INTERREG V-A ATCZ 251 FORRISK

Output T.1.2. – Manual for future crisis and risk management in forestry

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1. Introduction

Due to recent approaches to afforestation, forest establishment and/or regeneration, tending of forest stands (clear—cuts with artificial forest stands establishment, low thinning intensities etc.), and maintain labile forest structures (even-aged coniferous monocultures); changing and extremely varying environmental conditions (climate change- intensity and duration of drought, floods, wind-storm, high/persistent acid and nitrogen depositions, disturbance- wind, ice, fire etc.); wild game overpopulation (devastation of natural regeneration and young pole stands); insects gradation, fungi, pest and disseises occurrence and spreading, too many risks could be identified even worldwide in forestry. No borders exist in these actual as well as potential risks among countries. Rising problems can easily and rapidly enlarge in area and overcome national levels as it is experienced from droughts, and bark beetle calamity for example nowadays. Therefore, cross-border risk management as early warning system with possible solution offers should be established and keeping actual, to avoid such huge problems occurrence and to minimize economical and biological losses. After nineties of the last century, a law and forest ownership has changed dramatically as well as a forestry management approach of the state in the Czech Republic. Therefore, there are still obvious differences in forest management, operability etc. among European countries.

Presented manual guide the reader to brief orientation in potential current and future risks, risk identification and brief recommendation how to solve the occurred problems according to forest stand type (structure), site conditions, and size of owned forest land, specifically in neighbour regions of the Austria and the Czech Republic according to focus of the project FORRISK ATCZ251. Risks are simply scaled per its intensity.

2. Risk management basics (strategic and operational)

As outlined above, the forestry sector faces a variety of challenges and uncertainties, and numerous measures and instruments are available to deal with them. Since the importance of some risks as well as the suitability of the chosen risk management activities will likely vary over time, it is reasonable to stay up to date and adapt the risk management if necessary. This chapter provides a brief general introduction to the topics of risk (chapter 2.1) and risk management (chapter 2.3) and also addresses the individual risk attitude, perception and competence (chapter 2.2).

2.1. Risk

A range of possible outcomes

Businesses pursue certain goals (e.g. generating income, or non-economic goals) and set activities to achieve those goals and certain outcomes. Many components and developments affect the outcomes, but these so-called influencing factors vary and it is not yet clear at present how they will turn out in the future. This uncertainty in the influencing factors (e.g. wood price, quantity and quality of wood in upcoming harvest) also causes an uncertainty in outcomes (e.g. income from wood sold). Therefore, several outcomes – ranging from positive to negative – are possible, and this is referred to as „risk“. In everyday use of language, the term "risk" is mostly used for the possibility of negative outcomes.

Criteria for considering risk systematically

There is no uniform way of defining or categorising risk, however one can consider risks systematically by taking into account a series of criteria, including the future setting, expected frequency and extent of the damage, range of possible outcomes, availability and level of uncertainty, level of importance to the business or sector, interlinkages, origin, types and causes of risk (see Table 1) as well as personal bias: The future setting may differ from the present one.

- The risks and their causes, the likelihood or extent of damage may be known or unknown.
- The available knowledge is likely incomplete, and it may be certain or uncertain.
- A damage (or benefit) may occur rarely, occasionally or often, and it may be high, medium or low.

- The range of possible outcomes (from damage to benefit) may be narrow or wide.
- Some risks are more important than others: Risks may be normal (occurring frequently, low damage), marketable (occurring occasionally, medium damage) or catastrophic (occurring rarely, high damage).
- Risks are often interlinked and hence may reinforce or weaken one another.
- Risks may originate from inside or outside the business or sector.
- Risks occur in all areas of the business or sector, such as production or service, fixed assets, finance, markets, policy, people or other areas (see Table 2 for examples).
- It is not always clear whether a situation is the cause or the outcome of a risk (e.g. uncertain wood price: result of uncertainty in markets, at the same time cause of uncertainty in income).
- Moreover, it is helpful to distinguish between the actual (objective) situation and one's own risk attitude and (subjective) perception which may be biased (see chapter 2.2).

Criteria		Questions for considering risk systematically
Setting, field of action	present future	o What is the present setting? o How will the likely future setting differ from the present?
Availability of knowledge	none little medium extensive	o What knowledge is available on the possible future setting, likelihood of damage and range of possible outcomes?
Uncertainty of knowledge	(very) uncertain medium (almost) certain	o How certain is the available knowledge on the present setting and the possible future setting, likelihood of damage and range of possible outcomes?
Likelihood of damage	rare occasional often	o How likely is a damage (or benefit) to occur?
Extent of damage	(very) low medium (very) high	o How low or high is the damage (or benefit)?
Range of outcomes	narrow medium wide	o How narrow or wide is the range of possible outcomes (from highest damage to highest benefit)?
Importance of risk	normal marketable catastrophic	o How important is the risk to the business or sector? normal risks: likely occurrence, low damage marketable risks: occasional occurrence, medium damage catastrophic risks: rare occurrence, high damage
Interlinkages of risks	reinforcing weakening	o Which risks are interlinked? o Do they reinforce or weaken one another? o How, when etc. do they reinforce or weaken one another?

Origin of risks	internal external	○ Do the risks originate from inside or outside the individual business or sector?
Types of risks	production fixed assets finance markets policy people other	○ Which risks occur in the different areas of the business or sector? (see Table 2)
Cause or result of risks		○ What causes the risk? ○ What is the result of the risk?
Objectivity of analysis	objective subjective / bias	○ What is the actual (objective) risk? ○ What is the own (subjective) perception of the risk? ○ Is the risk perception potentially biased? (see chapter 2.2)

Table 1: Exemplary criteria and questions as an aid to considering risk systematically.
Remarks: Criteria and questions can be adjusted to the specific situation of the business or sector.
[Source: Compilation by Federal institute of Agricultural Economics, Rural and Mountain Research, based on Hambrusch et al. (2020), Frentrup et al. (2011a, 2011b), Hirschauer and Mußhoff (2012), Schaffnit-Chatterjee (2010), Schaper et al. (2012)]

2.2. Risk attitude, perception and competence

Risk management is shaped by the persons involved: Even if they are exposed to the same set of risks, they are likely to perceive these risks differently and deal differently with them. Therefore, it may be helpful to consider their risk attitude, perception and competence (see Gigerenzer (2013, 2014), Gigerenzer und Giessmaier (2006), Kahnemann (2016), Kahnemann et al. (2011)).

Risk attitude

A person's individual preference may range from avoiding risk by as much as possible to actively seeking risk:

- **Risk avoidance** refers to the attitude of persons who seek a high degree of certainty even if it comes at a high cost (e.g. will buy most expensive protective gear even though a more modest equipment would suffice to cover the actual level of risk).
- **Risk affinity** is attributed to persons who are more focused on the possibility of getting an advantage, even if there is a substantial risk involved; some find uncertainty itself appealing (e.g. will participate in a game with high stakes even at a very low chance of winning).

- A person may be a risk avoider in general (e.g. savings account instead of stock exchange shares), but may act differently under some circumstances (e.g. gamble on a night out with friends).

Risk perception

Risk perception refers to how persons assess differently the degree of uncertainty or the likely outcome, even if they look at the exact same situation. Perception may be biased by many factors, such as **previous experience, pressure, stimulus overload or misconception.**

Apart from own bias, bias can also be caused – and even intentionally used – by others, for instance in a purchasing process: It may happen that a sales person repeatedly overstates a product's advantages but purposely refrains from disclosing the disadvantages in order to close a deal and earn a commission – even if the customer ends up buying a product they do not need or want.

In terms of risk management, it is therefore advisable to consider and **identify bias, particularly when the decision to be made is essential, expensive and irreversible** (e.g. long-term obligations, large investment).

Risk competence

A person is deemed risk-competent if they are able to deal with risk – despite incomplete information – based on critical thinking and reflection, including statistical thinking, heuristics (e.g. "rules of thumb"), system knowledge or psychological knowledge. Risk competent persons are aware of risk attitude and risk perception and distinguish between the factual situation and subjective views.

2.3. Structured risk management

Every business is subject to an individual set of risks. One can **customise the risk management to the individual situation** by addressing aspects such as:

- What are the objectives of the risk management?
- How complex, frequent and costly are, or should be, the risk management activities?
- Which risks and risk management activities are interlinked, and how?
- What will, or may, happen if a certain risk is managed, or not managed?
- Which risk management strategies are, or should be, chosen for the different risks?
- Which mix of risk management activities and instruments is both effective and sustainable?
- At what point in time are risk management activities applied, or should be applied?
- Who is, or should be, responsible for implementing the risk management process and activities?

Common risk management **objectives** are to maintain a viable business in the long run and generate a certain level of income; another objective may be to prevent insolvency in the short run. These objectives will likely prompt a different set of risk management activities.

There are different ways of organising a structured risk management, e.g. as a **circular process** comprising the phases of risk identification, assessment, control and monitoring (see Figure 1 and chapters 2.3.1 to 2.3.4).

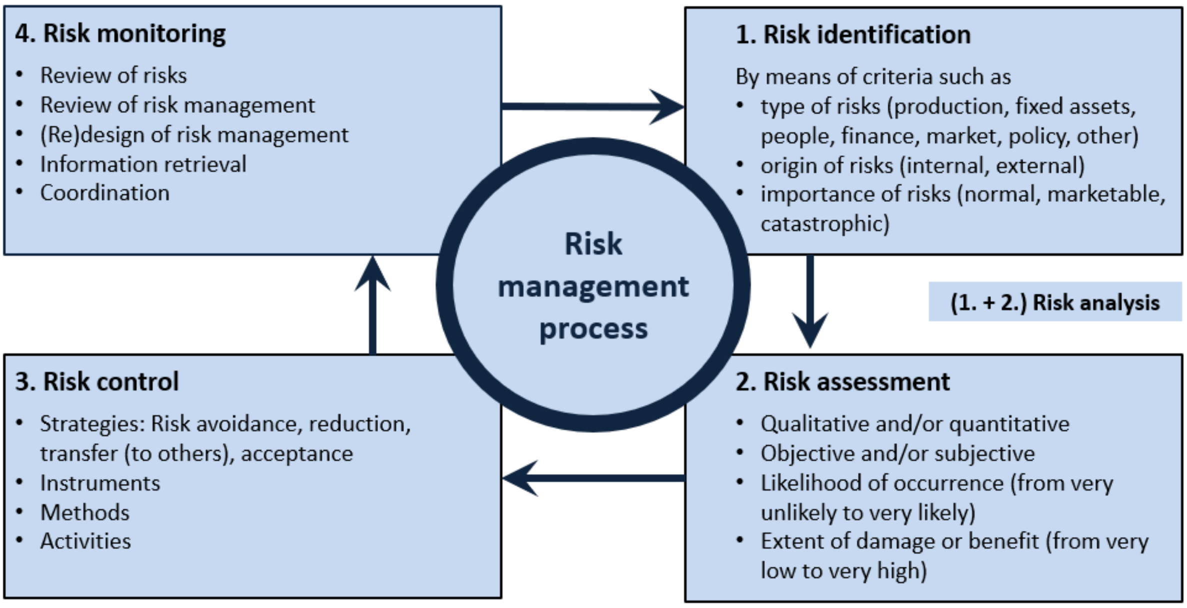

Figure 1: Example for a circular structured risk management process.
[Source: Federal Institute of Agricultural Economics, Rural and Mountain Research (2021), based on Frentrup et al. (2011a, 2011b), Hirschauer und Mußhoff (2012), Schaper et al. (2012), Schmitz (2007)]

2.3.1. Phase 1: Risk identification

One can use different **methods and instruments** to identify risks that are relevant for the business or situation, such as collecting information (e.g. checklists, interviews, surveys, records), applying analytical frameworks (e.g. list of questions, SWOT analysis – strengths/weaknesses, opportunities/threats) or creativity methods (e.g. brainstorming).

In order to identify as many relevant risks as possible, one can apply these identification methods to all **risk types** (see Table 2) or other criteria for systematically considering risk (see Table 1).

Risk types	Risks related to ... (examples)	Influencing factors (examples)
Production risks	yield quantity, yield quality	weather events, climate, pests, diseases, management, area loss
Fixed assets risks	usability (e.g. operating hours) or value (e.g. resale value) of fixed assets	fire, storm, technical progress, technical wear
Finance risks	liquidity, value of assets and liabilities, availability and terms of finance	solvency of contract partners, payment management, securities, re- or devaluation
Market risks	quantity and quality of goods and services, price levels and volatility	supply, demand, policy
Policy risks	legal requirements and scope of action, availability of public support	institutional and legal setting (e.g. rural, fiscal, trade policy)
People risks	availability, quality and cost of own and hired labour	accident, illness, death, knowledge, skills, motivation
Other risks	behaviour, environment, liability, legal protection, new technology, legal or contractual obligations, vandalism, theft, claims of different groups etc.	diverse

Table 2: Exemplary categorisation of risks by risk types.
[Source: Federal Institute of Agricultural Economics, Rural and Mountain Research (2021), based on Hambrusch et al. (2020), Hirschauer and Mußhoff (2012), Frentrup et al. (2011a, 2011b)]

2.3.2. Phase 2: Risk assessment

In this phase, the identified risks are assessed particularly with respect to their likelihood of occurrence and extent of damage (or benefit). Both **quantitative**

methods (e.g. records, statistical models, probability distributions) and **qualitative methods** (e.g. risk matrix) can be used for risk assessment.

The **risk matrix** is a simple and qualitative tool which provides a snapshot and a quick overview of the relevant risks and their importance at a point in time. One can compile the matrix with incomplete information and update it when needed (e.g. when better information is available). One could also develop a matrix for the status quo and another one for the expected future situation. The matrix can be drafted for an individual business or the sector. The assessment is mostly based on qualitative information including a person's experience and incomplete knowledge, hence one should bear in mind the matters of risk attitude and perception (see chapter 2.2).

To work out a risk matrix, one assesses for each identified risk:

- **Expected likelihood of damage** (x-axis): How likely is a damage to occur, on a scale from 1 (= very unlikely) to 9 (= very likely)?
- **Expected extent of damage** (y-axis): If a damage occurs, how low or high will it probably be, on a scale from 1 (= very low) to 9 (= very high)?

The risk is then marked in the matrix according to its expected likelihood and extent of damage. For risks appearing in the yellow to red areas, a damage occurrence is expected to be more likely and/or such a damage may even be existence-threatening, hence these risks need more attention and management than the ones in the green area.

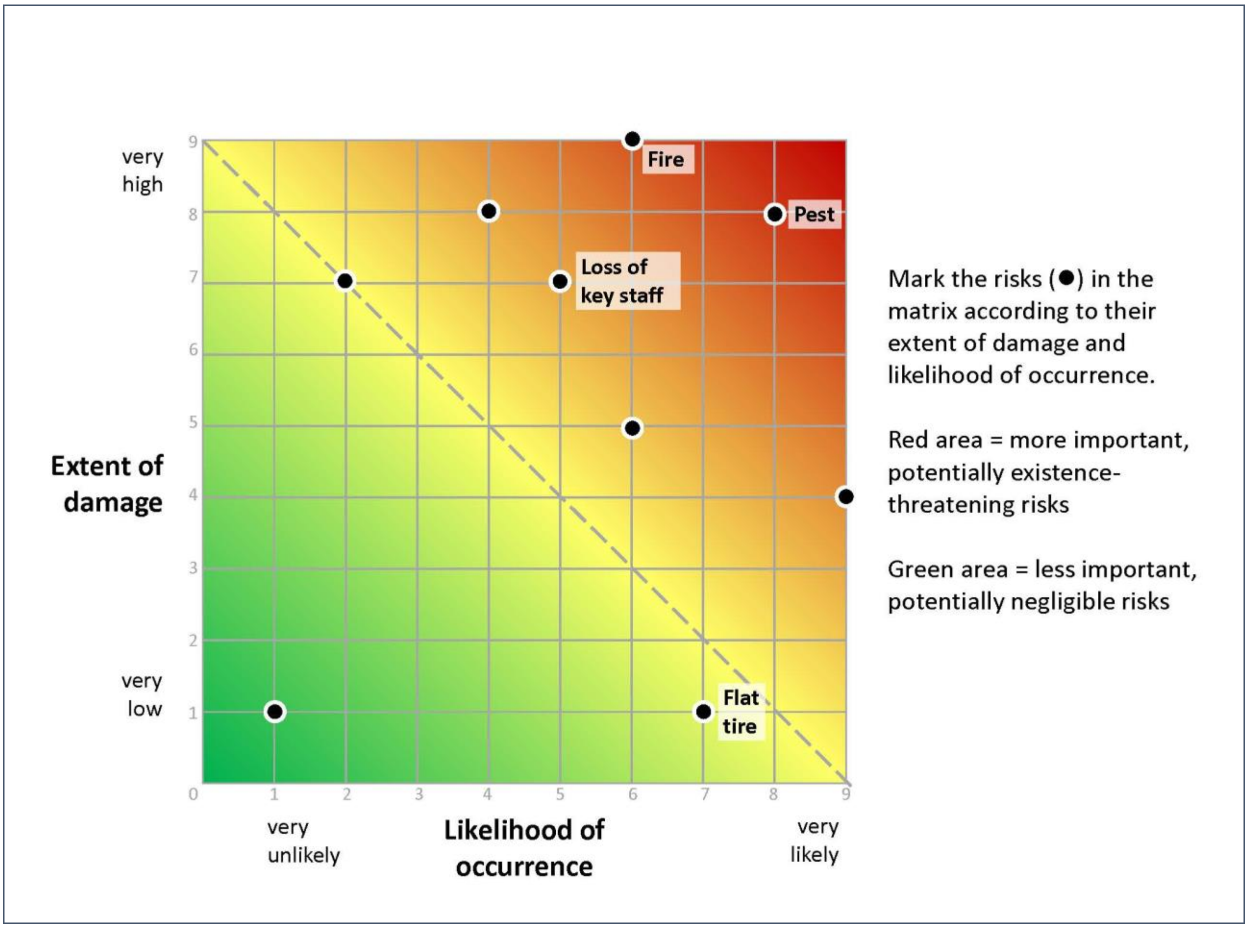

Figure 2: Exemplary risk matrix.
[Source: Federal Institute of Agricultural Economics, Rural and Mountain Research (2021) based on Frentrup et al. (2011a, 2011b), Schaper et al. (2012)]

2.3.3. Phase 3: Risk control

The risk control phase includes both the risk management strategy as well as the choice and implementation of risk management methods, instruments and activities. Decisions are based on the results from the risk analysis (i.e. identification and assessment).

Risk management strategies

A business can choose risk management strategies such as avoidance, reduction, transfer (to others) and acceptance (see Table 3). These strategies intervene at the likelihood of occurrence or/and the extent of damage. Bearing in mind the individual risks' importance to the business as well as the time and cost involved in their management, some strategies are more suitable than others. Therefore, by selecting a strategy for certain individual or groups of risks, one also narrows down the eligible risk management activities and instruments.

Risk management strategies	**Choose which strategy for which risk?** Bear in mind: • the relevance of risks to the business • the suitability of risk management activities (regarding cost, utility, efficiency etc.)	**Examples**
Risk avoidance	• Eliminate a risk entirely by eliminating the likelihood of occurrence or/and reducing the extent of damage to zero. • Particularly interesting in the context of existence-threatening risks.	• Giving up a line of business to avoid an expected required investment.
Risk reduction	• Reduce the likelihood of occurrence or/and the extent of damage to an acceptable level. • Problems and damage may still occur, but to a smaller extent.	• Installing a fence to avoid deer feeding on newly afforested tree stands. • Training staff in how to avoid severe injury.
Risk transfer (to others)	• No activities are set to reduce the likelihood of occurrence. • Pass on negative consequences of damage (cost, work) to others.	• Buy insurance that will compensate losses due to fire or pest.
Risk acceptance	• No activities are set to reduce the likelihood of occurrence or extent of damage. • Bear the consequences if a damage occurs.	• Take precautions, accumulate savings. • Buy replacement in case of a flat tire.

	• Suitable for negligible risks which do not seriously harm the business.	
Risk diversification	• Split the risk between several activities. • If a damage occurs, it only affects a part of the diversified business. • Hint: Risk diversification means that both the worst and the best outcome are prevented.	• Buy forest in areas with different climatic conditions. • Have available extra machinery for outages. • Train more staff in carrying out critical tasks.

Table 3: Risk management strategies.
[Source: Federal Institute of Agricultural Economics, Rural and Mountain Research (2021), based on Hambrusch et al. (2020), Hirschauer and Mußhoff (2012), Frentrup et al. (2011a, 2011b), OECD (2009), Schaffnit-Chatterjee (2010), Schmitz (2007)]

Risk management activities and instruments

The chosen risk management strategies set the direction with respect to which activities and instruments are implemented for each of the identified (individual or group of) risks. To systematically work out a risk management plan, one can again use different criteria, questions and frameworks as a guidance (see Table 1):

- Which activities and instruments are available for managing the different risk types?
- Who provides and who implements the activity or instrument?
- Where to implement the activity or instrument?
- Implement the activity or instrument at what point in time?

Criteria and questions		**Risk management (examples)**
Risk types	production	• tree diversification, insurance, health management
	fixed assets	• fire protection, maintenance contracts

Which activities and instruments are available for managing different the risk types?	finance	• liquidity management
	markets	• supply contracts, commodity futures
	policy	• off-farm income, staying up to date
	people	• training, first aid
	other	• legal protection, liability insurance
Provider and implementer Who provides and who implements the activity or instrument?	individual	• employer, employee
	business	• individual farm, cooperative
	market	• insurance, financial markets
	state	• different levels: EU, national, federal, municipality
Place of application Where to implement the activity or instrument?	in-house	• diversification (e.g. products, services, income) • management (e.g. liquidity, capacities, relationships to suppliers and customers, health) • use of technology (e.g. irrigation, safety gear) • choice of marketing strategy • information, education, advisory • quality assurance • contingency planning
	externally	• raising awareness • provision of objective data and information • provision or funding of education and training programmes • provision of acute measures (e.g. loans, subsidies, guarantees) during crises • provision of the legal and institutional framework • installation of monitoring, warning services and disaster relief fund
Time of application Implement the activity or	in advance (ex ante)	Before the damage occurs: • install technical precautions (e.g. smoke detector) • provide necessary training and skills • adequate investment planning • buy insurance • sign supply contracts

instrument at what point in time?		• accumulate savings
	early stage (early detection)	When the damage is setting in: • smoke detector alarm • treat illness before it spreads to entire tree stand • regularly carry out employee interviews • adapt production to changing environment
	in hindsight (ex post)	When the damage is unfolding or has already happened: • use fire extinguisher • downsize production programme or standard of living • talk to bank • take contingency measures (emergency sales or loan)

Table 4: Criteria, questions and examples for risk management.
[Source: Based on Federal Institute of Agricultural Economics, Rural and Mountain Research (2021), Frentrup et al. (2011a, 2011b), Hambrusch et al. (2011) and Hirschauer und Mußhoff (2012)]

Complexity, frequency and cost

The complexity, frequency and cost of risk management activities and instruments ranges from very simple, infrequent or cheap to very elaborate, frequent or costly ones, or any combination thereof. Examples are: handwritten notes on rainfall (simple and objective, occasional and cheap activity), risk matrix (simple and subjective, occasional and cheap activity; see chapter 2.3.2), buying insurance (simple and regular activity, cost depending on risk exposure) or setting up a new building to protect the machinery from the elements (complex, one-time and expensive activity). Simple, infrequent or cheap activities can be just as **effective** as more complex, frequent or expensive ones. While it is possible to eliminate many risks by implementing and paying for the respective activities and instruments, it may be more economical to bear the costs in case of a damage. Hence it is advisable to consider both **cost and utility:** What cost is justified for managing minor risks with negligible **consequences** (e.g. a broken window) compared to major risks that threaten the business' existence even if it the damage occurs only once (e.g. entire business including machinery destroyed by fire).

Interlinkages

Some risk management activities may reduce or eliminate a certain risk, but reinforce or create another risk, and vice versa (e.g. buying a new machine to reduce the risk of technical breakdown or injury, but at the same time the expense may increase financial risk by putting a strain on liquidity). Therefore, it makes sense to take into account the relevant risks and the set of management activities as a whole, in order to reduce unwanted negative effects and attempt to find the "optimum" mix of activities and instruments.

2.3.4. Phase 4: Risk monitoring

In the monitoring phase, risks and risk management are reviewed and, if necessary, revised. The review addresses changes in the internal and external setting, the effectiveness of implemented activities and instruments including their cost and utility etc. It is important to bring in up-to-date information. The risk profile as targeted is compared to the actual risk profile. Risk monitoring relies on verifiable goals in order to evaluate whether the implemented actions have been successful.

Due to interlinkages (and potentially reinforcing or weakening effects), it is advisable to consider the set of risks as well as risk management activities and instruments together in the monitoring phase as well. In a circular structured risk management process, the insights from the review are passed on to the subsequent phases (risk identification, assessment and control), thus acting as a starting point for adjusting or re-designing the future risk management.

Exemplary questions in the risk monitoring phase:

- Is the risk management up to date (often enough reviewed and revised)?
- Is the underlying information meaningful and recent enough?
- Which activities and instruments are effective, which ones are not?
- Which activities and instruments are overly expensive compared to their effects?
- Which activities and instruments are interlinked and how? Are there unwanted side effects?

- Which activities and instruments, or combinations thereof, should be maintained exactly as they are? Which ones should be adapted? Which ones should be suspended?

3. The initial situation: Overview of the identified current problems in forest management and forestry in the project area

The damage situation in the forests at the border region of the two countries, which has persisted for years, poses major problems and challenges for forest owners, authorities and stakeholders at the cross-border region Austria and Czech Republic.

The project region is shown in Figure 3 and covers a forest area of around 1,154,600 ha, of which approximately 820,000 ha are located in the border areas in the Czech Republic and approximately 340,000 ha of which in the Mühl- and Waldviertel in Austria (Table 5). By adding the region Hausruck-, Inn-, Most- and Weinviertel the forest area increases by around 170,000 ha.

With mean annual temperatures of 7 to 10°C and mean annual precipitation of 550 to 700 (1000) mm, natural forest types of mixed deciduous forests dominate in the colline and submontane zone (oak forest, oak-hornbeam forest, beech(-fir) forest), and in the montane zone mixed forests of deciduous and coniferous tree species prevail (beech-fir-spruce forest).

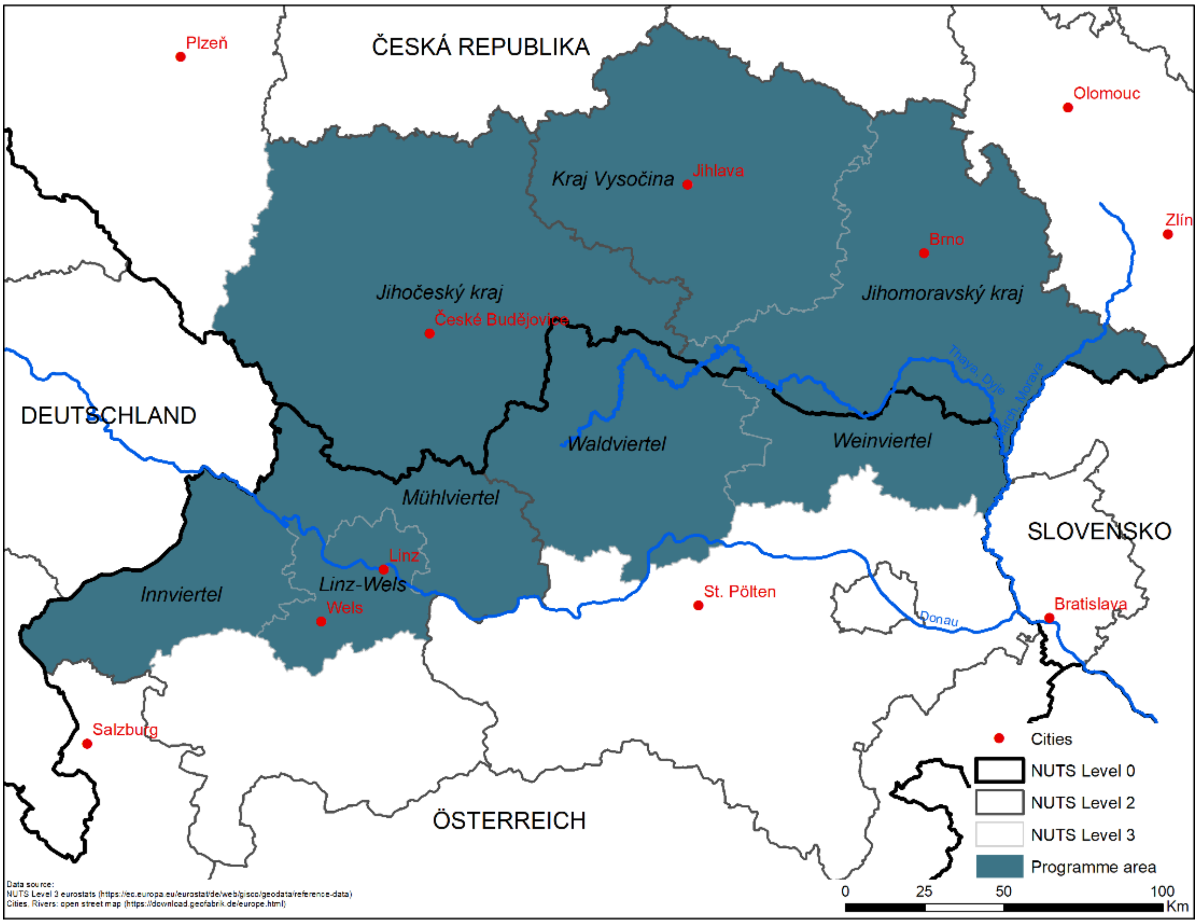

Figure 3: FORRISK project region on the border between Austria and Czech Republic

Region [ha]	Broad-leaved forest	Coniferous forest	Mixed forest	Transitional woodland-shrub	Total
Jihočesky kraj	7 600	321 500	53 000	15 500	397 600
Jihomoravsky kraj	74 300	58 300	65 100	12 000	209 700
Kraj Vysočina	2 800	177 100	20 800	6 600	207 300
total region CZ	84 700	556 900	138 900	34 100	814 600
Waldviertel	10 500	172 000	27 400	2 200	212 100
Mühlviertel	6 200	97 300	23 200	1 200	127 900
total region A	16 700	269 300	50 600	3 400	340 000
total region CZ_A	101 400	826 200	189 500	37 500	1 154 600

Table 5: Forest area (ha) of different forest mixture types and other land use types (ha) according to regions within the project region

Broad-leaved forests have a share of 9% and mixed forests of 17% in the project region. The high proportion of forests dominated by spruce and to some degree also by pine (secondary forest stands) of about 1,000,000 ha (74%) in the total area (826,200 ha core area and 170,000 ha extension area) underlines the challenge for forest management to reduce the existing and further expected risks for forest management, as many of these stands are highly susceptible to abiotic damaging factors (e.g. wind and ice), bark beetles and other biotic damaging factors.

In the Austrian border region, the category "small forest owner (< 200 ha)" dominates the ownership structure, with proportions of 45% (Waldviertel) and 60% (Mühlviertel). Medium-sized and large private forest enterprises each make up around 20% of the total forest area. Community forests and state forest (Austrian Federal Forests, Österreichische Bundesforste, ÖBf AG) manage less than 3% of the forested area.

The Czech border region is dominated by state forests (approx. 55%), the National Park Thayatal (approx. 8%), urban and municipal forests (approx. 20%) and private forests (approx. 17%). The average area of ownership is 1.6 ha

The current problems of forest management are connected to:

- Forest exploitation in history
- Common use of the clear-cut system
- Artificial regeneration as main regeneration method
- Establishment of unstable even-aged homogeneous stands of conifers (Norway spruce and Scots pine)
- Neglected tending (too late, if any, thicket-sized treatments and thinnings and/or at low intensity)
- Reduction of habitat value and biodiversity
- High population densities of wild game
- Change of chemical composition of air and soil
- Global climate change generally stressing forests and leading to a change in disturbance regimes
- Increasing attack of insects and (mainly fungal) pathogens
- Introduction of invasive alien plants, insect pests and tree pathogens
- Lack or shortage of appropriate reproductive material of many tree species
- Ownership structure with many small forest owners, often lacking expertise and infrastructure to appropriately manage forests.

The detailed description and comparison between AT and CZ can be seen in Output T.1.1 "Identification of common problems and synthesis of best forestry practices" (https://www.at-cz.eu/at/ibox/pa-4-nachhaltige-netzwerke-undinstitutionelle-kooperation/atcz251_forrisk/dokumente; https://www.at-cz.eu/cz/ibox/po-4-udrzitelne-site-a-institucionalni-spoluprace/atcz251_forrisk/dokumenty).

4. Overview Risks and forest management

4.1. Abiotic and biotic risk factors

Since the Middle Ages, when agricultural colonization of the border regions began, large areas of the natural forest landscape were transformed into farmland or pastures. The size of forests began to shrink considerably due to the growing population and steadily increasing consumption of timber for fire wood and construction purposes. This trend lasted until the 18th century, when the deforestation reached its culmination and when large-scale planting of forests revived. Afforestation efforts and reforestation of abandoned agricultural land and pastures since the 19th century were focused on the greatest possible benefit from the forest. This land-use change led the forest owners to the planting of tree species with the highest increment, best processing characteristics and most favourable marketability with high return rates, namely Norway spruce and Scots pine, even on inappropriate sites far outside of their natural ranges. At the same time, seed material was used regardless of its origin. Forests were established as homogeneous, even-aged forest stands with clear cutting and artificially established young plantations as the dominant silvicultural system. Broadleaved species, particularly oak species and European beech, as well as silver fir were often considered as undesirable tree species. This management practices, which were based on the decisions of the forest owners, continued in the 20th century with increasing mechanisation of timber harvesting, low timber prices, increasing labour costs and shortage of manpower. As a result, forest ecosystems in the border region are dominated by widespread homogenous, even-aged spruce and pine forests which are particularly prone to disasters such as storm damage, snow or ice breakage and bark beetle calamities at landscape (supranational) scale.

However, these secondary forests have provided forest owners and human societies with essential ecosystem services and great economic values for centuries. Some of these values are now increasingly threatened by climate change. Ongoing and projected climate change effects amplify the various hazards for almost all tree species and forest ecosystems and counteract any curative and preventive measures. The expected increase in climate variability will inevitably lead to an increase in the frequency, intensity and duration of extreme events.

