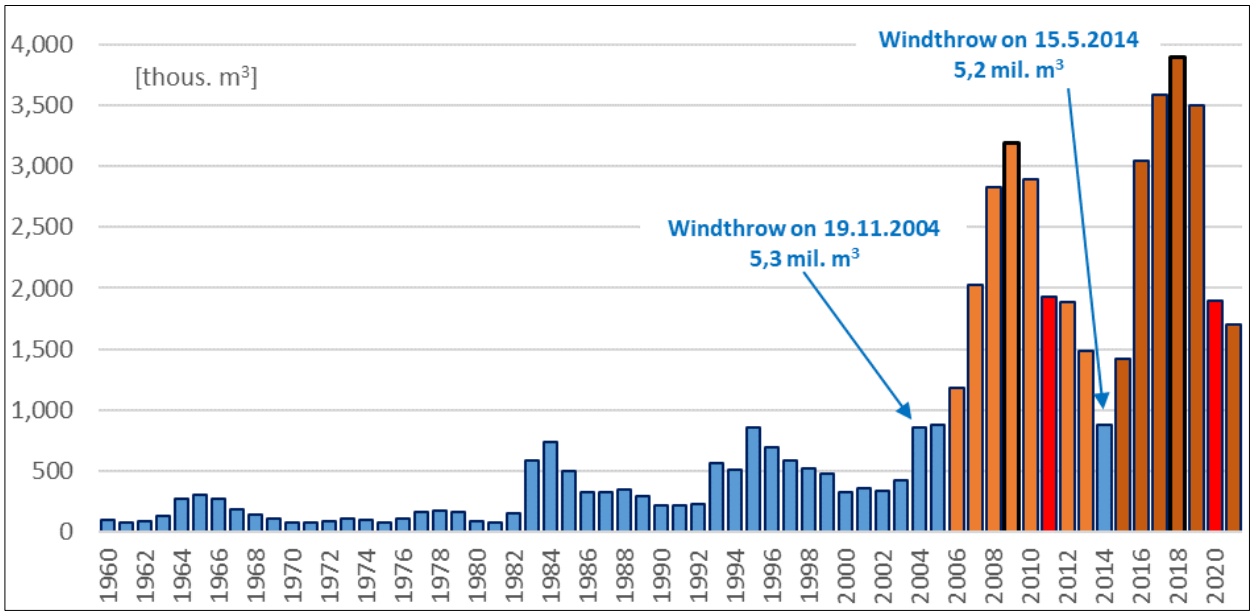

Fig. 1: *Development of Bark Beetle Outbreaks in Slovakia*

It ain't over… A new bark beetle outbreak in Austria 2021

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The amount of damage by bark beetles in Austrian forests as recorded in the annual Documentation of Forest Damaging Factors continued to decrease in 2021; total damage was 1.97 million m³. *Ips typographus* accounted for 86 % of this volume. Bark beetle damage peaked in 2018 at 5.21 mil. m³. This peak was mainly due to the vast outbreak of *I. typographus* in Austria along and north of the Danube, which had started in 2015 triggered by high temperatures and drought. The declining spruce bark beetle attack in the northern part of Austria is responsible for the overall decline. The year 2020 brought a slight relief of the drought situation at least in parts of the outbreak areas. Annual precipitation was around or slightly above the long term average. Moreover, the situation on the timber marked helped to get bark beetle attacked wood out of the forests.

There are important regional differences in the dynamics of bark beetles. Forests along the main ridge of the Alps suffered increasing damage. And an extremely steep increase occurred in mountainous regions in the south of Austria, again mostly attributed to *I. typographus*. Damage multiplied in the district of East Tyrol from 3000 m³ in 2020 to unprecedented 103 000 m³ in 2021. A similar but slightly less steep rise was documented in the westernmost parts of Carinthia. This outbreak is independent from the outbreak in Northern Austria and has been driven by different mechanisms. Storm Vaia caused extensive windthrow in large areas along the Southern Alps in fall 2018. E.g., 480 000 m³ were thrown or broken in East Tirol. Intensive efforts were made to clean the windthrows but not all could be finished within one year. This event was followed by two winters with extreme snowfall damaging 306 000 m³ in 2019 and 167 000 m³ in 2020, scattered all over the region. Spruce accounted for a high percentage of the damaged wood. Therefore, large amounts of breeding material allowed build-up of *I. typographus* populations, which switched to the attack of standing trees in spring and summer 2021. High temperatures assisted a fast population growth of the beetles. Two generations per year could develop successfully each year since 2019 even at elevations above 1000 m according to the development model PHENIPS. The affected terrain is generally extremely steep and many damaged areas are very difficult to access. Cable yarding is necessary to retrieve damaged wood. Many of the affected forests have protective functions for settlements or infrastructure.

Although the total numbers suggest a relief in the bark beetle situation in Austria with an apparent decline of the outbreak in the north of the country, the development in the Alps and particularly in the south suggest that levels of damage will remain high. Extreme lack of precipitation in the first months of 2022 in all regions in Austria may bring a challenging start of the growing season. Precipitation in spring will be extremely important. Overall, the trend of increasing bark beetle damage that has been observed in Austria has to be expected to continue considering the ongoing climate change.

Situation in spruce bark beetle calamity in Czechia in 2021–2022

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Recent bark beetle calamity is dated since 2018, when the enormous infestation of spruce stands started (with remarkable increase already in 2015). The main factors were the course of the weather, abnormal drought and heat, which weakened and reduced the defences of spruce stands, with consequent development of three generations of spruce bark beetles.

But the causes should be seen also in other areas, such as human reasons: permanent loss of skilled labour, inactivity of a number of forest owners, inflexible system of public procurement, protracted sales crisis in the timber market, which caused the related impacts like late processing of bark beetles and other infested wood and insufficient processing of bark beetles infested wood. In particular years of the recent calamity were recorded 8.4 mil m^3 in 2018, 14.5 mil m^3 in 2019, 14.9 mil m^3 in 2020 and 9.5 mil m^3 in 2021 (values from ca 70 % forest surface) of cut infested wood. It seems that the calamity is decreasing now, the first year-on-year decline in 2021 after eight years of permanent growth.

But these volumes are still high, calamitous, so the optimism is still out of place! The bark beetle calamity definitely spread throughout the whole Czechia in 2020. However, significant regional differences are evident. While in the eastern half of the country, in Silesia and Moravia, where the bark beetle calamity started, the gradation is mostly in decline, mainly due to a combination of a significant decline in the most attractive spruce stands and favourable weather conditions in the last two years.

The situation is similar in the Třebíč and Jihlava regions, while in other districts of the Vysočina ("Highland") region, as the most affected region, the unfavourable bark beetle situation continues. In the western half of the state (Bohemia), the extent of the bark beetle infestation will probably culminate this year.

The most problematic area is in the north and northwest of Bohemia, in the Ústí nad Labem and Liberec regions, where low precipitation totals were recorded last years and where the extreme gradation continued in the NP České Švýcarsko (Czech Switzerland NP).

At the same time, practically in the whole territory of Czechia, in addition to the unfavourable climatic influences of previous years, the collapsing forest protection continues, resp. the fact that the infested trees are not effectively sanitized in time, unfortunately across the entire ownership structure of the forest holders.

The main species of this bark beetle calamity is *Ips typographus,* accompaned by *Pityogenes chalcographus* and *Ips duplicatus*.

As a result of processing of infested trees, entire stands continue to disappear and large calamitous clearings and areas of unsecured stands are emerging, which often reach tens to hundreds of hectares and form subsequent heavy restoration and cultivation problems, especially considering the problems with overpopulated ungulate game. Hundreds, resp. thousands of hectares of young economically less interesting spruce dead stands, will also be problematic in the coming years.

The more favourable weather situation in 2020 and 2021 significantly influenced the further expansion of the bark beetle calamity. The year 2020 can be suggested as the culmination of the current bark beetle calamity. However, extreme extent of calamity is still persistent. It is absolutely necessary to use the favourable opportunity offered by nature and the sales situation and not resign in an effort of forest protection.

The priority is searching for bark beetle infested wood, its timely processing and effective sanitation. It is appropriate to speak of a lasting collapse in forest protection. The course of the weather will be determining factor in future development of bark beetle calamity in 2022 and subsequent years. Several months of drought, windy and relatively warm weather during the winter 2021/2022 and spring 2022 raised again the concerns about the possible further development. The spruce stands in Czechia are still enormously endangered!

Acknowledgement:

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Current situation of the spruce bark beetle *Ips typographus* (L.) outbreak in Poland with special regard to montane stand in the Carpathians and Sudety

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As presented in the last-year Forests' Future conference, after the drought from 2015 the bark beetle outbreak affected the Norway spruce stands in Poland, especially in the south-western part pf the country. This communication is aimed to present the current state of this outbreak, its dynamics as compared with the past years and regional variability of the infestations In two regions of southern Poland: in the Carpathians and in the Sudety in relation to the hydrothermic conditions.

Bark beetle outbreak in Bavaria

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The amount of damaged wood caused by beetle infestation, mainly by *Ips typographus,* decreased from over 5 million harvest solid meters in 2019 and 2020 to 3.1 million in 2021, reaching the lowest value since 2016. These damage is low in comparison with other states in Germany.

In 2021, the spruce bark beetle infestation showed a clear geographical pattern in Bavaria: high damage in the North, low damage in the South. The focus was on parts of Lower, Middle and above all Upper Franconia in the North – in particular the Franconian Forest – and with a lower intensity in the East in the former storm areas of „Kolle“ in Lower Bavaria. In the South the infestation with spruce bark beetles was insignificant. *Pityogenes chalcographus* was less important in 2021 than in previous years.

In summary, the overall situation in Bavaria for 2021 can be described as "losses at a high level, but lower than in the previous year and with very significant regional differences".

Tree protection of spruce stands using anti-attractants: summary of experimental results in 2018–2021

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We tested Norway spruce stand protection against *Ips typographus* using anti-attractants in a bark beetle outbreak landscape. We conducted experiments at the fresh forest edges in the eastern (VU Libavá, 2018) and in central (ŠLP Kostelec nad Černými Lesy, 2020–2021) parts of Czech Republic.

We have applied anti-attractants dispensers on 20 trees growing in two rows at the fresh forest edge, 10 trees per each row. In 2018, we have tested anti-attractants dispenses containing verbenone, cineol, trans-conophthorin and green leaf volatiles in conditions of extremely high bark beetle population and drought stress. Our data suggest a redirecting effect of anti-attractants that pushed the beetles into switch-area causing subsequent attacks, > than in areas containing treated trees.

In 2020 and 2021 we have tested modified dispensers similar in condition of bark beetle outbreak and relatively normal weather conditions. Verbenone was not used anti-attractant mixture. We have achieved protection effect in distance up to 40 m from applied dispensers.

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The current state of spruce bark beetle outbreaks in forests managed by the Romanian forest state administration

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Romania's forests cover approximately 28 % of the state territory, namely 6.93 million ha, of which the conifers represent 1.88 million ha. The dominant resinous species is the Norway spruce, which covers about 1.37 million hectares, both as pure and mixed stands. These forests are managed by different institutions, approximately 50 % being managed by the Romanian forest state administration (RNP).

The main biotic factor that affects the Norway spruce forests is represented by bark beetles (mainly *Ips typographus* and *Ips duplicatus*). These pests are developing outbreaks in the context of the presence of significant quantities of wind-blown trees and/or drought.

Thus, in the period 2015–2020, in RNP managed forests, the storms affected between 0.45–2.24 million m^3 trees/year. From these quantities, between 0.08–0.28 million m^3 were infested by bark beetles, which added to 0.06–0.11 million m^3 of standing infested trees. The droughts have contributed to the debilitation of spruce stands installed outside of natural area, thus favouring their infestation with bark beetles that killed trees totalizing 0.02–0.98 million m^3 per year.

During the last year, there were recorded only 0.36 million m^3 wind-blown trees, but the volume of bark beetle infested trees reached 0.11 million m^3 for wind-blown trees and 0.26 million m^3 for standing trees. This happened in the context of a much more moderate climate than that recorded in previous years. The high volume of infested standing trees is mostly due to the failure of carry out timely sanitary cutting in the affected stands. These volumes have been reported in areas where no severe outbreak of bark beetles has been recorded during the years 2015–2020.

In the last period (since 2015), no bark beetle calamity took place in Romania, but the attacks of these pests are an important problem mostly due to the poor management applied in such situations.

Spruce bark beetles in Finland during the last 12 years – the outbreaks are yet to come

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The northernmost populations of the European spruce bark beetle (SBB) occupy Fennoscandian Norway spruce dominated forests. In Finland SBB has so far not caused large-scale outbreaks. The population dynamics in this millennium are largely determined by the availability of trees weakened by abiotic disturbances. For instance, the summer of 2010 was exceptionally warm and dry, resulting in initiation of the second generation of SBB in Finland for the first time. Moreover, several major storms hit Southern Finland 2010–12, providing more breeding material for SBB.

Since 2010–12 SBB has been monitored in three complimentary ways: pheromone trapping program, National Forest Inventory and advance notices of timber harvesting due to SBB (collected by the Finnish Forest Centre). We will present the overall trends of SBB occurrence during the past 12 years in Finland.

Currently, National Forest Damages Prevention Act is the main tool for keeping SBB populations below outbreak densities in Finland. The SBB calamities in central Europe as well as the large timber losses in Sweden raised awareness of the risks posed by spruce bark beetle in the warming climate. Therefore, Finland aims for enhanced preparedness via contingency planning for handling future outbreaks and decreasing the risks due to increasing SBB populations and in the future.

Acknowledgement:
The initiated contingency planning for Preparedness for Emerging Forest Pest Risks in Finland is carried out with funding by the European Union via the Technical Support Instrument, in cooperation with the Directorate-General for Structural Reform Support of the European Commission.

Future transition to bark beetle outbreaks in Norway? – identifying climatic- and landscape risk factors

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In Norway, spruce reaches the north-western corner of its distribution. Norway experienced an Ips typographus epidemic in the 1970s killing ~5 million m^3 Norway spruce. Despite massive ongoing bark beetle outbreaks in southern Scandinavia and Central Europe, Norway has not had a large-scale Ips typographus outbreak in almost 40 years. In 2018, severe summer drought stressed Norwegian spruce forests, damaging trees, and enabling Ips typographus to complete two instead of one generation in some areas. Beetle attacks occurred in southern areas, but no outbreak has been initiated so far. With future climate change the overall likelihood of Ips typographus outbreaks is expected to increase. Pre-disturbance population sizes are likely important in determining outbreak risks. Here we present a study of how climatic and landscape factors influence bark beetle population sizes in Norway over an 18-year time series from ~ 560 yearly trap records.

Session 2: Ecology of post-disturbance areas – can we document negative effect of bark beetle outbreak on C sequestration, hydrology, soil erosion, biodiversity?

Environmental impacts spruce bark beetle outbreaks

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Ips typographus, the spruce bark beetle (SBB), is considered the most important forest pest in most of Europe. Outbreaks leading to substantial tree mortality occur frequently especially following windthrow events and drought periods which increase the availability of breeding material. Large-scale mortality of spruce trees can have a range of environmental effects including changes in biodiversity, hydrology and erosion, but to our knowledge, few studies have examined these impacts directly. In this presentation, I will review the theoretical expectations of environmental impacts of SBB outbreaks and give some examples from the literature and experiences of foresters.

Transformation of geochemical and hydrological dynamics in the forested catchment after the bark beetle infestation

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Tree mortality resulting from bark beetle infestation had become a widespread phenomenon under climate change, and such disturbance could result in alterations of streamflow and stream geochemistry. Our previous study found that these changes developed relatively rapidly after infestation and have long-lasting (decadal-scale) effects.

Furthermore, infestation-induced changes in event-scale dynamics of in-stream electric conductivity (EC) – discharge (Q) relations were found to be considerable, impacting even the annual average EC-values. In this study, therefore, all rainfall-induced runoff events occurring during a 10-year period were identified and their distinct EC-Q relations were evaluated.

The evaluation was done based on high frequency monitoring of EC and in four experimental catchments (~4 km^2 each; located in the Sumava Mountains, Central Europe), having different forest cover (disturbance) stages. Furthermore, snapshot sampling was carried out to map EC and chemical parameters in different hydrological landscape units (riparian area, hillslope, and terrace) and in multiple vertical layers of soil (surface, soil, and groundwater).

Results showed that after infestation the EC-Q hysteresis loops at the event-scale shifted from positive to negative relationships, implying changes in the subsurface chemical composition and runoff patterns. Specifically, healthy forest systems required event flows to mobilize substances in the soil and groundwater systems as the groundwater level rose into the relatively conductive, shallow part of the soil profile during an event.

Such flush-driven systems were known for their release of large fractions of total annual in-stream substance loads showing a positive EC-Q relationship. By contrast, after infestation-induced tree mortality, the mobilization and downward percolation of nutrients and carbon from litter and decomposing needles may be considerable even during moderate rain and infiltration events.

When the system is flooded under event conditions, substance-enriched soil water and groundwater may be mixed with and diluted by low-salinity event water, leading to a negative EC-Q relationships. This study exemplifies how EC monitoring techniques can be used as an alternative to high-cost geochemical monitoring in quantifying complex rainfall-runoff processes as well as runoff generation process, allowing for long monitoring periods at high temporal resolution and reasonable costs.

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Acknowledgement:

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Interception in young birch stands with different treatment

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The relationships between stand characteristics and interception were investigated in young forest (14 years) dominated by *Betula pendula* in northern Bohemia (altitude 450 m). Observation was conducted from May to November in 2021, 200 manual collectors with diameter 12 cm were installed in 5 stands with different treatments. A total of 24 measurements were realised in given period, range of rainfall in individual terms varied from 4 to 46 mm on clearcut.

Interception decreased with growing sum of precipitations on all variants (fig. 1). Different stand characteristics (N 870-11400 pcs/ha, BA 9-21.6 m^2/ha) affected interception, interception increased with rising stand density and leaf mass. Vital supressed trees in thinned variants increase interception up to 6 % in comparison with only target trees variant. Birch leaves started to fall from early July, seasonal change of leaf mass during summer months did not affected interception.

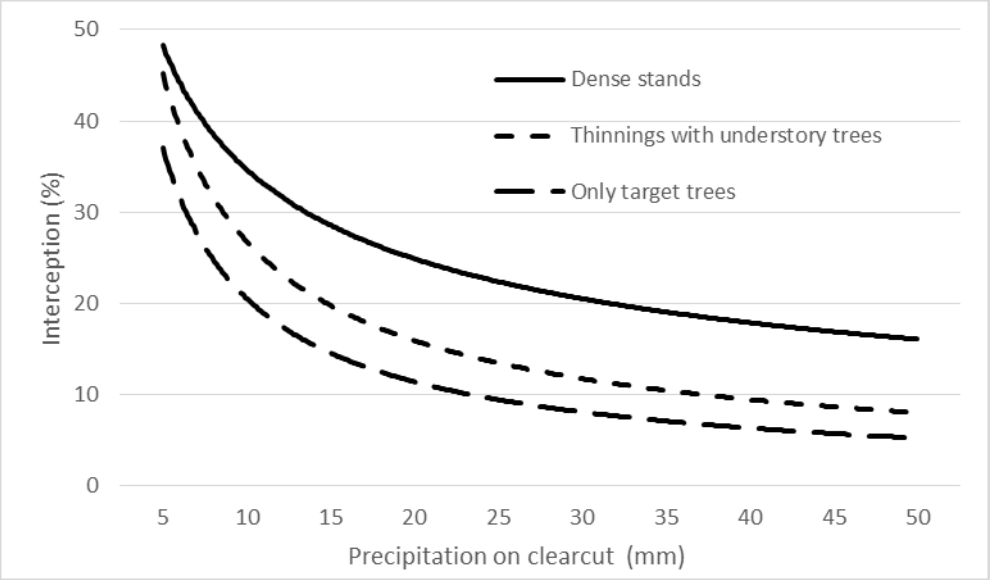

Fig. 1: *Balanced value of interception in birch stands with different densities during period with leaves*

Acknowledgement:
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Picea abies in Austria: Inclusion of climate-relevant damage factors from bark beetle calamities for the long-term increase of stress resistance in trees

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Due to its economic significance for wood and pulp production, Norway spruce (*Picea abies* (L.) Karst) has been widely cultivated outside its historic natural distribution range. In Austria, spruce is found on 57 % of forest area, but rising temperatures and drought caused regional mass gradation of bark beetles in recent years. Nonetheless, spruce will be part of the potential natural vegetation on approx. 60 % of its current Austrian distribution range and remain an economically important factor, also considering improved growth on higher elevation sites. Several studies report a potential high genetic variability within Norway spruce, due to glacial refugia and recolonization routes and as a result of long term adaptation to climatic and geomorphological environmental conditions. Hence, targeted tree breeding programs may be a solution for adaptation against impacts of climatic change.