4.2. Climatic change

The border region already experienced a significant temperature increase in recent decades. Depending on the further development of greenhouse gas emissions, a further increase in temperature of 2.3 to 3.9 degrees is projected until the end of the 21st century, compared with the temperature conditions in the past (1971-2000). Rapid climate warming and changing precipitation patterns foster a drastic shift of climate suitability for the different tree species, forest communities, types and structures. Since forest composition, type and structure can only slowly change, this shift will be accompanied by manifold problems concerning forest health and disasters.

The climatically suitable area for the cultivation of spruce has already markedly decreased in the border region during the last decades. In the past, the harsh climate in the high and deep montane zone supported a high share or dominance of spruce. Unsuitable areas for spruce were restricted to low elevations (planar-colline to sub-montane level) in the southern and south-eastern part of the border region. With projected climate warming, areas for vital growth of forest stands with high share of spruce will be restricted to the highest elevations in the region or could completely disappear.

Next page:

Table 6: Mean annual air temperature and mean annual sum of precipitation in the past and for two climate projections for the regions Mühl- and Waldviertel, Jihomoravský kraj, Jihočeský kraj and Vysočina
[Source: Own illustration; Climate data source for Austria: https://data.ccca.ac.at/dataset; Chimani *et al*., 2016; Climate data source for Czech Republic: https://www.chmi.cz/historicka-data/pocasi/uzemni-teploty?l=en; https://www.chmi.cz/historicka-data/pocasi/uzemni-srazky?l=en]

Austria

	past climate	effective measures (rcp 4.5)				business as usual (rcp 8.5)			
	1971-2000	near future		far future		near future		far future	
region	mean	climate change signal	mean	climate change signal	mean	climate change signal	mean	climate change signal	mean
Mühl- and Waldviertel									
annual temperature	7.6°C	+ 1.3°C	8.9°C	+2.3°C	9.9°C	+1.5°C	9.1°C	+3.9°C	12.0°C
annual sum of precipitation	729 mm	+5.5%	768 mm	+9.7%	798 mm	+7.2%	781 mm	+12.0%	816 mm

Czech Republic

	past climate		effective measures (rcp 4.5)				business as usual (rcp 8.5)			
			near future		far future		near future		far future	
region	mean 1961–1990	mean 1981–2010	climate change signal	mean	climate change signal	mean	climate change signal	mean	climate change signal	mean
Jihomoravský kraj										
annual temperature	8.3°C	8.9°C	+1.8°C	10.7°C	+2°C	10.9°C	+1.9°C	10.8°C	+2.6°C	11.5°C
annual sum of precipitation	543 mm	559 mm	-7 mm	552 mm	-34 mm	525 mm	-7 mm	552 mm	-37 mm	522 mm
Jihočeský kraj										
annual temperature	7.1°C	7.4°C	+1.8°C	9.2°C	+2.2°C	9.6°C	+1.9°C	9.3°C	+2.7°C	10.1°C
annual sum of precipitation	659 mm	687 mm	+7 mm	694 mm	-54 mm	633 mm	+7 mm	694 mm	-57 mm	630 mm
Vysočina										
annual temperature	7.2°C	7.4°C	+1.8°C	9.2°C	+2.1°C	9.5°C	+1.9°C	9.3°C	+2.6°C	10.0°C
annual sum of precipitation	644 mm	673 mm	+5mm	678 mm	-40mm	633 mm	+4 mm	677 mm	-44 mm	629 mm

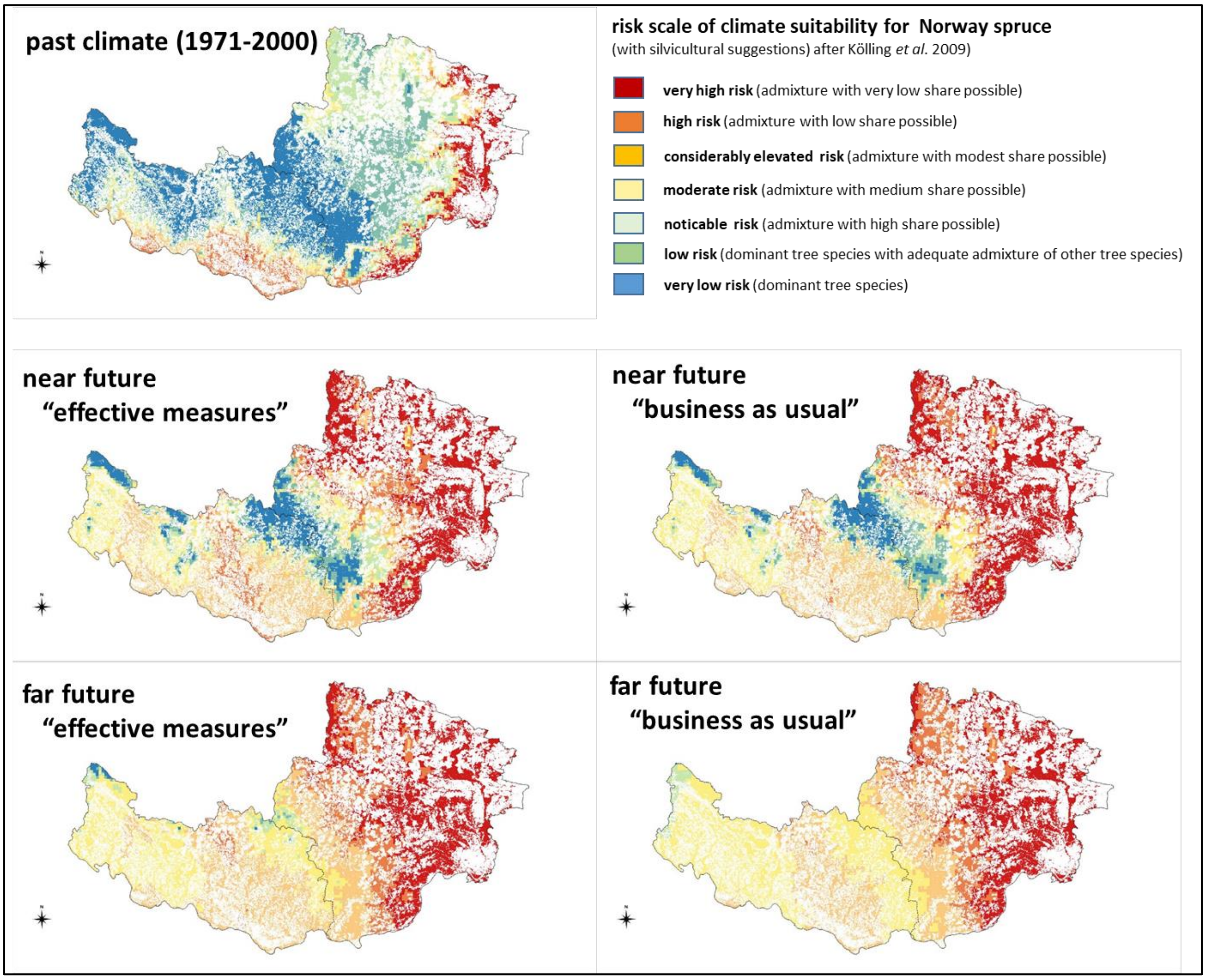

Figure 4: Climate suitability for Norway spruce (Kölling et al., 2009) in the regions Wald- and Mühlviertel in the past and in the near and far future for two different scenarios ("effective measures": substantial reduction of green-house gas emissions (rcp4.5); "business as usual": further increase of emissions (rcp8.5))
[Source: Own illustration; Climate data source: https://data.ccca.ac.at/dataset; Chimani et al., 2016]

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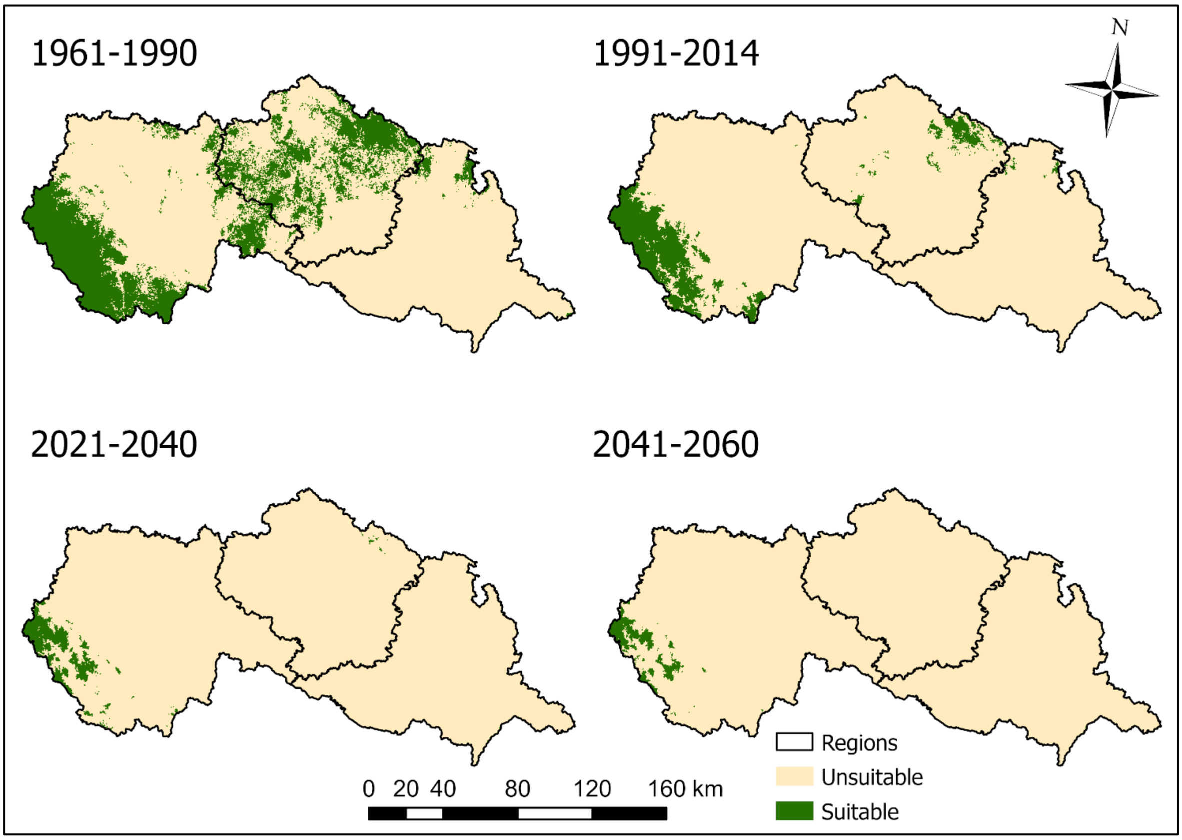

Figure 5: Climate suitability for Norway spruce in the regions of South Bohemia and Moravia in the past and in the near and far future for scenario rcp4.5.
[Source: Čermák et al., 2021]

Besides climatic conditions, static site factors and soil properties, a multitude of natural tree diseases and extreme weather events (like storms, wet snow, ice, rime, frost as well as drought, heat and fire) act as limiting factors for health and productivity of the different tree species. Furthermore, a wide variety of anthropogenic activities (e.g. air pollution, high game densities, introduction of novel pest insects and pathogens due to global change) endanger forest ecosystems. Subsequently, a brief overview of major tree specific hazards and the interaction with projected climate change is compiled.

4.3. Wind damage

The probability of wind damage generally increases with tree height. Evergreen conifer tree species are more prone to wind damage compared with deciduous tree species. In particular, spruce has a very high susceptibility to wind damage when growing in dense pure stands with shallow rooting and increased height/diameter ratios. With climate change, the risk of wind damage caused by local strong winds and higher frequency of thunderstorms (downbursts) during the summer will increase due to higher energy in the atmosphere in a warmer climate and thus could increase also the hazard of wind damage for deciduous stands. Wind damage by frontal storms is expected to decrease with climate warming in Central Europe due to the shifting of the polar frontal zone more to the north.

4.4. Snow (ice, rime) damage and frost

Snow damage (top tree, crown, and stem breakage, bending and uprooting) and damage by ice and rime are important ecological factors limiting vegetation distribution, growth, and regeneration. Snow damage can be caused by shorter-lasting, wet snow loads as well as by heavy snowfalls and high snow accumulation throughout the winter. Snow damage is primarily related to the developmental stage of the stand with the highest risk for young stands (thicket and pole stage). Evergreen conifers are more susceptible to snow damage than deciduous trees. The risk of snow damage is highest for pine and spruce, followed by silver fir and Douglas fir. Larch is widely considered resistant to snow damage. Hardwoods are not susceptible to snow damage in winter, due to the little snow loads in the leafless state. In the event of wet snowfall in early autumn or spring, however, particularly severe damage can also occur in hardwood stands (especially in the thicket phase). Snow (in addition to late frost) is considered a limiting factor for the range of oak forests. Beech, oak and other hardwood species are susceptible to damage caused by ice and rime. As a consequence of climate warming, more frequent stable weather conditions during the winter period with long lasting temperature inversion in the valleys and basins could contribute to higher damage caused by ice and rime.

Frost (especially late frost) endangers regenerations and young stands. In general, pioneer tree species and mountain forest species are more frost-tolerant than lowland tree species. Highly susceptible to late frost are early flushing tree species (pedunculate oak and silver fir), but also ash, beech and Douglas fir. Scots pine, larch as well as hornbeam are considered as hardy tree species. Most noble hardwood species are little to not frost tolerant. Late frost damage could increase in future, since the expected higher climate variability and the projected earlier start of the vegetation period could be occasionally followed by extreme late frost events. A longer growing season (early flushing dates and delayed senescence) could increase productivity. On the contrary, prolonged exposure to drought stress could induce a higher susceptibility to early frost and reduced winter chilling.

The projected increase in winter temperatures reduces snow cover and snow accumulation. However, with the projected increase of winter precipitation, an increase in weather episodes leading to wet snow accumulation at temperatures close to 0°C can be expected. A decrease in snow damage due to an increase in winter temperature at lower altitudes is offset by a possible increase in snow damage at higher altitudes. In addition, the increase in temperature reduces the time of frozen soil, so that more uprooting (instead of trunk or crown breakage) could result from heavy snow loads. The future increase or decrease of snow damage (primarily in young to middle-aged stands) also interacts with other disturbances (storm damage, bark beetle infestation). A higher proportion of young stand development phases as a consequence of increased losses of mature stands due to bark beetle attack could promote the occurrence of snow damage in the future.

4.5. Degradation

The risk of degradation of the soil is in particular high with spruce and pine. Acidification and raw humus formation due to the slow transformation and accumulation of un-decayed needle litter and plant debris occurs especially in dense pure spruce and pine stands. Clear-cutting and whole tree harvesting as the commonly applied management system in these forest types further contribute to degradation of the soil. Soil degradation fosters shallow rooting of spruce and therefore amplifies the predisposition to storm and snow damage (uprooting), root rot, drought stress and secondary damage by bark beetle infestation.

4.6. Drought

Drought is a severe risk factor for almost all relevant tree species in the border region and interacts with other damaging agents (e.g. fire, bark beetle infestations). Drought and heat limit the growth, competitiveness and health of tree species. Drought damage occurs when the demands of living plant cells and tissues for water and carbon can no longer be met by reduced water uptake from the soil and reduced photosynthesis. Water and carbon pools and fluxes are interdependent and maintain the defences against insects (such as bark beetles) and pathogens.

Spruce is considered highly susceptible to soil drought because of its shallow rooting system and rapid carbon depletion due to stomatal closure during drought conditions, which leads to the failure of defences against bark beetles. Especially, the high productivity of secondary pure spruce stands during periods of (above) normal precipitation make them prone to recurrent (occasional) periods of drought. Larger biomass requires water and carbon during droughts and heatwaves and accelerates progression towards the lethal thresholds. Increased stand density could also reduce water and carbon supply through increased competition for finite resources. Secondary pine stands are frequently planted on dry, poor soils that predispose to drought and bark beetle attack. Larch is considered rather drought-intolerant with high demands on water supply. Therefore, larch should not be planted on south-exposed, dry sites. Silver fir and Douglas fir are more robust against drought compared to spruce. Beech as well as sycamore maple can suffer from severe drought showing symptoms of die-back (premature leaf discoloration, growth reduction and dying back of branches) and increased vulnerability to diseases. Deep-rooting oak trees are considered as highly resistant to drought damages, but growth reduction due to severe drought can impair timber quality.

Recently, secondary spruce and pine stands at lower elevations in the border region suffered from prolonged drought stress followed by unprecedented bark beetle infestations. These recent increases in background tree mortality and extreme regional die-off are associated with climate warming and a corresponding increase in vapour pressure deficit and evapotranspiration. With further increase of warming, higher frequency and longer duration of heatwaves and soil drought, tree mortality is also expected to increase in the future. As a result of greater water loss from foliage and soil surfaces, historically non-lethal soil droughts could lead to widespread mortality of trees and entire forests.

4.7. Bark beetles

Bark beetles are represented with many different species on practically all tree species. Their importance varies depending on their propensity for mass reproduction and the economic importance of the host tree species. In particular, spruce is endangered by outbreaks of the European spruce bark beetle, *Ips typographus*. The spruce bark beetle has a high reproductive potential and the ability to overcome the trees' defences at high population densities. The beetles' reproduction and development are mainly regulated by temperature. Depending on the annual thermal sum, up to three generations per year are possible. Spruce trees have developed several defence systems to mechanically and chemically repel biotic invaders such as bark beetles. Therefore, bark beetles at low population densities rely on broken, fallen or otherwise injured/stressed trees with low or almost no defences, for example resin flow. Low-density bark beetle populations are controlled by multiple species of predators, parasitoids and pathogens. Triggered by storm events or drought periods, bark beetle populations can raise rapidly and can infest standing, vigorous trees by pheromone-mediated mass attack. Outbreaks can spread rapidly and eruptively in spruce dominated forest landscapes from small spots to landscape level. Hence, bark beetle outbreaks are not the primary cause of spruce dieback but the consequence of other stressors which reduce the trees' defences.

Due to widespread occurrence of pure mature spruce stands and synchronized extreme weather events including particularly an extreme drought period from 2015 to 2018, recent bark beetle outbreaks have already reached a supranational scale. Climate change intensifies bark beetle outbreaks. Infestations by the spruce bark beetle are likely to increase further in extent and severity in the future due to climate change. Rising temperatures and more frequent drought periods accelerate the development of bark beetles, reduce the tree defence abilities and facilitate the beetles' dispersion to new territories. These increases of bark beetle infestations are expected to come in waves, which will be triggered by extreme weather events (storm and snow breakage events or large-scale droughts), and are likely to occur simultaneously over large areas. In the course of climate change, bark beetles are also gaining in importance on other tree species, such as pines, Douglas fir, silver fir and even some deciduous tree species.

4.8. Fire

In general, coniferous forests (especially pine stands at dry sites) are more prone to wildfire than deciduous forests. Highly volatile compounds of resin, which are stored in large quantities in plant tissue of coniferous tree species, are essential for the elevated fire hazard in conifer forests. These volatile substances can ignite the fire explosively at high temperature and dryness. In the event of a fire, large fire intensities (crown fire with high temperatures) could arise that make the fire uncontrollable. Additionally, accumulated thick duff layers contribute to elevated risks of forest fires in pure coniferous forest. Uncleared disturbed conifer stands (eq. after wind throw or bark beetle infestation) could contribute to a temporarily increased fire risk during drought periods. Time since disturbance, quantity and structure of the fuel are crucial for fire hazards. Depending on the infestation phase and the degree of decay after dying, the fire hazard of untreated bark beetle infestations is likely to vary greatly. With the loss of needle mass, fine twigs and branches, the degradation of the raw humus layer and the beginning decomposition of timber, the hazard decreases. If large quantities of lying (dead) wood accumulate, this accumulation of fuel represents a great risk.

The vast majority of all wildfires are caused directly or indirectly by humans. Only a small proportion of forest fires have natural causes (lightning). Projected changes in climate are expected to increase wildfire frequency, intensity and extent in the future. Higher temperatures, more frequent and longer droughts and heat waves, associated with higher tree mortality (e.g. higher damage by bark beetle infestations and other tree pests and diseases), are likely to result in more frequent and extreme fire events and higher susceptibility to wildfire of forest ecosystems in which fire has so far been insignificant.

4.9. Game damage

For wild animals, buds, annual shoots as well as bark are very rich in nutrients and elements. They contain many nourishing elements and necessary substances for animal nutrition and serve as an indispensable source of energy. At high animal densities and low habitat quality (e.g. monospecific, dense stands, particularly of conifers, managed in the age class system), browsing and rubbing from ungulates can lead to significant damage on forest regeneration. Regeneration can be killed by browsing. The diversity of young stands is reduced through selective browsing (especially by roe deer) since specimens of rare tree species, such as silver fir and broadleaved species, are preferred for consumption and dominant (and sometimes undesired) trees which are not favoured for browsing are left over. Ungulates are the most significant contributors to browsing damage. However, browsing damage on natural and artificial regeneration is not only caused by roe deer or red deer. Browsing damage can also be caused by high densities of other wild mammals such as mice, voles, hares and rabbits.

Bark peeling (mainly caused by red deer) impacts growth and quality of individual trees and stands. Infections of stem and roots with wood decay fungi, entering through wounds, as a consequence of bark peeling reduces also the stability of stands towards other major damaging agents (such as wind throw, snow breakage and drought). In order to make forests more resilient to disturbances in the face of climate change, tree species diversity should be increased and small-scale mosaic-like stand structures promoted. Both require a functioning natural regeneration. If this is made impossible by browsing, this has a direct and far-reaching negative impact on future forest stability and health.

4.10. Emerging pests and diseases

The risk profile of tree species is increasingly becoming dynamic not only due to climate change but also because of new and emerging pests and diseases, and these phenomena strongly interact with each other. The emergence of pests and pathogens is due to varying factors. Climate change can facilitate the unprecedented occurrence of certain native pests and diseases by stressing host trees (e.g. due to drought and heat periods) or creating conditions favouring fungal infection (e.g. high levels of precipitation and humidity) or insect development and reproduction (e.g. warmer climate).

The main factor facilitating the emergence of new pests and diseases is, however, the introduction and establishment of alien organisms, which are showing an increasing trend corresponding with the intensification of globalization and global trade. Some of these agents cause so high damage levels that they lead to widespread tree decline and mortality, with the consequence that the affected tree species are at such a high risk that their use in silviculture is seriously impaired. Examples include Dutch elm disease (caused by *Ophiostoma novo-ulmi*) threatening elm (*Ulmus*) species, ash dieback (caused by *Hymenoscyphus fraxineus*) endangering common ash and the oak net bug (*Corythucha arcuata*), which will spread into the project area in coming years, having as yet unknown consequences towards oak species.

It is to be expected that further introductions of organisms seriously damaging tree species will occur in the future. Such introductions are, however, difficult to predict and it is impossible to forecast precisely which tree species could be affected in the future. Together with the challenges posed by climate change, this results in unknown future risks and insecurity for forest management, silviculture and forest protection.

4.11. Major risk factors of the main tree species

Norway spruce

- Storm
- Snow
- Drought
- Game (browsing, rubbing, bark peeling followed by wood decay caused e.g. by *Stereum sanguinolentum*)
- Soil degradation: acidification and raw humus formation due to the slow transformation and accumulation of un-decayed needle litter and plant debris, especially in dense pure stands
- Annosum root rot (*Heterobasidion annosum sensu lato)*, commonly known among practitioners as "red root" and honey fungus (*Armillaria* spp.)
- Bark beetle infestations and severe outbreaks occur in dry years, after windthrow or snow breakage. Besides the European spruce bark beetle (*Ips typographus*), other species can also be damaging: Northern bark beetle (*Ips duplicatus*), Small eight-toothed spruce bark beetle (*Ips amitinus*) and sixtoothed spruce bark beetle (*Pityogenes chalcographus*)
- defoliating insects on spruce prone to calamities: spruce web-spinning sawfly (*Cephalcia abietis*), mountain spruce sawfly (*Pachynematus montanus*), or nun moth (*Lymantria monacha*)

Silver fir

- Game (browsing)
- Frost: especially late frost on natural regeneration (particularly on clear-cuts) and in young stands
- Silver fir woolly adelgid (*Dreyfusia nordmannianae*) and the recently introduced bow-legged fir aphid (*Cinara curvipes)*
- Silver fir bark beetles (*Pityokteines* spp.): hazard, however, significantly lower than with spruce

Larch

- Game (rubbing, browsing)
- Drought: relatively high water consumption (sun-exposed sites with shallow soils should be avoided)
- Larch bark beetle (*Ips cembrae*): however, the risk of bark beetles is lower than for spruce
- diverse sucking and defoliating insects (e.g. larch needle adelgid, *Adelges geniculatus* or larch casebearer, *Coleophora laricella*) and needle cast fungi (usually only lead to a loss of growth, but not to tree death)
- European larch canker (causal agent: *Lachnellula willkommii)*

Pine

- Game (rubbing, browsing)
- Snow breakage (especially in unthinned stands)
- Soil degradation: acidification and raw humus formation due to the slow transformation and accumulation of un-decayed needle litter and plant debris, especially in dense pure stands
- Complex disease "pine decline": caused by the interaction of multiple agents and environmental factors (e.g. drought and heat stress); numerous insect and pathogen species are involved
- Bark beetle species: lesser pine shoot beetle (*Tomicus minor*) and common pine shoot beetle (*Tomicus piniperda*), sharp-toothed bark beetle (*Ips acuminatus*), six-toothed bark beetle (*Ips sexdentatus*), steelblue jewel beetle (*Phaenops cyanea*)

Douglas fir

- Douglas fir needle cast (*Rhabdocline pseudotsugae* and *Phaeocryptopus gaeumannii* especially at sites with high humidity and in years with high spring precipitation; particularly young stands are at risk
- Frost (winter and spring frost; Douglas fir is also particularly susceptible to frost desiccation)
- Game (rubbing, browsing)
- Bark beetles: native bark beetles can infest Douglas fir; so far, the infestation risk is low, but this may become a greater hazard in the future with the promotion of this tree species and in the context of drought.

European beech

- Game (browsing, bark peeling)
- Storm: on sites with sub-optimal soil conditions such as low nutrient availability, shallow and waterlogged sites, where beech tends to establish a shallow rooting system; in the growing season when foliated
- Drought: beech decline driven by climatic extremes; signs of death after prolonged periods of drought and heat stress up to extensive failures on a wide variety of sites with infestation by the beech bark beetle (*Taphrorychus bicolor*), the beech splendour beetle (*Agrilus viridis*) and pathogen infections (*Phytophthora* spp.)

Sycamore maple

- Game (browsing): highly endangered by all ungulate species
- Drought and heat: dry summers combined with heat favour the development of disease, particularly sooty bark disease of maple caused by *Cryptostroma corticale*
- In recent years, various types of damage were recorded on sycamore maple (e.g. stem cracks, wood discolouration and wood decay); various fungal pathogens appear to be involved, e.g. *Verticillium dahliae* (causal agent of Verticillium wilts) and *Fusarium* spp.; bark beetle infestations (i.e. *Anisandrus dispar*) are also increasingly observed

Ash

- Game (browsing)
- Frost (late frost)
- ash dieback: a highly destructive disease of ash trees caused by the invasive, alien fungal pathogen *Hymenoscyphus fraxineus*; it is characterized by a wide range of symptoms (leaf necrosis and loss; shoot, twig and branch dieback; necrosis and wood discoloration at the root collar) leading to mortality of a large portion of ash trees

Oak (pedunculate oak and sessile oak)

- Frost (late frost)
- Snow: cold-harsh climate and snow are limiting factors for the natural distribution and occurrence of oak trees
- Game (browsing)

- Insects: numerous defoliating insects, which usually only cause growth losses; warm summers and prolonged drought favour mass reproduction of the spongy moth (*Lymantria dispar*) in sparsely stocked oak and mixed oak-other hardwood forests as well as the spread and high populations of the oak processionary moth (*Thaumetopoea processionea*)
- Oak net bug *Corythucha arcuata*, a recently introduced pest insect with rapid range expansion; it causes yellowing and/or drying of the leaves early in summer with possible negative impacts on growth, vigour and fructification of oak trees; the oak net bug is rapidly spreading in Austria but has not yet been recorded in Czech Republic; its impact on oak species and their cultivation and use in silviculture need to be determined
- Pathogen infections such as oak powdery mildew (*Microsphaera alphitoides*) can be part of complex diseases also involving abiotic stressors (drought) and insect infestations.

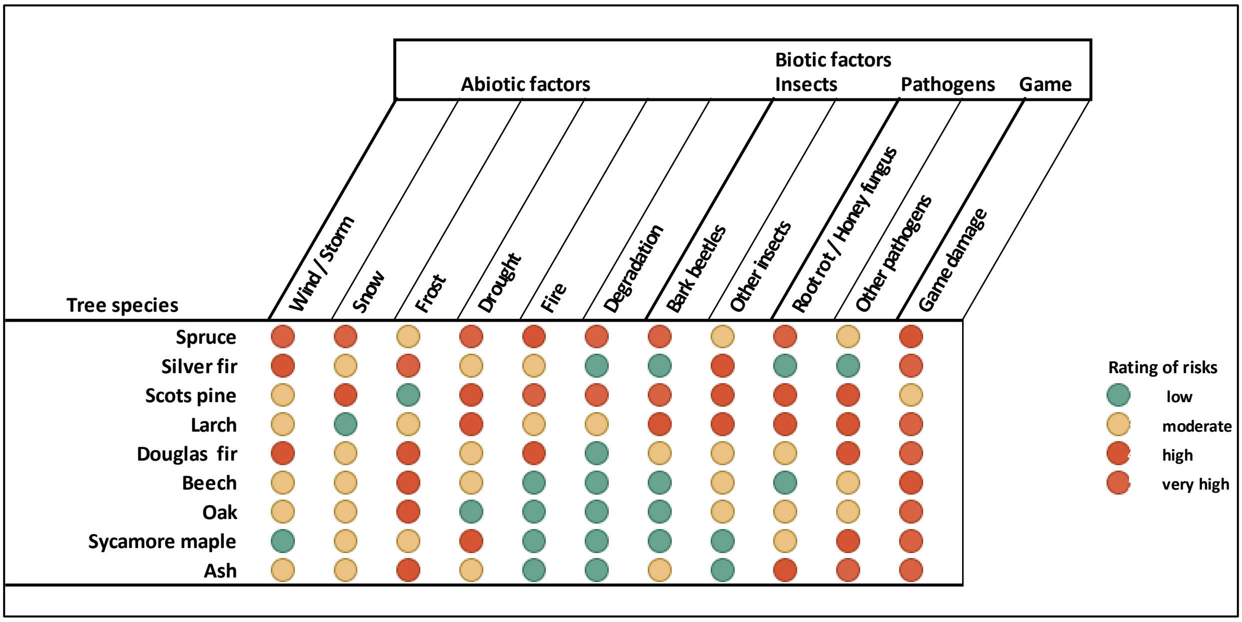

Table 7: Rating of tree species to various risk factors.

Further readings, information on other tree species and the diverse assemblage of forest insects and tree diseases as well as data from monitoring are available under the following links:

Austria

Federal Research and Training Centre for Forests, Natural Hazards and Landscape
https://www.bfw.gv.at/

Austrian bark beetle-monitoring
https://bfw.ac.at/rz/bfwcms2.web?dok=5312

Institute of Forest Entomology, Forest Pathology and Forest Protection
https://ifff-server.boku.ac.at/

Tree species selection in the Mühlviertel – recommendations for the growth-areas of Mühlviertel and Sauwald
https://www.land-oberoesterreich.gv.at/files/publikationen/lfw_baumartenwahl_muehlviertel.pdf

Silvicultural recommendations for forestry in Lower Austria
https://www.noe.gv.at/noe/Forstwirtschaft/Wb-Empfehlugen-17-11-2015.pdf

Austrian forest-fire database
https://fire.boku.ac.at/firedb/de/

Central Institution for Meteorology and Geodynamics
https://www.zamg.ac.at/

Austrian Forest Fund – the package for our forests in the future
https://www.waldfonds.at/

Information- and communication-platform waldwissen.net – informations for forestry in practice
https://www.waldwissen.net

Climate adapted forest
https://www.klimafitterwald.at/

Czech Republic

Weather actual and historical info
https://www.chmi.cz/aktualni-situace/aktualni-stav-pocasi/ceska-republika/pocasi-a-kurovec

Current drought situation
https://www.intersucho.cz/

Fire potential risk
https://www.firerisk.cz/

Agricultural risks
https://www.agrorisk.cz/

Information about forest status
https://www.vulhm.cz/monitoring-stavu-lesa/

Current monitoring of tree stem increment (similarly to tree talker**)**
http://www.emsbrno.cz/p.axd/en/DendroNETWORK.DendroNET.html future
http://dendronet.cz/

Current bark beetle information https://www.kurovcoveinfo.cz/ and/or
https://www.kurovcovamapa.cz/

4.12. Current distribution of main stand types

Primarily, the current presence of the main stand types (Table 12) was detected specifically for three different vegetation zones within the project area. However, vegetation zones (reflecting vertical stratification of natural vegetation) could be simply specified by elevation above sea level (a.s.l.), there are unmatched values in the total annual amount of precipitation between CZ and AT. Therefore, vegetation zones characteristic slightly differs among CZ and AT.