Our study is based on single trees of Norway spruce (so called plus-trees), which survived within bark-beetle calamity sites. These survivors might inhibit higher resistance against drought and specific defence mechanisms against bark beetles. For this study we conducted a nationwide search and found 305 plus-trees fulfilling specific selection criteria. In a second step we tested progenies of 85 such trees against 5 standard provenances in a drought-stress experiment to reveal effects of drought on shoot growth. We applied also next generation genomic analysis approaches (RNA-Seq) and analysis of plant secondary metabolites to reveal specific differences of the plus-tree progenies under drought.

Preliminary results show a high variability of plus-trees progenies with regard to general shoot growth (in well watered conditions) and also regarding the effect of drought treatment on growth. Five out of 85 plus-tree progeny groups show significantly more growth under drought conditions compared to standard provenances. For the RNA expression we focused on differences of drought effect and tested eight well performing and eight low performing plus-trees with regard to relative change of growth under drought conditions. Results show that low-performing trees express genetic pathways connected to stress, while high-performing trees can maintain general growth processes better under drought.

Results underpin the successful selection process of plus-trees within calamity sites in the forest, but also reveal that further interdisciplinary research and tests of other traits regarding drought and beetle attack resistance are necessary to make a further qualified selection of resistant individuals for subsequent spruce breeding programs.

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Removal of logging residues on the clear-cut areas: a way to economic profit or to soil degradation?

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Increasing demand on use of logging residues in energy production has led to intensifying export of biomass from forest ecosystems in the last decade. In regions affected by bark beetle calamity this phenomenon is even accelerated due to technological need of site preparation before the clear-cuts areas can be reforested. Removing of logging residues can at least partly cover owner's expenses for site preparation, on the other hand it can conflict the principle of sustainability in term of the ecosystem nutrients stock. Although the weight of branches, and thin wood represents usually less than 15 % of the total (aboveground) tree biomass, it may contain more than 50 % of nitrogen and phosphorus, 40 % of potassium, 35 % of magnesium and 30 % of calcium stock.

We have assessed soil chemical properties from the Aggregated Forest Soil Database for 27 "Target Management Units" (CHS) – categories used to plan forestry management procedures according to forest typology for the risk of removing logging residues. Phosphorus and calcium were detected as the most limiting nutrients. Only 4 CHS representing 7 % of forest area of the Czech Republic were characterized by "low risk" for nutrient removal by use of logging residues. Results suggest that uncontrolled use of logging residues can lead to discrepancies in forest nutrition in close future.

The need of reforestation, however, requires some management procedures for handling of logging residues on the clear-cut areas. We recommend to chop forest residues and use e.g. soil milling cutter for their distribution. If needed, just an appropriate part of logging residues – preferably without the foliage - should be removed and deficient nutrients should be supplied by adequate use of soil fertilizing, liming, or wooden ash distribution.

For the forest state administration we suggest to support management of logging residues *in situ* as chopping and soil milling; legally regulate the possibility of use of wooden ash as fertilizer in forest stand and support fertilizing and liming of forest soils in justified cases.

Acknowledgement:
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Session 3: Reproductive sources – are they sufficient in amount and species structure? Should we use non-native/introduced species?

Climate change, biodiversity, raw materials – Challenges for the procurement of forest reproductive material in Germany

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Climate change is influencing the conditions for sustainable forestry with increasing rate. The conservation of biodiversity and the growing importance of ecosystem services of forests especially the production of timber as raw material are additional challenges. This development has a considerable drive. The three topics are connected and influencing each other. A discussion on the consequences for the forests of the future and the selection of tree species will follow.

Based on the existing range of tree species, the potential for the procurement of forest reproductive material will be given as well as a discussion of scopes of action and their limitations. To be in the position to respond to the future challenges, additional options are required regarding tree species and reproductive material with high adaptability, resistance and productivity. The need for action and the consecutive steps will be presented.

Establishment of research areas with introduced potentially drought-resistant tree species

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In the course of 2017–2021, 2 projects of the Grant Service of the Czech State Forest were solved simultaneously. The aim of these projects was to establish research areas with introduced tree species potentially resistant to drought. The region of northern Moravia was selected for the establishment of these areas, i.e. the hilly area that was first affected by the bark beetle calamity in the Czech Republic.

Within the project solution, the following was implemented:

- selection of an assortment of suitable introduced tree species on the basis of a literature search (see references – Catalog of taxons ……),
- obtaining seeds of these trees and growing planting material,
- own establishment (planting) of research areas,
- evaluation of the established research areas.

For the purposes of the project, an assortment of 28 species and provenances of introduced tree species was selected (19 species and provenance of coniferous trees, 9 species of deciduous trees). The research areas were based on 2 localities in the Nízký Jeseník area at the forest administration of Vítkov of the Czech State Forest (Lesy České republiky, s. p.). Each individual tree species (or provenance) was planted on area of 20 x 20 m (4 acres), plantings were performed in repetition.

The research area at the Červený kopec locality is at an altitude of 600 m above sea level, the acreage is 4.32 ha, and the plantings are carried out in 3 repetitions. Within the solved projects, it was a basic area.

The research area at the Odra locality is at an altitude of 475 m above sea level, the acreage is 2.32 ha, and the plantings are carried out in 1-2 repetitions. This is an additional area within the solved projects.

The establishment of these research areas provides the prerequisites for obtaining future serious information about the growth of these tree species in probably changing climatic conditions.

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Acknowledgement:
The projects were implemented with the support of the Grant Service of the Czech State Forest (Lesy České republiky, s. p.).

Preservation, propagation and practical use of valuable Norway spruce ecotypes

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The relative resistance of some Norway spruce individuals, which for a long time survived during several periods of imission load in the recent past in the Czech Republic in Ore Mountains, this is basis for another practical utilization of this phenomenon in the forestry practice. Previous research activities in mentioned area were aimed to preservation and reproduction of resistant variants of the local Norway spruce ecotype, incl. use of DNA analyses. Implementation of indicated rescue programs requires, among others, the use of proven vegetative propagation technology of surviving spruce individuals, resp. of their *ex situ* conserved clonal variants, for their repatriation back to original area of their occurrence. Those sub-populations of resistant spruce have proven their adaptability and vitality in the past period of air pollution, so it is possible to also suppose their vitality and resistance to adverse effects of current deteriorated environment on mountain forests ecosystems. Similarly, the Czech Republic also approaches the rescue and propagation of other valuable Norway spruce ecotypes with the aim of their other use in forest practice, eg. in case of hurst ecotype of this tree species.

Fig. 1: *Course of preservation and propagation of resistant variants of Norway spruce in Ore Mts: Selection, propagation and clonal archives ex situ establishment*

Fig. 2. *Propagation ex situ and repatriation back to in situ Ore Mts. Localities*

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Session 4: Silviculture – what kind of forest we want to have? How to start and continue on clear-cut area?

Modelling tree species suitability for Styria, Austria

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Tree species selection is an important strategic decision in forest management, especially in the context of adapting forests to climate change. However, uncertainty in future climatic conditions makes tree species selection a complex task. This calls for the development of new instruments to support forest managers.

Therefore, we developed a static expert model, which enabled us to map the suitability of 18 tree species under current and projected future climatic conditions for the forest area of Styria in Austria (Fig. 1). Within the model, tree species suitability is derived from the ecophysiological characteristics of the tree species regarding nutrient and water supply as well as the thermal conditions, which are represented by a set of individual soil and climate variables.

Additionally, the model integrates the risk of drought periods and bark beetle infestation. The computation of tree species suitability is accomplished in a hierarchical framework by 1) calculating the monocausal response of tree species with regard to indicators for nutrient and water supply as well as the thermal conditions, and 2) aggregating these monocausal response values by means of mathematical operators considering ecological phenomena such as limitation, intensification and compensation.

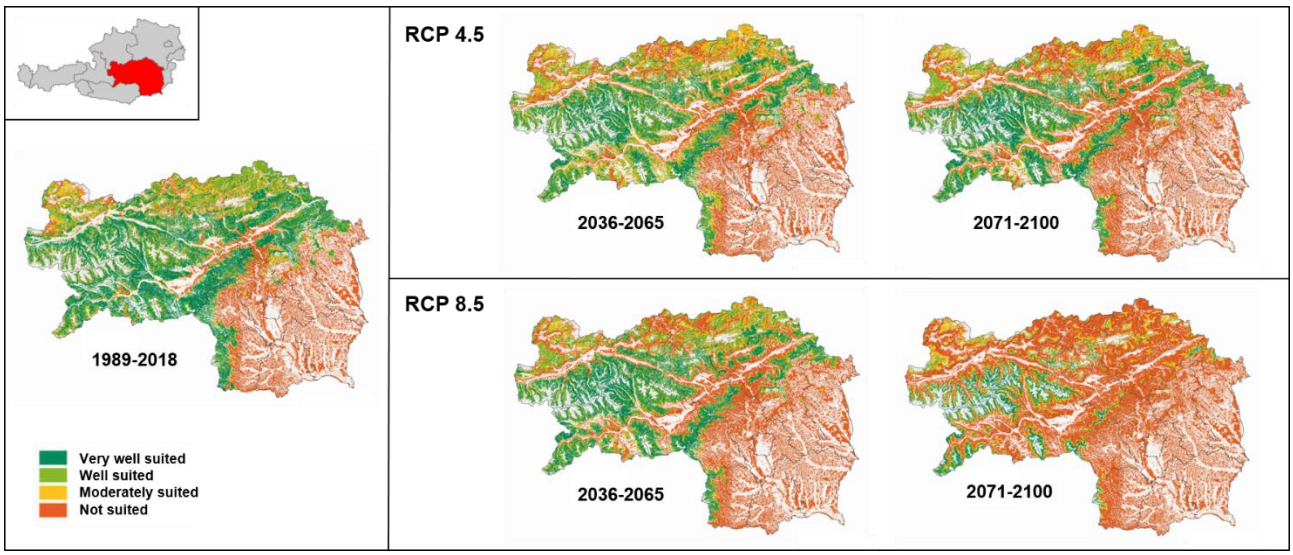

Fig. 1: *Simulated tree species suitability for Picea abies (L.) Karst. in Styria, Austria under current (period 1989-2018) and projected future climatic conditions (periods 2036–2065 and 2071–2100, for an average RCP 4.5 and an average RCP 8.5 climate change scenario, respectively).*

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Measures in post-calamity young stands

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Forest regeneration of clear-cuts after bark beetle calamity continue and large areas should be regenerated by mixtures with higher share of broadleaves. These new stands, established by both artificial and natural regeneration (or by combination), will need suitable management. We start to create possible setups and recommendations based of new experimental knowledge combined with experiences from practice. Measures for support of growth, stability, production and also other forest services of new stands are defined and differentiated by species composition, environmental conditions and last but not least according to the goals of the forest owner.