Vegetation zone characteristic (see Table 8):

COLLINE = planar and colline zone, in CZ 1st and 2nd vegetation zones, ca below 350 m a.s.l.; annual amount of precipitation varying between 400 – 600 mm, in AT (9.1,9.2) 200 – 300 m a.s.l., precipitation 500 mm 700mm

SUBMONTANE = in CZ 3rd–5th vegetation zones, ca 350 – 650 m a.s.l.; amount of precipitation varying between 600 – 800 mm, in AT (9.1,9.2) 200 – 500 m a.s.l., precipitation 700 – 1000 mm

MONTANE = in CZ 6th–8th vegetation zones, ca above 650 m a.s.l.; precipitation over 800 mm, in AT (9.1,9.2) above 500 m a.s.l. precipitation up to 1100 mm

Stand types/altidude level	CZ c < 350 m	CZ sm 350 - 650 m	CZ m >650 m	AT c < 300 m	AT sm 300 - 500 m	AT m > 500 m
Secondary pure spruce stands	rare	middle	high	middle	high	high
Scots pine stands	high	middle	low	middle	low	
Mixed oak stands	high	low		low	low	
Oak - noble hardwood stands	low	low				
Mixed noble hardwood stands	low	low				
Red oak stands				low	low	
European beech stand	rare	high	low	rare	low	low
Beech - noble hardwood stands						
beech - fir stands					rare	
Mixed pioneer tree species	rare	low	middle	rare	rare	rare
Mixed Scots pine-oak stands	low	rare		low	low	
Mixed spruce hardwood stands	low	middle	low	rare		
spruce -beech stand						
larch-beech stands					rare	
Mixed European beech, larch, fir	rare	high	low			
Spruce fir beech stands		low	middle		low	middle
spruce- fir stands					low	low
spruce -alder - fir stand				low	low	
Scots pine - spruce stand					middle	low
spruce -larch stand					low	
Natural spruce dominated stands			middle			middle
Mixed Douglas fir - oak stands	rare	rare		rare	rare	rare
Mixed Douglas fir - beech stands				rare	rare	rare

Table 8: Current presence of main stand types across the three main altitudinal vegetation zones (c = colline, sm = submontane, m = montane) in the Czech Republic (CZ) and Austria (AT)

5. General recommendations on forest protection

5.1. Preventive forest protection

The discipline and practice of forest protection aim to prevent and mitigate the negative effects of disturbances caused by abiotic factors (e.g. wind, snow, drought, fire) and biotic agents (mainly insects, fungi and mammals including especially ungulates) in relation to the goals of forest management. The traditional and still most important forest management goal is timber production, but other forest ecosystem services (e.g. protection of infrastructure against natural hazards, preservation of drinking water reserves, conservation of biodiversity, climate regulation or carbon sequestration), which are of high importance for the society, are also seriously impaired by disturbances. In forest protection emphasis should always be put on prevention/prophylaxis of damage because possibilities of effective control (curative/therapeutic forest protection) are limited and e.g. the application of chemical control against forest pest insects and pathogens counteracts multi-trophic interactions in food-webs and self-regulation processes of complex forest ecosystems.

Prevention of forest damages can be accomplished by establishing resistant/resilient forest stands, which is the only option towards abiotic damaging factors. Measures to protect forests from biotic damage also aim at keeping the population densities of damaging agents at a low level, below the threshold when significant damage occurs. The promotion of diversity at all ecosystem levels facilitates effective self-regulation processes in forest ecosystems, e.g. by creating niches for natural enemies of insect pests and fungal pathogens. Particularly for bark beetles and other bark and wood colonizing insects "forest hygiene", i.e. the preventive salvage of potential food resources and the removal and treatment of already infested trees (sanitation), is an effective control method and a widely practiced strategy.

Prevention of forest damages can be achieved by following "good practices / best standards" according to the current state of knowledge of managing forests, thus through silviculture, forest engineering, wildlife management and forest planning. When following such forest practices, there is the perspective that forest health problems can be avoided or occur at lower severity. These practices are essential in order to mitigate the effects of climate change, by enhancing resistance, resilience and adaptive potential of forests.

Elements of "best practices" for damage prevention, which are in line with current state-of-the-art concepts of forest management, include:

- selection of tree species adapted to the conditions of particular sites according to the species' ecological characteristics (static approach);
- considering the risk profile of tree species to various damaging factors (Table 7) in tree species selection; avoiding particular species at sites

where risks are high (or admixing them only at a low proportion at such sites);

- considering hazards related to important damaging factors (e.g. wind, snow, spruce bark beetle, *Ips typographus*): predisposition assessments systems (PAS) to rate site- and stands-related probabilities of disturbance have been developed, which can be used for forest inventories and planning, and silvicultural decisions;
- considering the changing site and climatic conditions (due to climate change) in risk assessment for tree species choice (dynamic approach);
- use of ecotypes and provenances of tree species that are appropriate for the area for artificial regeneration; if appropriate provenances of tree species are not available in forest nurseries, vigorous, site-adapted wild seedlings can be an alternative;
- establishment and promotion of mixed species stands if according to site conditions; mixing of species with different functional and ecological traits (e.g. light-shade tolerant, pioneer-late successional, deep rooting-flat rooting, conifer-broadleaved tree species) is particularly recommendable;
- supporting diversity in terms of tree species, genotypes and age, as well as stand structure, both vertically (two-or multi-layered stands) and horizontally (small-scale distribution of different stand elements); promoting particularly also natural regeneration;
- preferring small-scale silvicultural systems using natural regeneration over clear-cuts with artificial regeneration;
- promoting stability and vigor of individual trees and entire stands by appropriate tending of thicket stands and thinning of pole-sized stands; early and frequent measures of moderate to high intensity to reduce competition of tree individuals can prevent damages by various abiotic and biotic disturbance agents;
- executing silvicultural treatments (afforestation, tending, harvesting) according to the state-of the art and as careful as possible, e.g. manipulate plants carefully and use appropriate planting methods (according to plant size and site characteristics), avoiding of wounds and damage to residual trees and soil compaction in the course of stand entries; choosing the

most advantageous time periods for treatments (with regard to the occurrence of potential damaging factors), e.g. cold periods of the year;

- performing a form of wildlife management that allows natural regeneration of forests, particularly of more rarely represented tree species such as silver fir and broadleaved species; in many areas increased game population densities (particularly of ungulates) lead to selective elimination of valuable admixed species and costly protection (fencing, tree shelters) of desired tree species is necessary;
- executing "forest hygiene" in order to prevent outbreaks of secondary insect pests colonizing bark and wood of forest trees, mainly bark beetles (and to some extent also longhorn and jewel beetles as well as weevils) by removing and/or treating trees fallen and broken by wind and snow, weakened standing ones as well as freshly infested trees (sanitation); to promote more conifer deadwood in forests but avoid insect calamities complete or partial debarking is necessary; the same applies to inaccessible sites where logging is difficult or not possible at all; the importance of forest hygiene concerns mainly conifers, while risks for hardwoods are low;
- creating stable and diverse forest edges, ideally consisting of several rows of woody plants, starting with shrubs, followed by trees gradually increasing in height; alternatively, forest edges should consist of a belt of wind-firm trees (both conifers and broadleaved species) established at low density or/and intensively thinned, so that they show high stability against abiotic forces; such edges protect adjacent stands from wind damage;
- promoting diversification of forest stands, forest edges, the shrub and herb layer and increasing the share of deadwood support natural enemies of forest insects; such measures provide habitat and food for natural enemies (e.g. flowering plants provide nectar for parasitoids of pest insects and dead trees are important nesting sites for cavity breeding birds and bats); moreover, stands with a light and warm microclimate are beneficial for many natural enemies (e.g. forest ants);
- finally, it is important to keep the various abiotic and biotic disturbance and risk factors carefully in mind, and consequently, monitor forest stands regularly for important damaging factors (e.g. damage due to wind, snow, bark beetles and game) in order to be able to react as timely as possible;

here, online available digital tools and internet platforms (see chapter 4) on the current occurrence of diverse damaging agents, phenology and development of bark beetles and monitoring of population density of forest pests provide essential information for the planning and timing of forest protection measures.

As outlined in chapter 4, there is a high share of secondary spruce and pine forests at inappropriate sites in the project area. This substantial deviation from the somewhat ideal situation outlined above severely exposes forests to various disturbance risks, which will likely further increase due to climate and global change. The high susceptibility of forests to disturbance events in the bordering regions of Austria and Czech Republic became obvious with a prolonged, intensive drought period triggering a severe bark beetle outbreak from 2015 to 2020, which is at a lower level still continuing. Restoring and converting the presently unstable even-aged homogenous conifer stands into more stable mixed broadleaved-conifer or (mixed) broadleaved stands is thus a task of high priority in order to adapt these forests to warmer and drier future conditions.

In the following sections the question whether mixed forests are more resistant to disturbance and the role of non-native tree species with regard to forest protection are briefly outlined. Thereafter, brief recommendations on the prevention of and response to important risk factors in the project area are presented.

5.2. Are mixed forests more resistant to disturbance?

Mixed species forests have long been suggested and viewed to be advantageous for forest management and conservation, e.g. regarding ecological processes, growth potential and productivity. Species diversity has been regarded to come along with the fulfilment of multipurpose goals, various ecosystem services and biodiversity. Species-rich forests serve as a habitat for manifold organisms and have been thought to be particularly resistant and resilient towards disturbances and damages. Thus, establishing and tending mixed species forests is suggested as a key strategy to adapt forests to future climatic conditions and changing disturbance regimes. This is especially the case for the project area, which has been enormously affected by abiotic and biotic damaging factors since 2015.

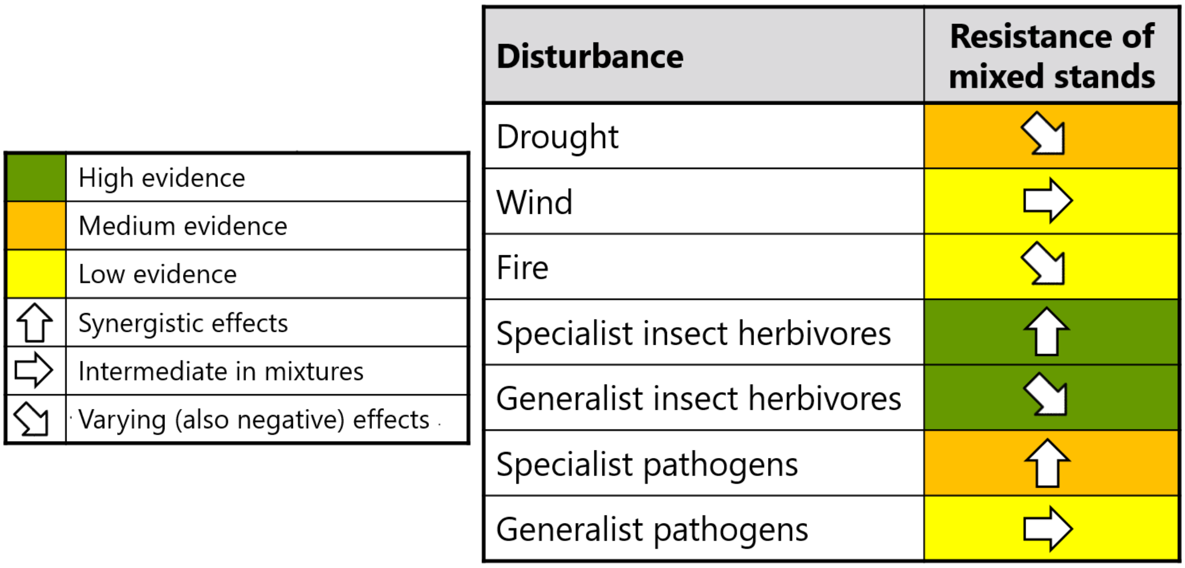

Figure 6: Overview of effects of mixing tree species and tree species diversity on the resistance of the entire tree community to different disturbance factors compared to monocultures of all participating species. Figure adapted from Bauhus, J., Forrester, D. I., Gardiner, B, Jactel, H., Vallejo, R., Pretzsch, H. (2017): Ecological stability of mixed-species forests. In: Preztsch, H., Forrester, D. I., Bauhus, J. (Hrsg.), Mixed-species forests. Berlin, Heidelberg: Springer, pp. 339-384.

Mixed forests may offer promising perspectives that tree species grown in mixture with other species show "associational resistance", i.e. that they are more resistant to disturbance as compared to monocultures. However, the opposite pattern, "associational susceptibility", can also occur. Evidence regarding higher resistance of mixed versus monospecific forests varies and is partly contradictory. Mixed forests appear to be more resistant to disturbances that occur on a relatively small scale and act selectively (Figure 6; small mammals, soil-borne fungal pathogens such as root rots as well as pathogens and insect herbivores with a narrow host range). Likewise, broadleaved tree species admixed to conifers increase the resistance of stands to fire and storms in comparison to pure conifer stands. However, evidence for general positive effects of mixtures is less clear for larger-scale disturbances (e.g. drought, fire, large mammals), and pathogens and insects with a larger host range, as well as airborne pathogens. Towards some of these damaging agents, associational susceptibility of mixed forests has also been observed. Moreover, in order to promote resistance, tree species diversity *per se* (i.e. the number and share of species in a stand) appears to be less important than mixing species with different and complementary functional and ecological traits and different levels of susceptibility to various hazards, e.g. broadleaved and conifer species.

Forest and ecological research have only relatively recently been focusing on mixed forests, and much of the literature on the relationship between tree species diversity and resistance to disturbance is observational. Likewise, comparisons between monocultures and mixed species stands are methodological difficult, e.g. due to the availability of comparable stands on comparable sites. In addition, the topic is complicated due to the various damaging agents to consider: mixtures providing benefits towards one agent, may be negative towards other agents. Nevertheless, although mixed forests are not the universal solution to cope with disturbance and risks, current knowledge supports the view that establishing and tending mixed forests is an important strategy to respond to ongoing changing disturbance regimes due to climate and global change. Further research, based on inventory data, field experiments and modelling will show which tree species mixtures are particularly suitable to promote associational resistance in mixed forests.

5.3. Non-native tree species – chance or risk?

Regulations and practices regarding non-native tree species are different in the two countries participating in the FORRISK project. In both countries, the spread, promotion and management of non-native species included in EU list of invasive species of European significance is not allowed. Regarding tree species, this presently concerns only Tree of Heaven (*Ailanthus altissima*).

In Czech Republic, where regulations are stricter, the deliberate spread of a non-native species into the landscape is only possible with the permission of the nature protection authority. Such a permission is not necessary if a non-native tree species is managed in accordance with an approved forest management plan. However, approval of forest management plans requires a positive statement of the nature conservation authority. In determining the proportion of non-native tree species, the forest management plans are based on the regional forest development plan (https://www.uhul.cz/portfolio/oblastni-plany-rozvoje-lesu/) prepared for specific natural forest areas. In these plans, the recommended maximum proportions of selected non-native tree species can be found (https://www.uhul.cz/wp-content/uploads/2019_SY_PLO_30.pdf).

Throughout the territories of national parks, the deliberate spread of non-native plant species is forbidden. Throughout the territories of national parks, the deliberate spread of non-native plant species is forbidden.

In In contrast, in Austria the forest owner is, in principle, free to choose tree species in the genera listed in an annex of the forest law. However, subsidies for afforestation are usually tied to certain tree species, particularly broadleaved species, and define maximum percentages (in relation to numbers of plants) for the use of conifers and non-native species.

In Austria, practitioners and stakeholders frequently demand that "novel tree species", i.e. non-native ones, are needed for forestry because of increasing forest health problems of native species. In the project area (and overall in Austria) Douglas fir (from North America) is the most important non-native tree species for forestry. It shows a higher growth potential, is less susceptible to abiotic damage (especially drought) as well as to insect pests (especially bark beetles) and diseases than Norway spruce and Scots pine. However, from a longer-term forest protection perspective, it is not wise to promote pure Douglas fir stands at large scale. The probability is high that pest organisms from the species' natural range in North America may be introduced into Europe or/and that native insects and pathogens will adapt to Douglas fir. In fact, such a trend may already have started, as e.g. in years with severe drought, attacks of standing Douglas fir trees by native bark beetle species (e.g. *Pityophthorus pityographus*, *Pityogenes chalcographus* and *Ips acuminatus*) have been recorded. Another example is the fungal pathogen *Diplodia sapinea*, causing severe epidemics on Black pine and Scots pine in Central Europe, which has recently been found to kill Douglas fir trees of considerable size in Lower Austria. This calls for careful, continuous and dynamic assessment of the risk profile of Douglas fir and other non-native-species, e.g. red oak from North America, for which little is known regarding damaging factors. From the view of forest protection, Douglas fir should be considered as one of many options for forest restoration in the project region, meaning that it should not be planted extensively over large areas and preferable planted in mixture (i.e. in small or large groups) with other tree species (e.g. broadleaved species).

When considering non-native tree species for forestry, highly invasive species should be avoided. These outcompete native tree species and are so competitive that after their establishment a re-change of a stand to other tree species is difficult, costly and often appears to be even impossible. They can also spread naturally over large areas and thus from the area of one forest owner to adjacent areas of other owners. The highly invasive Tree of Heaven (*Ailanthus altissima*) was therefore included in the EU list of invasive species of European significance and is no longer allowed to be spread, promoted and managed. On the contrary, a method of biological control of this species with the vascular wilt pathogen *Verticillium nonalfalfae* has recently been developed and established (i.e. an emergency licenced plant protection product based on this principle of biological control is available on the market).

Another tree species which should be used with caution for new afforestations in warm and dry areas is Black locust (*Robinia pseudoacacia*), which is drought tolerant but also very competitive and invasive, and can enrich nitrogen in the soil with the help of nodule bacteria. A final example is princess tree (*Paulownia tomentosa*), whose competitiveness makes it also to a potential invasive species that should not be planted and promoted in forests. It is not currently listed in the Annex of the Austrian Forestry Law as a species that may be planted in forests.

In summary, the potential benefits of some non-native tree species for forestry are acknowledged, due to their high growth potential and presently lower susceptibility to damaging factors. However, the latter may change over time, and we recommend only the modest use of such species. In the project area mainly Douglas fir and red oak can be considered for planting on sites that match with their ecological characteristics, preferably in mixture with other tree species. Planting and promoting tree species with highly invasive characteristics should be handled restrictively.

5.4. Wind damage

Resistance Resistance and resilience of forests towards wind damage can only be partly influenced by silviculture and forest management planning. Risk rating systems, such as a predisposition assessments system (PAS), are available for wind damage, and it is generally important to consider the susceptibility of particular tree species to wind damage with regard to site conditions. Specifically, forests growing at sites with shallow soils or temporal or permanent water logging, on ridges or upper slopes are more prone to damage by wind.

The most important prophylactic measure to avoid wind damages is the selection of tree species and provenances appropriate for and adapted to the site conditions. At sites with high risk, susceptible species such as Norway spruce should be avoided or admixed at low share. Stands composed of hardwoods and mixed conifer-hardwood forests are generally less susceptible than pure coniferous stands. Wind is most relevant as disturbance factor in forests of advanced stand development phases (from a tree height of 20 m onwards). Yet, the susceptibility of a forest stand is determined from the time of stand initiation and subsequently modified by timing and intensity of tending during juvenile phases and thinning of pole-sized and mature stands. Low initial planting densities for afforestation as well as early and regular tending (at medium to high intensity) leads to stands consisting of trees with well-developed root systems displaying lower susceptibility to wind damage. The higher the wind risk in an area is, the higher the thinning intensity in a stand should be. At sites with a high risk of wind damage, shortening the rotation period can be an option to mitigate damage.

Uneven aged and vertically well-structured forests are often appraised as more resistant towards wind damage. However, evidence is contradictory, and there are contrasting recommendations to promote stands with a homogenous crown layer of dominant trees (which is, on the other hand, less desirable, as these are often monocultures of conifers). Nevertheless, uneven-aged and structurally diverse forests are generally more resilient to storm damage because they contain young trees under the canopy of old trees which accelerate forest recovery.

Stable, well-structured forest edges protect stands towards wind and other climatic stressors (see above). In a classical age-class system, stands of different age are arranged with respect to the prevailing wind direction, so that younger stands lead to a gentle upgliding of wind and thus provide protection for older and taller stands. Thus, if clear-cuts cannot be avoided, they should spatially be executed against the main wind direction.

Despite their beneficial effects on forest stability in the longer run, thinnings immediately lead to decreased resistance of stands to wind (and snow). This destabilising effect lasts for several years and is the more pronounced, the denser and higher the stand was prior to the thinning. In the project area, densely stocked spruce and pine stands, untended or tended too late and/or at low intensity are widespread. In such stands, late stand entries are risky with regard to wind disturbance, especially if they are conducted as high thinnings. The decision to thin or not to thin depends on the individual situation, and when the wind damage risk is high, low thinnings may be preferable. In such unstable stands or stands already affected by windthrow, larger gaps can be used as opportunity to diversify forests and to start their transformation, through natural regeneration or by planting of rarely occurring tree species such as hardwoods or silver fir.

If wind damage occurs in coniferous stands, timely salvaging of up-rooted and broken trees is important in order to prevent attacks by bark beetles and an increase of their population levels bearing the risk of mass outbreaks. Scattered patches of damaged trees and smaller wind-thrown areas should be processed first. On larger wind disturbed areas, bark beetles may be allowed to infest the fallen stems before the timber is processed. However, it is important to remove the infested material, when broods still contain adult beetles in the galleries as well as larvae. Thereby, salvaging and sanitation are combined, and large parts of the beetles' initial population can be caught and destroyed.

5.5. Snow damage

Most Most that has been mentioned for wind as damaging factor (section 5.4) is also relevant for snow. As for wind, evergreen conifers are more susceptible than broadleaved trees; however, younger stand development phases (up to a height of 20 m), i.e. thicket, pole-sized and younger mature stands, are at highest risk. In the past, snow damage was most severe at elevations between 350 and 900 m asl., where large quantities of wet snow are frequently deposited. However, due to climate change, it can be expected that zones of massive wet snow accumulation extend towards higher elevations. Snow damage can also be incited by excessive quantities of dry snow.

As for wind damage, risk rating, tree species and provenance selection as well as stand establishment and tending are key elements to prevent snow damage to forests. The height/diameter (h/d) ratio of trees is considered as a reliable indicator for snow damage. For spruce and pine, damage levels increase above a h/d ratio from 80 to 90, and it is thus recommended to tend conifer stands in such a way that h/d values stay well below 90 (spruce) or 80 (pine), or better even lower (70 to 80), especially at sites with a high risk. Trees with lower h/d ratios develop longer crowns and a lower point of gravity, increasing their resistance to breakage, bending and uprooting by snow. Thus, resistance of forest stands to snow can be achieved by early and heavy thinnings. For Norway spruce, tree densities between 1200 to 2000 trees per hectare at a height of 10 m of dominant trees are recommended for areas with a high risk of snow damage. However, in secondary Central European Norway spruce stands affected by snow disturbance, the h/d ratio of trees had little influence on damage levels.

Snow damage can also promote subsequent attack by conifer bark beetles. Which species will be promoted, depends on the dimensions of the damaged timber. On spruce, for example, *Pityogenes chalcographus* develops on smaller and *Ips typographus* on larger breeding material. Scattered patches of snow-damaged trees, e.g. with broken crowns, which cannot not be salvaged in time, are highly susceptible to bark beetle infestation. Broken crowns themselves can also support an increase of bark beetle population levels, especially of smaller bark beetle species.

5.6. Frost damage

Parts Parts of the project area are characterized by a harsh climate, with frost occurring throughout spring or even during summer. Likewise, with increasing temperatures in late winter and early spring, which promote an earlier flushing of tree species, extreme late frost events can be expected across Central Europe in the future. In particular, young plants can be severely damaged by frost. Such extreme events may limit the potential recommendable range of tree species, especially of those sensitive to late frosts. For example, oak species, which show relative high drought tolerance and other favorable ecological characteristics, are not very well adapted to sub-zero temperatures occurring during the growing season. *Quercus petraea* is more vulnerable to frost than *Quercus robur*. European beech is also sensitive to late frost.

Frost damage can mainly be avoided by planting and favoring tree species and provenances tolerant to frost at risk areas. Using vigorous and large seedlings for planting is also recommendable. Frost sensitive tree species (e.g. fir, beech, Douglas fir) thrive best when naturally regenerated or planted under the canopy or aside of mature stands, which provide frost protection. On open sites, frost tolerant tree species (e.g. birch, aspen, alder, rowan, pine), either naturally regenerated or planted in advance, can serve as nurse crops for late successional, frost sensitive tree species, particularly fir and beech.

5.7. Soil degradation

The negative effects of soil degradation described in section 4.5 can be diminished by changing forest practices, including a change from the presently prevailing clear-cut system with subsequent artificial regeneration, focusing on spruce and pine, to silvicultural systems using a range of regeneration and tenting techniques to promote fir and broadleaved species and aiming at creating mixed-species, structurally diverse and resistant forest stands. This is in line with preventing or mitigating disturbance caused by various factors. In order to avoid the removal of nutrients from forest sites, whole tree harvesting should at best be avoided at all or applied only on nutrient-rich sites, but not at sensitive sites with shallow soils and low nutrient levels.

5.8. Drought

As In the project area, as in large parts of Europe, severe drought periods have been occurring since 2015, interacting with other damaging factors such as fire, bark beetle infestation or fungal diseases. With climate change, such extreme weather events that potentially weaken or directly kill trees, alone or in combination with biotic agents, will likely occur more frequently and even become more severe. As a consequence, many forest stands, particularly those composed of spruce and pine, will increasingly grow under conditions that do not correspond with their ecological requirements. Hence, there is an urgent need to restore and convert such stands to more resistant and resilient forests, consisting of species that are more robust to drought and extreme temperatures. Planting and favouring tree species and provenances tolerant to drought is thus the main silvicultural measure to mitigate future damage. During drought periods, conifer stands in particular should be regularly surveyed for attacks by bark beetles, in order to initiate timely sanitation measures.

With the risk of drought, autumn planting, allowing for the establishment of roots during mild periods in autumn and winter, should be preferred over spring planting. Likewise, planting can be conducted during any mild, but moist periods outside the growing season or early in spring. Careful planting with appropriate planting techniques, utilizing nurse crops, which provide shade, and planting of trees under the canopy of or adjacent to stands are recommended. Pioneer tree species acting as nurse crops and existing stands provide shade and protect trees from extensive insolation. Soil preparation facilitates rooting of plants as does weed control, which also reduces evaporation. If technically possible, it is recommended to irrigate newly initiated plantings, otherwise high mortality levels can be expected during drought periods. If irrigation is not possible, planting of seedlings in spring should be terminated during drought periods. Repeated replacement of dead plants will become more and more necessary in the future.

5.9. Fire

Due to climatic conditions not conducive for forest fires in the past, spruce and pine dominated forests in the border region were not particularly prone to large and frequent forest fires. In the last years, devastating forest fires around the world and also in Austria (Hirschwang in 2021, military training ground Allensteig in 2022) and in the Czech Republic (Bohemian Switzerland National Park in 2022) indicated that a further increase in the threat of wildfires is likely due to climate change. More frequent heatwaves, higher temperatures in combination with longer drought periods, the change in forest management and disturbance regimes, rural abandonment or more intense recreational use of forests are generally known as factors that increase the probability of more frequent and intense wildfires (characterised by rapid fire spread, intense burning, long-range fire spotting and unpredictable shifts). In addition to their serious ecological impact, extreme wildfire events have an extraordinary socio-economic impact in terms of both loss of human life and economic damage.

This upcoming new threat and rising concerns about changes of the forest fire regime call for the implementation of integrated forest fire management which includes amongst others:

- precise fire mapping and statistics describing how wildfires are changing in time and space for a better understanding of driving factors and mapping of areas at risk;
- science-based forest fire management and risk-informed decision-making, which account for the socio-economic, climatic and environmental factors associated with wildfires;

- shifting the focus from suppression to prevention in integrated fire management and increasing the awareness and preparedness of human populations at risk;
- implementation of more balanced and sustainable forest management strategies that integrate prevention, climate adaptation, education, preparedness, suppression and post-fire restoration aspects.

Current efforts to manage forest fires are unable to prevent the occurrence of extreme forest fire events. In the long term, the improvement of forest management planning and the establishment of forest fire risk maps are key issues to prevent devastating fires in the future. Preventive silvicultural measures, like thinning and change of tree species composition towards less flammable species, are effective responses for long-term fire prevention. However, the selection of tree species is mostly driven by the preferences of the forest land owner. A change in tree species composition to specifically reduce forest fire hazards is rarely done.

Currently, few measures are taken to raise awareness of and knowledge about forest fires in the public. The general awareness of forest fires and the knowledge about fire prevention measures, hazardous behaviour and self-protection is low in the population. Awareness-raising of the population, dissemination of fire danger via internet and traditional media (newspaper, radio, television) to the public and effective visitor information at forest entrances about the current fire danger in the region as well as visitor guidance in the forests are essential for short-term fire prevention in times of high meteorological fire danger.

The prevention of fires includes also measures connected to firefighting preparation and creation/maintenance of infrastructure for fire suppression. Adequate equipment and training of firefighters and action forces in forest areas, well planned and maintained forest infrastructure, safety and contingency plans and mapping of all available fire-fighting infrastructure in the forest are crucial issues for save and effective fire-fighting, especially in remote forest areas.

5.10. Game

Damage Damage by game, especially by roe and red deer, has impeded the establishment of resistant and resilient forests for many decades. This has even become more problematic in times of climate change, when diverse mixed species stands are seen as a main way to adapt forests to the changing environmental conditions. In many regions, browsing and rubbing of game leads to selective suppression or elimination of highly desired tree species such as silver fir, beech and other hardwoods. In addition, bark peeling, creating wounds and entrance courts for decay fungi, destabilises forest stands and causes substantial economic losses.

Avoiding damage by game is a wide topic that can only briefly be covered here. In many areas, a substantial, at least temporal, reduction of game populations is a prerequisite to establish natural and artificial regeneration at large scale. While this could be relatively easily and effectively implemented by large forest owners (if forestry and not hunting is the main management purpose), it is difficult for small forest owners, who strongly depend on the way and quality of wildlife management in neighbouring forests. Thus, protection of seedlings from browsing, rubbing and possibly also bark peeling, by fencing of regeneration areas or individually by tree shelters or repellents (applied by coating or spraying), is usually necessary for more rarely occurring tree species. Among forest protection measures, expenditures for protection from game damage are highest, often covering estimated two thirds or three quarters of total forest protection expenditures. This highlights the importance of the problem.

In the mid to long term, forest management needs to change from the widely practiced clear-cut system and planting to a form of silviculture where several silvicultural systems with a combination of natural and artificial regeneration are applied. Such transition to a more close-to-nature forestry offers the perspective that habitat and food supplies for game and the bearing capacity for wildlife are substantially improved and, consequently, damage levels on juvenile trees will decrease. Again, this transition requires increased control of game populations, allowing for large-scale natural regeneration of tree species without protective measures, especially of species that are highly susceptible to browsing.

5.11. Root rot and stem decay

Root Root rot and stem decay are the most economically important forest diseases. Despite this, these diseases are often neglected because they do in most cases not lead to immediate mortality. Yet, root rot and stem decay substantially devalue the timber due to wood decay and lead to significant financial losses for the forest owner. The causative fungal pathogens also interact with other damaging factors, as affected trees are predisposed to throw and breakage by wind and snow and also become susceptible to other biotic factors.

The most important root rot fungi are *Heterobasidion* species (causing Annosum root rot) and *Armillaria* species (honey fungus, causing Armillaria root rot). The former species almost exclusively affect conifers, with spruce and pine being most susceptible. Using broadleaved species and more resistant conifers (silver fir, larch or, with caution, Douglas fir) and establishing mixed stands of hardwoods and conifers (with the rationale of risk spreading and leading to fewer root-to-root contacts between conifer trees which are important infection routes) are thus major strategies to avoid infection and spread by *Heterobasidion* spp. Likewise, it is important to avoid wounds on roots and at the stem base (often caused by harvesting operations), which serve as infection courts. An effective measure is to restrict harvesting operations to periods when temperatures are at or below 0°C, when infectious basidiospores are not produced by *Heterobasidion* species. Following best standards of tree planting is also important, in order to avoid weakening and predisposition of seedlings to *Heterobasidion* and *Armillaria* species as well as other root rot pathogens and generally to allow the development of a vigorous root system. Finally, treatment of stumps after felling with urea or the biological control agent *Phlebiopsis gigantea* prevents stump infections by *Heterobasidion* spp. Stump treatment is commonly applied in Northern European countries, Great Britain and Poland, and regionally also in Germany. However, it is presently not practised in Czech Republic and Austria.

Armillaria species can infect both broadleaved and conifer species; however, conifers are usually more susceptible. Mixed species forests and increasing diversity on several levels (e.g. tree and shrub species, herbaceous plants, mycorrhizal fungi) thus offer the perspective to decrease infections and losses by honey fungus. Avoiding stress to trees is also important. In forest management, this can be mainly achieved by tending and thinning in a way (early, strong, repeatedly; i.e. high and target tree thinning methods) that trees have sufficiently large growing space to show large diameter growth and develop long crowns and thus a high vigour and resistance towards honey fungus. Such tending concepts are also recommended to prevent damages by wind and snow (see chapter 5.4 and 5.5) and are generally recommendable to increase the stability of forest stands. The importance of careful planting has already been mentioned before.

Stem decay can mainly be prevented by avoiding wounds (due to harvesting and logging, rockfall and bark peeling by red deer), which are entrance courts for the causative fungi. Wounds can be avoided by best standards of forest engineering such as the careful execution of appropriate harvesting and logging methods and techniques, employment and careful training of skilled forest workers, engagement of reliable harvesting companies and harvesting in autumn and winter at times when the soil is frozen. Likewise, wildlife management should aim at reducing bark peeling wounds by red deer, mainly by reducing its populations and enriching the habitat and food supply for these ungulates. Tree species vary in their susceptibility to stem decay fungi. Spruce is more susceptible than silver fir, pine and larch (e.g. to *Stereum sanguinolentum*); and this can be a criterion for tree species selection.

Levels of decay increase with tree age. Thus, for stands seriously affected by root rot and/or stem decay, heavy thinnings, management for fast growth, reduction of the rotation period and earlier initiation of natural and/or artificial regeneration with the aim to change tree species composition in the next generation are reasonable responses.

5.12. Emerging pests and diseases

The observed accelerated trend that new forest pests and diseases emerge increases uncertainty regarding forest protection and forest management. It is impossible to foresee which additional and novel pests and diseases (e.g. because of unintentional introductions or increased susceptibility of trees in a changing climate) may become important in the future. Diversification of forests (in terms of tree species, genetic, vertical and horizontal structural diversity) and thereby spreading risk might be the only safeguard to mitigate unpredictable new forest health problems.

Two important diseases caused by introduced fungal pathogens in the project area are Dutch elm disease (DED, caused by *Ophiostoma novo-ulmi*) and ash dieback (caused by *Hymenoscyphus fraxineus*). They substantially limit the use of elm species and ash. Elm, particularly wych elm, frequently regenerates vigorously, but as trees grow taller, many succumb due to the disease. A strategy to respond to this disease is to maintain a certain share of naturally regenerated elm, at best admixed singly, with the chance that they reach maturity and commercially usable dimensions. On the other hand, if elm trees admixed singly or in small groups die and form gaps, neighbouring trees can take over and fill these gaps. In riparian areas and at other suitable moist sites, European white elm is still frequently occurring and can be a useful species, because elm bark beetles (which transmit *Ophiostoma novo-ulmi*) to some extent avoid it for their regeneration frass, but prefer field elm. Thus, European white elm suffers much less mortality from DED than field elm and still can grow to a large tree, despite the presence of the disease.

With regard to ash dieback, individual trees display high resistance to the pathogen *Hymenoscyphus fraxineus*. Thus, slightly damaged trees can occasionally be observed also in severely affected stands. The existence of more resistant ash trees forms the basis for *ex situ* conservation measures and resistance breeding to conserve ash, which have been initiated in several European countries. Simultaneously, *in situ* conservation, thus preserving and promoting undamaged or slightly damaged trees in severely affected stands (Figure 9) and facilitating their natural regeneration, is equally important, in order to potentially allow the adaption of ash populations to the novel selection factor ash dieback. Both strategies, *ex situ* and *in situ* conservation, will hopefully lead to the preservation of this tree species and to a restoration of forests where ash is a potentially important stand component.

Figure 7: Photos from 2014, 2018 and 2021 of an ash tree in a pole-sized forest stand; while overall damage levels due to ash dieback in the stand have been high, this particular tree remained only slightly damaged from 2014 to 2021; it is therefore suspected to display high resistance to the disease, should be preserved and considered for *in situ* and *ex situ* conservation measures

5.13. Bark beetles

Since 2015, unprecedented bark beetle mass outbreaks, especially of the European spruce bark beetle (*Ips typographus*) have been the most important problem threatening forests in the project area. These calamities were triggered by drought (leading to stress and weakening of standing trees) and to a minor extent also by preceding wind, snow and rime damages, which facilitated the build-up of high population levels of the insects.

Bark beetle outbreaks are favoured by climate change and have been increasing in importance worldwide since the 1990s. Higher temperatures accelerate the development of the spruce bark beetle and promote the completion of two or three generations per year. Likewise, extreme climatic events such as drought weaken spruce host trees and thus make them more susceptible to bark beetle infestation. Moreover, extreme climatic events, particularly storms, lead increasingly to fallen and broken trees, on which bark beetles can build up high population densities. It can therefore be foreseen that bark beetle management, for which forest owners are responsible according to the respective laws in Austria and Czech Republic, will remain extremely important in the future, in areas where spruce stands still occur.

Elements of integrated bark beetle management are illustrated in Figure 8, which focusses on the European spruce bark beetle (*Ips typographus*), but is relevant for other conifer bark beetle species as well. An important preventive future strategy in areas at high risk is the establishment of mixed species stands (e.g. with hardwoods or silver fir depending on the site conditions) with a low share of Norway spruce. Here, the impact of bark beetles can be decreased due to several mechanisms. In the worst situation, even if all spruce trees are killed, non-host tree species (i.e. hardwoods) and much less preferred conifers (i.e. silver fir) will survive a bark beetle outbreak. Surviving residual trees can still provide important ecosystem services and facilitate forest restoration, and such mixed-species forests are thus more resilient.

In more favourable situations, spruce trees growing in mixed-species stands have a higher chance to escape or survive bark beetle outbreaks. This can be because the lower amount of available host substrate provides less favourable conditions for the insects' population growth or because of difficulties of the beetles to locate host trees. In addition, the higher diversity and abundance of natural enemies (predators and parasitoids) in diverse forest stands may more effectively regulate bark beetle population levels. Diversifying stands in terms of tree, shrub and herbaceous species as well as forest structure favour biodiversity and also increase the habitat value of predators and parasitoids of bark beetles. Moreover, two or multi-layered stands with tree cohorts of different ages are more resilient to bark beetles because they increase the likelihood that some trees survive outbreaks and that affected forests remain with advanced regeneration, from which forest recovery can start.

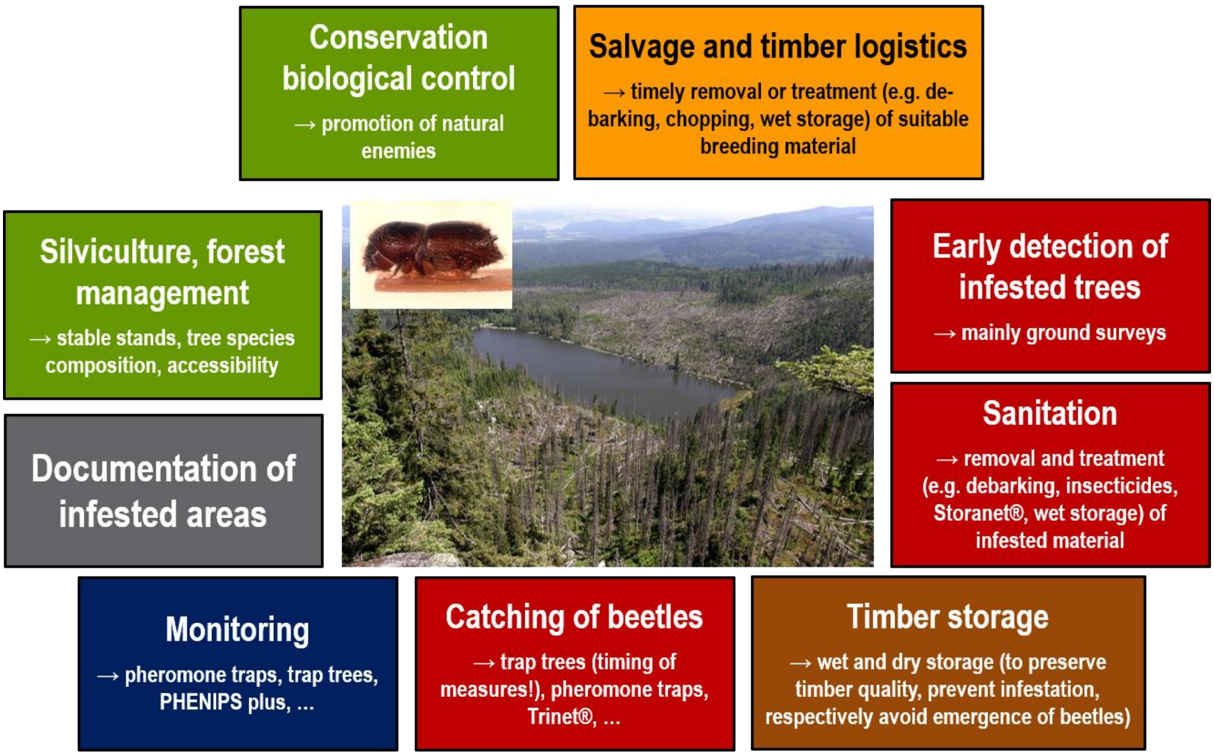

Figure 8: Elements of integrated management of bark beetles, especially of the European spruce bark beetle (*Ips typographus*), recommended / practiced in Austria and Czech Republic

Since Clear-cut areas due to bark beetle infestations offer the chance to promote tree species better adapted to the changing climatic conditions, by planting or by combing planting with natural regeneration. In existing spruce-dominated stands, heavy thinnings, management for fast growth, shortened rotation periods, initiation of natural regeneration as well as advanced planting and underplanting may be considered to speed up transformation of unstable stands to more resistant and resilient forests. Low planting densities (e.g. for spruce not higher than 2000 to 2500 trees per hectare) and early, frequent tending of moderate to high intensity increase the stability of stands towards wind and snow, so that the provision of large quantities of breeding material for bark beetles is avoided. Bark beetle prevention and control also require accessibility to forests; a good and well-maintained network of forest roads, skidding trails and extraction lines is therefore essential in managed stands.

In the case wind and snow damage occurs, potential breeding material needs to be removed or treated (e.g. debarked, chopped) timely or appropriately stored (e.g. by wet storage). If bark beetle infestations on live, standing trees are increasing (e.g. after an extreme drought as experienced since 2015 in the project area), a regular monitoring of forest stands, mainly ground surveys, at short intervals, is essential, in order to detect infested trees and sanitate (remove and treat) them as soon as possible. The documentation of infested areas facilitates follow-up surveys to locate bark beetle-attacked trees, as further infestations often occur in close proximity to previously attacked trees and stands.

Monitoring of bark beetles (with pheromone traps or trap trees) helps to appropriately time management measures (i.e. scouting for infested material and its timely removal). If forest owners do not conduct monitoring themselves, they can use online tools showing beetle catches in pheromone traps over the season at various sites (e.g. www.borkenkaefer.at in Austria) or, for the European spruce bark beetle (*Ips typographus*), the modelled current phenology and development of the insects (e.g. in Austria PHENIPS and PHENIPS plus at https://ifff-server.boku.ac.at/).

Other than for monitoring, traps are of limited use to reduce bark beetle populations significantly, and they are therefore not recommended as a control measure. In larger areas with thrown and broken trees due to storm or snow, processing can be timed as such that beetles are allowed to infest the breeding material, which needs to be sanitated at the latest when broods are in the pupal stage. Thereby, a large quantity of beetles can be caught and salvaging and sanitation be combined in a meaningful way. Wet and dry storage of timber, with the aims to preserve timber quality, to prevent infestation or/and to avoid or delay emergence of beetles, complement the integrated management of bark beetles (Figure 8).

6. General Silvicultural recommendation

6.1. Recommendation for tree species relevance in future site conditions (2100)

All the predictions for tree species relevance in near (several or tens of years) or far (several tens of years or even one century) future come from global climate change models including several greenhouse gases emissions scenarios. These predictions also reflect previous or current ecological demands of tree species and their spatial distribution both in vertical as well as horizontal scale. Nevertheless, tree species response (by acclimatization and later on adaptation) to changing soil and atmosphere environment in their properties (i.e. physiological, anatomical, morphological, chemical, phenological etc.), growth rate and strategy as well as in modified ecological demands, which are more less not reflected in these future predictions from the point of view of lack of sufficient complex knowledge.

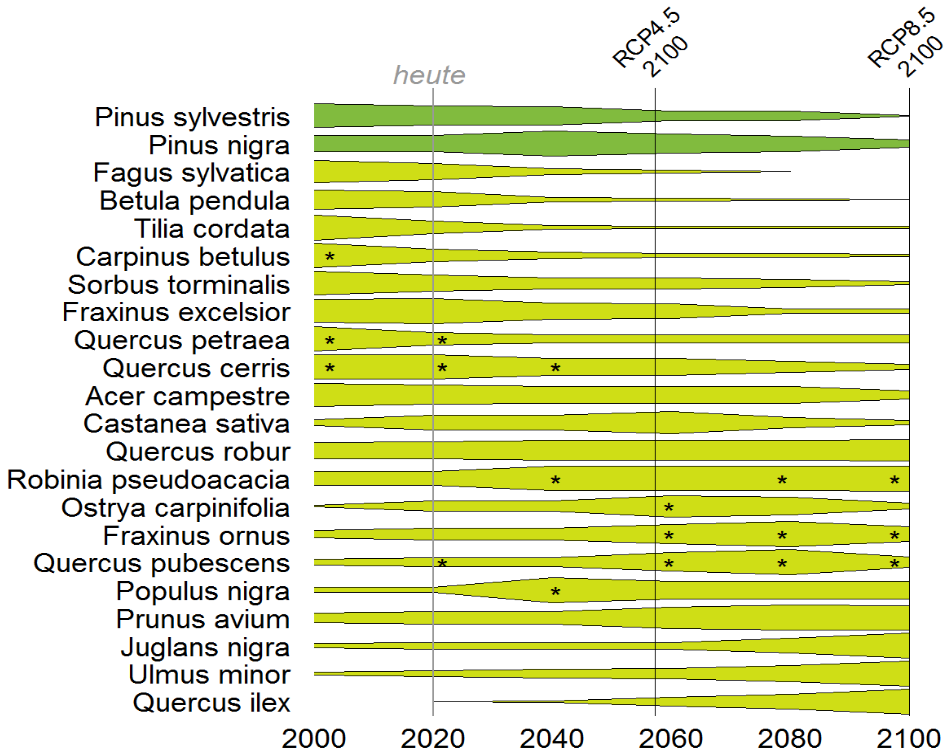

Figure 9: Tree species suitability for 2100 according to two different scenarios rcp4.5 and rcp8.5 for South Moravia region (CZ; source: T. Mette et al. LWF, 2021, see ASFORCLIC project).

In the presented case (Figure 9), future tree species representation was predicted by combination of ANALOG and BaRIS models. The ANALOG evaluates information from forests/ forestry in regions where the future climate of a site (e.g. Brno, CZ) already prevails today. ANALOG focuses on the future potential of important tree species and has proved a very successful communication tool in practice. BaRIS aims to predict tree species presences/ absences with climate and soil information from species distribution models (SDMs) of 32 tree species including also lesser used wood species. Model predictions for future climates can be greatly enhanced by including occurrence data from the edges of a species distribution range in the model fitting process (Figure 9).

Tree species suitability for climatic conditions predicted for the end of the 21st century could be also predict from the point of view of professional estimate (Table 9).

CZ	AT	nutrient/site typ	water regime	Quro	Qupe	Quce	Qupu	Quil	Cabe	Fasy	Acps	Acpl	Frex	Soto	Sodo	Prav	Algl	Alin	Tisp	Qure	Be. sp	Po.sp.	Soau	Pisy	Piab	Lade	Abal	Psme
c < 300 m	c < 350 m		dry	x	x	x	x	x	x					x	x				x			x		x				
		nutrient-rich	moderate fresh- fresh	x	x				x	x	x	x	x	x	x	x	x	x	x	x		x		x		x	x	x
sm 300-500 m	sm 300-650 m	nutrient-poor	dry	x	x				x	x	x										x	x		x			x	x
		gley	fresh, wet	x	x				x	x	x										x	x			x		x	x
		nutrient-rich	moderate fresh- fresh	x	x				x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x
		nutrient-poor	moderate dry-dry		x					x	x								x	x	x	x		x	x	x	x	x
m > 500 m	m > 650m	nutrient-poor	moderate fresh- fresh							x	x										x	x	x	x	x		x	x
		gley	fresh, wet							x	x										x	x	x		x		x	x
		nutrienrt-moderate	moderate fresh- fresh							x	x		x				x				x	x	x		x	x	x	x
		gley	gley														x				x	x	x	x	x	x	x	x
Flood plain				x						x	x						x		x			x						

Table 9: Tree species suitability and nutrient/sites type and water regime and altitudinal vegetation zones (c = colline, sm = submontane, m = montane)

Quro – Quercus robur, Qupe- Quercus petraea, Quce- Quercus cerris, Qupu- Quercus pubescens, Quil- Quercus illex, Cabe- Carpinus betulus, Fasy- Fagus sylvatica, Acps- Acer pseudoplatanus, Acpl- Acer platanoides, Acca- Acer campestre (missing), Frex- Fraxinus excelsior, Soto- Sorbus torminalis, Sodo- Sorbus domestica, Prav- Prunus avium, Algl- Alnus glutinosa, Alin- Alnus incana, Tisp- Tilia species, Quru- Quercus rubra, Be sp. (Betula pendula, Betula verrucosa), Po sp. (Populus tremula, Populus species, Populus nigra), Soau- Sorbus aucuparia, Pisy- Pinus sylvestris, Piab- Picea abies, Lade- Larix decidua, Abal- Abies alba, Psme- Pseudotsuga menziesii

6.2. Planning for artificial regeneration

The target of growing stock is understood to mean the forest structure according to the tree species composition and mixture, the horizontal and vertical structure of the target stocking of the stand ready for harvest. The decision on the production (wood quantity, quality, production period) and biological (ecosystem stability via resistance and resilience, biodiversity and biological balance) target is tightly linked to the definition of the tree species choice. Based on the tree species recommendations, MGTs were specified.

For deriving the **management goal type (MGT)** it is necessary taking into account

- Site-specific tree species suitability and their cultivation worthiness
- Adaptability to changing site conditions (climate)
- the compatibility of the tree species
- Economic conditions and operational objectives
- silvicultural technological aspects

to build up stable, adaptable and high-yield stocks with little effort and to keep the economic risk low.

Despite the variety of tree species combinations, the focus was to deliberately keep the number of MGTs low and to limit oneself to relevant types, as well as to specify framework values for the tree species shares (degree of mixture). Therefore, the specified MGTs and their subtypes should be understood as brief recommendations/guidelines (Table 10).

Local, micro-site conditions i.e. soil moisture and nutrient availability, vegetation zone, site slope and exposition mainly determine the tree species selection and mixing, specifically for reforestation and natural/artificial regeneration.

Management goal/ types [MGT]/ altidude leve/ tree species share [%]	CZ_AT colline	CZ_AT submontane	CZ_AT montane	birch sp.	oak sp.	black alder	noble sp.	other deciduous sp.	poplar sp	beech	red oak	Scots pine	spruce	fir	larch	Douglas fir
Mixed oak stands					70-90			10-30								
Ook - noble hordwood stonds					20-60	20-60		10-30								
Mixed noble hardwood stands							70-90	10-30								
Red oak stands								10-30			70-90					
Beech stand										>90						
Beech - noble hardwaod stands							40-60			40-60						
Beech - fir Stands										50-70				30-50		
Mixed pioneer tree species				>90					>90							
Mixed Scots pine -oak stands					10-40							60-90				
Mixed spruce hardwood stands																
Spruce -beech stand										40-80			20-60			
Larch-beech stands										30-40					60-70	
Beech - larch - fir stand										20-40				20-40	20-60	
Spruce fir beech stands										20-40				20-40		
Spruce- fir stands													50-70	30-50		
Spruce -alder - fir stand						20-50							20-50	20-50		
Scots pine - spruce stand								10-20				30-50	30-50			
Spruce -larch stand													50-70		30-50	
Natural spruce dominated stands													>90			
Douglas fir - oak stands					20-40											60-80
Douglas f ir - beech stands										20-40						60-80

Table 10: Tree species composition and tree species shares (%) for the defined MGTs (Management goal types)

6.3. Age class system

6.3.1. Artificial regeneration

Table 11 provides an overview of the recommended number of plants per hectare for the various tree species in the main stand for "pure stand cells", based on narrow and/or wider spacing. This are framework values (n/ha), because operational conditions (mechanized planting and tending) play an important role in the choice of planting design. In the case of artificial planting of a secondary stand (hornbeam, linden, beech and other deciduous trees), it is recommended to adapt the row spacing to that of the main stand.

Recommended frame values (n/ha) and spacing

Tree species	Share (%)I	Normal spacing (without pruning) n/ha and spacing		Wide spacing (with pruning) n/ha and spacing		Remarks
Oak sp.	100%	4,400 – 5,000	2*1.1 m	2,000 – 2,500	3*1.3 m; 4*0.9 m	Cluster planting: 80 cluster with 25 plants per cluster [2000 n/ha]
Oak sp.		9,000	1*1.1 m			
Maple sp., ash	100%	3,500 – 4,200	2*1.2/1.4 m	1,100 – 1,600	3*3 m; 6*1.5 m	
Maple sp., Alnus gl.	100%	4,000	2*1.25 m			
Ash, Lime, Hornbeam, Elm, other oaks	100%	6,000	1*1.6 m			
Wild service tree, wild fruit tree sp.	100%	3,500 – 4,200	2*1.2/1.4 m	2,000 – 2,500	3*1.3 m; 4*0.9 m	
Walnut, blacknut	100%	----- 2,000 – 2,500	---- 2*2 m	600 – 800 600 – 800	6*2.5 m; 4*3 m	
Wild cherry	100%	-----	----	600 – 800	6*2.5 m; 4*3 m	
Wild cherry, Aspen, Birch, Rowan, Willow, Walnut	100%	3,000	2*1,6 m			
Birch	100%	-----	----	1,100 – 1,600	3*3 m	
Black alder	100%	-----	----	1,100 – 1,600	4*2 m; 3*3 m	

Red oak	100%	2,500 – 3,500	2*2 m; 2*1.4 m	1,100 – 1,600	3*3 m; 3*2,5 m	other broadleaved tree species (natural regeneration)
Beech	100%	8,000 – 10,000	1*1.3 m	----	---	
	100%	9,000[1]	1*1.1 m			
Scots pine	100%	8,000 – 10,000	1*1.3 m	---		
Scots pine	100%	8,000[1]	1*1.25 m			
White pine	100%	5,000[1]	2*1m			
Dwarf pine	100%	2,500[1]	2*2 m			
Austrian pine + other pines	100%	7,000[1]	1*1,4 m			
Larch	100%	1,600 - 2,000	2*2.5 m	---		
Larch, Douglas fir, Grand fir	100%	2,500[1]	2*2 m			
Spruce, fir	100%	2,000 - 2,500	2*2 m	---		
Spruce	100%	3,000[1]	2*1.6 m			
Fir + other conifers	100%	3,500[1]	2*1.4 m			

[1]Relevant minimum numbers for the Czech Republic respecting Act. No. 456/2021

Table 11: Recommended frame values for planting densities [n(ha] and spacing
[Source: Own illustration]

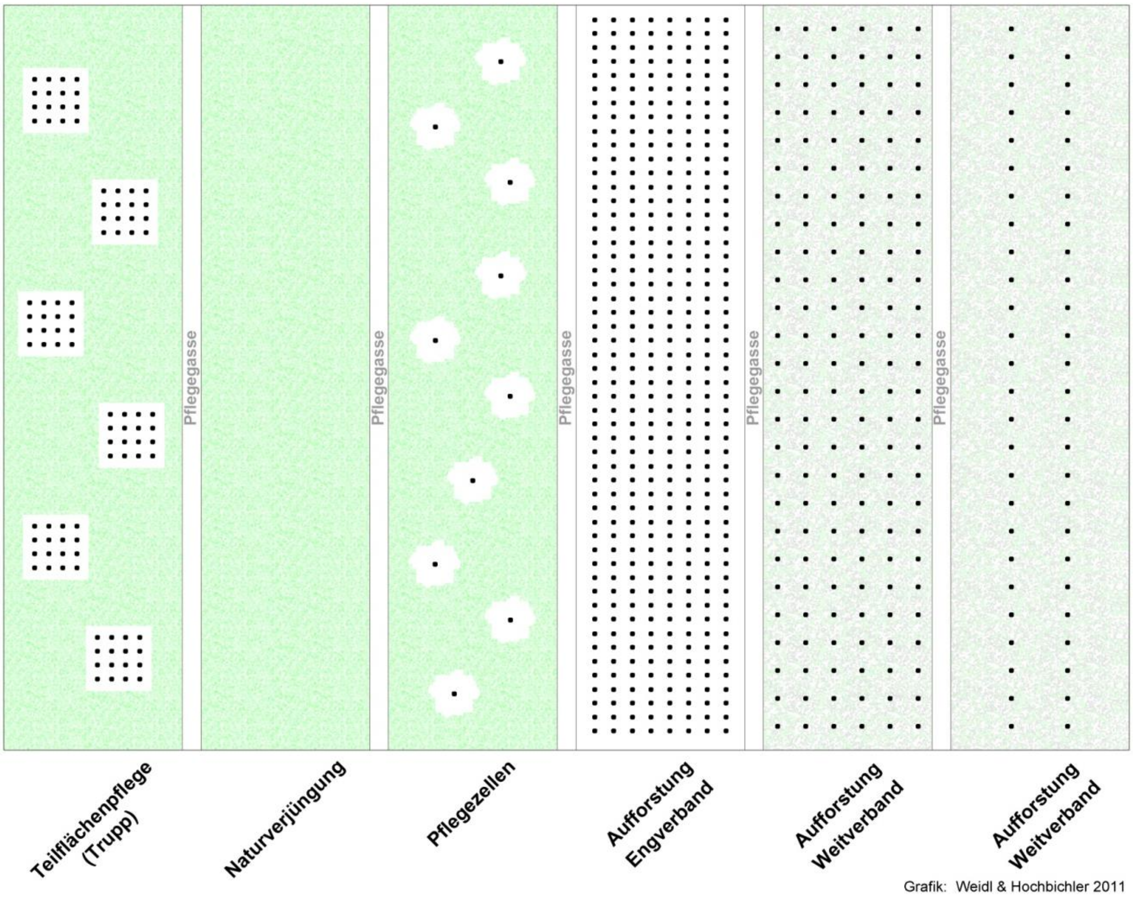

Figure 10: Regeneration designs (natural regeneration; admixed planting) and spacing possibilities [Source: Own illustration]

Natural regeneration and succession should be preferred on areas with presence of mature trees in (or around) clear area. Monitoring of presence of natural regeneration should be done continuously in time.

Large clear area should be divided into sub-plots for planting (Figure 5). These plots represent areas with the same tree species composition, the same spacing design and plots that are naturally regenerated in the same time. Optimum area of planting sub-plots is 0.2 ha.

Regeneration of large areas can be designed as a matrix of planting sub-plots. Light demanding and mainly pioneer species should be used for regeneration process of large clear areas (Figure 10).

Planting of seedling (or seeding) of local provenance should be preferred or provenances originating from similar (or rather dried) conditions; in case of introduction use of planting material from geographically near area should be preferred; high genetic quality of seed and planting material use is obligatory.

Seeding reduces regeneration costs and increases the drought resistance of now forest. Prevention of rodent damage on these areas is a necessary precondition.

- single mixed stands: wild cherry (service trees) + hornbeam, linden, beech.
- support mixture species for oak stands (nurse shade tolerate species as linden, hornbeam, beech or field maple)
- sycamore or Norway maple can be managed in group or as monoculture;
- in case of group mixture avid monoculture larger than approx. 0.1(2) ha;
- avoid gap in regeneration;
- pruning of stands with lower densities (oak below 5,000 n/ha; maple below approx. 3,000 n/ha;

6.3.2. Release treatments (thicket)

From the beginning of the pole stand phase, the focus is on controlling the growth in tree height. In the young stand phase, the future value of the tree/stand is decided by the pruning process (naturally or by artificial pruning). At the end of this growth phase, a defined number of future crop trees - derived from the production target - with a branch-free bottom log (quality height) in a favorable spatial distribution should be aimed for. Stands that are expected to be naturally pruned (natural regeneration, afforestation in a normal spacing) should be kept dense, vital and stable.

If pruning process is unsatisfactory, artificial pruning measures are required. This is the case for oak and other noble hardwood trees when the green branches do not overcome diameter of more than 2 - 3 cm in the section of the future knot-free stem part. Pruning measures should start as early as possible and be carried out consistently in 2 - 3 interventions in 1-2 years interval and be completed when the stem diameter at breast height reaches 10 - 12 cm.

6.3.3. Thinning methods (pole stand)

From the beginning of the pole stand phase, the focus is on controlling the growth in stem thickness and the production of knot-free stem volume on the selected future crop trees (C-trees). According to the criteria of vitality, quality and distribution (minimum distance), the thinning interventions to promote the growth space of the C-tree must be carried out in such a way that "free" crown development is ensured. The intervention intervals depend on the site and tree species-specific growth dynamics (Table 12).

Tree species	Target stem diameter (cm)	Crown cover percentage (%) (main stand)	Crown width (m)	Number of future crop trees (n/ha)
Oak sp., maple sp., wild cherry, ash, elm	***60+***	***80***	***12 (10-14)***	***70 (60-80)***
Beech	***60+***	***90***	***10 (8-12)***	***90 (80-100)***
Wild service tree	***50***	***80***	***10 (9-11)***	***90 (80-100)***
Birch, Black alder	***40***	***80***	***9 (8-10)***	***140 (130–150)***
Scots pine	***45+***	***90***	***7 (6-8)***	***200 (180-220)***
Larch	***60+***	***90***	***9 (8-10)***	***120 (10-140)***
Fir	***60+***	***90***	***8 (6-10)***	***300 (150-350)***
Spruce	***45+***	***90***	***6 (5-7)***	***300 (120-250)***
Douglas fir	***50+***	***90***	***7 (6-8)***	***200 (180-220)***

Table 12: Relation of target diameter and crown width and average number of future crop trees in relation to target diameter and crown cover percentage of main stand

6.3.4. Harvesting and regeneration

Harvesting and regeneration basic criteria are as following:

- In the course of harvesting mature trees/small areas, the proportion of valuable types of timber should be exploited as best as possible.
- An optimal logging track system is essential to avoid crop damage to the remaining stock and/or young growth trees.
- Regeneration area and regeneration system depends on the light-ecological requirements of the tree species.
- Natural regeneration should be promoted

6.4. Continuous cover forestry (CCF, Dauerwald)

- **Regeneration**: mostly natural regeneration in groups after target tree felling, in forest gaps up to ca 0.1 ha respecting regenerated tree species ecological demands; long time period or rather continuous regeneration period; missing target and valuable tree species could be added artificially (e.g. spruce, pine, larch, oak, fir, cherry, service tree etc.)
- **Tending**: no full-area (per groups), two-phases → 1. phase (up to thicket stage): leave it to spontaneous development (except of co-ordination of stand tree species composition), automatic initialization of tree height increment, development of more-less final length of clear stem ca 10 – 12 m and co-ordination of tree species composition, 2. phase (*pole stage - timber*) – target tree method approach = initialization of stem thickness increment by systematic release cuts surrounding target C-trees (varying in time with the stand development, e.g. from ca 100 – 150 to later on 30 – 60 of C-trees, Table 12)
- **Cutting** of target trees – *timber/mature stage*: full-area irregular selection of trees from the point of view of – health, quality, yield respecting stand and site conditions, from individual to group selection approach up to 0.1 or 0.2 ha, cutting criteria:
    - health status
    - mechanical stability (especially during transformation, reflecting slenderness ratio and crown size and position, see Table 12)
    - quality (of stem and crown)
    - yield – target dimensions (around 50-60 cm in dbh, see Table 12)
    - occurrence and development of natural regeneration (valid mostly for spruce and sun-loving tree species)
    - intensity of cutting – respecting concrete site conditions and stand demands, preliminary follow the value of total current increment (in m^3/ha/year), usually 1 or 2 (4 at once as maximum) concurrent trees are reduced

7. Risk assessment – forest protection – management type

7.1. Secondary pure spruce stands

A) RISK ASSESSMENT

RISK FACTOR/STAND DEVELOPMENT	REGENERATION/ YOUNG STANDS			THICKET			POLE STAGE			TIMBER			TIMBER/ MATURE			DAUERWALD PERMANENT TREE COVER		
	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M
Storm	0	0	0	0	0	0	2	2	2	3	3	3	3	3	3	–	1	1
Snow/ice/rime	1	1	1	2	3	2	2	3	2	2	3	2	2	3	2	–	1	1
Drought	3	2	1	3	2	1	3	3	1	3	3	1	3	3	1	–	1	1
Fire	3	2	2	3	2	2	3	2	2	2	1	1	2	1	1	–	3	2
Bark beetles	0	0	0	1	1	1	2	2	1	3	3	2	3	3	3	–	2	1
Game	3	3	3	3	3	3	2	2	2	0	0	0	0	0	0	–	1	1

Vegetation zone: C – colline, S – submontane, M – mountane

SCALE: 0 – no risk… 3 – extreme high risk; – absent (see context with the previous table with current presence of stand tapes in CZ)

0	1	2	3	–

B) FOREST PROTECTION

Secondary pure spruce stands

stand development	relevant damage factor	measurement / action
1 regeneration/ young stands	1.1 drought	**Respecting vegetation soil and climate conditions** when establishing stand, planting of quality planting material, control and replacement of dead seedlings

		• autumn planting • optimization of weed control practices – only strip reduction (shading), reduction only if necessary (according to height and density of weed and weather condition) **Maintaining suitable air and soil moisture** • preservation of the remains of the mother stand – shade • use of pioneer woody plants – preparatory vegetation
	1.2 fire	**Effective fire control –** to identify the riskiest areas, early fire detection, barriers or firebreaks that may limit fire spread • control and reduction of dry hazardous material • in period with high risk (heat, drought, wind) frequent control of riskiest places • in extremely risky areas creation of barriers for wildfire – firebreaks, fuelbreaks, belts with low flammable woody plants (deciduous trees)
	1.3 game	**Controlling of game population and damage prevention** • controlling of population density, reduction of population density of overpopulated game • game-proof protection (fencing, browsing repellents, biotechnical protection – keeping no-target trees for browsing), increase of environment usability for game (e.g. planting of fruit trees)
2 thicket	2.1 snow/ice/rime	• work with stand density – suitable crown length • processing of damaged wood (risk of bark beetle outbreak)
	2.2 drought (and subsequent bark beetle calamity)	• frequent control of the stands • search for trees secondarily infested by bark beetles • bark beetle monitoring (pheromone traps, trapping trees) • timely sanitation (larval/pupal stage) • optimization of stand density (maintaining a favourable stand climate)
	2.3 fire	--> see above 1.2
	2.4 bark beetles (*P. chalcographus*)	**Prevention and control** • search for trees infested by bark beetles, processing of damaged wood, bark beetle monitoring (pheromone traps) **Defense** • removal of mining residues (branches, peaks), use traps (upper part, weaker trees, trapping stacks) and pheromone traps
	2.5 game	--> see above 1.3

3 pole stage	3.1 storm and snow damage (and subsequent bark beetle calamity)	**Action for stands with structure remains** • processing of damaged wood (risk of bark beetle outbreak) • search for trees infested by bark beetles • bark beetle monitoring (pheromone traps, trapping trees) **Action for stands with density reduction ≤ 0.3-0.4** • supplement/regeneration in advance with hardwoods under shelter • utilisation of natural successions (pioneer crops, Vorwald)/natural rejuvenation
	3.2 drought (and subsequent bark beetle calamity)	--> see above 2.4
	3.3 fire	--> see above 1.2
	3.4 bark beetles	**Prevention and control** • search for trees infested by bark beetles, processing of damaged wood, bark beetle monitoring (pheromone traps, trapping trees) **Defense** • removal of all material suitable for the development and multiplication of the pest • thorough search, timely and effective sanitation of infested wood and trees • concentration and control of the pest by means of various capture devices
	3.5 game	--> see above 1.3
4 timber	4.1 storm and snow damage	--> see above 3.1 (but threshold of reduction of the stand density slightly higher: ≤ 0.4-0.5)
	4.2 drought	--> see above 2.2
	4.3 fire	--> see above 1.2
	4.4 bark beetles	--> see above 3.4
5 mature timber	5.1 storm and snow damage	--> see above 3.1 and 4.1 (Initiation of the rejuvenation, transformation or conversion)
	5.2 drought	--> see above 2.2 (Initiation of the rejuvenation, transformation or conversion)

	5.3 fire	--> see above 1.2
	5.4 bark beetles	--> see above 3.4 (Initiation of the rejuvenation, transformation or conversion)
6 Dauerwald	6.1 fire	--> see above 1.2
	6.2 bark beetles	--> see above 3.4