Fig. 1: *Young mixtures established by combination of natural and artificial regeneration on calamity clear-cut.*

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Forest site protection and reforestation of calamity areas by means of pioneer vegetation – from the Alps to the Franconian Forest

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Over the course of climate change, more frequent storms and fires, as well as a rapid spread of bark beetles in forests, are to be expected. In some cases, these extreme events produce baren areas that cover considerable dimensions. Soil exposure is particularly significant on rocky humus soils in mountain forests in the limestone Alps and on nutrient-poor sites in the lowlands and low mountain ranges, wherein it has the following effects:

- Loss of nutrients due to mineralization and erosion of the soil, especially in that of humus.
- Reduction of water storage capacity
- Hindrance of the establishment of natural or artificially introduced regeneration of trees due to rapid grass growth in the damaged areas
- High costs for restoring protective functions of forests

To date, the seeding effects of herbaceous plants (e.g., Fireweed (*Epilobium angustifolium* L.), non-damping grasses, and woody plants (e.g., Red Elderberry (*Sambucus racemosa* L.), rowan (*Sorbus aucuparia* L.), birch (*Betula pendula* Roth)) of pioneer seed character on disaster sites at sensitive locations have hardly been considered in scientific analyses. As a result of rapid seeding after extreme events and biomass buildup, these could play a critical role in minimizing initial humus and nutrient losses in soil. Likewise, these plants could act as a type of pre-forest species and, therefore accelerate reforestation.

In the following paper, the methods and techniques used so far on various experimental plots in the Alps, the Nuremberg Reichswald and the Franconian Forest will be presented. The most important plants of the seed mixture will also be discussed, which have been applied using practicable application methods such as pelleting and drone seeding. In addition, the results from germination tests with seeds and soil additives used for sowing are shown, which have been tested under structural elements such as tripods on protected forest rehabilitation areas. The soil additives are intended to provide water to emergent seedlings during dry periods. The tripods are therefore expected to act as "pioneer stepping stones" and to promote methods of reforestation.

Ways of silvicultural treatment on large-scale areas after wind calamity in northern Poland

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The hurricane which passed over the northern part of Poland in the night 11th/12th of August 2017 destroyed the forest ecosystems on area of more than 40 thousands hectare. It was the greatest wind damaged in the history of our forestry. The most affected were forest districts belonged to Regional Direction of State Forests in Toruń (18 425 ha). Currently about 80 % of this area is already reforested. However such large-scale area of regeneration brings a great challenge for local foresters. They must operate in radically changed ecological conditions, especially varying humidity, temperature and wind strength. They are obliged to make decisions concerning: soil preparation, species composition and type of their mixture, use of natural regeneration (which is often impossible to achieve in a case of large-scale damage) and tending operations in early stages of forest growth in the context of protection against abiotic and biotic factors.

Fig. 1: *Use of natural Scots pine and silver birch regeneration on reforested areas (Forest District Rytel)*

The goal of the project started in 2021 and coordinated by Forest Research Institute is to answer the question how to regenerate successfully the post-windthrow areas and to disperse the risk connected to such large-scale regeneration. The series of experimental plots will be established to test different soil preparation and planting methods, age of seedlings, their type (container or bareroot) in a case different tree species. In older plantations (already established) the different methods of tending cuts will be researched.

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Selection principles in pioneer stands – from clearing to Dauerwald

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In ecology point of view, pioneer stands are the best solution for the process of forest regeneration (restoration) in large clearing. Pioneer species are biologically well adopted to conditions of clearing – they often produce a lot of seed; they growth fast and are tolerate to climatic extremes in their youth. Results of research experiments also confirmed the economic justification of pioneer stands as a first steps of forest regeneration. There are many silvicultural approaches within pioneer stands – depending of economic goal: energetic utilization; high volume timber production or as preparatory stands only. Dauerwald is considered as a top art of silvicultural effort. What does means Dauerwald for clearing? It is just combination of economic goal within pioneer stands.

Dauerwald means first and foremost respecting natural conditions; pioneer species as Silver birch or European aspen have a wide ecological amplitudes, they growth naturally in the area of allochthones Norway spruce stands. In addition, to get Dauerwald means to followed natural processes; i.e. use of pioneer species as a first step of reforestation. The third assumption of Dauerwald is continuous cover of canopy; this means long-term transformation of easy structure of pioneer stands to rich structure forest. The last based of Dauerwald is economic utilization of the forest, and selection principles is the way to achieved this.

Wild ungulates as a limiting factor of forest regeneration in post-calamity stands?

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Central Europe has been affected by bark beetle calamity in last few years. Currently, the originated clear-cuts has to be afforested by mixtures of tree species with higher proportion of broadleaves compared with previous decades. This challenging task of afforestation of tens of thousands hectares is affected not only by unfavourable climatic conditions on clear-cuts but moreover by other negative factors including game damage.

High-density populations of large ungulates are now widespread not only in the Czech Republic, but also in other European countries. Specifically, nine species of ungulates are mentioned as overabundant in the context of Europe, including the most common native species like wild boar, roe deer and red deer. However, in Czech conditions, introduced ungulates becomes major problem, especially fallow deer and sika deer. Five-year data on hunting bags are presented in the table below, from which the long-term trend of increase in population growth is evident, because the hunting data are considered as a most credible data from hunting statistics.

Table 1. Hunting bags of wild ungulates in time period 2015–2020

species	year					
	2015	2016	2017	2018	2019	2020
Sus scrofa	185 496	160 139	229 182	137 823	239 818	160 811
Cervus elaphus	23 978	26 152	27 878	28 287	29 017	29 842
Capreolus capreolus	99 828	100 834	103 455	102 229	103 018	105 570
Cervus nippon nippon	14 541	16 144	17 106	18 368	17 535	19 382
Dama dama	18 968	20 402	23 069	23 800	28 978	30 982
Ovis musimon	9 495	9 506	9 400	9 531	10 105	10 580

Note: Data are available at Czech Statistical Office (https://www.czso.cz/).

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Session 5: Economy and Forest Policy – what are needs of forest owners and wishes of the public? Are the calamity consequences reflected on European level?

Consequences of the disturbance of spruce and pine forests on forestry and the cultural landscape in Saxony

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The forest vegetation landscapes and the forestry of Saxony are characterized by spruce forests in the mountain ranges and pine forests or their transitional stages to site-adapted forests in the Pleistocene lowlands.

Current disturbances correspond to the production dynamics of both forest ecosystem types. Local site properties and ecological characteristics of the forest biocoenosis act as predisposing factors. The latter increasingly influence the current disturbance dynamics. Triggering events include the warm and dry growing seasons of 2018 to 2020, storm and wet snow damages associated with the gradation of cambio- and xylophagous insect species on spruce and pine.

An estimate of predisposition describes the probable spatial and temporal dimension of this process. For the period of 2021 to 2050, it shows an area of about 100,000 ha of spruce forests that are highly to very highly susceptible to wet snow, storm and bark beetle infestation. In addition, there are at least another 30,000 ha – 50,000 ha of pine forests in a phase of a critical biocoenotic stability in the Pleistocene lowland. Here, high interception and evapotranspiration rates of the herbaceous and shrub layer (sand cane, blackberry) cause water stress for the tree layer during dry periods. This leads to a high disposition of pine trees for infestation by cambio- and xylophagous insects or their immediate death by wilting. In case of disturbances, spruce and pine forest ecosystems show in general a low level of resilience. Especially in pine forests, due to the high competition of grasses and subshrubs, the natural regeneration potential is neither effective from a forest ecological nor from a silvicultural point of view.

Considering the probable expansion of disturbances to large-scale system collapses, critical impacts on ecosystem services can be expected that are essential for the functionality of the Saxon cultural landscape. This will affect the runoff regulation related to precipitation events, snowmelt, groundwater and spring water recharge, soil and climate protection. Due to the massive accumulation of deadwood, the function and usability of forests as recreational space would be noticeably reduced for a longer period of time. However by maintaining health and safety regulations, the latter also limits the practicability of forestry work, especially silvicultural activities and hunting-related measures.

The wood stock of about 60 million m^3 assessed in the spruce and pine forests can be used as an indicator for the dimension of these problems. If the expected risks were to occur, the performance of ecosystem services will change that are important for the landscape ecology. Despite this it would lead to a drastic reduction of the potential of regional timber availability for decades. Simultaneously, the utilisation structure would change in favour of weaker and poorer quality of wood. A collapse of the regional timber supply can be assumed. In the event of system failures, serious and long-term socioeconomic effects are predictable.

The transition from disturbance to system collapse is conditioned by the extensive absence of a second tree or rejuvenation layer, in addition to the critical biocoenotic stability. Overall, the need to manage the transition from spruce and pine forests to site-adapted cultural forests programmatically is evident. The silvicultural strategy implemented from 2003 to 2018 corresponded to this.

As a reference for the evaluation of the regeneration potential of spruce and pine forests effected by significant disturbances, a forest area of 180,000 ha was used, characterized by an available up-to-date site mapping. On 30,000 ha, the tree species composition of the rejuvenation layer correspond to the forest development target. A similar potential can be observed on 51,000 ha with tolerable deviations in tree species composition, generally in favour of the natural regeneration of spruce. On 46,000 ha, initials for the development of a site-adapted tree species composition are present. This estimate of regeneration areas is a conservative estimate, which is exceeded by unrecorded natural regeneration in reality. Therefore, in the disturbance dynamics that are very probable to continue, the spruce and pine forests show a significantly increased resilience in the initial phase of forest conversion. In particular, the increased resilience contributes to the steadiness of ecosystem services.