C) SILVICULTURAL MEASURES

Management type	**Secondary pure spruce stands**
Silvicultural system	Age class system
Vegetation zone	colline – submontane
Target of growing stock	Conversion and/or transformation • colline: mixed deciduous and/or mixed oak stands • submontane and montane: deciduous and coniferous mixed stands
Production goal	Timber of high quality (saw timber); target diameter: spruce 45 cm
Rotation period	60 - 80 (100) y;
Growth classes	**initial state - measures/action**
young stands height	weeding and/or cleaning; promoting of mixed tree species; integrating of pioneer tree species spruce: normal density negative selection; stem number reduction in dense stands mixture regulations
thicket	promoting of mixed tree species; integrating of pioneer tree species spruce: normal density negative selection; stem number reduction in dense stands mixture regulations
pole stage	spruce: positive thinning (future crop tree thinning) maintaining of mixed tree species and promoting mixed tree species of god quality maintain and promote nurse shade tolerant species; **treatment of previously managed stands:** combination of light thinning from above and selective thinning; maintenance and support of mixed tree species
timber dbh 20 – 50 cm	spruce: further positive thinning activities (future crop tree thinning) - release target trees; maintenance and support of mixed tree species **treatment of previously managed stands:** combination of light thinning from above and selective thing; maintenance and support of mixed tree species; with dbh > 30 cm transition to stock maintenance

timber/mature regeneration	**Transformation:** tree species change by clear cut and reforestation; **Conversion:** combination of natural and artificial regeneration; shelterwood cut and group- selection cut [target tree diameter harvesting] **colline: transformation to mixed deciduous stands** Reforestation: normal spacing: spruce (2*2 m; 2,500 n/ha), oak (2*1 m; 5,000 n/ha), maple (2*1.3 m-; 4,000 n/ha), cherry (wide spacing: cherry (4*3m; 700 n/ha) **submontane: transformation to mixed spruce hardwood stands** Reforestation: normal spacing: spruce (2*2 m; 2,500 n/ha), oak (2*1 m; 5,000 n/ha), maple (2*1.3 m-; 4,000 n/ha), cherry (wide spacing: cherry (4*3 m; 700 n/ha) - single mixed stands: wild cherry (service trees) + hornbeam, linden, beech. - support mixture species for oak stands (nurse shade tolerate species as linden, hornbeam, beech or field maple) - sycamore or Norway maple can be managed in group or as monoculture; - in case of group mixture avid monoculture larger than approx. 0.1(2) ha; - avoid gap in regeneration

Management type	**Secondary pure spruce stands**
Silvicultural system	Continuous Cover Forestry [CCF] not recommended
Vegetation zone	colline – submontane

7.2. Secondary Scots pine stands

A) RISK ASSESSMENT

RISK FACTOR/STAND DEVELOPMENT	REGENERATION/ YOUNG STANDS			THICKET			POLE STAGE			TIMBER			TIMBER/ MATURE			DAUERWALD PERMANENT TREE COVER		
	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M
Storm	0	0	0	0	0	0	1	1	1	2	2	2	2	2	2	1	1	1
Snow/ice/rime	1	1	1	2	3	2	2	3	2	2	3	2	2	3	2	1	1	1
Drought	1	1	0	1	1	0	1	1	0	1	1	0	1	1	0	1	1	0
Fire	3	2	2	3	2	2	3	2	2	3	2	2	3	2	2	3	2	2
Bark beetles	0	0	0	1	1	1	2	2	1	3	3	2	3	3	3	2	2	1
Game	3	3	3	2	2	2	2	2	2	0	0	0	1	1	1	1	1	1

Vegetation zone: C – colline, S – submontane, M – mountane

SCALE: 0 – no risk… 3 – extreme high risk; – absent (see context with the previous table with current presence of stand tapes in CZ)

0	1	2	3	–

B) FOREST PROTECTION

Secondary Scots pine stands

stand development	relevant damage factor	measurement / action
1 regeneration/ young stands	1.1 fire	**Effective fire control –** to identify the riskiest areas, early fire detection, barriers or firebreaks that may limit fire spread • control and reduction of dry hazardous material • in period with high risk (heat, drought, wind) frequent control of riskiest places

		• in extremely risky areas creation of barriers for wildfire – firebreaks, fuelbreaks, belts with low flammable woody plants (deciduous trees)
	1.2 game	**Controlling of game population and damage prevention** • controlling of population density, reduction of population density of overpopulated game • game-proof protection (fencing, browsing repellents, biotechnical protection – keeping no-target trees for browsing), increase of environment usability for game (e.g. planting of fruit trees)
2 thicket	2.1 snow/ice/rime	• work with stand density – suitable crown length • processing of damaged wood (risk of bark beetle outbreak)
	2.2 fire	--> see above 1.1
	2.3 game	--> see above 1.2
3 pole stage	3.1 storm and snow damage (and subsequent bark beetle calamity)	**Action for stands with structure remains** • processing of damaged wood (risk of bark beetle outbreak) • search for trees infested by bark beetles • bark beetle monitoring (pheromone traps) • work with stand density – suitable crown length • slenderness coefficient =/< 120 **Action for stands with density reduction ≤ 0.3-0.4** • supplement/regeneration in advance with hardwoods under shelter • utilisation of natural successions (pioneer crops, Vorwald)/natural rejuvenation)
	3.2 fire	--> see above 1.1
	3.3 bark beetles	**Prevention and control** • search for trees infested by bark beetles, processing of damaged wood, bark beetle monitoring (pheromone traps) **Defense** • removal of all material suitable for the development and multiplication of the pest • thorough search, timely and effective sanitation of infested wood and trees • concentration and control of the pest by means of various capture devices
	3.4 game	--> see above 1.2

4 timber	4.1 storm and snow damage	--> see above 3.1
	4.2 fire	--> see above 1.1
	4.3 bark beetles	--> see above 3.3
5 mature timber	5.1 storm and snow damage	--> see above 3.1 (Initiation of the rejuvenation, transformation or conversion)
	5.2 fire	--> see above 1.1 (Initiation of the rejuvenation, transformation or conversion)
	5.3 bark beetles	--> see above 3.3 (Initiation of the rejuvenation, transformation or conversion)
6 Dauerwald	6.1 fire	--> see above 1.1
	6.2 bark beetles	--> see above 3.3

C) SILVICULTURE MEASURES

Management type	**Secondary Scots pine stands**
Silvicultural system	Age class system
Vegetation zone	colline - submontane
Target of growing stock	Conversion and/or transformation mixed deciduous and/or mixed oak stands; deciduous and Scots pine mixed stands
Production goal	**Timber of high quality (saw timber); target diameter: Scots pine 45+ cm**
Rotation period	**Scots pine 80 -100 y;**
Growth classes	**initial state - measures/action**
young stands	weeding and/or cleaning; promoting of mixed tree species; integrating of pioneer tree species Scots pine: normal density negative selection; stem number reduction in dense stands mixture regulations
thicket	promoting of mixed tree species; integrating of pioneer tree species Scots pine: normal density negative selection; stem number reduction in dense stands mixture regulations

pole stage	Scots pine: positive thinning (future crop tree thinning) maintenance of mixed tree species and promotion of mixed tree species of god quality maintain and promote nurse shade tolerant species; **treatment of previously managed stands:** combination of light thinning from above and selective thing; maintenance and support of mixed tree species
Timber dbh > 20cm	Scots pine: further positive thinning activities (future crop tree thinning) - release target trees; maintenance and support of mixed tree species **treatment of previously managed stands:** combination of light thinning from above and selective thing; maintenance and support of mixed tree species with dbh > 30 cm transition to stock maintenance
timber/mature regeneration	**Transformation:** tree species change by clear cut and reforestation **Conversion:** combination of natural and artificial regeneration; shelterwood cut and group- selection cut [target diameter harvesting] **Colline: transformation to mixed deciduous and Scots pine stands** Reforestation: normal spacing: pine (1*1.3 m; 7,000 n/ha), oak (2*1 m; 5,000 n/ha) **submontane: transformation to** mixed beech and Scots pine stands Reforestation: normal spacing: Scots pine (1*1.3 m; 7,000 n/ha) beech 1*1.3 m; 7,000 n/ha in case of group mixture avid monoculture larger than approx. 0.1(2) ha;

Management type	**Secondary Scots pine stands**
Silvicultural system	Continuous Cover Forestry
Vegetation zone	colline - submontane
Target of growing stock	Conversion and/or transformation • Colline - submontane: mixed deciduous and/or mixed oak stands; deciduous and Scots pine mixed stands
Production goal	**Timber of high quality (saw timber); target diameter: Scots pine 45+ cm**
Growth classes	**initial state - measures/action**

Pole stage/timber (20 – 40 cm)	use maximum self-thinning process; girdling, support quality trees, remove wolf trees; **structural thinning**
timber/mature stand	**target diameter harvesting** • support for natural regeneration; • species composition can be modified

7.3. Natural spruce dominated stands

A) RISK ASSESSMENT

RISK FACTOR/STAND DEVELOPMENT	REGENERATION/ YOUNG STANDS			THICKET			POLE STAGE			TIMBER			TIMBER/ MATURE			DAUERWALD PERMANENT TREE COVER		
	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M
Storm	–	–	0	–	–	0	–	–	2	–	–	3	–	–	3	–	–	1
Snow/ice/rime	–	–	1	–	–	2	–	–	2	–	–	2	–	–	2	–	–	1
Drought	–	–	1	–	–	1	–	–	1	–	–	1	–	–	1	–	–	1
Fire	–	–	2	–	–	2	–	–	2	–	–	2	–	–	2	–	–	2
Bark beetles	–	–	0	–	–	1	–	–	1	–	–	2	–	–	3	–	–	1
Game	–	–	3	–	–	3	–	–	2	–	–	1	–	–	2	–	–	1

Vegetation zone: C – colline, S – submontane, M – mountane

SCALE: 0 – no risk… 3 – extreme high risk; – absent (see context with the previous table with current presence of stand tapes in CZ)

0	1	2	3	–

B) FOREST PROTECTION

Natural spruce dominated stands

stand development	relevant damage factor	measurement / action
1 regeneration/ young stands	1.1 fire	**Effective fire control –** to identify the riskiest areas, early fire detection, barriers or firebreaks that may limit fire spread • control and reduction of dry hazardous material • in period with high risk (heat, drought, wind) frequent control of riskiest places • in extremely risky areas creation of barriers for wildfire – firebreaks, fuel breaks, belts with low flammable woody plants (deciduous trees)
	1.2 game	**Controlling of game population and damage prevention** • controlling of population density, reduction of population density of overpopulated game • game-proof protection (fencing, browsing repellents, biotechnical protection – keeping no-target trees for browsing), increase of environment usability for game (e.g. planting of fruit trees)
2 thicket	2.1 snow/ice/rime	• work with stand density – suitable crown length • processing of damaged wood (risk of bark beetle outbreak)
	2.3 fire	--> see above 1.1
	2.5 game	--> see above 1.2
3 pole stage	3.1 storm and snow damage (and subsequent bark beetle calamity)	**Action for stands with structure remains** • processing of damaged wood (risk of bark beetle outbreak) • search for trees infested by bark beetles • bark beetle monitoring (pheromone traps, trapping trees) **Action for stands with density reduction ≤ 0.3-0.4** • supplement/regeneration in advance with hardwoods under shelter • utilisation of natural successions (pioneer crops, Vorwald)/natural rejuvenation
	3.2 fire	--> see above 1.1
	3.3 game	--> see above 1.2
4 timber	4.1 storm and snow damage	--> see above 3.1 (but threshold of reduction of the stand density slightly higher: ≤ 0.4-0.5)

	4.2 fire	--> see above 1.1
	4.3 bark beetles	**Prevention and control** • search for trees infested by bark beetles, processing of damaged wood, bark beetle monitoring (pheromone traps, trapping trees) **Defense** • removal of all material suitable for the development and multiplication of the pest • thorough search, timely and effective sanitation of infested wood and trees concentration and control of the pest by means of various capture devices
5 mature timber	5.1 storm and snow damage	--> see above 3.1 (Initiation of the rejuvenation, transformation or conversion)
	5.2 fire	--> see above 1.1
	5.3 bark beetles	--> see above 4.3 (Initiation of the rejuvenation, transformation or conversion)
6 Dauerwald	6.1 fire	--> see above 1.2
	6.2 bark beetles	--> see above 4.3

C) SILVICULTURE MEASURES

Management type	**Natural spruce dominated stands**
Silvicultural system	Age class system
Vegetation zone	montane
Target of growing stock	Spruce dominated stand
Production goal	**Timber of high quality (saw timber); target diameter: spruce 50+ cm**
Rotation period	100 - 120 y
Growth classes	**initial state - measures/action**
Regeneration	Natural regeneration and/or (added) planting: spruce: 2,500 n/ha (normal spacing 2*2 m),

young stands	weeding and/or cleaning; promoting of mixed tree species; integrating of pioneer tree species normal density negative selection; stem number reduction in dense spruce-fir stands mixture regulations
thicket	promoting of mixed tree species; integrating of pioneer tree species spruce: normal density negative selection; stem number reduction in dense stands; mixture regulations
pole stage	spruce: positive thinning (future crop tree thinning) maintaining of mixed tree species and promoting mixed tree species of god quality maintain and promote nurse shade tolerant species; **treatment of previously managed stands:** combination of light thinning from above and selective thinning; maintenance and support of mixed tree species
Timber dbh > 20cm	spruce: further positive thinning activities (future crop tree thinning) - release target tress; maintenance and support of mixed tree species **treatment of previously managed stands:** combination of light thinning from above and selective thinning; maintenance and support of mixed tree species with dbh > 30 cm transition to stock maintenance
timber/mature regeneration	**regeneration:** combination of natural and artificial regeneration; strip and/or group- selection cutting or in combination

Management type	**Natural spruce dominated stands**
Silvicultural system	CFF
Vegetation zone	montane
Target of growing stock	Spruce dominated stand
Production goal	**Timber of high quality (saw timber); target diameter: spruce 50+ cm**
Growth classes	**initial state - measures/action**
Pole stage/timber (20 – 40 cm)	use maximum self-thinning process; girdling, support quality trees, remove wolf trees;

	structural thinning
timber/mature stand	**target diameter harvesting** • support for natural regeneration; • species composition can be modified

7.4. Mixed spruce hardwood stands

A) RISK ASSESSMENT

RISK FACTOR/STAND DEVELOPMENT	REGENERATION/ YOUNG STANDS			THICKET			POLE STAGE			TIMBER			TIMBER/ MATURE			DAUERWALD PERMANENT TREE COVER		
	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M
Storm	0	0	0	0	0	0	1	1	1	2	2	2	2	2	2	–	–	1
Snow/ice/rime	1	1	1	2	2	2	2	2	2	1	1	1	1	1	1	–	–	1
Drought	3	2	1	3	2	1	3	2	1	3	2	1	3	2	1	–	–	1
Fire	3	2	2	2	1	1	2	1	1	2	1	1	2	1	1	–	–	2
Bark beetles	0	0	0	0	0	0	1	1	1	2	1	1	2	2	2	–	–	1
Game	3	3	3	3	3	3	2	2	2	0	0	0	1	1	1	–	–	1

Vegetation zone: C – colline, S – submontane, M – mountane

SCALE: 0 – no risk… 3 – extreme high risk; – absent (see context with the previous table with current presence of stand tapes in CZ)

0	1	2	3	–

B) FOREST PROTECTION

Mixed spruce hardwood stands

stand development	relevant damage factor	measurement / action
1 regeneration/ young stands	1.1 drought	**Respecting vegetation soil and climate conditions** when establishing stand, planting of quality planting material, control and replacement of dead seedlings • autumn planting • optimization of weed control practices – only strip reduction (shading), reduction only if necessary (according to height and density of weed and weather condition) **Maintaining suitable air and soil moisture** • preservation of the remains of the mother stand – shade • use of pioneer woody plants – preparatory vegetation
	1.2 fire	**Effective fire control –** to identify the riskiest areas, early fire detection, barriers or firebreaks that may limit fire spread • control and reduction of dry hazardous material • in period with high risk (heat, drought, wind) frequent control of riskiest places • in extremely risky areas creation of barriers for wildfire – firebreaks, fuelbreaks, belts with low flammable woody plants (deciduous trees)
	1.3 game	**Controlling of game population and damage prevention** • controlling of population density, reduction of population density of overpopulated game • game-proof protection (fencing, browsing repellents, biotechnical protection – keeping no-target trees for browsing), increase of environment usability for game (e.g. planting of fruit trees)
2 thicket	2.1 snow/ice/rime	• work with stand density – suitable crown length • processing of damaged wood (risk of bark beetle outbreak)
	2.2 drought (and subsequent bark beetle calamity)	• frequent control of the stands • search for trees secondarily infested by bark beetles or defoliators • bark beetle monitoring (pheromone traps, trapping trees) • timely sanitation (larval/pupal stage)
	2.3 fire	--> see above 1.2

	2.4 game	--> see above 1.3
3 pole stage	3.1 storm and snow damage	**Action for stands with structure remains** • processing of damaged wood (risk of bark beetle outbreak) • search for trees infested by bark beetles • bark beetle monitoring (pheromone traps, trapping trees) **Action for stands with density reduction ≤ 0.3-0.4** • supplement/regeneration in advance with hardwoods under shelter • utilisation of natural successions (pioneer crops, Vorwald)/natural rejuvenation
	3.2 drought	--> see above 2.2
	3.3 fire	--> see above 1.2
	3.4 game	--> see above 1.3
4 timber	4.1 storm and snow damage	--> see above 3.1 (but threshold of reduction of the stand density slightly higher: ≤ 0.4-0.5)
	4.2 drought	--> see above 2.2
	4.3 fire	--> see above 1.2
	4.4 bark beetles	**Prevention and control** • search for trees infested by bark beetles, processing of damaged wood, bark beetle monitoring (pheromone traps) **Defense** • removal of all material suitable for the development and multiplication of the pest • thorough search, timely and effective sanitation of infested wood and trees • concentration and control of the pest by means of various capture devices
5 mature timber	5.1 storm and snow damage	--> see above 3.1 (Initiation of the rejuvenation, transformation or conversion)
	5.2 drought	--> see above 2.2 (Initiation of the rejuvenation, transformation or conversion)
	5.3 fire	--> see above 1.2
	5.4 bark beetles	--> see above 4.4 (Initiation of the rejuvenation, transformation or conversion)

6 Dauerwald	6.1 fire	--> see above 1.2
	6.2 bark beetles	--> see above 4.4

C) SILVICULTURE MEASURES

Management type	**Mixed spruce hardwood stands**
Silvicultural system	Age class system
Vegetation zone	Submontane
Target of growing stock	50/(40 – 60)% spruce (larch, fir) 50 (40 - 60)% deciduous (beech, Norway maple)
Production goal	Timber of high quality (saw timber); target diameter: spruce, fir 45+ cm, larch 60+ cm; deciduous tree species 60+ cm
Rotation period	Spruce, fir: 80 – 120y; larch 80 - 120 y; beech and Norway maple 80 - 120 y
Growth classes	**initial state - measures/action**
Regeneration	Reforestation: normal spacing: spruce/fir (2*2 m; 2,500 n/ha), larch (2*2.5 m; 2,000 n/ha); beech (1*1.3 m; 8,000 n/ha - single mixed stands: wild cherry (service trees) + hornbeam, linden, beech. - support mixture species for oak stands (nurse shade tolerate species as linden, hornbeam, beech or field maple) - sycamore or Norway maple can be managed in group or as monoculture; - in case of group mixture avid monoculture larger than approx. 0.1(2) ha; - avoid gap in regeneration
young stands	weeding and/or cleaning: negative selection; artificial pruning: pruning of stands with lower densities (oak below 5,000 n/ha; maple below approx. 3,000 n/ha; pruning for wild cherry)
Thicket	normal density: negative clearing – remove wolf trees - mixture control - keep full canopy
pole stage	normal density - positive thinning; - support nurse shade tolerant species;
timber	- release target tress;

timber/mature	- preparation felling – release target tress, remove undesirable trees, support for natural regeneration; combination of natural and artificial regeneration; strip and/or group- selection cutting or in combination target diameter harvesting

Management type	**Mixed spruce hardwood stands**
Silvicultural system	CFF – depends on MGT (light demanding vs. shade tolerant tree species)
Vegetation zone	montane
Target of growing stock	50/(40 – 60)% spruce (larch, fir) 50 (40 -60)% deciduous (beech, Norway maple)
Production goal	**Timber of high quality (saw timber); target diameter: spruce, fir 45+ cm, larch 60+ cm; deciduous tree species 60+ cm**
Growth classes	**initial state - measures/action**
Pole stage/timber (20 – 40 cm)	use maximum self-thinning process; girdling, support quality trees, remove wolf trees; **structural thinning**
timber/mature stand	**target diameter harvesting** • support for natural regeneration; • species composition can be modified

7.5. Mixed oak stands

A) RISK ASSESSMENT

RISK FACTOR/STAND DEVELOPMENT	REGENERATION/ YOUNG STANDS			THICKET			POLE STAGE			TIMBER			TIMBER/ MATURE			DAUERWALD PERMANENT TREE COVER		
	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M
Storm	0	0	–	0	0	–	0	0	–	1	1	–	1	1	–	0	0	–
Snow/ice/rime	1	1	–	1	2	–	1	2	–	1	1	–	1	1	–	1	1	–
Drought	2	1	–	2	1	–	2	1	–	2	1	–	2	1	–	1	1	–
Fire	3	2	–	2	1	–	2	1	–	3	2	–	3	2	–	3	2	–
Bark beetles	1	1	–	1	1	–	1	1	–	1	1	–	1	1	–	1	1	–
Game	3	3	–	2	2	–	1	1	–	0	0	–	1	1	–	1	1	–

Vegetation zone: C – colline, S – submontane, M – mountane

SCALE: 0 – no risk… 3 – extreme high risk; – absent (see context with the previous table with current presence of stand tapes in CZ)

0	1	2	3	–

B) FOREST PROTECTION

Mixed Oak Stands

stand development	relevant damage factor	measurement / action
1 regeneration/ young stands	1.1 drought	**Respecting vegetation, soil and climate conditions** when establishing stand, planting of quality planting material, control and replacement of dead seedlings • autumn planting • optimization of weed control practices – only strip reduction (shading), reduction only if necessary (according to height and density of weed and weather condition) • maximum utilization of natural forest regeneration

		Maintaining suitable air and soil moisture • preservation of the remains of the mother stand – shade use of pioneer woody plants – preparatory vegetation
	1.2 fire	**Effective fire control –** to identify the riskiest areas, early fire detection, barriers or firebreaks that may limit the fire spreading • control and reduction of dry hazardous material • in period with high risk (heat, drought, wind) frequent control of riskiest places • in extremely risky areas creation of barriers for wildfire – firebreaks, fuel breaks, belts with low flammable woody plants (deciduous trees)
	1.3 game	**Controlling of game population and damage prevention** • controlling of population density, reduction of population density of overpopulated game • game-proof protection (fencing, browsing repellents, biotechnical protection – keeping no-target trees for browsing), increase of environment usability for game (e.g. planting of fruit trees)
2 thicket	2.1 snow/ice/rime	• work with stand density – suitable crown length • processing of damaged wood (risk of bark beetle outbreak)
	2.2 drought	• optimization of stand density (maintaining a favourable stand climate)
	2.3 fire	--> see above 1.2
	2.4 game	--> see above 1.3 and moreover other methods of individual game-proof protection
3 pole stage	3.1 snow / ice / rime	**Action for stands with structure remains** • processing of damaged wood (risk of bark beetle outbreak) **Action for stands with density reduction <= 0.3-0.4** • supplement/regeneration in advance with hardwoods under shelter • utilisation of natural successions (pioneer crops, Vorwald)/natural rejuvenation
	3.2 drought	--> see above 2.2
	3.3 fire	--> see above 1.2
4 timber	4.1 drought	• frequent control of the stands • search for trees infested by bark beetles

		• bark beetle monitoring (visual controlling)
	4.2 fire	--> see above 1.2
5 mature timber	5.1 drought	--> see above 4.1 and moreover initiation of the forest regeneration (transformation or conversion)
	5.2 fire	--> see above 1.2
6 Dauerwald	6.1 fire	--> see above 1.2

C) SILVICULTURE MEASURES

Management type	**Mixed oak stands**
Silvicultural system	Age class system
Vegetation zone	colline (submontane)
Target of growing stock	• 70 – 80% oak; 20 – 30% deciduous tree species (hornbeam, lime, beech)
Production goal	Timber of high valuable quality; target diameter: oak 60+ cm
Rotation period	100/80 - 120 y
Growth classes	**initial state - measures/action**
Regeneration	Natural regeneration Reforestation: normal spacing: oak (2*1 m; 5,000 n/ha), wider pacing: oak (3*1.0 m; 1,600 – 2,000 n/ha); partial area planting (cluster) (70 cluster a 25 n) Secondary stand: hornbeam (lime, beech) 400 -500 n/ha
young stands	weeding and/or cleaning: negative selection; artificial pruning in stands with wider spacing
Thicket	Transition to positive selection (stem number reduction in upper storey (3*3m); mixture control; further pruning steps in case of wider spacing and/or unsatisfactory natural pruning
pole stage	Future crop tree thinning (70/(60 -80) crop trees per ha
timber	Continue future crop tree thinning (70/(60 -80) crop trees per ha
timber/ mature	Natural regeneration: shelterwood cut and irregular cut and/or in combination

Management type	**Mixed oak stands**
Silvicultural system	CFF -> Coppice with standards -> depends on site conditions
Vegetation zone	Colline – (submontane)
Target of growing stock	70 – 80% oak; 20 – 30% deciduous tree species (hornbeam, lime, beech)
Production goal	Timber of high valuable quality; target diameter: oak 60+ cm
Growth classes	**initial state - measures/action**
CWS	CWS-cut; 30 y rotation period
	HF = High forest
pole stage/timber (20 – 40 cm)	use maximum self-thinning process; girdling, support quality trees, remove wolf trees; **structural thinning**
timber/mature stand	**target diameter harvesting** • support for natural regeneration; • species composition can be modified

7.6. Mixed Scots pine-oak stands

A) RISK ASSESSMENT

RISK FACTOR/STAND DEVELOPMENT	REGENERATION/ YOUNG STANDS			THICKET			POLE STAGE			TIMBER			TIMBER/ MATURE			DAUERWALD PERMANENT TREE COVER		
	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M
Storm	0	0	–	0	0	–	1	1	–	1	1	–	1	1	–	0	0	–
Snow/ice/rime	1	1	–	1	1	–	1	1	–	1	1	–	1	1	–	1	1	–
Drought	2	1	–	2	1	–	2	1	–	2	1	–	2	1	–	1	1	–
Fire	3	2	–	3	2	–	3	2	–	3	2	–	3	2	–	3	2	–
Bark beetles	0	0	–	1	1	–	1	1	–	2	2	–	2	2	–	1	1	–
Game	3	3	–	2	2	–	1	1	–	0	0	–	1	1	–	1	1	–

Vegetation zone: C – colline, S – submontane, M – mountane

SCALE: 0 – no risk… 3 – extreme high risk; – absent (see context with the previous table with current presence of stand tapes in CZ)

0	1	2	3	–

B) FOREST PROTECTION

Mixed Scots pine-oak stands

stand development	relevant damage factor	measurement / action
1 regeneration/ young stands	1.1 drought	**Respecting vegetation soil and climate conditions** when establishing stand, planting of quality planting material, control and replacement of dead seedlings • autumn planting

		• optimization of weed control practices – only strip reduction (shading), reduction only if necessary (according to height and density of weed and weather condition) **Maintaining suitable air and soil moisture** • preservation of the remains of the mother stand – shade • use of pioneer woody plants – preparatory vegetation
	1.2 fire	**Effective fire control –** to identify the riskiest areas, early fire detection, barriers or firebreaks that may limit fire spread • control and reduction of dry hazardous material • in period with high risk (heat, drought, wind) frequent control of riskiest places • in extremely risky areas creation of barriers for wildfire – firebreaks, fuel breaks, belts with low flammable woody plants (deciduous trees)
	1.3 game	**Controlling of game population and damage prevention** • controlling of population density, reduction of population density of overpopulated game • game-proof protection (fencing, browsing repellents, biotechnical protection – keeping no-target trees for browsing), increase of environment usability for game (e.g. planting of fruit trees)
2 thicket	2.1 drought (and subsequent bark beetle calamity)	• frequent control of the stands • search for trees secondarily infested by bark beetles or defoliators • bark beetle monitoring (pheromone traps, trapping trees) • timely sanitation (larval/pupal stage)
	2.2 fire	--> see above 1.2
	2.3 game	--> see above 1.3
3 pole stage	3.1 drought	--> see above 2.1
	3.2 fire	--> see above 1.2
4 timber	4.1 drought	--> see above 2.1 (management of bark beetles process according 4.3)
	4.2 fire	--> see above 1.2
	4.3 bark beetle	**Prevention and control** • search for trees infested by bark beetles, processing of damaged wood, bark beetle monitoring (pheromone traps, trapping trees)

		Defense • removal of all material suitable for the development and multiplication of the pest • thorough search, timely and effective sanitation of infested wood and trees • concentration and control of the pest by means of various capture devices
5 mature timber	5.1 drought	--> see above 2.1 (Initiation of the rejuvenation, transformation or conversion and management of bark beetles process according 5.3)
	5.2 fire	--> see above 1.2
	5.3 Bark beetle	--> see above 4.3 (Initiation of the rejuvenation, transformation or conversion)
6 Dauerwald	6.1 fire	--> see above 1.2

C) SILVICULTURE MEASURES

Management type	Mixed Scots pine-oak stands
Silvicultural system	Age class system
Vegetation zone	colline
Target of growing stock	40 -60% oak, 40-60% Scots pine
Production goal	**Timber of high quality (saw timber); target diameter: Scots pine and oak 45+ cm**
Rotation period	**80 - 120 y;**
Growth classes	**initial state - measures/action**
Regeneration	**Natural regeneration** **Reforestation:** normal spacing: pine (1*1.3 m; 7,000 n/ha), oak (2*1 m; 5,000 n/ha) in case of group mixture avid monoculture larger than approx. 0.1(2) ha;
young stands	weeding and/or cleaning; promoting of mixed tree species; integrating of pioneer tree species Scots pine: normal density negative selection; stem number reduction in dense stands mixture regulations
thicket	promoting of mixed tree species; integrating of pioneer tree species

	Scots pine: normal density negative selection; stem number reduction in dense stands mixture regulations
pole stage	positive thinning (future crop tree thinning) maintaining of mixed tree species and promotion mixed tree species of god quality **treatment of previously managed stands:** combination of light thinning from above and selective thinning; maintenance and support of mixed tree species
Timber dbh > 20cm	further positive thinning activities (future crop tree thinning) - release target tress; maintenance and support of mixed tree species **treatment of previously managed stands:** combination of light thinning from above and selective thinning; maintenance and support of mixed tree species with dbh > 30 cm transition to stock maintenance
timber/ mature	Natural regeneration: combination of shelterwood cut and group selection system

Management type	Mixed Scots pine-oak stands
Silvicultural system	CFF - depends on site conditions
Vegetation zone	colline
Target of growing stock	40 -60% oak, 40-60% Scots pine
Production goal	**Timber of high quality (saw timber); target diameter: Scots pine and oak 45+ cm**
Growth classes	**initial state - measures/action**
pole stage/timber (20 – 40 cm)	use maximum self-thinning process; girdling, support quality trees, remove wolf trees; **structural thinning**
timber/mature stand	**target diameter harvesting** • support for natural regeneration; • species composition can be modified

7.7. Spruce fir beech stands

A) RISK ASSESSMENT

RISK FACTOR/STAND DEVELOPMENT	REGENERATION/ YOUNG STANDS			THICKET			POLE STAGE			TIMBER			TIMBER/ MATURE			DAUERWALD PERMANENT TREE COVER		
	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M
Storm	–	0	0	–	0	0	–	1	1	–	1	1	–	2	2	–	1	1
Snow/ice/rime	–	1	1	–	2	2	–	2	2	–	1	1	–	1	1	–	1	1
Drought	–	2	1	–	2	1	–	2	1	–	2	1	–	2	1	–	1	1
Fire	–	1	1	–	1	1	–	1	1	–	1	1	–	1	1	–	2	1
Bark beetles	–	0	0	–	1	1	–	2	2	–	2	2	–	2	2	–	1	1
Game	–	3	3	–	3	3	–	2	2	–	0	0	–	1	1	–	1	1

Vegetation zone: C – colline, S – submontane, M – mountane

SCALE: 0 – no risk… 3 – extreme high risk; – absent (see context with the previous table with current presence of stand tapes in CZ)

0	1	2	3	–

B) FOREST PROTECTION

Spruce fir beech stands

stand development	relevant damage factor	measurement / action
1 regeneration/ young stands	1.1 drought	**Respecting vegetation soil and climate conditions** when establishing stand, planting of quality planting material, control and replacement of dead seedlings • autumn planting

		• optimization of weed control practices – only strip reduction (shading), reduction only if necessary (according to height and density of weed and weather condition) **Maintaining suitable air and soil moisture** • preservation of the remains of the mother stand – shade • use of pioneer woody plants – preparatory vegetation
	1.2 game	**Controlling of game population and damage prevention** • controlling of population density, reduction of population density of overpopulated game • game-proof protection (fencing, browsing repellents, biotechnical protection – keeping no-target trees for browsing), increase of environment usability for game (e.g. planting of fruit trees)
2 thicket	2.1 snow/ice/rime	• work with stand density – suitable crown length • processing of damaged wood (risk of bark beetle outbreak)
	2.2 drought (and subsequent bark beetle calamity)	• frequent control of the stands • search for trees secondarily infested by bark beetles or defoliators • bark beetle monitoring (pheromone traps, trapping trees) • timely sanitation (larval/pupal stage)
	2.3 game	--> see above 1.2
3 pole stage	3.1 snow/ice/rime	**Action for stands with structure remains** • processing of damaged wood (risk of bark beetle outbreak) • search for trees infested by bark beetles • bark beetle monitoring (pheromone traps, trapping trees) **Action for stands with density reduction ≤ 0.3-0.4** • supplement/regeneration in advance with hardwoods under shelter • utilisation of natural successions (pioneer crops, Vorwald)/natural rejuvenation
	3.2 drought	--> see above 2.2 (management of bark beetles processed according 3.3)
	3.3 Bark beetles	**Prevention and control** • search for trees infested by bark beetles, processing of damaged wood, bark beetle monitoring (pheromone traps, trapping trees) **Defense**

		• removal of all material suitable for the development and multiplication of the pest • thorough search, timely and effective sanitation of infested wood and trees • concentration and control of the pest by means of various capture devices
	3.4 game	--> see above 1.2
4 timber	4.1 drought	--> see above 2.2 (management of bark beetles processed according 4.2)
	4.2 Bark beetles	--> see above 3.3
5 mature timber	5.1 Storm	**Action for stands with structure remains** • processing of damaged wood (risk of bark beetle outbreak) • search for trees infested by bark beetles • bark beetle monitoring (pheromone traps, trapping trees) **Action for stands with density reduction ≤ 0.4-0.5** • supplement/regeneration in advance with hardwoods under shelter • utilisation of natural successions (pioneer crops, Vorwald)/natural rejuvenation • Initiation of the rejuvenation, transformation or conversion
	5.2 drought	--> see above 2.2 (Initiation of the rejuvenation, transformation or conversion and management of bark beetles processed according 5.3)
	5.3 Bark beetles	--> see above 3.3 (Initiation of the rejuvenation, transformation or conversion)
6 Dauerwald	6.1 fire	**Effective fire control –** to identify the riskiest areas, early fire detection, barriers or firebreaks that may limit fire spread • control and reduction of dry hazardous material • in period with high risk (heat, drought, wind) frequent control of riskiest places • in extremely risky areas creation of barriers for wildfire – firebreaks, fuelbreaks, belts with low flammable woody plants (deciduous trees)

C) SILVICULTURE MEASURES

Management type	**Spruce fir beech stands**
Silvicultural system	Age class system
Vegetation zone	Montane (submontane)
Target of growing stock	deciduous and coniferous mixed stands (40% spruce, 30% fir, 30% beech)
Production goal	Timber of high quality (saw timber); target diameter: spruce and fir 45(50) cm; beech 50+ cm
Rotation period	100 – 120 y;
Growth classes	**initial state - measures/action**
Regeneration	**Natural regeneration** **Artificial regeneration:** normal spacing: spruce and fir (2*2 m; 2,500 n/ha), beech (1.0*1.3 m; 8,000 n/ha); group mixture 0.1(2) ha new stand can be managed as single or group mixture; - in case of group mixture avoid monoculture larger than approx. 0.2 ha;
young stands height < 2m (cleaning, tending)	weeding and/or cleaning; promoting of mixed tree species; integrating of pioneer tree species; normal density negative selection; stem number reduction in dense spruce-fir stands; mixture regulations
thicket dbh < 10cm	promoting of mixed tree species; integrating of pioneer tree species normal density negative selection; stem number reduction in dense spruce-fir stands, negative selection (beech) mixture regulations; remove wolf beech tress. **in submontane (colline) region** beech and fir can be preferred within clearing process (reduce spruce composition); promotion of vertical differentiation in conifer dominant stands and keep large crown of spruce and fir trees;
pole stage 10cm< dbh <20cm	**positive thinning (future crop tree thinning)** maintaining of mixed tree species and promoting mixed tree species of good quality maintain and promote nurse shade tolerant species;

	treatment of previously managed stands: combination of light thinning from above and selective thing; maintenance and support of mixed tree species reduce spruce composition in submontane region;
Timber dbh > 20cm	further positive thinning activities (future crop tree thinning) support of mixed tree species **treatment of previously managed stands:** combination of light thinning from above and selective thing; maintenance and support of mixed tree species
timber/ mature	**Natural regeneration:** combination of natural and artificial regeneration; strip cut and/or group- selection cut

Management type	**Spruce fir beech stands**
Silvicultural system	CFF
Vegetation zone	Montane (submontane)
Target of growing stock	deciduous and coniferous mixed stands (40% spruce, 30% fir, 30% beech)
Production goal	Timber of high quality (saw timber); target diameter: spruce and fir 45(50) cm; beech 50+ cm
Growth classes	**initial state - measures/action**
pole stage/timber (20 – 40 cm)	use maximum self-thinning process; girdling, support quality trees, remove wolf trees; **structural thinning** Promote natural regeneration of beech and fir mainly in submontane region
timber/mature stand	**target diameter harvesting** • support for natural regeneration; • species composition can be modified • control of mixture and diameter distribution

7.8. Pure Douglas fir stands and/or mixed Douglas fir stands

A) RISK ASSESSMENT

RISK FACTOR/STAND DEVELOPMENT	REGENERATION/ YOUNG STANDS			THICKET			POLE STAGE			TIMBER			TIMBER/ MATURE			DAUERWALD PERMANENT TREE COVER		
	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M
Storm	0	0	–	0	0	–	1	1	–	1	1	–	1	1	–	–	–	–
Snow/ice/rime	1	1	–	1	1	–	1	1	–	1	1	–	1	1	–	–	–	–
Drought	2	1	–	2	1	–	2	1	–	2	1	–	2	1	–	–	–	–
Fire	2	2	–	2	2	–	1	1	–	1	1	–	2	2	–	–	–	–
Bark beetles	0	0	–	1	1	–	1	1	–	1	1	–	1	1	–	–	–	–
Game	2	2	–	1	1	–	1	1	–	0	0	–	1	1	–	–	–	–

Vegetation zone: C – colline, S – submontane, M – mountane

SCALE: 0 – no risk… 3 – extreme high risk; – absent (see context with the previous table with current presence of stand tapes in CZ)

0	1	2	3	–

B) FOREST PROTECTION

Pure Douglas fir stands and/or mixed Douglas fir stands

stand development	relevant damage factor	measurement / action
1 regeneration/ young stands	1.1 drought	**Respecting vegetation soil and climate conditions** when establishing stand, planting of quality planting material, control and replacement of dead seedlings

		• autumn planting • optimization of weed control practices – only strip reduction (shading), reduction only if necessary (according to height and density of weed and weather condition) **Maintaining suitable air and soil moisture** • preservation of the remains of the mother stand – shade • use of pioneer woody plants – preparatory vegetation
	1.2 fire	**Effective fire control –** to identify the riskiest areas, early fire detection, barriers or firebreaks that may limit fire spread • control and reduction of dry hazardous material • in period with high risk (heat, drought, wind) frequent control of riskiest places • in extremely risky areas creation of barriers for wildfire – firebreaks, fuel breaks, belts with low flammable woody plants (deciduous trees)
	1.3 game	**Controlling of game population and damage prevention** • controlling of population density, reduction of population density of overpopulated game • game-proof protection (fencing, browsing repellents, biotechnical protection – keeping no-target trees for browsing), increase of environment usability for game (e.g. planting of fruit trees)
2 thicket	2.1 drought (and subsequent bark beetle calamity)	• frequent control of the stands • search for trees secondarily infested by bark beetles • timely sanitation (larval/pupal stage) • optimization of stand density (maintaining a favourable stand climate)
	2.4 fire	--> see above 1.2
3 pole stage	3.1 drought	**Action for stands with structure remains** • processing of damaged wood • search for trees infested by bark beetles **Action for stands with density reduction ≤ 0.3-0.4** • supplement/regeneration in advance with hardwoods under shelter • utilisation of natural successions (pioneer crops, Vorwald)/natural rejuvenation
4 timber	4.1 drought	--> see above 2.1
5 mature timber	5.1 drought	--> see above 2.1 (Initiation of the rejuvenation, transformation or conversion)
	5.2 fire	--> see above 1.2

C) SILVICULTURE MEASURES

Management type	**Mixed Douglas fir - beech stands [pure Douglas fir stands]**
Silvicultural system	Age class system
Vegetation zone	(colline) - submontane – (montane)
Target of growing stock	70 - 80% Douglas fir; 20 -30% beech and/or other deciduous tree species
Production goal	Timber of high quality; target diameter: Douglas fir 50 (60)+ cm
Rotation period	70 / (60-80) y
Growth classes	**initial state - measures/action**
Regeneration	Reforestation: Douglas fir (wider spacing; 3*3 m; 1,100 n/ha), beech: natural regeneration and/or planting (1*1.3 m; 7000 n/ha)
young stands	weeding and/or cleaning; beech: negative selection Douglas fir: artificial pruning (high quality timber)
Thicket Dbh < 10cm	Beech: negative selection Douglas fir: further pruning steps
pole stage	Future crop tree thinning: Douglas fir (200/ (180 - 220 crop trees per ha; beech 90/(80 - 100) n/ha
timber	Continue future crop tree thinning (70/(60 - 80) crop trees per ha
timber/ mature	Artificial regeneration: clear cut Natural regeneration: irregular shelterwood cut/group selection thinning

Management type	**Mixed Douglas fir - beech stands [pure Douglas fir stands]**
Silvicultural system	CFF
Vegetation zone	(colline) - Submontane – (montane)
Target of growing stock	70 – 80% Douglas fir; 20 -30% beech and/or other deciduous tree species
Production goal	Timber of high quality; target diameter: Douglas fir 50+ cm
Growth classes	**initial state - measures/action**

pole stage/timber (20 – 40 cm)	use maximum self-thinning process; girdling, support quality trees, remove wolf trees; **structural thinning** Promote natural regeneration of beech and fir mainly in submontane region
timber/mature stand	**target diameter harvesting** • support for natural regeneration; • species composition can be modified • control of mixture and diameter distribution

7.9. Mixed noble hardwood stands

A) RISK ASSESSMENT

RISK FACTOR/STAND DEVELOPMENT	REGENERATION/ YOUNG STANDS			THICKET			POLE STAGE			TIMBER			TIMBER/ MATURE			DAUERWALD PERMANENT TREE COVER		
	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M
Storm	0	0	–	0	0	–	0	0	–	1	1	–	1	1	–	0	0	–
Snow/ice/rime	1	1	–	1	1	–	1	1	–	1	1	–	1	1	–	1	1	–
Drought	3	2	–	3	2	–	3	2	–	3	2	–	3	2	–	2	1	–
Fire	2	2	–	1	1	–	1	1	–	1	1	–	1	1	–	2	1	–
Bark beetles	0	0	–	0	0	–	1	1	–	1	1	–	1	1	–	0	0	–
Game	3	3	–	2	2	–	1	1	–	0	0	–	1	1	–	1	1	–

Vegetation zone: C – colline, S – submontane, M – mountane

SCALE: 0 – no risk… 3 – extreme high risk; – absent (see context with the previous table with current presence of stand tapes in CZ)

0	1	2	3	–

B) FOREST PROTECTION

Mixed noble hardwood stands

stand development	relevant damage factor	measurement / action
1 regeneration/ young stands	1.1 game	**Controlling of game population and damage prevention** • controlling of population density, reduction of population density of overpopulated game • game-proof protection (fencing, browsing repellents, biotechnical protection – keeping no-target trees for browsing), increase of environment usability for game (e.g. planting of fruit trees)
	1.2 drought	**Respecting vegetation, soil and climate conditions** when establishing stand (relevant species composition), planting of quality planting material, control and replacement of dead seedlings • autumn planting • optimization of weed control practices – only strip reduction (shading), reduction only if necessary (according to height and density of weed and weather condition) • maximum utilization of natural forest regeneration **Maintaining suitable air and soil moisture** • preservation of the remains of the mother stand – shade • use of pioneer woody plants – preparatory vegetation
	1.3 fire	**Effective fire control –** to identify the riskiest areas, early fire detection, barriers or firebreaks that may limit fire spread • control and reduction of dry hazardous material • in period with high risk (heat, drought, wind) frequent control of riskiest places • in extremely risky areas creation of barriers for wildfire – firebreaks, fuel breaks, belts with low flammable woody plants (deciduous trees)
2 thicket	2.1 drought	• optimization of stand density (maintaining a favourable stand climate)
	2.2 game	--> see above 1.1 and moreover other methods of individual game-proof protection
3 pole stage	3.1 drought	--> see above 2.1

	3.2 game	--> see above 1.1 and moreover other methods of individual game-proof protection
4 timber	4.1 drought (and subsequent bark beetle attack)	• frequent control of the stands • search for trees infested by bark beetles • bark beetle monitoring (visual controlling)
5 mature timber	5.1 drought (and subsequent bark beetle attack)	--> see above 4.1 and moreover initiation of the forest regeneration (transformation or conversion)
6 Dauerwald	6.1 drought	--> see above 1.2 and 2.1
	6.2 fire	--> see above 1.3

C) SILVICULTURE MEASURES

Management type	Mixed noble hardwood stands
Silvicultural system	Age class system
Vegetation zone	Colline – submontane
Target of growing stock	• 70% cherry, 30% other deciduous tree species • 70% (Sycamore, Norway maple, wild service tree), 30% other deciduous tree species
Production goal	Timber of high quality; target diameter: noble hardwood trees 60+ cm
Rotation period	wild cherry 40/(35 - 50)y maple sp. 80 y, wild service tree 80 - 120 y
Growth classes	**initial state - measures/action**
Regeneration	Natural regeneration Reforestation: normal spacing: maple sp., ash 3,500 –4,200 n/ha (2.0*1.2–1.4 m); wider spacing: maple sp., ash 1,100 – 1,600 n/ha (3.0*2.0 m; 6.0*1.5 m); cluster planting: maple sp., ash: 630 n/ha a 70 partial areas à 9 plants (1.4*1.4 m) Other deciduous trees: (hornbeam, lime, beech other trees: 300 – 750 n/ha (z. B.: 2.0*2.4–2.8 m)
young stands height < 2m (cleaning, tending)	weeding and/or cleaning; negative selection, release of wolfes bad quality trees; promoting admixed tree species;
Thicket Dbh < 10cm	weeding and/or cleaning: negative selection; artificial pruning in stands with wider spacing Transition to positive selection (stem number reduction in upper storey (3*3 m); mixture control; further pruning steps in case of wider spacing and/or unsatisfactory natural pruning

	pruning of stands with lower densities (oak below 5,000 n/ha; maple below approx. 3,000 n/ha;
pole stage	Future crop tree thinning
timber	Continue future crop tree thinning
timber/ mature	Natural regeneration: • group-selection cut

Management type	**Mixed noble hardwood stands**
Silvicultural system	Canopy Cover Forestry
Vegetation zone	(colline) - Submontane – (montane)
Target of growing stock	• 70% cherry, 30% other deciduous tree species • 70% (Sycamore, Norway, maple, wild service tree), 30% other deciduous tree species
Production goal	**Timber of high quality; target diameter: noble hardwood trees 60+ cm**
Growth classes	**initial state - measures/action**
pole stage/timber (20 – 40 cm)	use maximum self-thinning process; girdling, support quality trees, remove wolf trees; **structural thinning** Promote natural regeneration of beech and fir mainly in submontane region
timber/mature stand	**target diameter harvesting** • support for natural regeneration; • species composition can be modified • control of mixture and diameter distribution

7.10. European beech stands

A) RISK ASSESSMENT

RISK FACTOR/STAND DEVELOPMENT	REGENERATION/ YOUNG STANDS			THICKET			POLE STAGE			TIMBER			TIMBER/ MATURE			DAUERWALD PERMANENT TREE COVER		
	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M
Storm	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
Snow/ice/rime	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Drought	3	2	1	3	2	1	3	2	1	3	2	1	3	2	1	2	2	1
Fire	1	1	0	1	1	0	1	1	0	1	1	0	1	1	0	2	1	1
Bark beetles	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
Game	3	3	3	2	2	2	1	1	1	0	0	0	2	2	1	1	1	1

Vegetation zone: C – colline, S – submontane, M – mountane

SCALE: 0 – no risk... 3 – extreme high risk; – absent (see context with the previous table with current presence of stand tapes in CZ)

0	1	2	3	–

B) FOREST PROTECTION

European beech stand

stand development	relevant damage factor	measurement / action
1 regeneration/ young stands	1.1 game	**Controlling of game population and damage prevention** • controlling of population density, reduction of population density of overpopulated game • game-proof protection (fencing, browsing repellents, biotechnical protection – keeping no-target trees for browsing), increase of environment usability for game (e.g. planting of fruit trees)

	1.2 drought	**Respecting vegetation, soil and climate conditions** when establishing stand, planting of quality planting material, control and replacement of dead seedlings • autumn planting • optimization of weed control practices – only strip reduction (shading), reduction only if necessary (according to height and density of weed and weather condition) • maximum utilization of natural forest regeneration **Maintaining suitable air and soil moisture** • preservation of the remains of the mother stand – shade • use of pioneer woody plants – preparatory vegetation
	1.3 fire	**Effective fire control –** to identify the riskiest areas, early fire detection, barriers or firebreaks that may limit fire spread • control and reduction of dry hazardous material • in period with high risk (heat, drought, wind) frequent control of riskiest places in extremely risky areas creation of barriers for wildfire – firebreaks, fuel breaks, belts with low flammable woody plants (deciduous trees)
2 thicket	2.1 drought	• optimization of stand density (maintaining a favourable stand climate)
	2.2 game	--> see above 1.1 and moreover other methods of individual game-proof protection
3 pole stage	3.1 drought	--> see above 2.1
	3.2 game	--> see above 1.1 and moreover other methods of individual game-proof protection
4 timber	4.1 drought (and subsequent bark beetle attack)	• frequent control of the stands • search for trees infested by bark beetles • bark beetle monitoring (visual controlling)
5 mature timber	5.1 drought (and subsequent bark beetle attack)	--> see above 4.1 and moreover initiation of the forest regeneration (transformation or conversion)
	5.2 game	• controlling of population density, reduction of population density of overpopulated game • game-proof protection of beginning forest regeneration
6 Dauerwald	6.1 drought	--> see above 1.2 and 2.1
	6.2 fire	--> see above 1.3

C) SILVICULTURE MEASURES

Management type	**Beech stand**
Silvicultural system	Age class system
Vegetation zone	Submontane
Target of growing stock	90% beech; 10% other deciduous tree species
Production goal	Timber of high quality; target diameter: 60+ cm
Rotation period	100/ (90 - 110) y
Growth classes	**initial state - measures/action**
Regeneration	Natural regeneration Reforestation: Beech (1*1.3 m; 8,000 n/ha)
young stands	weeding and/or cleaning; beech: negative selection
Thicket	Beech: negative selection
pole stage	Future crop tree thinning
timber	Continue future crop tree thinning
timber/mature	Natural regeneration: • shelterwood cut/group-selection cut • target diameter harvesting

Management type	**Beech stand**
Silvicultural system	Continuous cover system (Dauerwald)
Vegetation zone	Submontane
Target of growing stock	90% beech; 10% other deciduous tree species
Production goal	Timber of high quality; target diameter: 60+ cm
Growth classes	**initial state - measures/action**
pole stage/timber (20 – 40 cm)	use maximum self-thinning process; girdling, support quality trees, remove wolf trees; **structural thinning**

timber/mature stand	**target diameter harvesting** • support for natural regeneration; • species composition can be modified • control of mixture and diameter distribution

7.11. Mixed European beech, larch, fir

A) RISK ASSESSMENT

RISK FACTOR/STAND DEVELOPMENT	REGENERATION/ YOUNG STANDS			THICKET			POLE STAGE			TIMBER			TIMBER/ MATURE			DAUERWALD PERMANENT TREE COVER		
	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M
Storm	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1
Snow/ice/rime	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Drought	3	2	1	3	2	1	3	2	1	3	2	1	3	2	1	2	2	1
Fire	1	1	0	1	1	0	1	1	0	1	1	0	1	1	0	2	1	1
Bark beetles	0	0	0	0	0	0	1	1	0	1	1	1	1	1	1	1	1	1
Game	3	3	3	3	3	3	2	2	2	0	0	0	1	1	1	1	1	1

Vegetation zone: C – colline, S – submontane, M – mountane

SCALE: 0 – no risk… 3 – extreme high risk; – absent (see context with the previous table with current presence of stand tapes in CZ)

0	1	2	3	–

B) FOREST PROTECTION

Mixed European beech, larch, fir

stand development	relevant damage factor	measurement / action
1 regeneration/ young stands	1.1 game	**Controlling of game population and damage prevention** • controlling of population density, reduction of population density of overpopulated game • game-proof protection (fencing, browsing repellents, biotechnical protection – keeping no-target trees for browsing), increase of environment usability for game (e.g. planting of fruit trees)
	1.2 drought	**Respecting vegetation, soil and climate conditions** when establishing stand, planting of quality planting material, control and replacement of dead seedlings • autumn planting • optimization of weed control practices – only strip reduction (shading), reduction only if necessary (according to height and density of weed and weather condition) • maximum utilization of natural forest regeneration **Maintaining suitable air and soil moisture** • preservation of the remains of the mother stand – shade • use of pioneer woody plants – preparatory vegetation
	1.3 fire	**Effective fire control –** to identify the riskiest areas, early fire detection, barriers or firebreaks that may limit fire spread • control and reduction of dry hazardous material • in period with high risk (heat, drought, wind) frequent control of riskiest places in extremely risky areas creation of barriers for wildfire – firebreaks, fuelbreaks, belts with low flammable woody plants (deciduous trees)
2 thicket	2.1 drought	• optimization of stand density (maintaining a favourable stand climate)
	2.2 game	--> see above 1.1 and moreover other methods of individual game-proof protection
3 pole stage	3.1 drought	--> see above 2.1

	3.2 game	--> see above 1.1 and moreover other methods of individual game-proof protection
4 timber	4.1 drought (and subsequent bark beetle attack)	• frequent control of the stands • search for trees infested by bark beetles • bark beetle monitoring (visual controlling)
5 mature timber	5.1 drought (and subsequent bark beetle attack)	--> see above 4.1 and moreover initiation of the forest regeneration (transformation or conversion)
	5.2 game	• controlling of population density, reduction of population density of overpopulated game • game-proof protection of beginning forest regeneration
6 Dauerwald	6.1 drought	--> see above 1.2 and 2.1
	6.2 fire	--> see above 1.3

C) SILVICULTURE MEASURES

Management type	Mixed European beech, larch, fir
Silvicultural system	Age class system
Vegetation zone	Submontane (montane)
Target of growing stock	• **50% beech, 50% fir** • **40% beech, 60% larch** • **30% beech, 40% larch, 30% fir**
Production goal	Timber of high quality; target diameter: spruce 45+ cm; beech 60+ cm, larch 60+ cm
Rotation period	**100/ (80 - 120) y**
Growth classes	**initial state - measures/action**
Regeneration	Natural regeneration Reforestation: normal spacing beech (1*1.3 m; 8,000 n/ha); larch (2*2.5m; 2.000 n/ha); fir (2*2m; 2500 n/ha)
young stands	weeding and/or cleaning;
Thicket	Beech: negative selection
pole stage	Future crop tree thinning

timber	Continue future crop tree thinning
timber/mature	Natural regeneration: • group-selection cut • target diameter harvesting

Management type	**Mixed European beech, larch, fir**
Silvicultural system	CFF
Vegetation zone	Submontane (montane)
Target of growing stock	• **50% beech, 50% fir** • **40% beech, 60% larch** • **30% beech, 40% larch, 30% fir**
Production goal	Timber of high quality; target diameter: spruce 45+ cm; beech 60+ cm, larch 60+ cm
Growth classes	**initial state - measures/action**
pole stage/timber (20 – 40 cm)	use maximum self-thinning process; girdling, support quality trees, remove wolf trees; **structural thinning**
timber/mature stand	**target diameter harvesting** • support for natural regeneration; • species composition can be modified • control of mixture and diameter distribution

7.12. Mixed pioneer tree species

A) RISK ASSESSMENT

RISK FACTOR/STAND DEVELOPMENT	REGENERATION/ YOUNG STANDS			THICKET			POLE STAGE			TIMBER			TIMBER/ MATURE			DAUERWALD PERMANENT TREE COVER		
	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M	C	S	M
Storm	0	0	0	0	0	0	1	1	1	2	2	2	2	2	2	–	–	–
Snow/ice/rime	1	1	1	3	3	3	2	2	2	2	2	2	2	2	2	–	–	–
Drought	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	–	–	–
Fire	1	1	0	1	1	0	1	1	0	1	1	0	1	1	0	–	–	–
Bark beetles	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	–	–	–
Game	2	2	2	2	2	2	1	1	1	1	1	1	1	1	1	–	–	–

Vegetation zone: C – colline, S – submontane, M – montane

SCALE: 0 – no risk… 3 – extreme high risk; – absent (see context with the previous table with current presence of stand tapes in CZ)

0	1	2	3	–

B) FOREST PROTECTION
Mixed pioneer tree species

stand development	relevant damage factor	measurement / action
1 regeneration/ young stands	1.1 game	**Controlling of game population and damage prevention** • controlling of population density, reduction of population density of overpopulated game • game-proof protection (fencing, browsing repellents, biotechnical protection – keeping no-target trees for browsing), increase of environment usability for game (e.g. planting of fruit trees)

2 thicket	2.1 drought	**Respecting vegetation, soil and climate conditions** when establishing stand, planting of quality planting material, control and replacement of dead seedlings • autumn planting • optimization of weed control practices – only strip reduction (shading), reduction only if necessary (according to height and density of weed and weather condition) • maximum utilization of natural forest regeneration **Maintaining suitable air and soil moisture** • preservation of the remains of the mother stand – shade • use of pioneer woody plants – preparatory vegetation
	2.2 game	--> see above 1.1 and moreover other methods of individual game-proof protection and game-proof protection of new planting or beginning forest regeneration (target successive species) during conversion
	2.3 storm and snow/ice/rime	• reduction of stand density • support of individual tree stability processing of damaged wood
3 pole stage	3.1 storm and snow/ice/rime	• reduction of stand density • support of individual tree stability • processing of damaged wood
	3.2 game	--> see above 2.2
4 timber	4.1 storm and snow/ice/rime	• timely logging (before the damage occurs)
	4.2 game	--> see above 2.2
	4.3 drought	• timely logging (before the damage occurs)
5 mature timber	5.1 storm and snow/ice/rime	--> see above 4.1
	5.2 game	--> see above 2.2
	5.3 drought	--> see above 4.3

C) SILVICULTURE MEASURES

Management type	**Mixed pioneer tree species**
Silvicultural system	Age class system
Vegetation zone	Colline – submontane
Target of growing stock	• **birch - poplar**
Production goal	Timber of high value: target diameter birch: 40 cm; poplar 50 cm
Rotation period	Birch 40/ (30 – 50) y, poplar 30/ (25-35)y
Growth classes	**initial state -** measures/action
Regeneration	Natural regeneration - natural regeneration (succession process) support for soil preparation; - artificial regeneration by seeding (birch) or planting (densities ranged from 2,000 – 4,0000 n/ha); support all long live admixture species in young pioneer stands.
young stands	weeding and/or cleaning; negative selection
Thicket dbh < 10cm	- negative clearing – remove wolf trees; - in dense stands regenerated naturally intensive clearing - reduced densities depending on the initial density close to 5.000 pcs/ha; support long live crown (about 50% of the height). positive selection; pruning
pole stage	Future crop tree thinning - select of high value (target) trees; - positive thinning – release target trees; - branching of target trees; removal understory in drought sensitive sites
timber	Continue future crop tree thinning - positive thinning – release target trees; underplanting of shade tolerate species.
timber/ mature	- underplanting of shade tolerate species; - shortening rotation period to 50 (60 years) prevents core rot; shelterwood felling or clear-cut felling.

Management type	**Mixed pioneer tree species**
Silvicultural system	CFF
Vegetation zone	Colline – submontane
Target of growing stock	• **birch** • **poplar**
Production goal	Timber of high value: target diameter birch: 40 cm; poplar 50 cm
pole stage/timber (20 – 40 cm)	use maximum self-thinning process; girdling, support quality trees, remove wolf trees; - support all long live admixture species in all stage; - differentiated clearing and thinning intensities; - positive thinning – release target trees; **structural thinning**
timber/mature stand	**target diameter harvesting** • support for natural regeneration; • species composition can be modified • control of mixture and diameter distribution - combine long and short rotation period in one stand; • combine regeneration methods.

8. Assessment and consequences of risk factors and associated challenges

8.1. Production and economic risks in Czech Republic

Factors involved in the implementation of the forest enterprise goals	Relation to change of production and risk (i - intensive, e - extensive)	Possibility of change (y - yes, n - no)
Habitat conditions affecting the increment and quality of wood (timber)	i	n
Representation of tree species	i	y
Age and spatial composition of forest tree stands	i	y
Quantity and quality of wood stocks on the stump	e	y
Limitations in the choice of forest production technologies	e	n
State of the forest transport and forest road network	e	y
Equipment with long-term tangible assets	e	y
Numbers of employees	e	y
Qualifications of employees	i	y
Work shifts	i	y
Transport distance of employees to the workplace	i	n
Current status of assets	e	y

Table 13: Structure and classification of the main factors of forest enterprise development in CZ

LOGGING AND TRANSPORT COSTS					
AVARAGE PERFORMANCE COSTS	FELLING	SKIDDING	TIMBER TRANSPORT	FULL COST (F+S)	FULL COST (F+S+T)
CZK/m^{-3}	210	233	185	443	628
EUR/ m^{-3}	8,75	9,71	7,71	18,46	24,17
FINANCIAL CONTRIBUTIONS TO ECOLOGICAL AND ENVIRONMENTALLY FRIENDLY TECHNOLOGIES					
TYPE OF CONTRIBUTION	SKYLINE SKIDDING	HORSE SKIDDING	IRON HORSE SKIDDING	FORWARDIND (max. 6000 kg/axle)	CRUSHING AND CHIPPING
CZK/m^{-3}	200	120	80	50	60
EUR/ m^{-3}	8,33	5	3,33	2,08	2,5
Share of full cost (F+S)	45,15%	27,09%	18,06%	11,29%	13,54%
Share of full cost (F+S+T)	31,85%	27,09%	18,06%	11,29%	13,54%

Table 14: Logging and transport cost and Contributions in CZ (relevant for years 2019, 2020)
Note: 1 EUR = 24 CZK

COSTS OF REFORESTATION AND MEASURES						
AVARAGE PERFORMANCE COSTS	REFORESTATI ON	SILVICULTUR AL MEASURES	FOREST PROTECTIO N	CLEANING	AVARAGE COST MEASURES (CZK/ha^{-1}(EUR/ha^{-1})of woods)	FULL COSTS OF ESTABLISHE D PLANTATIO N
CZK/ha^{-1}	100 800	12 200	400	14 700	3 500	237 500
EUR/ha^{-1}	4 200	508,3	16,7	612,5	145,8	9 895,8

FINANCIAL CONTRIBUTIONS TO REFORESTATION AND MEASURES						
TYPE OF CONTRIBUTION	NATURAL REGENERATION	ARTIFICIAL REGENERATION	SILVICULTURAL MEASURES	CLEANING	FENCING	ESTABLISHED forest stand
CZK/ha^{-1} EUR/ha^{-1}	25 000 1 041,7	78 000 3 250	16 000 666,7	10 000 416,7	28 000 1 166,7	50 000 2 083,3
Share of average performance costs	24,80%	77,38%	126,98%	68,03%	---	---
Share of full costs of established plantation	76,63%					

Table 15: Reforestation and measures cost and Contributions in CZ (relevant for years 2019, 2020) [Source: Ministry of agriculture, 2020]
Note: 1 EUR = 24 CZK

Information available at:
https://eagri.cz/public/web/mze/lesy/lesnictvi/zprava-o-stavu-lesa-a-lesniho
https://eagri.cz/public/web/mze/legislativa/pravni-predpisy-mze/tematicky-prehled

8.2. Risk and corporate structure (small, medium-sized, large companies) and institutions (especially public authorities) in Czech Republic

CATEGORY	FOREST AREA (ha)	SHARE OF THE AREA	AVERAGE SIZE OF OWNERSHIP (ha)	NUMBER OF OWNERS
State	1,417,324	53.24%	-	1
Legal entities	752,943	28.28%	56.03	13,439
Individuals	464,807	17.46%	1.34	346,345
Non-share ownership of spouse	27,315	1.03%	1.01	27,079
Total	2,662,389	100.01%	3.22*	386,863*
* all without a state				

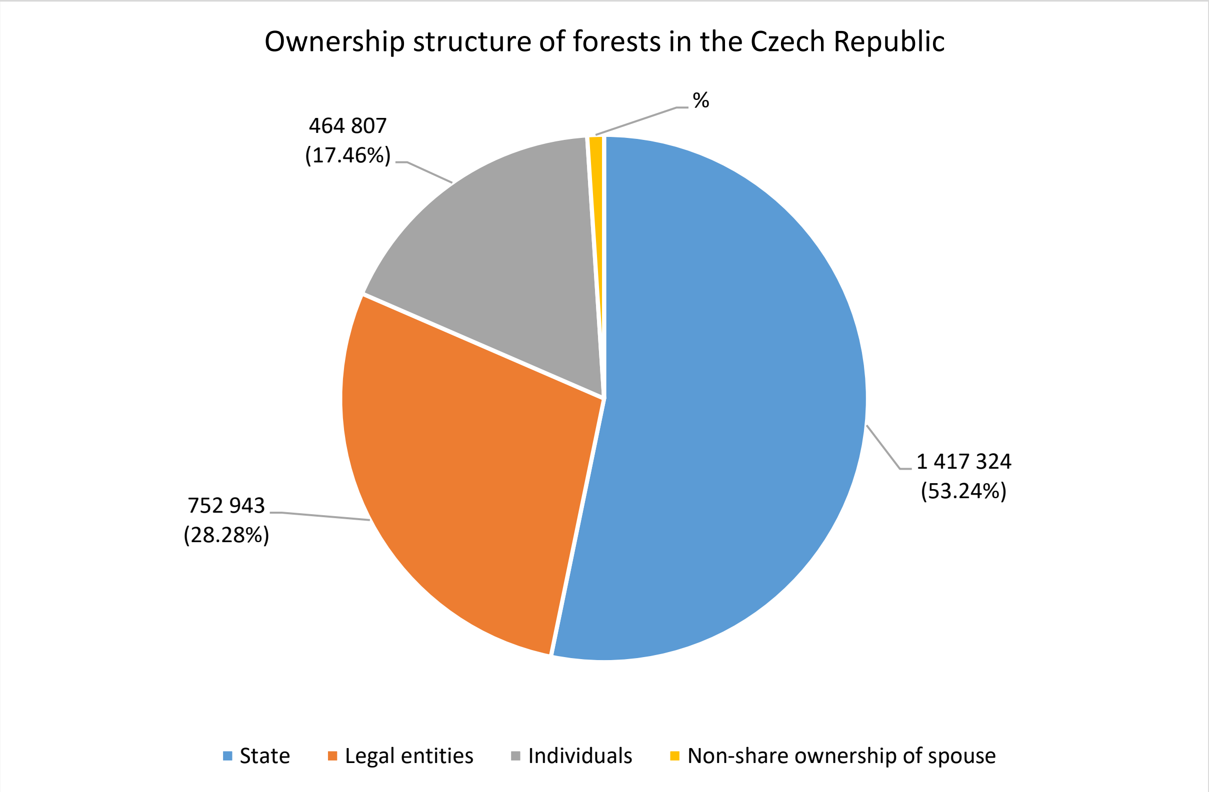

Figure 11: Ownership structure of forests in the Czech Republic
[Source: Ministry of agriculture, 2020]

CATEGORY without state forests	SHARE OF THE NUMBER <50 ha	SHARE OF THE NUMBER 50-250 ha	SHARE OF THE NUMBER >250 ha	TOTAL	SHARE OF AREA <50 ha	SHARE OF AREA 50-250 ha	SHARE OF AREA >250 ha	TOTAL
Municipalities	67.48%	25.67%	6.85%	100.00%	10.61%	32.89%	56.50%	100.00%
Church	92.22%	5.45%	2.33%	100.00%	6.43%	4.91%	88.66%	100.00%
Companies	96.88%	2.04%	1.08%	100.00%	13.58%	11.34%	75.08%	100.00%
Individuals	99.87%	0.10%	0.03%	100.00%	66.41%	8.07%	25.52%	100.00%