As of 10th October 2021, based on Sentinel 2 data, 13,933 ha of open field sites were identified as having no detectable young growth stage or shrub layer. On 8,156 ha of disturbed areas, the young growth stage of the new forest generation was already established. In addition, small-scale disturbances have characterized forest development so far. These disturbances are interruptions of crown shooting on areas less than 0.5 ha.

The following requirements for the control of further disturbance dynamics result from the existing forest ecological development potential and functional requirements for the respective forest development unit:

In order to limit the risk of large-scale system collapse and to shape the transition from spruce or pine forests to site-adapted forests, efficient forest protection control is essential. The legislative framework of the Forest and Plant Protection Act should be fully utilized for definite operational forest protection measures. The forest protection monitoring forms here the basis for decision-making.

The intensity of a silvicultural input into the reforestation of disturbed areas is determined by the structural type of the disturbance, the resilience of the particular silvicultural treatment unit, and the vulnerability of landscape ecosystem services. Notwithstanding, establishing a hierarchy for the timing and intensity of measures to reforest disturbed areas is required.

For the renewal of biocoenotic stability, artificial regeneration of site-adapted tree species should be carried out primarily in small-scale disturbed areas. This limits transition to the stage of critical biocoenotic stability.

Disturbances with open field character where the secondary succession develops into a pioneer forest can be left to this development. Supplementing tree species that contribute to a better development of functional aspects under these conditions is appropriate. This primarily concerns the development of the soil and thus the infiltration potential of water, erosion control, carbon sequestration, the development of the wood supply, the timber yield and the diversity in structure and tree species of the new forest generation. The availability of labour force and forest planting stock, or the implementation of a silviculturally effective regulation of deer populations, may limit these opportunities. For this disturbance type, the following continues to apply: If pioneer forest does not develop on the entire area but succession stages of grasses, subshrubs, and shrubs develop in part, no short-term reforestation takes place. The areas are to be structured according to their successional mosaic. This results in a differentiated silvicultural input into reforestation. If this approach results in increased functional vulnerability of landscape areas, such as the occurrence of rapid surface runoff, these areas should be favoured for reforestation.

In general, the current disturbance dynamics in spruce and pine forests indicate a development that will have a far-reaching impact on forests and forestry. Consequently, the socio-economic relationship structure in the forest-dominated regions of Saxony will also be strongly influenced. In order to mitigate this development, it is indispensable to manage the system transition from spruce and pine forests to site-adapted forests in an evidence-based, systematic and programmatic way.

Macroeconomic position of forestry and wood processing industry during the bark beetle disaster

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The position of forestry and wood processing industry in the Czech Republic in the national economy, assessed using selected macroeconomic indicators, is very volatile during the bark beetle disaster. Since the beginning of the bark beetle disaster in 2014, the volume of total timber harvesting in the Czech Republic has more than doubled. The share of salvage cutting of total timber harvesting reached 95 %. However, the increase in the share of Forestry and logging (CZ-NACE 02) in the national economy of the Czech Republic during the bark beetle disaster was only 10 percentage points, expressed in gross value added. The value of the total production of the forestry sector has been declining since 2019, which indicates a declining self-financing capacity of the sector.

The paper addresses the issue of the position of the forestry sector and the wood processing industry in the Czech Republic in the bark beetle disaster and with the help of selected macroeconomic and sectoral economic indicators and tries to predict the development after the bark beetle disaster subsides. At the same time, it compares economic indicators with sectoral indicators in Austria.

Tab. 1: *Selected macroeconomic characteristics of forestry and wood processing industry*

Year	Annual cut: Total (mil. m^3)		Proportion of salvage cutting (%)		Forestry and logging (NACE 02)/ Manufacture of articles of wood and of wood products and cord, except furniture (NACE 16) on gross value added at basic prices 2015 (%)	
	CZ	AT	CZ	AT	CZ	AT
2010	16.74	17.83	38.6	28.6	0.681/0.712	0.407/0.736
2016	17.61	16.76	53.4	32.0	0.657/0.534	0.384/0.780
2017	19.39	17.65	60.6	36.7	0.669/0.548	0.381/0.780
2018	25.69	19.19	89.6	51.7	0.593/0.505	0.366/0.842
2019	32.58	18.90	95.0	62.1	0.749/0.460	0.321/0.855
2020	35.80	16.79	94.8	53.1	not yet published	

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Spruce, spruce and more spruce – silvicultural decisions, ungulates, and the spruce bark beetle in Finland. Have we learned anything from the European calamities?

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Compared to Central or Eastern Europe, Finland has been relatively safe from large-scale forest damages, which is why we have watched the bark beetle calamities with horror and curiosity: could the same happen in Finland? As bark beetles are expected to expand northwards and increase in abundance in Finland one might think we would be doing our best to learn from the lessons of the large-scale damages of Europe. Unfortunately, this is yet to happen.

The use of spruce in forest regeneration has increased continuously in the 2000s while that of pine has decreased simultaneously. The use of birch and other deciduous species in forest regeneration is minuscule at best. These trends have been the strongest in southern Finland – the area that is first to face the future troubles with bark beetles. In addition, spruce is the species most susceptible to climate change in Finland: storm damages will increase due to loss of frost while hot summers will bring drought-related stress. These will all benefit the bark beetle, which itself is already benefitting from the warming.

The reasons behind the “sprucification” are related to the pricing of spruce logs and its fast growth rate, but also to dense ungulate populations due to which the use of deciduous trees and pines is practically impossible in some areas. Yet, the probability that a spruce planted today will be hit with bark beetle damages in southern Finland before the assumed final felling 60-80 years later is ever increasing. Therefore, a valid question to ask is whether we have learned anything from the European examples, and if we have, why the better silvicultural policies have not been successfully implemented.

Planting subsidies assist spruce forest owners to switch to uneven-aged mixed management and climate change mitigation

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Forest owners of old even-aged spruce forests urgently need to decide about the future of their forests to face damage by bark beetle and / or storms related to ongoing climate change. Relying on natural regeneration threatens to repeat the failure of spruce in the following stand generation. To shift towards a near-natural, uneven-aged, stable, mixed forest management including fir and beech requires high financial investments. Public expects forests to conserve biodiversity and to store carbon, and thus supports funding for planting fir and beech. In the study, a financially driven simulation and optimisation detects optimal stand management pathways for five initial stand situations in the Beskydy mountains, West Carpatians, by estimating numbers of harvested and planted trees of spruce, fir, and beech. The approach combines benefits of modelling for even-aged (planting and tending age < 30 years) and uneven-aged (density-dependent matrix transition model diameter > 10 cm). An ecologically realistic modelling considers natural regeneration only in case of seed trees. Planting is only possible on free area uncovered by older trees, and its survival is limited by density of the mature stand. Probability of mortality was estimated from salvage harvest records and increases with spruce proportion by a factor up to three. The model integrates timber prices reduced in case of damage by mortality and costs of planting for five funding scenarios. A long term scenario under complete funding compared to no funding show standing volume increased by 11%, harvest volume increased 7%, mortality volume decreased by 35%, and fir and beech standing volume increased by 117%.

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Recapitulation of state services provided to small forest owners in the Czech Republic and Austria

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The aim of the paper is to recapitulate and compare, if necessary, the services provided by the state or its institutions to small forest owners. In many cases, owners do not know what they are entitled to or which information or services can help them in their management. Often they also do not know where to look for this information. The interactions between ownership type, forest management approaches, and policy, are of fundamental importance in understanding and shaping forestry.

The limited knowledge is specific for smale scale forest owners. For instance, differing national statistical systems make cross-country comparisons difficult. It also becomes apparent that we have a good understanding of the behaviour of classical forest holdings but we know much less about other forest owner types with their specific motives and preferences. It can be assumed that there will be a different approach to service delivery in the two countries. The paper should summarise this information and compare the differences between the Czech Republic and Austria.

POSTERS

Session 1: The calamity – has it already passed?

Bark beetles/Ophiostomatoid fungi/Norway spruce interactions in the Extemit-K research. Can our findings bring practical outputs for forestry?

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We will introduce the overview of selected research topics which we study in the laboratories and field research plots in the project Extemit-K.

In the extensive research forest area, we built several roofs in the forest to prevent the watering of selected trees. In a series of experiments, our aim is to understand if and by which mechanism physiological and biochemical changes in Norway spruces exposed to sudden stress (drought or sun radiation after clear cut creation) cause their higher vulnerability to bark beetle attacks. We also study the volatiles that bark beetles can percept when searching for the most suitable host tree.

Compounds with attraction activity for beetles, except well-known aggregation pheromone, can be emitted also by the spruces themselves. As we found, these compounds are functional only in complex mixtures, synergized with pheromone or with volatiles released by mycelia of ophiastomatoid fungi inoculated by beetles to their galleries. Importantly, we search the natural habitat of the beetle for compounds that repel beetles from spruce.

The origin of such repellents is in nonhost mainly broadleaves trees, can be emitted as defence compounds by spruce itself or was found in the smell of fungi. From such compounds a cocktail was prepared and optimized, which is now tested for protection of individual trees, forest fragments, and wood storages. There is a chance with further development it can be used in a more complex methodology for the protection of fresh forest edges.

Our research team study beetles also on their genetic level. We identified the whole genome of *Ips typographus*. It helps to select genes, which are important for the features that make this species so aggressive. In scrutiny of our interest are genes coding the aggregation pheromone production or the resin detoxification ability, which bark beetles possess to survive tree defence. Surely, we also target genes of crucial metabolism. We plan to use the new technique, RNAi, allowing us to specifically silence genes of interest and consequently influence listed bark beetle features or even kill the individual.