Table 16: Fragmentation of private forest ownership in CZ
[Source: Own illustration, Information available at: http://www.vlastnictvilesu.cz]

OWNERSHIP CATEGORY/RISK FACTOR-RATE	State	Municipalities			Church			Companies			Individuals		
Property size		<50ha	50-250ha	>250ha	<50ha	50-250ha	>250ha	<50ha	50-250ha	>250ha	<50ha	50-250ha	>250ha
Damage identification, reaction speed	1	3	2	1	3	1	1	3	1	1	3	2	1
Ensuring production capacities	2	2	2	2	2	2	1	2	2	1	3	2	1
Processing, sanitation	3	2	2	1	3	2	1	3	2	1	3	2	1
Warehousing, sales, logistics	2	2	2	1	3	2	0	3	2	0	3	2	0
Communication with the state administration, administration of applications	0	1	1	0	2	1	0	2	1	0	3	1	0
Creating financial reserves, economic stabilization of property	0	3	3	2	3	2	0	2	2	1	3	2	0

Table 17: Risk qualification according to the type of ownership and size of forest property in CZ

Information available at: http://svol.cz, members must log in: http://svol.cz/informace-clenum/
Information on professional forest managers available at: http://ckolh.cz , http://lesycr.cz/najdete-sveho-spravce/

SCALE: 0 – no risk; 1 – low risk; 3 – extreme high risk

0	1	2	3

OWNERSHIP CATEGORY/RISK FACTOR-RATE	State	Municipalities			Church			Companies			Individuals		
Property size		<50ha	50-250ha	>250ha	<50ha	50-250ha	>250ha	<50ha	50-250ha	>250ha	<50ha	50-250ha	>250ha
Possibilities of calamity wood storage	1	3	3	2	3	3	1	3	2	0	3	3	0
Possibility of sanitation of stored wood	1	3	3	2	3	3	1	3	2	1	3	3	1
Transport of calamity wood - road transport	1	3	2	1	3	2	1	3	1	1	3	2	1
Transport of calamity wood - railway transport	1	3	3	2	3	3	1	3	2	1	3	3	1
Order of railway wagons for timber transport	1	3	3	2	3	3	1	3	2	1	3	3	1
Possibilities of selling saw log	0	2	2	1	2	2	0	2	1	0	3	2	0
Possibilities of selling pulp wood	0	2	2	2	2	2	0	2	2	0	3	2	0

Table 18: Risk and logistics and market in CZ

Information available at: http://eagri.cz/public/web/mze/lesy/lesnictvi/ (Katalog ploch vhodných pro skladování dřeva – revise ploch ke dni 31. 1. 2021)
http://cdcargo.cz/cs_CZ/seznam-zeleznicnich-stanic

SCALE: 0 – no risk; 1 – low risk; 3 – extreme high risk

0	1	2	3

General consent of road managers II. and III. Class/county	weight to 48 t, width to 3.5 m, height to 4.5 m, length to 30 m	weight to 48 t, width to 4.5 m, height to 5.0 m, length to do 35 m	weight to 52 t, width to 2.8 m, height to 4.5 m, length to do 23 m
Středočeský kraj	approval	**approval up to a length of 30 m**	approval
***Jihomoravský kraj**	approval	**disapproval**	**disapproval**
***Jihočeský kraj**	approval	**disapproval**	**disapproval**
Pardubický kraj	approval	**disapproval**	**disapproval**
Královéhradecký kraj	approval	approval	**disapproval**
***Kraj Vysočina**	approval	**disaprrovals**	**disapproval**
Karlovarský kraj	approval	approval	**disapproval**
Liberecký kraj	**conditional approval only up to 21 t**	**disapproval**	**disapproval**
Olomoucký kraj	approval	approval	**disapproval**
Plzeňský kraj	approval	**disaprroval**	**disapproval**
Moravskoslezský kraj	approval	approval	**disapproval**
Ústecký kraj	**approval with the exception of the listed road sections**	**disapproval**	**disapproval**
Zlínský kraj	approval	approval	approval

Table 19: Permitting the transport of heavier or larger loads in CZ (*project area)

8.3. Information risks in Czech Republic

OWNERSHIP CATEGORY/RISK FACTOR-RATE	State	Municipalities			Church			Companies			Individuals		
Property size		<50ha	50-250ha	>250ha	<50ha	50-250ha	>250ha	<50ha	50-250ha	>250ha	<50ha	50-250ha	>250ha
Approach and knowledge of MGS	0	2	1	0	2	1	0	2	1	0	3	2	0
Knowledge of inclusion in a specific mode of management	0	2	1	0	3	1	0	2	1	0	3	2	0
Ability to apply a measure derogating from the provision	0	3	2	0	3	2	0	3	2	0	3	2	0

Table 20: Information risk in CZ

SCALE: 0 – no risk; 1 – low risk; 3 – extreme high risk

0	1	2	3

Measures of a general scope (MGS) (issued on 2 April 2020, File No. 17110/2020 MZE 16212 for an indefinite period), derogating from the provisions of § 29 para. 1, § 31 para. 6, § 32 para. 1 and § 33 para. 3 of Act No. 289/1995 Coll., On Forests and on Amendments to Certain Acts.

1. In forests in the territory of the Czech Republic, with the exception of forests in the territory of national parks and their protection zones
   1.1 stipulates that tree effected by bark beetle is not subject to the obligation of the forest owner to prefer incidental harvesting until 31 December 2022; the obligation of the forest owner to actively search for trees effected by bark beetle, to carry out their timely harvesting and effective sanitation is maintained;
   1.2 stipulates that clear cut created as a result of salvage cutting must be afforested within 5 years and forest stands secured within 10 years of its occurrence;
   1.3 stipulates that, in the period up to 31 December 2022, by way of afforestation from the provisions of Section 29 (1) of the Forest Act, forest reproductive material from any natural forest area and altitude may be used. This does not apply to afforestation with spruce reproductive material. Rules for the management of forest tree reproductive material pursuant to Act No. 149/2003 Coll. forest tree material), as amended, are not affected.
2. In forests in the region which consists of cadastral regions, which are listed in Annex No. 1 to this measure of a general scope, which is an integral part of it
   2.1 stipulates that the forest owner is not obliged to use traps and set traps trees as a defensive measure; the obligation of the forest owner to actively search for trees effected by bark beetle, carry out their timely harvesting and effective sanitation is maintained;
   2.2 for afforested calamitous clear cuts with a continuous area of more than 2 ha, unforested stripes up to 5 meters wide, clearing forms the edge of the forest, it is allowed to leave an unforested strip up to 5 meters wide to create a vegetation mantle;

2.3 it is stipulated that if the forest owner leaves an unforested strip or strips in accordance with point 2.2, these strips are considered to be forest-free and the area designated for afforestation within the clearing area may be reduced by their area.

Information available at: https://eagri.cz/public/web/mze/lesy/lesnictvi/pestovani-a-ochrana-lesu/kurovcova-kalamita/informace-k-oop1a2.html

8.4. Assessment and consequences of risk factors and associated challenges in Austria

Legal form	Area (ha)	Share in area (%)	Average size (ha)	Number of holdings
Natural persons	1,748,043	51.33%	13.68	127,814
of which Communities of spouse and close relatives	212,902		10.39	20,493
Partnerships	184,718	5.42%	34.60	5,339
Legal persons (excl. Austrian Federal Forests)	962,893	28.27%	155.68	6,185
Austrian Federal Forests	510,000	14.98%	510,000.00	1
Total	3,405,654	100.00%	20.78	139,339

Table 21: Number, cultivated hectares and average size of forestry farms by legal forms in AT [Sources: Statistics Austria: Farm Structure Survey 2016. Austrian Federal Forests. Homepage]

Legal form	Area (ha)	Share in area (%)	Average size (ha)	Number of holdings
Natural persons	1,748,043	51.33%	13.68	127,814

of which Communities of spouse and close relatives	212,902		10.39	20,493
Partnerships	184,718	5.42%	34.60	5,339
Legal persons (excl. Austrian Federal Forests)	962,893	28.27%	155.68	6,185
Austrian Federal Forests	510,000	14.98%	510,000.00	1
Total	3,405,654	100.00%	20.78	139,339

Table 21 shows that about 51 % of Austria's forest area is managed by natural persons with an average area of 13.7 hectares per holding.

Partnerships manage about 5 % of the total forest area and almost 35 hectares on average, which is notably larger than the average area managed by natural persons.

Legal persons (excluding the Austrian Federal Forests) manage about 28 % of the total forest area, corresponding to about 156 hectares per holding on average.

The Austrian Federal Forests manage around 510,000 hectares, or 15% of the total forest area.

The following Table 22 shows that of all legal forms considered, approx. 95 % of the holdings manage a forest area of less than 50 hectares, which accounts for 39 % of the total forest area.

Farms of 50 to less than 250 hectares amount to only 4.1 % of the total number of holdings; at the same time, they manage approx. 21 % of the forest area.

About 0.9 % of all farms (excluding Austrian Federal Forests) manage a forest area of more than 250 hectares per farm and almost 41 % of the total forest area. In this size class, holdings of the provinces and municipalities (12.7 %) and other legal entities (excluding Austrian Federal Forests) (11.7 %) represent the largest groups.

In terms of area, the natural persons managing less than 50 hectares account for approx. 57 %. Farms with a forest area of more than 250 hectares under the legal form of "natural person" have the share of around 20 %, but represent only 0.36 % of all farms of this legal form.

Size of holding (ha) / Legal form	Holdings <50 ha	Holdings 50-<250 ha	Holdings >=250 ha	Holdings total	Holdings <50 ha	Holdings 50-<250 ha	Holdings >=250 ha	Holdings total
	Share in total number of holdings (%)				Share in total forest area (%)			
Individuals	96.47%	3.17%	0.36%	100%	57.44%	22.69%	19.87%	100%
Partnerships	94.24%	4.02%	1.74%	100%	21.61%	13.72%	64.67%	100%
Municipalities	64.30%	22.98%	12.72%	100%	6.40%	15.82%	77.78%	100%
Public bodies (e.g. church, schools)	79.84%	12.18%	7.98%	100%	6.31%	6.44%	87.25%	100%
Other legal persons (excl. Austrian Federal Forests)	61.25%	27.05%	11.69%	100%	7.38%	22.53%	70.09%	100%
Total (except Austrian Federal Forests)	95.02%	4.10%	0.88%	100%	38.69%	20.41%	40.90%	100%

Table 22: Distribution of farms by size of holding, share in total forest area and selected legal form (excluding Austrian Federal Forests) in AT
[Source: Statistics Austria. Farm Structure Survey 2016. Own calculation.]

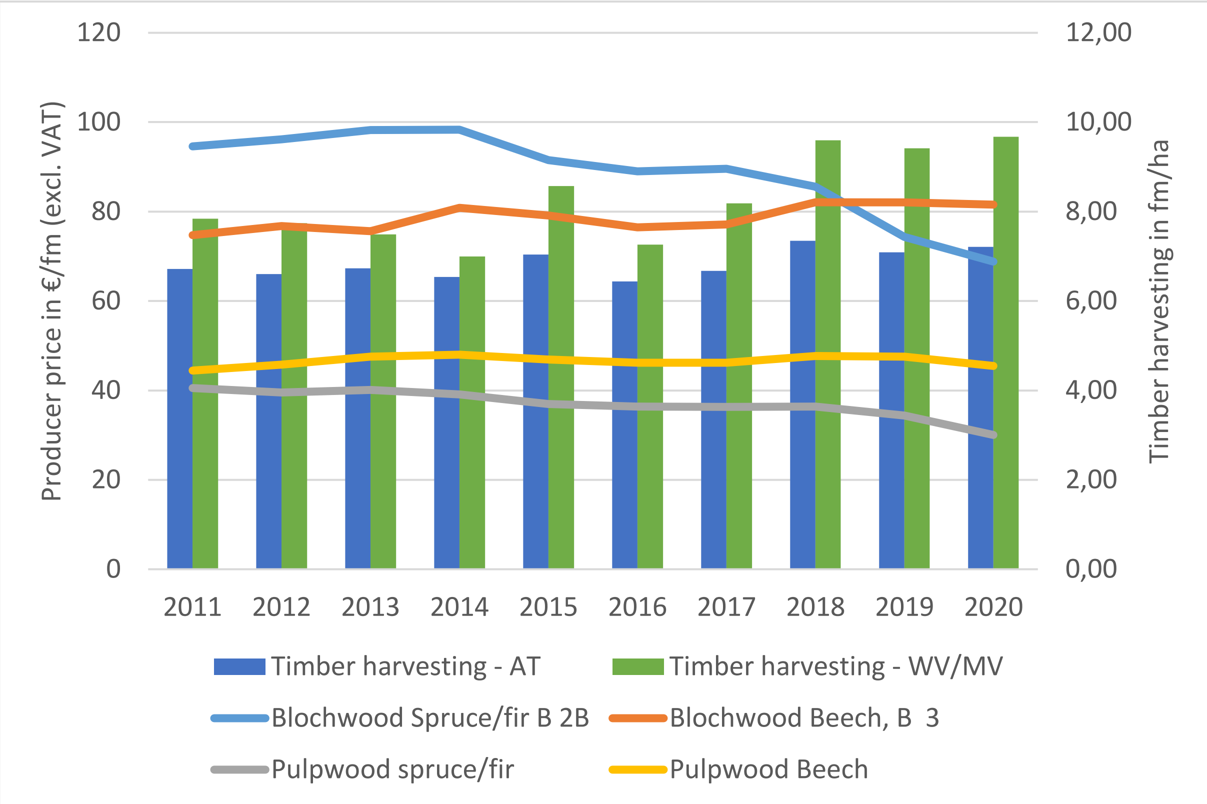

Figure 12: Timber harvest by region and timber prices from 2011 to 2020 in AT.
Notes: AT = Austria, WV = Waldviertel, MV = Mühlviertel
[Source: Statistics Austria: Producer prices. BMLRT. Kleinwalderhebung. Land&Forstbetriebe. Österreichischer Forstbericht. Own illustration.]

Figure 12 shows that, especially in the Waldviertel and Mühlviertel regions, timber harvesting has increased significantly starting in 2017 (from 7 to 8 fm in 2011 to 2016 up to about 9 to 10 fm in 2018 to 2020). At the same time, prices for logs and pulpwood, especially spruce and fir, have declined sharply.

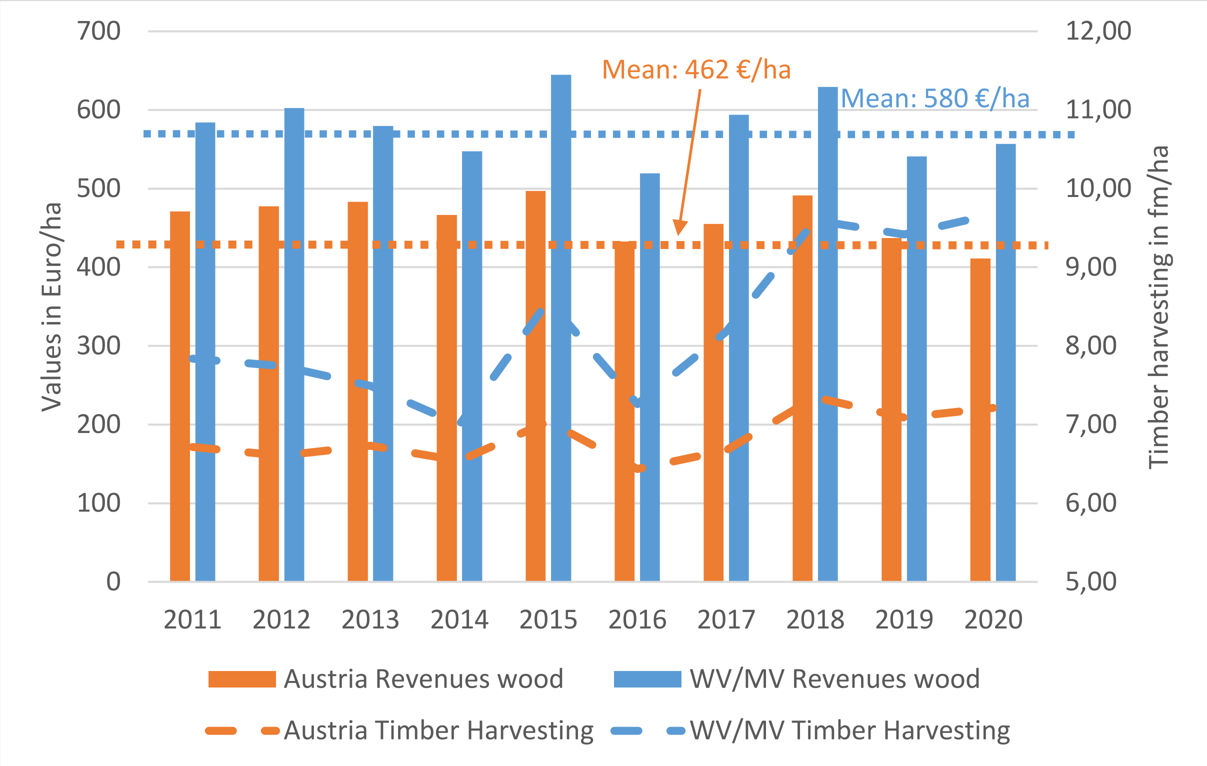

Figure 13: Timber harvesting and Timber revenue from 2011 to 2020 in AT.
[Source: Land&Forstbetriebe. Österreichischer Forstbericht. Own illustration.]

Figure 13 illustrates that timber revenues in 2019 and 2020 were below the long-term average of 580 euro per hectare and year, especially for the production area Wald- und Mühlviertel, despite the high logging. This is primarily due to the low price level for logs.

On average in Austria, an increase in logging was also observed with the year 2017, but less pronounced than in the Waldviertel and Mühlviertel. Timber revenues were below average in 2020 (mean value of the years 2011 to 2020: 462 euro per hectare).

Figure	**Unit**	**Small forest enterprises (< 200 ha)** [*)]	**Large-scale forest enterprises (> 500 ha)**	**Federal Austrian forests**
Timber revenue	€/fm	55.5	59.7	69.2
Timber harvesting costs	€/fm	47.3	27.6	47.2
Harvesting costs free revenue	**€/fm**	**8.2**	**32.1**	**22.0**
Silviculture Costs	€/fm	6.9	5.9	7.8

Table 23: Economic key figures by sizes of forestry (Mean of 2019 and 2020) in AT
*) Timber harvesting costs includes imputed wages for non-salaried employees
[Source: BMLRT. Kleinwalderhebung. Land&Forstbetriebe. Österreichischer Forstbericht. Own illustration.]

At 55 euro per solid cubic metre, small holdings (< 200 hectares) registered in the years 2019 and 2020 a notably lower timber revenue than the Austrian Federal Forests (69 euro per solid cubic metre).

	Figure	**Unit**	**Austria**	**Wald- und Mühlviertel**
	Timber harvesting	fm/ha	7.15	9.54
	Timber revenue	€/ha	418.1	533.4
-	Timber harvesting costs	€/ha	175.1	210.9
=	**Gross Margin I**	**€/ha**	**243.0**	**322.4**
+	Revenue skidding plants	€/ha	4.4	2.3
-	Costs skidding plants	€/ha	31.4	25.4
=	**Gross Margin II**	**€/ha**	**216.0**	**299.3**
+	Revenue 1. Production stage	€/ha	9.7	15.4
-	Costs Silviculture	€/ha	42.1	60.4
=	**Gross Margin III**	**€/ha**	**183.5**	**254.3**
+	Revenue buildings & equipment	€/ha	12.4	10.5
-	Costs buildings & equipment	€/ha	23.7	28.1
=	**Gross Margin IV**	**€/ha**	**172.2**	**236.8**
+	Other revenues	€/ha	3.2	5.8
-	Administration Costs	€/ha	104.5	131.6
=	**Gross Margin V**	**€/ha**	**70.9**	**111.0**

Table 24: Stepwise gross margin calculation for large forestry (> 500 ha) for Austria total and Wald- und Mühlviertel (Mean of years 2019 and 2020)
[Source: Land&Forstbetriebe. Österreichischer Forstbericht. Own illustration.]

	Figure	Unit	Austria	Wald- und Mühlviertel
	Timber harvesting	fm/ha	7.15	9.54
	Timber revenue	€/ha	418.1	533.4
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=	**Gross Margin I**	**€/ha**	**243.0**	**322.4**
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=	**Gross Margin IV**	**€/ha**	**172.2**	**236.8**
+	Other revenues	€/ha	3.2	5.8
-	Administration Costs	€/ha	104.5	131.6
=	**Gross Margin V**	**€/ha**	**70.9**	**111.0**

Table 24 shows the stepwise gross margin calculation for Austria as a whole and for the production area Wald- und Mühlviertel. In it. the large forest (over 500 ha forest area) is shown as an average for the years 2019 to 2020.

Based on a higher amount of timber logged in the Wald- und Mühlviertel, a higher timber revenue could be achieved compared to Austria.

Deducting the timber harvesting costs. a gross margin 1 of 243 euro per hectare and 322 euro per hectare remains for the Waldviertel and Mühlviertel. respectively.

Taking into account the other cost items. the remaining gross margin V is 71 euro for Austria as a whole and 111 euro per hectare for the Waldviertel and Mühlviertel.

8.5. Administration and legislation in CZ

Area	Measures (Area)	Judicature (document)

Calamity harvesting and forest condition - implementation of inspections by administrative authorities (CEI)	Requirement to perform forest condition control with the participation of the owner	Judgment of the Supreme Administrative Court of 13 November 2020. file no. No. 4 As 210/2018
		Judgment of the Municipal Court in Prague of 18 May 2020. File no. 6 A 112 / 2017-37
Use of public roads connected to the forest road network for the transport of calamity wood	Approval of exemptions from the maximum permissible weight and load limits	Resolution of the Supreme Court of the Czech Republic of 27 November 2008. file no. No. 22 Cdo 3429/2007
		Decision of the Supreme Administrative Court of 20.06.2019. file no. No. 6 As 19/2019
		Judgment of the Municipal Court in Prague of 05.12.2019. file no. stamp no. 10 A 43 / 2017-46
Restoration of the forest	Use of MGS (measures of a general scope) in imposing corrective measures by the CEI	Judgment of the Regional Court in Hradec Králové of 25 October 2017. file no. No. 52 A 6/2017

Table 25: Examples of deviating procedures from current legislation in CZ

9. Case studies excursion material

9.1. Šumava National Park (CZ)

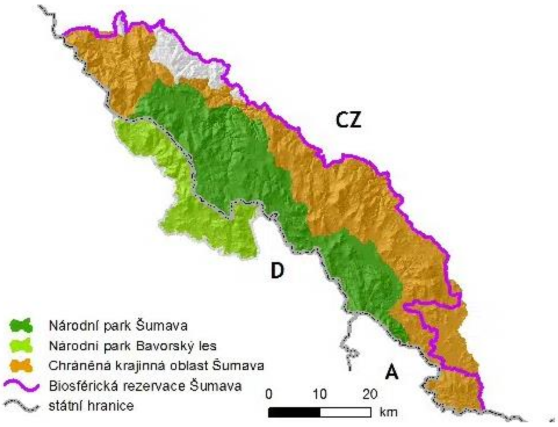


Figure 14: Map of National Park Šumava (dark green). Bavarian forest National Park (slight green). Protected Landscape Area (orange). Biosphere Reservation Šumava (violet border). state border (grey line). and target forest structure (on the right side).

Initial situation comes from unstable eve-aged monocultures of Norway spruce. which are sensitive to harmful effects caused by snow. ice. frost. wind. drought. insects. bark beetle overpopulation etc. As a **long-term goal** of all national parks is the gradual restoration of natural forest ecosystems. transformation of forest stands has been necessary. In Šumava National Park (ŠNP). stand transformations are carried out in areas with active restoration management (zones close-to-nature and concentrated management). The interventions influence the tree species composition. alter the stand structure. disrupt the forests of "age classes" model and also the management of even-aged stands.

These interventions are based on:

- Selection principles;
- The elements of the conversion from forests managed under systems involving coupes to those unmanaged;
- Nature-friendly forest management;
- The knowledge of variable density thinning (VDT).

Through these approaches. the biological diversity and ecological stability of forest ecosystems are enhanced. Originally. a forest managed under systems involving coupes is transformed into the forest with rich structure. thus creating conditions for long-term protection of ŠNP. This goal is the gradual improvement of the state of forest ecosystems and the gradual restoration of natural ecosystems. including the ensuring of an undisturbed course of natural processes in their natural dynamics.

The goals of stand transformation

1. To spatially differentiate forest stands;
2. To support natural ecological functions and biological diversity of the forest through targeted influence of the stand microclimate;
3. To create favourable conditions for continuous natural regeneration and its spontaneous selection;
4. To bring the tree species composition closer to the natural;
5. To limit the risk of extensive damage due to different interventions in the upper stand layers.
6. To gradually restore the natural ecosystems and ensure the uninterrupted flow of natural processes.

Reasons for transformation

Homogeneous forest stands

Forest stands in ŠNP intended for active restoration management are undergoing transformation. This concerns stands whose tree species composition and spatial structure often differ from potential stand types of the pertinent site. they are ecologically unstable and classified as distant and transitional. Many of these forest stands were influenced by man through his activity. including management under systems involving coupes. The consequences today. of this influence. are in the form of even-aged all-spruce stands. A number of them had come about within a short period as a result of artificial or combined regeneration on clear-cut areas because the previous stands had been damaged by wind (or secondary biotic factors). often even before these forests were declared ŠNP.

Support of biological diversity and prevention of disturbance

Especially young. homogeneous and spatially unstructured stands may present a risk of extensive disturbance in future if there is no intervention. Without the appropriate silvicultural treatment. there can arise dense stands with highly competitive crown and root storeys. where the risk of ecological and static instability of the stands (made up of individuals with disproportionate crowns. insufficiently developed root systems and unfavourable slenderness ratio) is high. Simultaneously. extensive. mainly spatially unstructured spruce stands. could reduce the diversity of forest ecosystems and limit the occurrence of species protected by ŠNP.

Transformation as a means of active restoration management

The transformation of forest stands. with the application of the selection principles. ecological forestry and variable density thinning. is the means via which it is possible to improve the condition of forest stands and support natural biological diversity. An important part of active restoration management is the transition from forests managed under systems involving coupes to those unmanaged. With regard to the high percentage of salvaged felling. these interventions are employed in the transformation of stands. Disturbances by wind and insects contribute to the preservation of natural structural elements of the ecosystem (biological heritage of the ecosystem). thanks to which windthrow structures. together with parts of biomass (stubs. fractures. wood intended for decomposition) are preserved. natural regeneration. standing trees and low-level plants are spared. Part of this transformation is the regulation of the numbers of and the appropriate care for deer.

Transformation tools

1. **Working plans (WP) based on operational inventory** – The silvicultural system is a selection system. the WP are drawn up according to the

methodology for forests with a richer structure. The basic planning units are the forest development type (FDT) and stand type (ST).

2. **Return period** – The optimal period of return (with an effective transformation) is 6 years (i.e. half the validity of the WP in ŠNP).
3. **Treatment blocks** – A forest with active restoration management is divided into blocks for planning and monitoring. maintaining return periods of 6 years with equal silvicultural treatment for the entire forest.
4. **Subdivision of forest stands** – Subdivision of extensive young spruce stands can reduce the risk of windbreaks and windfalls by inserting reinforcing forest belts.
5. **Reduction in the number of trees** – Uneven reduction on the number of tress initiates the growth of long and well-built crowns. it improves the slenderness ratio (to below 0.9) and stabilizes the stands.
6. **Positive selection** – This supports healthy. stable trees that create the skeleton of the stands and interspersed species. which are native to that site. including pioneer species (target trees). Sterile dead standing trees and den trees are left in the stands.
7. **Special-purpose selection** – In order to carry out species conversion. support heterogeneous spatial structure and biological diversity of forest stands. individual-to-group selection is performed. for example:
    a. **Structural special-purpose selection** – Target trees are supported by uneven positive selection in the upper stand layer and the intermediate and suppressed layers are left. After this intervention. the dispersion of the thicknesses of the trees increases. which gives rise to the successive differentiation of stands.
    b. **Special-purpose selection with varying intensity** – Intervention with a broad range of intensities creates a heterogeneous mosaic of stands. which simulates a structure of a heterogeneous forest with trees of all ages. These are tools aimed at increasing the stability of the stands. the variety of the species. and the biological values of younger stands which have been uniform and had been artificially established.
8. **Natural regeneration** – This is the most suitable means of species conversion and the preservation (and improvement) of genetic diversity of forest stands.

9. **Reduction in the number of deer** – Effective and efficient hunting of deer is a necessary part of stand transformation.
10. **Leaving trees to die** – Original species. besides spruce. are left to die. Dead standing trees and den trees are not removed from the stands because their presence increases the diversity.

9.2. Municipal Forests Volary (CZ)

Figure 15: Location of Municipal forest Volary (on the left) as a neighbour of ŠNP. First tending interventions to structuralize Norway spruce monocultures (in the middle picture) and initial transformation of mature forest stands to target structure (on the right side).

Initial situation: Since 1925. city Volary owned forest enterprise. Before. it was owned by old citizens of Volary. until 1810 by family of Schwarzenberg. Eggenberg and before them by Rudolf II. who bought it from the last Rosumberg Petr Vok.

Municipal enterprise was nationalized in 1951. The three fourth of historical enterprise located out of National park Šumava were returned back in June 1991. Forests located at National park were returned back to Volary in August 2000. The city Volary establish its own company to manage owned forest in1991 – Municipal Forest Volary (as a private limited company from1999).

Municipal Forests Volary have its own **target goals**:

- sustainable yield from owned enterprise
- maintenance and even improvement of health status of forest stands.

The way how to reach such goals MF Volary see in realization of **transformation of age-class forest to selection one.**
Resources to make easy that way are in:

- stabilized team of high-quality staff.
- operation with a high-tech and its early recovery.
- maintaining and improving of immovable as well as movable property.

Other activities
Beekeeping. Utilization of solar radiation.

Basic information about Forest Enterprise

- **Area of managed forest is 3333 ha.**
- **Forests are located from 620 to 1152 m a.s.l.**
- Annual average air temperature below 5 °C.
- **Annual amount of precipitation reaches ca 800 mm.**
- **Growing season duration ranging due to forest vegetation zones from 110 to 130 days.**
- **More than half of forest stands is influenced by water (periodically or permanently. peaty soils).**
- The dominant representative tree species are Norway spruce (72%). Scotch pine (8%). European beech (7%). White fire (4%). Dwarf pine (4%). Birch (2%). Tree species below 2% in representation are: larch. alder. sycamore. rowan. elm. ash. banks pine. Douglas fir. white pine.

More than one half of forest stand area is affected by water (gley. waterlogged. peat lands etc.) Middle-age forest stands established in years 1980 – 1990 are damaged by bark stripping from more than 70%.

Actual forest management plan is valid for: 2015 - 2024.
Maximal harvest: 346 926 m^3.
Minimal size of tending interventions in young forest stands (till 40 years): 653.51 ha.

From1992. several calamity events occurred in MF Volary.
Wind calamities:
- in1995. disturbed and processed 12 thousand m^3 of wood.
- in 2003. 14 thousand m^3.
- in 2007 (Kyril). 45 thousand m^3.
- in 2013. 24 thousand m^3. from these 6 thousand m^3 stay unprocessed at 1. zone of National Park Šumava.

Bark beetle calamity lasting from 2015 as a result of direct neighbourhood with intervention free zones of National park Šumava reached the volume of 40 thousand m^3 together from 2015 to 2020.
Frost calamity in 2014 - 3 thousand m^3 at elevation around 900 m a.s.l.

Necessary steps for forest transformation to „Dauerwald“ – permanently creative forest

- Forest personal must take the transformation idea as yourself.
- Harvest technology must reflect specific site conditions.
- Game population must be reduced to the ecological and management tolerable level.

Tools

- Making of permanent net of extraction tracks
- Long-term evidence and feedback of realised forest interventions.
- Diminishing of damages made by game with a use of hunting and forest protection.

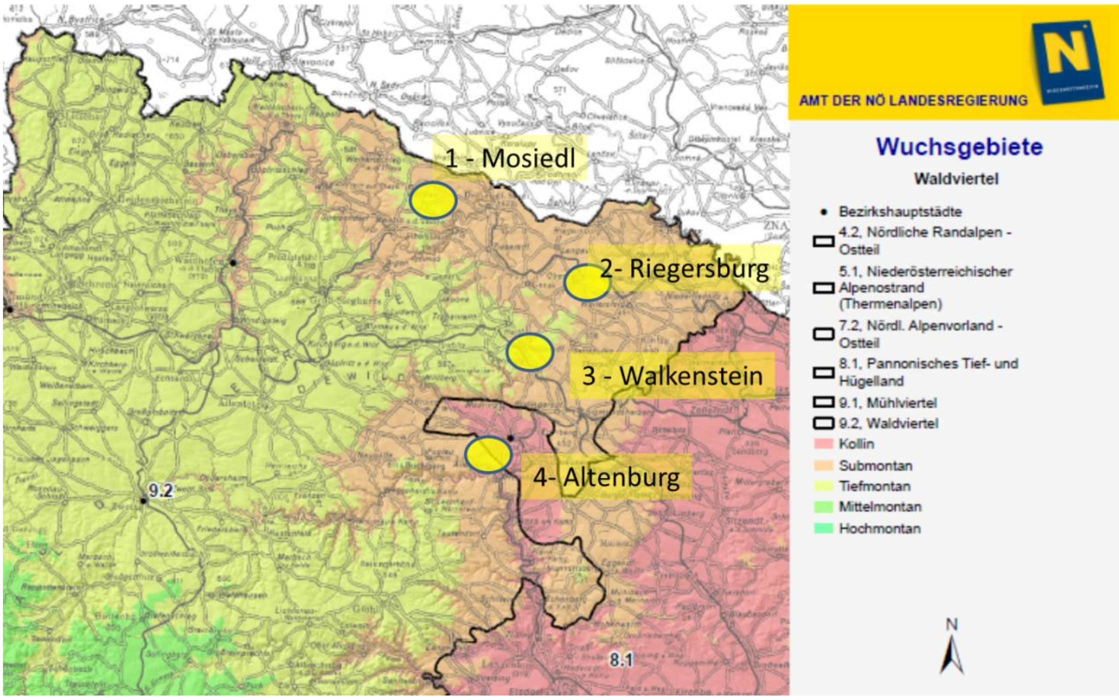
Feedback

- In total 740 of inventory points are located within forests to monitor wood increment. wood stock and health status of forest.
- Four experimental plots. with size of 1 ha of each for detail inventory of forest development after harvest intervention etc.. are established at different sites.