Acknowledgement: "EXTEMIT-K," No. CZ.02.1.01/0.0/0.0/15_003/0000433, Ministry of Education, Youth and Sport, Operational Programme Research, Development and Education

Primary and secondary *Ips typographus* attacks on Norway spruce depend on host tree crown characteristics and phenolic-based defenses

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Severe bark beetle outbreaks intensified by climate change affect extensive areas of coniferous forest in the Northern Hemisphere. The mechanisms of individual tree resistance remain poorly understood, particularly regarding the role of phenolics in defensive metabolomics. In this study, we experimentally investigated carbon-dependent Norway spruce (*Picea abies*) chemical defense system against bark beetle *Ips typographus* attacks. In spring 2003, in a biological reserve of La Chatte Pendue in Vosges Mountains, France, we inoculated sterile malt agar into the phloem of 97 mature trees, growing in a natural stand affected by the ongoing bark beetle outbreak. Catechin, astringin, taxifolin, piceid, and isorhapontin contents were measured before and after inoculation. Trained field experts evaluated tree crown parameters, such as total and primary crown defoliation, frequency of secondary shoots, crown transparency, etc., that serve as robust indicators of tree vigor. We used machine learning techniques and non-linear logistic regression fit in likelihood framework to quantify the effects of morphological structure and phenolic compound contents on tree survival. We found that elevated rates of induced catechin production were associated with increases in tree survival potential. Increase in distance from a previously colonized neighbor facilitated tree resistance. Survival probability diminished with increasing crown defoliation and stem sun exposure. Primarily attacked trees had significantly lower juvenile crown ratios as compared with trees secondarily attacked. Beetles prioritized targeting trees that had higher total and primary crown defoliation ratios than secondarily attacked and non-attacked individuals. Our results show that incorporating crown parameters into analyses improves survival predictions. We demonstrate that phenolics play direct role in spruce defenses against bark beetle *Ips typographus*.

Acknowledgement:

This work was supported by OP RDE, EXTEMIT-K, grant No. CZ.02.1.01/0.0/0.0/15_003/0000433; Internal Grant Agency FFWS CULS in Prague, grant No. A_21_09; Ministry of Agriculture of ČR, grant No. QK1910480; EU Marie Curie fellowship, grant No. QLK5-CT-2002-51692; FFWS CULS in Prague, grant No. 43950/1322/3244 "Probabilistic modelling of tree survival in Norway spruce during severe bark beetle outbreaks".

Current spruce bark beetle calamity in the Czech Republic – year by year

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The current bark beetle outbreak in spruce stands of the Czech Republic represents the worst and biggest bark beetle calamity in the history of the Czech lands. The beginning of this long-term outbreak can be dated back to 2003 (extreme drought, over average warm growing season). In the following years, the development of bark beetles was supported by a number of suitable climatic episodes. After the culmination of the recorded volumes of harvested spruce wood infested by bark beetles at the end of the decade before last, there was a renewed increase, first in the eastern half of the state (especially in the north and central Moravia and Silesia) since 2011. The increase in 2013 and 2014 was more noticeable and especially then the bark beetle calamity between the climatically extreme (dry and warm) years 2015 and 2018 with culmination mainly in 2019. In the western part of the country (Bohemia), there was a more significant increase in bark beetle infestation since 2015 again (calamity with exponential increase was recorded here mainly between 2018 and 2020), culminating in most of Bohemia in 2020.

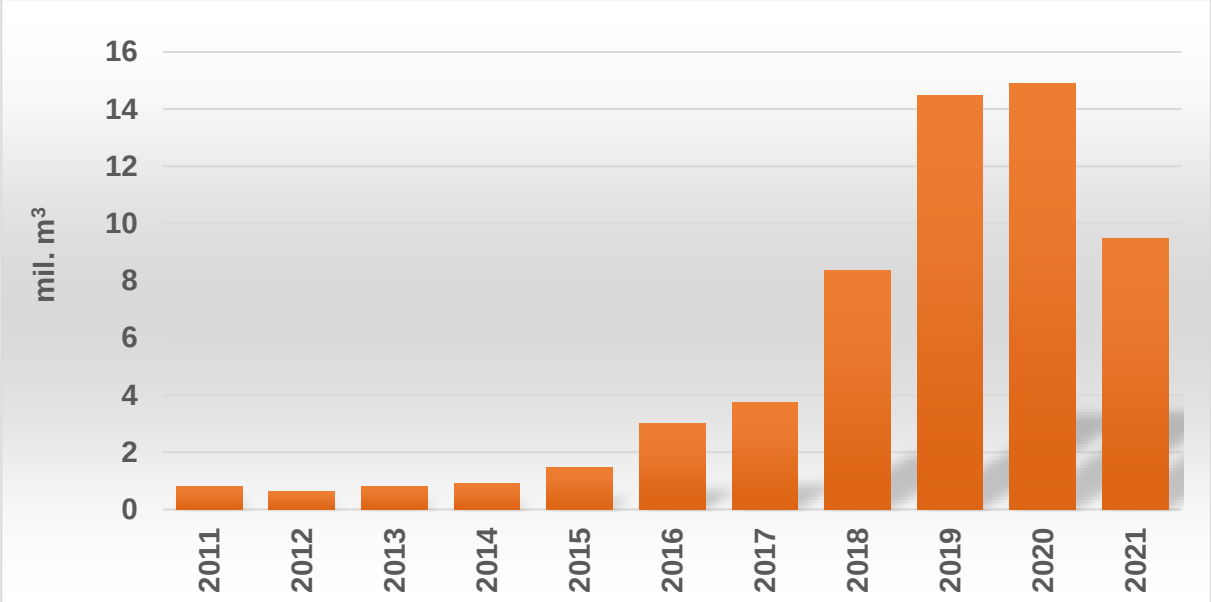

Fig. 1: *Recorded volume of harvested spruce wood infested by bark beetles in Czechia since 2011 (values from ca 70% forest surface; data source: FPS FGMRI)*

Acknowledgement:

This work was made with the support of the Ministry of Agriculture under a contract to provide the Forest Protection Service and institutional support MZE-RO0118.

Vegetation index monitoring of bark beetle attack in Norway spruce forests of Central Europe using Planet Multispectral Imagery

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Bark beetle attacks in Norway spruce forests are one of the critical problems in Central Europe. Quick monitoring help to identify the green attack phase and allow it not to spread quickly. It is hard to identify green attacks with the human eye, but having satellite remote sensing data with at least one near-infrared band, we can calculate Vegetation Indexes (VI) that could track changes in extensive areas. Planet Multispectral Imagery data is an excellent tool to get periodical time series of Imagery and using different VI. We used 22 Planet Multispectral Imagery datasets to track changes in 11 VI in 2020 for Školní lesní podnik v Kostelci nad Černými lesy (ŠLP, The School Forest Enterprise in Kostelec nad Černými lesy), in the Czech Republic and significant changes in VI of attacked and controlled groups of trees were identified.

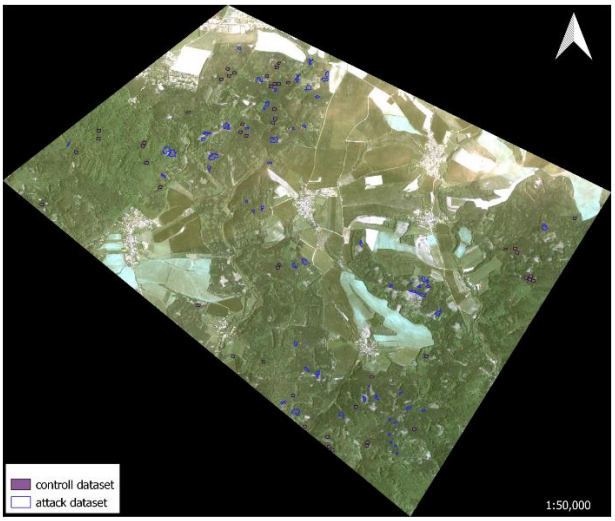

Fig. 1: *Planet Multispectral Imagery data of the area of the ŠLP study area*

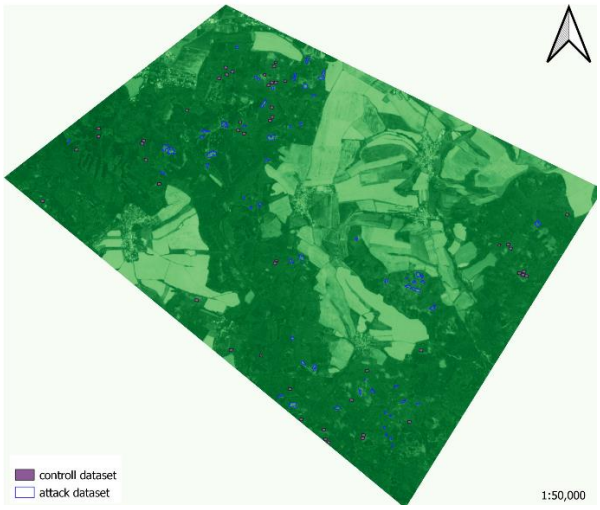

Fig. 2: *NDVI VI based on Planet Multispectral Imagery data of the area of the ŠLP study area*

Acknowledgement:

This work was supported by grant No. CZ.02.1.01/0.0/0.0/15_003/0000433, "EXTEMIT – K project," financed by the Operational Program Research, Development and Education (OP RDE), grant no. 43950/1312/3128 "Green attack identification with the use of multi
and hyperspectral data" financed by Internal Grant Agency FFWS CULS in Prague.

Successful development of the European spruce bark beetle *Ips typographus* on Scots pine

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The European spruce bark beetle (*Ips typographus*) is the most critical forest pest in Central Europe. It is associated mainly with older Norway spruce (*Picea abies*) trees. It can be found on other conifer species only rarely. As a rule, beetles' development on these 'non-typical' tree species is not very successful, and infested trees survive. Therefore, planting mixed forest stands seems advantageous because other trees than spruce remain undamaged by this bark beetle species. This assumption is disturbed by the results of our study, in which we observed a heavy infestation of Scots pine (*Pinus sylvestris*) in northwestern Bohemia. The infested trees were initially located in mixed spruce and pine forest stand. When the spruces were eliminated by sanitation cutting, beetles attacked the pines.

Approximately one-half of the infested trees did not survive. The reproductive success rate of bark beetles was unusually high (10–20 %). The density of the entry holes was also high (more than 10 holes/dm^2). The highest amount of holes was located approximately 6–12 m from the trunk base. Only a small number of holes were situated near the first green branches (ca 18–20 m high). In contrast, the infestation of spruces typically starts in the upper third of the trunk at the interface between dry and green branches. Like spruce, the infestation of the lowest part of the trunk (up to a height of 1–2 m) was not observed.

Infestation of pines was linked to the calamitous occurrence of the bark beetles in spruces and a subsequent search for a substitute food source. The question remains why bark beetles did not preferentially attack spruces growing near the damaged forest stands.

Fig. 1: *Ips typographus galleries on a Scots pine trunk.*

Acknowledgment:
The study was supported by the Ministry of Agriculture of the Czech Republic, institutional support [grant number MZE-RO0118].

Session 2: Ecology of post-disturbance areas – can we document negative effect of bark beetle outbreak on C sequestration, hydrology, soil erosion, biodiversity?

Deforestation of small catchment and impact on water regime – project introduction

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The ongoing bark beetle calamity is bringing rapid deforestation at a scale that can have serious consequences for hydrological conditions in forest catchments. It also gives researchers the opportunity to monitor the impact of this process on forest hydric functions and the quality and quantity of runoff water.

In the catchment areas of the Suchý, Sokolí and Slučí brooks (3S, Fig. 1) in the Hrubý Jeseník Mountains, hydrological balance measurements were started in 2020. The catchment areas are mainly covered by spruce forests (from 91 % to 96 %) and all are currently threatened by bark beetle calamity, however with different intensities due to their different location and management (Suchý vrch nature reserve, NATURA 2000 area, catchment areas with normal management). Over the next few years, we expect the progression of the calamity in all three catchments, but with different intensity and with different forest management approaches.

Between 2022 and 2025, a project is being implemented in the 3S catchments to:

- quantify changes in the water regime of small forest catchments in the context of ongoing deforestation - a consequence of the bark beetle calamity,
- identify the risks in terms of reduced infiltration and retention, increased erosion, reduced ability to buffer rainfall and changes in runoff water quality, including as a result of forest management practices in dealing with the calamity,
- propose measures to minimise these risks.

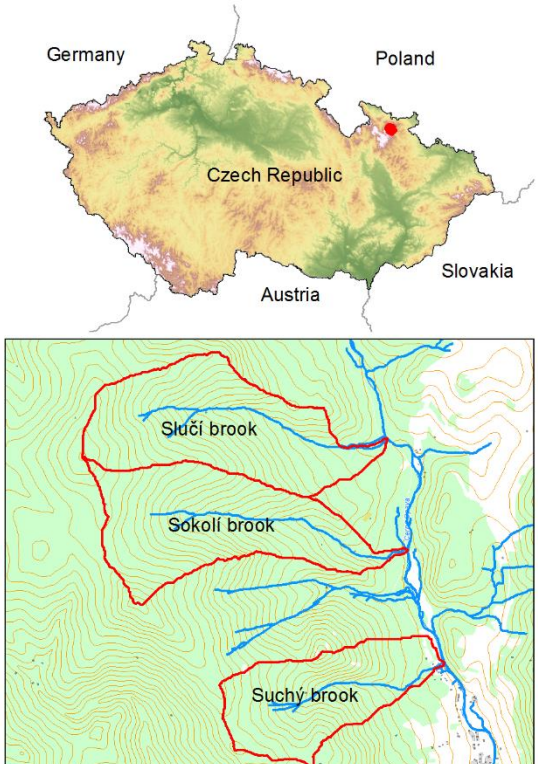

Fig. 1: *Location of 3S catchments in the Hrubý Jeseník Mountains*

Acknowledgement:
This work was supported by the project of the Ministry of Agriculture of the Czech Republic – (MZE-RO0118) and QK22010189 (National Agency of Agricultural Research).

Impact of deforestation on carbon sequestration, nutrient balance and risk elements mobility – project introduction

Radek Novotný[1)], Vít Šrámek[1)], Věra Fadrhonsová[1)], Martin Valtera[2)], Václav Tejnecký[3)]

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[2)] *Mendel University in Brno, Faculty of Forestry and Wood Technology*
[3)] *Czech University of Life Sciences Prague, Faculty of Agrobiology, Food and Natural Resources*

Forests are an important carbon sink, but the current bark beetle calamity is upsetting this positive balance. Deforestation has reached enormous scale during last few years (2015-2021). In the Czech Republic was drought period 2014-2019 one important factor which accelerated the course and extent of the calamity.

The aim of this three-year project is to evaluate changes in forest soils on clearcuts compared to undisturbed stands and to quantify changes in carbon sequestration and predict their development with the progress of bark beetle outbreak. Other question is which changes we should expect in soil carbon sequestration due to changes in the species composition of forests. And, subsequently, if species composition is changing, we can expect changes in organic layer quality and quantity as well and there is a risk of heavy metals being released into the soil solution. That's way one important result should be a recommendation for forest management supporting soil carbon sequestration and other soil functions on clearcuts.

Field work is focused on the ICP Forests Level I plots which were deforested during last five years and in three work packages is carrying out/is assessing i) the rate of decomposition of organic matter, ii) chemical and microbiological changes in top soil (up to 30 cm depth) and iii) chemical changes in whole soil profile up to 80(100) cm depth.

Acknowledgement:
This work is supported by the project Nr. QK22020217 (National Agency of Agricultural Research) and by the Ministry of Agriculture of the Czech Republic – (Project Nr. MZE-RO0118).

Figure 1: *Clearcut on the ICP Forests level I plot 0101 Český Krumlov*

Figure 2: *Clearcut on the ICP Forests level I plot 2526 Okrouhlá Radouň*

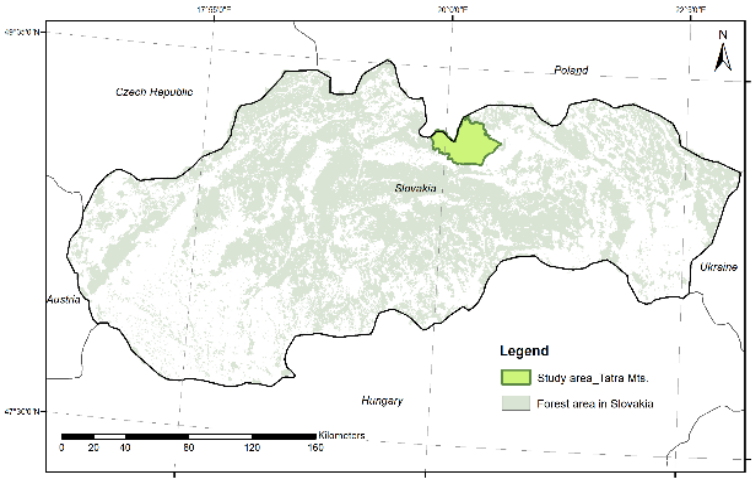
Integrated forestry-ecological research of rare mountain forests in the Tatra Mts. area

Zuzana Sitková, Pavel Pavlenda, Ivan Barka, Vladimír Šebeň

National Forest Centre – Forest Research Institute, T.G. Masaryka 22, 960 01 Zvolen, Slovakia

The poster focuses on the new research project titled "Integrated forestry-ecological research of rare mountain forests in the Tatra Mts. Area" (acronym FORECALL), that is implemented at the National Forest Centre in Zvolen (NFC) during the period from 2021 to 2024. The main objective of the project is to comprehensively assess the temporal and spatial dynamics of changes in unique montane forest ecosystems of the Tatra Mts. (Fig. 1), and to analyze the effects of climate change factors and development of forests after large-scale windthrow disaster and bark beetle outbreak on water regime, surface destruction, carbon balance, biodiversity, tree growth and forest regeneration. The intention is to link up the existing widely fragmented research activities, to integrate hitherto unanalyzed but high-value historical data of remote sensing and terrestrial surveys, which the NFC disposes with. The ambition is to establish a basis for comprehensive ecological-nature conservation forestry research and to obtain scientifically based arguments that would contribute to better harmonization of forest management and nature protection.

The partial objectives of the project are defined as follows: i/ to analyse long-term development of forests in the territory concerned on the basis of remote sensing data sources with different detailed temporal and spatial resolution (satellite scenes, aerial photographs - LiDAR and multispectral - aerial and terrestrial); ii/ to analyse the impact of the gradual post-disaster decline of forests and climate change on the water regime and degradation processes of surfaces and soil in the selected part of study area; iii/ to map and evaluate temporal changes in carbon stock balance in the north part of High Tatra Mts.; iv/ to assess the dynamics of the post-disturbance development of mountain forests and to map changes in the growth of forest trees, in the biodiversity of species and changes in other site indicators based on precise terrestrial measurements at minimum interval of 20 years and in view of the ongoing climate change; and v/ to implement and compare development of artificial and natural regeneration in relation to climate factors and the intensity of forest interventions.



Acknowledgement:
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Session 3: Reproductive sources – are they sufficient in amount and species structure? Should we use non-native/introduced species?

Conservation of valuable remaining populations of Norway spruce in interest areas of the Czech Republic

Martin Fulín, Josef Cafourek, Jaroslav Dostál, Petr Novotný, Jiří Čáp, Helena Cvrčková, Pavlína Máchová

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Ongoing research is based on the use of technologies of vegetative reproduction and genetic characterization using molecular genetics. The four-year project (06/2020–05/2024) focuses on valuable residual populations of Norway spruce of Hurst ecotype and spruce survivors of drought and bark beetle calamity. In localities of interest, their genetic characteristics are determined from selected and comparative individuals using DNA analyses. From the selected areas, the most suitable graft donors will be selected for the establishment of seed orchards/clone archives *in situ* to obtain reproductive material for the strengthening of the indigenous spruce population in suitable habitats. The aim of the project is to connect research activities and conservation practice with the use of resistant potential to adverse environmental factors at the part of the gene pool of Norway spruce survived in the lower and middle elevations, thus saving this species as a natural part of forest ecosystems.

Fig. 1 and 2: *Selected parent trees and produced grafted plants (M. Fulín)*

Acknowledgement:
This work was supported by the project of the Technology Agency of the Czech Republic with reference number SS01020260 and the project of the Ministry of Agriculture of the Czech Republic – Resolution RO0118.

Use of DNA analyzes for verifying the declared origin of Forest Reproductive Material

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Identity of forest tree reproductive material is essential in artificial forest regeneration. The Czech Republic as a member state of the European Union and on the base of international legislation (Council Directive 1999/105/EC on the marketing of forest reproductive material on the market) has the obligation to create a functioning control system for determination of forest reproductive material. The purpose of our study was to investigate the possibilities of using objective methods of DNA analysis to verify the declared origin of reproductive material of selected forest species (Norway spruce, European beech) in terms of the Czech Republic.

Monitoring of the identity of reproductive material was realized during three years, i.e. from seed collection to transplanted plants production. Seven and nine optimally polymorphic markers with sufficient informative value were selected for the subsequent evaluation of the genetic structure of the monitored sets of Norway spruce and European beech reproductive material by Bayesion clustering.

Analyses of microsatellite markers were performed on 1920 samples of the 32 sets of Norway spruce reproductive material from 8 selected sources of forest reproductive material (units of forest reproductive material) and on 1702 samples of the 30 sets of European beech reproductive material from 10 selected sources of forest reproductive material (units of forest reproductive material), the obtained genetic compositions of sets were compared after statistical processing.

Using the performed Structure analysis, the obtained profiles of monitored units of reproductive material of different origin were distinguishable from each other. Optimized methodological procedures could be used in the state control systems of verifying declared origin of forest reproductive material and to increase consumer protection of forest owners and nursery producers in the Czech Republic.

Acknowledgement:
This work was supported by grants from the Ministry of Agriculture of the Czech Republic (No. NAZV QK1810129, and Institutional Support (MZE-RO0118).

Artificial forest renewal from a forest reproductive material availability perspective

Alžběta Pařízková

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The need of reforestation large areas after the bark beetle calamity is a significant challenge for forest owners. Plantations require new approaches including changes in tree species composition and variability. In order to succeed, it is necessary to have a whole production chain from seed zones of various species, seed-collection capacities, processing, storage and pre-germinative treatments up to forest nursery capacities and planting operations as well as to follow European (the Directive 105/ ES/1999) and national (decree 149/2003 coll.) legislation.

Approved seed sources are usually certified forest stands and seed orchards. In the Czech Republic approved sources of totally 18 species of conifers and 57 species of broadleaves are registered. The official list includes all commercial trees such as Norway spruce, Scots pine, silver fir, both pedunculated and sessile oaks, European beech and other important accompanying species such as Douglas fir, European larch, sycamore maple, Norway maple, European ash, elms, wild cherry and also rare species needed for forest biodiversity, for example crab apple, wild pear, service tree and many others. The total area of the approved stand sources is 140 498.87 hectares, there are further 109 seed orchards and 22 clone mixtures and 604 other seed sources. The amount of collected seeds is influenced not only by the need of reforestation but also by the yearly fructification which is irregular (see the table). Most of the seed stock is processed and stored at the Seed Plant of the Forests of the Czech Republic in Týniště nad Orlicí. Over the last years new technologies and equipment were acquired in order to increase the capacity and to manage the increasing share of broadleaves. The Seed Plant may deliver seed´s amount which allow to grow 100 million up to more than 200 million plants of all woody species. New technologies and increasing capacity were implemented also in forest nurseries. Annual planting stock production has increased from 139 million plants up to 290 million plants during the calamity period, nearly 30 % of which was in form of containerized seedlings.

Table 1: *Kilograms of collected seeds of commercial tree species*

	2018	**2019**	**2020**	**2021**
Norway spruce	77 858	23 192	10 477	158 817
Scots pine	12 033	26 530	77 128	45 341
Silver fir	78 951	5 875	115 670	42 740
European beech	147 300	39 917	245 843	310
Pedunculated oak	505 067	29 086	569 816	19 650
Sessile oak	281 699	6 089	429 573	18 727

Session 4: Silviculture – what kind of forest we want to have? How to start and continue on clear-cut area?

Implementation of innovative forest regeneration procedures on large-scale clearings with regard to the support of biodiversity and increasing the functionality of forest ecosystems

Monika Vejpustková[1)], Jan Leugner[1)], Štěpán Lukeš[2)]

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[2)] *Forest cooperative of municipalities Přibyslav*

The extreme drought in recent years and the associated bark beetle outbreaks have led to a dramatic increase in harvested volume of wood and the formation of large-scale clearings. The Czech forestry has thus found itself in an unprecedented situation, when it is necessary to establish new forest stands on a large area, resistant to predicted climate change and at the same time fulfilling all ecosystem and economic functions. The knowledge schemes used so far are difficult to apply in these circumstances.

The ongoing project, which began in April 2022, is focused on the implementation of innovative forest restoration procedures on clearings formed as a result of bark beetle outbreak on the property of Forest cooperative of municipalities Přibyslav. Specific measures will be proposed on the basis of an initial field survey, including a mapping of site conditions and an assessment of biodiversity parameters. When designing the measures, an individual approach will be applied to each area, taking account of its natural potential. The choice of differentiated restoration procedures will ensure the diversity and stability of future forest ecosystems. Measures to support biodiversity will include: a combination of natural regeneration and artificial afforestation or the use of two-phase regeneration to foster species, age and spatial diversity of emerging stands; consistent support for the presence of mother trees; leaving part of dead wood in the forest for spontaneous colonization by other organisms; selection and preservation of habitat trees. In addition, the establishment of advanced restoration elements (gaps) in adjacent mature spruce monocultures, which are acutely threatened by disturbances, will be proposed. The result of application of innovative forest restoration procedures will serve as an example of good practice for other forest owners whose property has been hit by bark beetle gradation.

Acknowledgement:
The work is supported by Norway grants and State environmental fund of the Czech Republic – project no. 3211100015.

Session 5: Economy and Forest Policy – what are needs of forest owners and wishes of the public? Are the calamity consequences reflected on European level?

Impact of bark beetle calamity on forests owners in the Czech Republic

Jiří Novák[1)], Dušan Kacálek[1)], Martin Fojt[2)], Jiří Remeš[3]

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[2)] *Association of Municipal, Private and Church Forest Owners in the Czech Republic (SVOL)*
[3)] *Czech University of Life Sciences, Prague, Faculty of Forestry and Wood Sciences*

In the Czech Republic, about 54% of forest land is state-owned. As for the non-state ownership, there is only one forest estate larger than 10,000 ha owned by one person. The number of owners whose land exceeds 250 ha is 103 and 435 persons have more than 50-ha forests. On the other hand, 77% of forest owners have just 1-ha or smaller forested lands; one third of owners share even smaller land than 0.1 ha. The private forests ranging from 1 ha to 10 ha of the area account for 42% of the forested area in the Czech Republic. The only economically independent estates are those with an appropriate diversification of both age and stand structures, which allows a maintenance of annual and/or periodical costs and yields. This applies only to 17.5% of the private forested area.

It is estimated that current bark beetle calamity represents in forestry sector the economic damage amounting to 100 billion CZK. Therefore, the financial support from Ministry of Agriculture to private, public and state forest owners was prepared. However, this support was not entirely sufficient. The one-year calculated damage was 44 billion CZK in 2020. On the other hand, amount of financial contributions (for the whole period 2017–2020) was only 12.9 billion CZK. The situation got better following spring 2021 as the price of coniferous timber increased again.

About 70% of the small estates are supervised by State forests of the Czech Republic; the annual costs of such service are 158 million CZK. It is debatable whether the money were spent effectively. For example, the owners have not met supervising forestry staff for many years or they have not known them yet. Besides that, these foresters were not able to help organize operations needed and sell the timber. With no facilities and qualified staff the owners get into trouble. The future solution can be a service organization providing owners with all operations needed. The SVOL is the organization that has been supporting the small-estate owners over a long time (www.svol.cz).

Preparedness for emerging forest pest risks in Finland (PREPARE)

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It is expected that Finland is soon facing the same problem with the European spruce bark beetle (*Ips typographus* L.) (SBB), prevailing today in Central Europe and Sweden. The combined effect of more frequent abiotic agents and an additional bark beetle generation can be devastating. The objective of the project is to suggest organization and *modus operandi* of a SBB Risk Management System for Finland. To reach the goal, which is increased resilience of Finnish forests from emerging pest risk through effective contingency arrangements, building international networks and raising awareness in the forest sector, there is a need for extensive and active stakeholder contact. Our approach is based on contacting relevant stakeholders and defining their role in implementing the contingency plan. The roles will be mapped based on the actions outlined in the forest risk management cycle (Fig. 1), i.e. Prevention, Preparation, Monitoring, Response, Recovery, and specified in the stakeholder engagement plan. Lessons learned reports will be gathered from Sweden, Austria, Slovenia, Czech Rebublic, Germany and Slovakia. The project provides a unique opportunity for Finland to develop best practices in response to increased risks of the SBB.

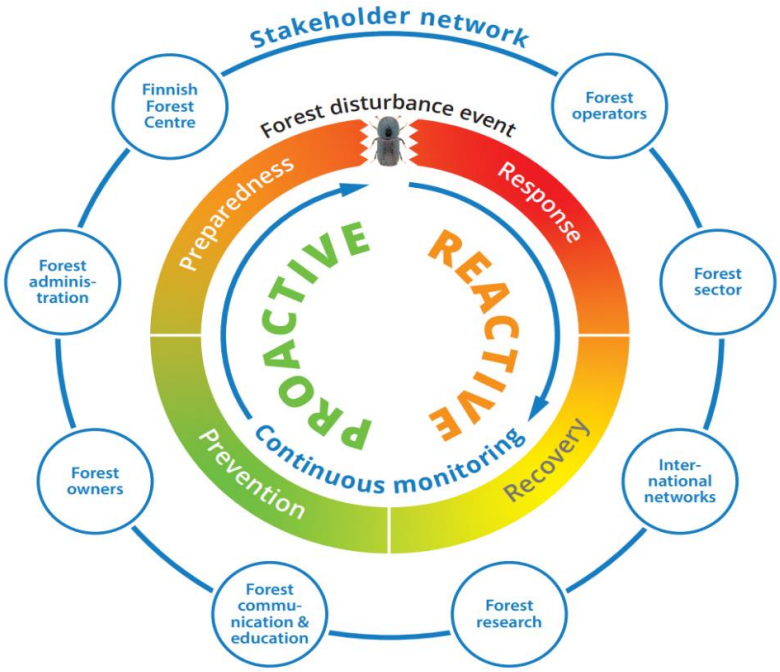

Fig. 1: *Forest risk management cycle for the SBB. (Modified from the crisis management cycle, European Forest Risk Facility 2020).*

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