- Whole forest land area is affected by nature protection interests. which are limiting forest management by different ways.

9.3. Facts about the excursion area in Waldviertel (Austria)

9.3.1. Overview excursion area



- average annual precipitation per year: 450 - 700 mm
- average annual temperature: 7(8) - 10 °

9.3.2. Forest ecoregions

8.1. Pannonisches Tief- und Hügelland

altitudinal zones: colline-planar ~100 - 350(400)m; submontane (150) 350 -500 m

kollin-planar: Quercetum petraeae – cerris; Carpinetum (oak-hornbeam forests)

submontan: Fagetum ((beech, oak)

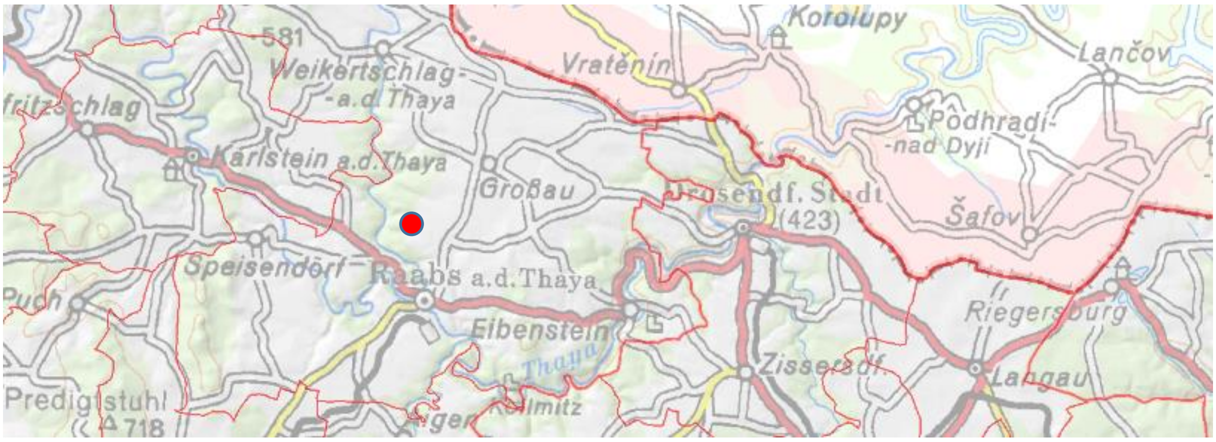
9.2 Waldviertel

altitudinal zones: colline (200 – 300 (350)m; submontane (200) 300 -500 (650) m

kollin: Carpinetum (oak-hornbeam forests); scots pine-oak forests submontane: Fagetum (beech; fir, oak, (spruce)).

9.3.3. Excursion point 1: Modsiedl, family-farm Fischer

- **Modsiedl, family-farm Fischer**



Franz Fischer, 3820 Zemmendorf 1, farmer and forester

President of the Forest-Owner Association of Lower Austria with more than 6500 members

Whole Farm: 80 hectares

Forest area : 35 hectares

- 400-500 m above sea level
- tree species composition: 80% Norway spruce, 15% Scotch pine, 5% other species) on 25 different stands/forest parcels
- damaged forest area since 2015: 18 ha spruce, 1 ha pine, total irregular cuttings 6000 m³

Forest owner structure

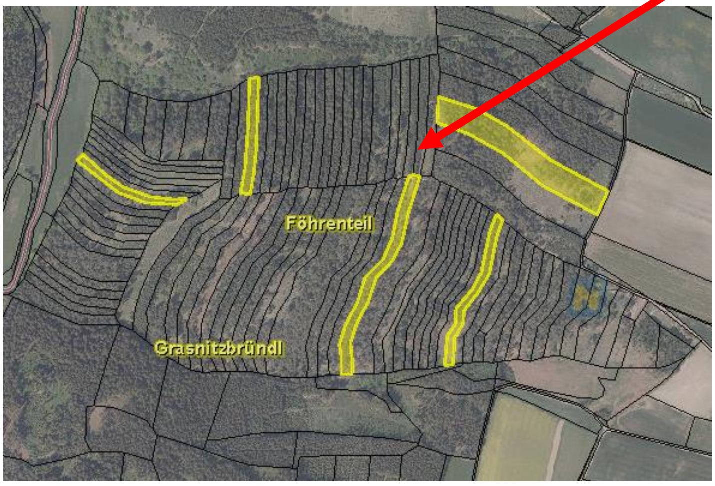
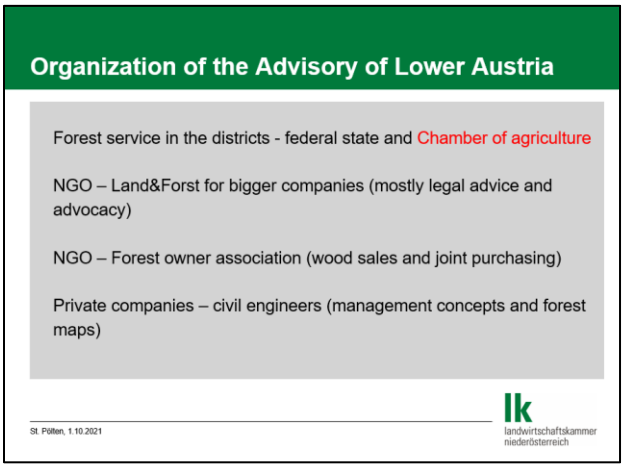
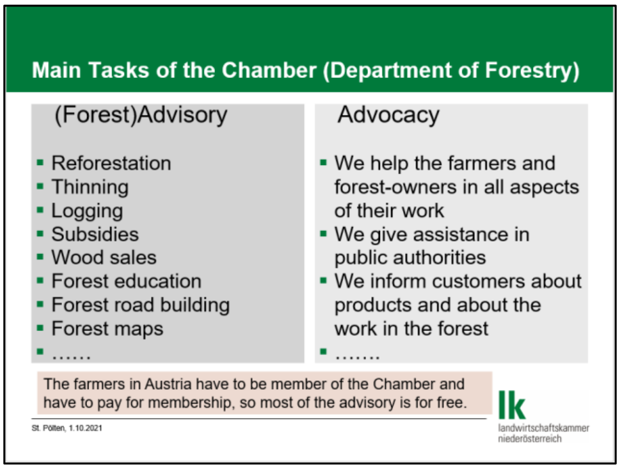
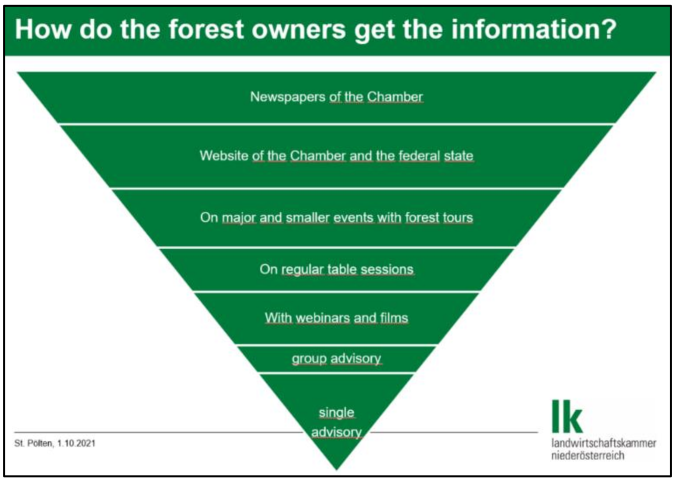


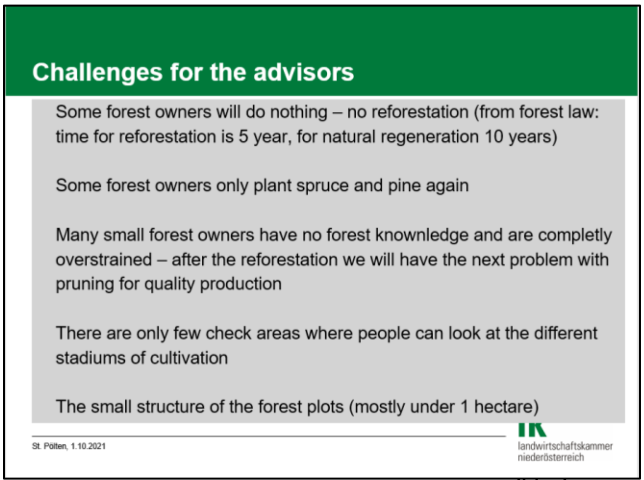
Figure 16: Structure of the forest plots, small plots of one owner, 17 x 330 m

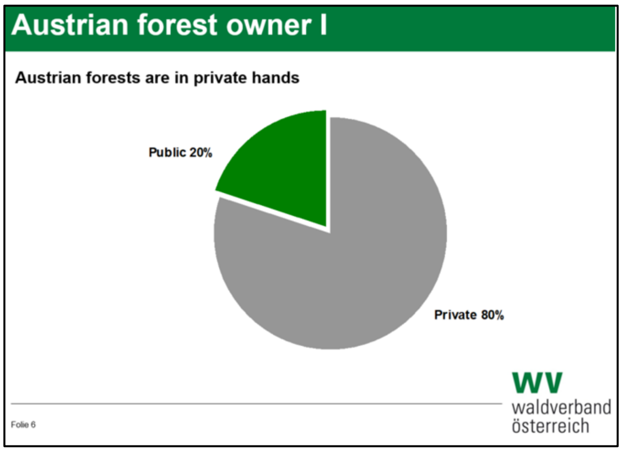
Basics about Chamber of Agriculture in Lower Austria

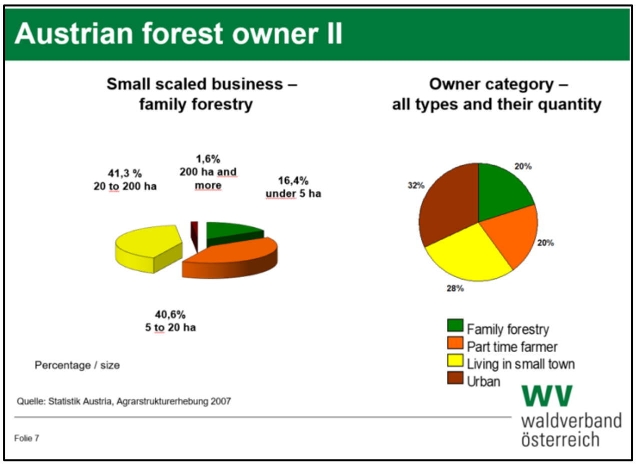


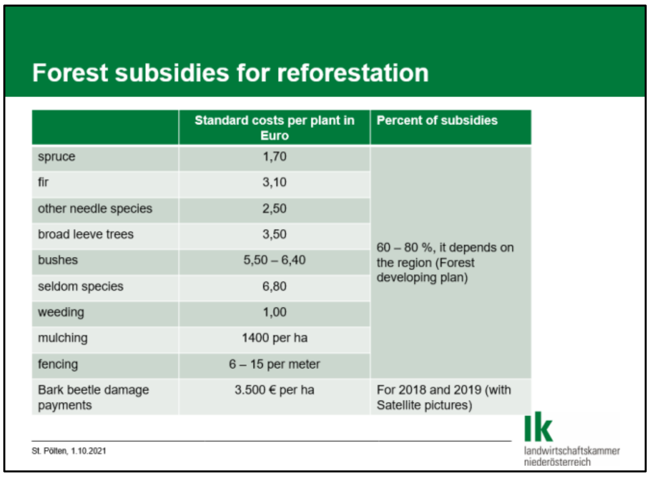











Forest subsidies for reforestation

	Standard costs per plant in Euro	Percent of subsidies
spruce	1,70	60 – 80 %, it depends on the region (Forest developing plan)
fir	3,10	
other needle species	2,50	
broad leeve trees	3,50	
bushes	5,50 – 6,40	
seldom species	6,80	
weeding	1,00	
mulching	1400 per ha	
fencing	6 – 15 per meter	
Bark beetle damage payments	3.500 € per ha	For 2018 and 2019 (with Satellite pictures)

St. Pölten, 1.10.2021
lk landwirtschaftskammer niederösterreich

Site types and mapping (2003), KG Modsiedl

KG Modsiedl with about 350 ha (about 500 m above sea level): in cooperation with the Federal Forest Research Institute in Vienna.

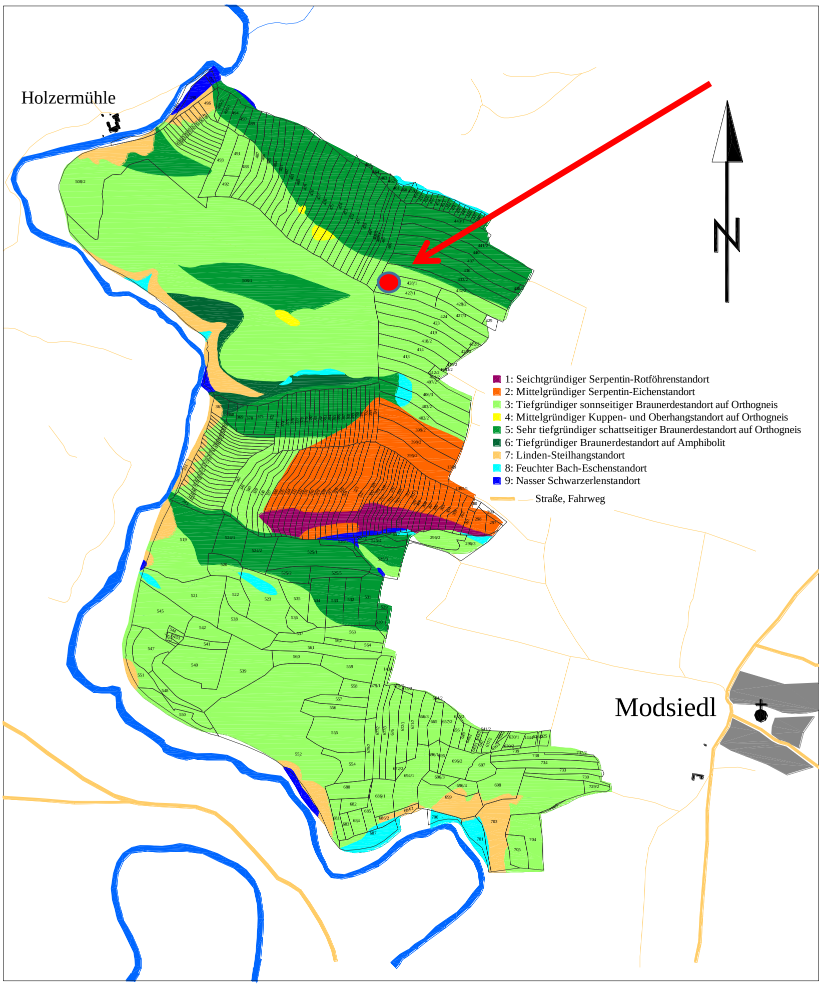


Figure 17: light green – fresh, deep brown earth, south exposition, on Orthogneiss, soil type: sandy loam to loamy sand, water capacity good, pH between 4 and 5

Tree species choice (recommendations)

One result of the site mapping was a visualization of the possibilities of tree species for the different sites in form of a traffic light table

Site	Spruce	Pine	Oak	Beech	Ash	Linden	Black alder	Fir	Larch	Douglas fir	Mountain maple	Common maple	Plane maple	Cherry	Hornbeam	Birch
1	orange	green	orange	orange	red	orange	red	orange	orange	orange	red	orange	red	red	red	
2	orange	green	green	orange	red	green	red	orange	orange	orange	orange	green	orange	red	green	
3	orange	orange	green	green	orange	green	orange	orange	orange	orange	orange	green	green	orange	green	
4	orange	green	green	orange	red	orange	red	red	orange	orange	orange	orange	orange	red	orange	green
5	orange	orange	green	green	orange	green	orange	green	orange	orange	green	orange	green	orange	green	green
6	orange	orange	green	green	green	green	orange	orange	orange	orange	green	green	green	green	green	
7	red	orange	green	green	green	green	red	orange	orange	red	green	green	green	orange	green	green
8	red	red	green	red	green	orange	green	orange	red	red	green	red	orange	orange	orange	orange
9	red	red	orange	red	green	red	green	red	red	red	orange	red	red	red	orange	orange

Table 26: Tree species recommendations
[Green: well-suited, orange: suitable, Red: not suitable]

Excursion stands

Forest stand 1 : KG Modsiedl , GNR: 428/1 - 0,66 ha (33 x 200 meter)

Site type (light green): fresh, deep brown soil (sandy loam to loamy sand) on Orthogneis, south exposition, water capacity good, pH between 4 and 5.

reforestation: tree species composition and spacing: 30 % spruce, 15 % fir, 25 % mountain maple (2,5 x 2,5 m), 30 % oak (2,5 x 1,25 m)

forest owners made common fencing

subsidies (Waldfonds): 60 % of standard costs

Forest stand 2 (age: 20 y)

natural succession: pioneer crop dominated by poplar, willow and birch, admixed oak, spruce, pine; canopy cover and the tree species fulfill the requirements of the Austrian Forest Act

9.3.4. Excursion point 2 - State Forest (ÖBF AG) in Riegersburg

Forstbetrieb Waldviertel-Voralpen (Bernhard Funcke)

Forest area 37.300 ha; annual cutting volume 162.000 m³

Forstrevier Droß (Martin Schönsgibl)

Revierteil Riegersburg (1.100 ha)

- **damaged area since 2015: 140 ha (severe drought; bark beetle)**

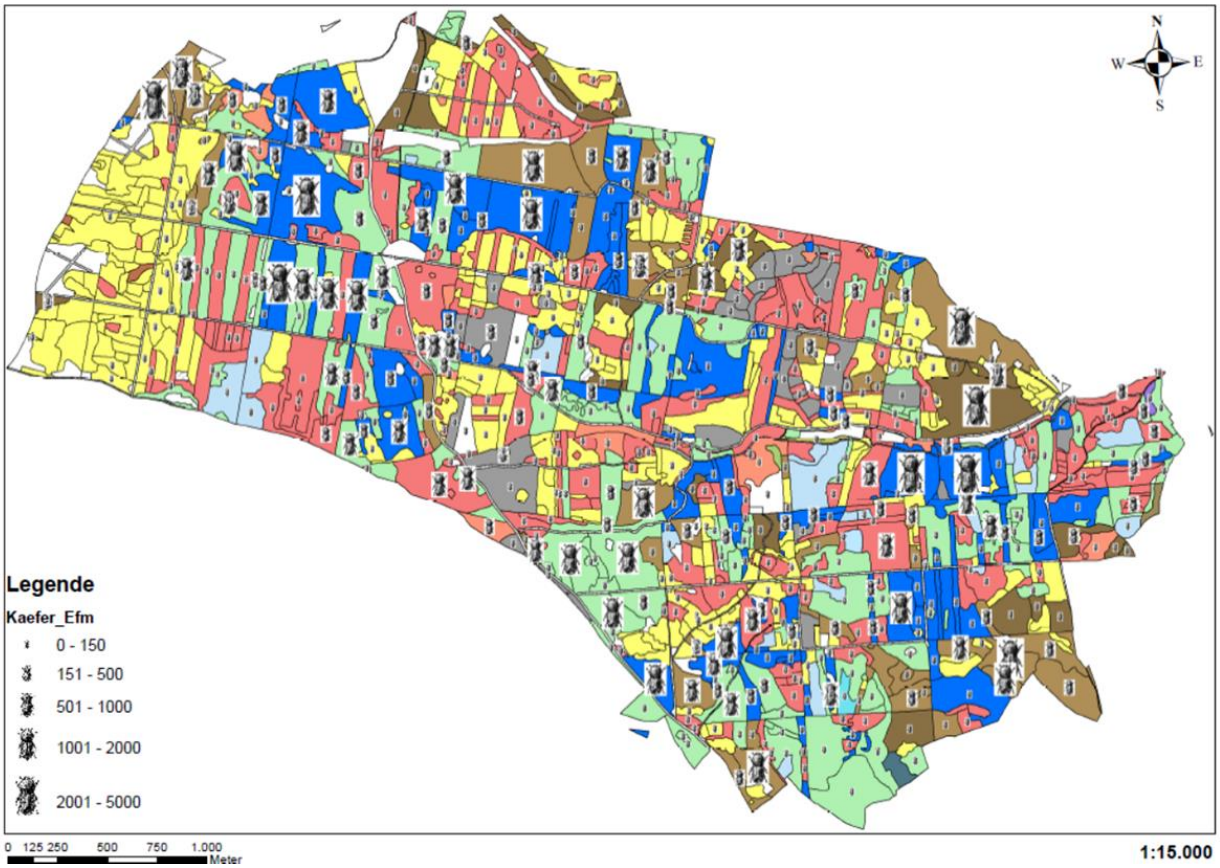


Figure 18: Forest map (age class; amount of damaged volume)

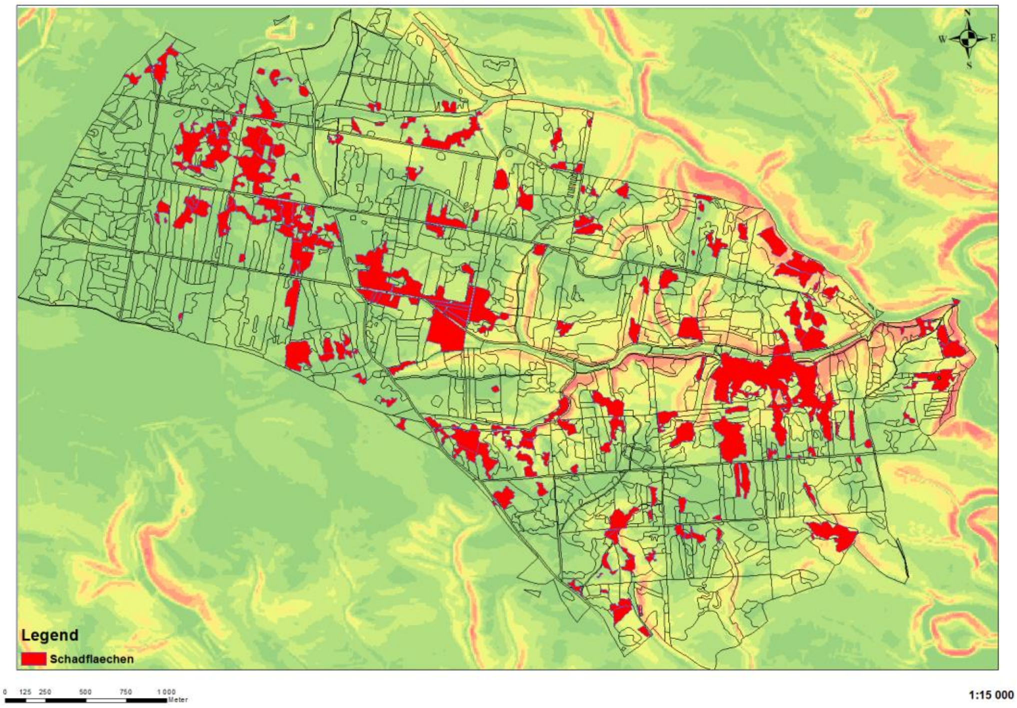


Figure 19: Damaged area of bak beetle (2106 – 2019

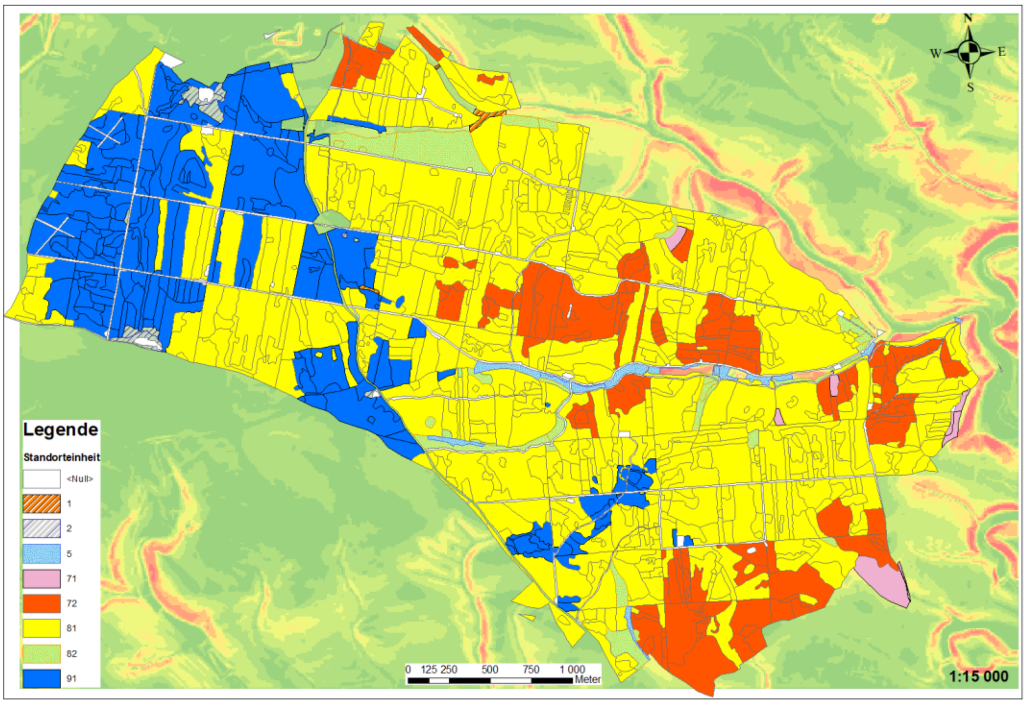
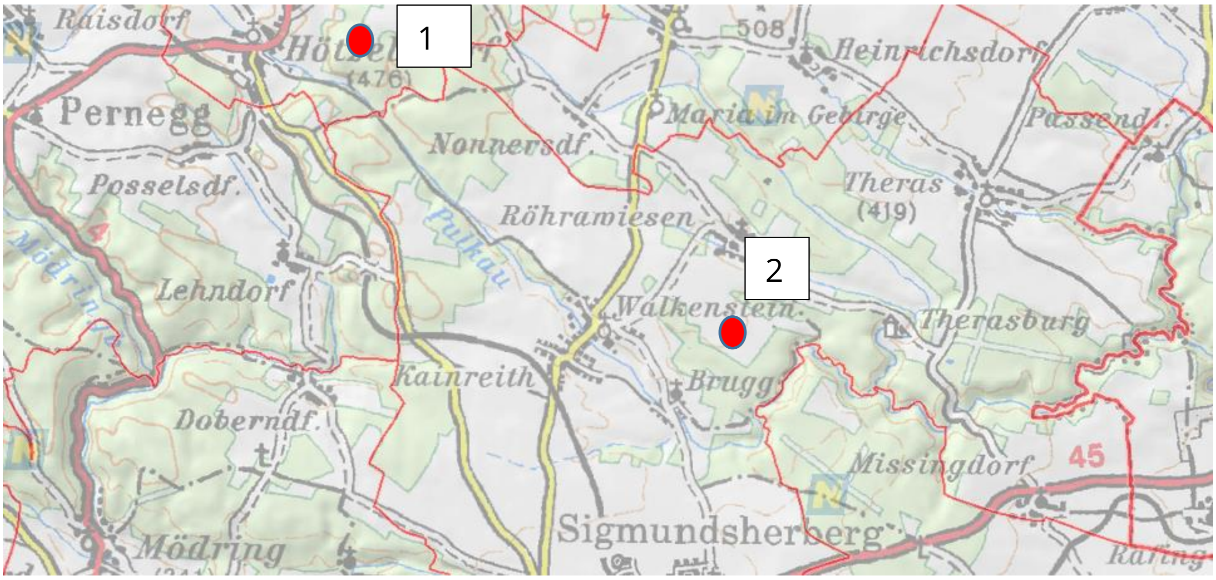


Figure 20: Site types and mapping

9.3.5. Excursion point 3: Walkenstein, family-farm Hofer



Herbert and Christoph Hofer, 3952 Röhrawiesen 7, farmer and forester

Chairman of the district Horn Chamber of Agriculture (representative of the farmers in Horn)

Whole Farm: 128 hectares

organic production of different agricultural crops

Christmas tree plantations

Forest: 54 hectares (36 stands/forest parcels)

- tree species compostion: 24% spruce, 19% scots pine, 21% fir, 14% oak, 6% larch, 8% douglas fir, 8% other broad-leave trees (beech, ash, maple, cherry]
- Damages 2015: 6,5 ha spruce, 3,5 ha pine, 0,5 ha fir; irregular cutting volume 1600 m³

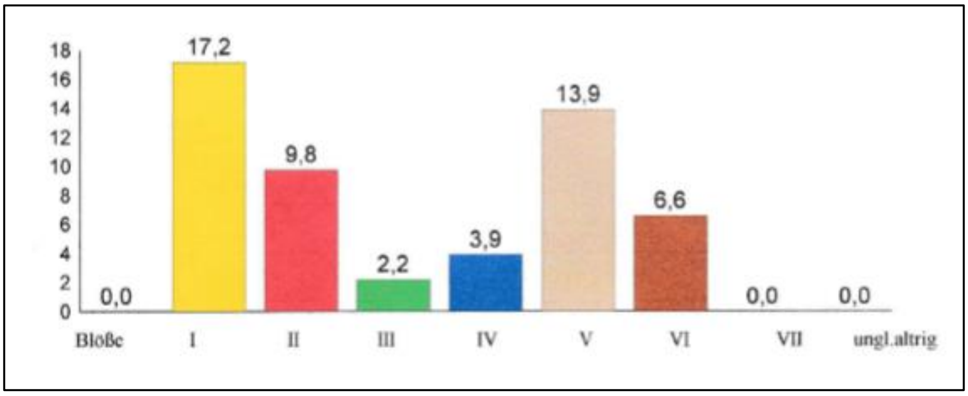


Figure 21: Age class structure (ha)

<u>Forest stand 1:</u>

Site characteristic: 530 m sea level; site type: pseudogley with loamy sand to sandy loam, deeper with loamy clay
Reforestation: partial area planting (spacing 14*14m; **small group: (nest):** 25 oaks in 1.5 x 1.5 m;, total 1000 oaks per ha), spruce 2.0 x 2.0 m; protected against browsing with wooden boards; competition of Calamagrostis grass
advantage to normal spacing [2.0 x 1.0 m, only 1/5 of oak-plants are needed]

<u>Forest stand 2</u> (age 40 y)

Site characeteristic: 450 m sea level; leached brown soils with silt loam, pH from 4-5, high water capacity
100 % douglas fir, mean height 24 m, dbh up to 45 cm, yield class 14;
plus-trees are pruned;
thinning acitivities are planned in short term
some damages from Pityogenes chalcographus mostly on unfavorable sites

9.3.6. Excursion point 4: Monastery of Altenburg

Manager (Betriebsleiter): FD Ing. Herbert Schmid

Forest area: 2800 ha (800 ha Natura2000) - 2 forest districts: Altenburg, Wildberg; 260 und 600 m a.s.l.

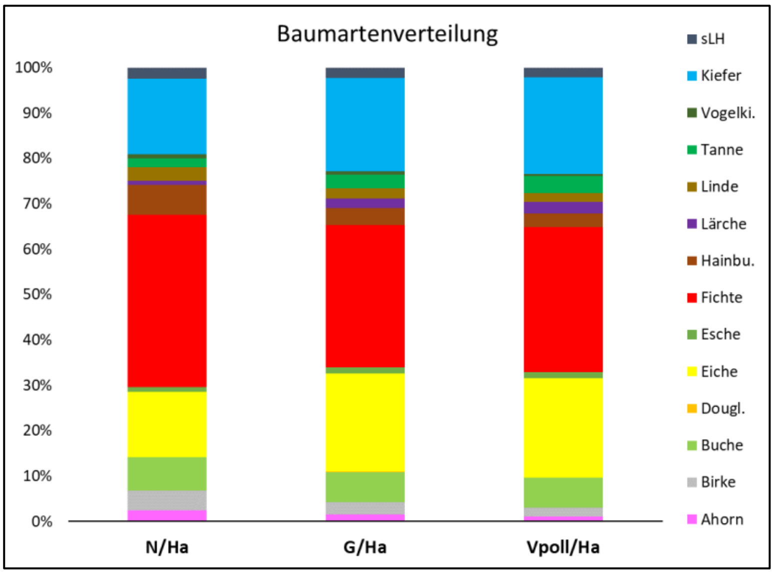


Figure 22: Tree species composition (stand; dbh >=8cm)

- damaged area since 2015: 240 ha (snow breakage; bark beetle)
- age class I: about 340 ha (young growth stand; thicket)

➢ **Forest conversion strategy: natural succession (regeneration)**

Young stand characteristic (stem number per ha; tree species composition)

young growth stand and thicket:14.765 n/ha (sx%= +-7,8 %)
thicket :450 n/ha (sx%= +- 9,5 %)

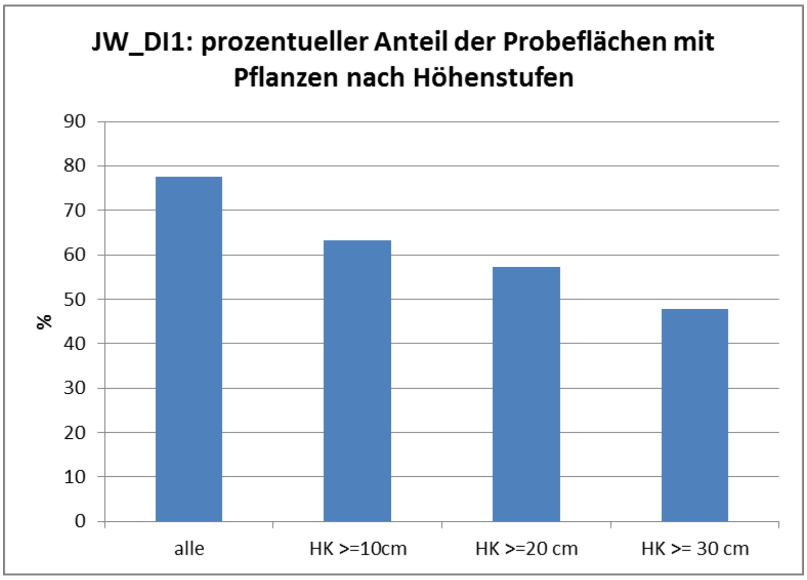


Figure 23: Relative frequency (in %) of sample plots with young trees over height classes

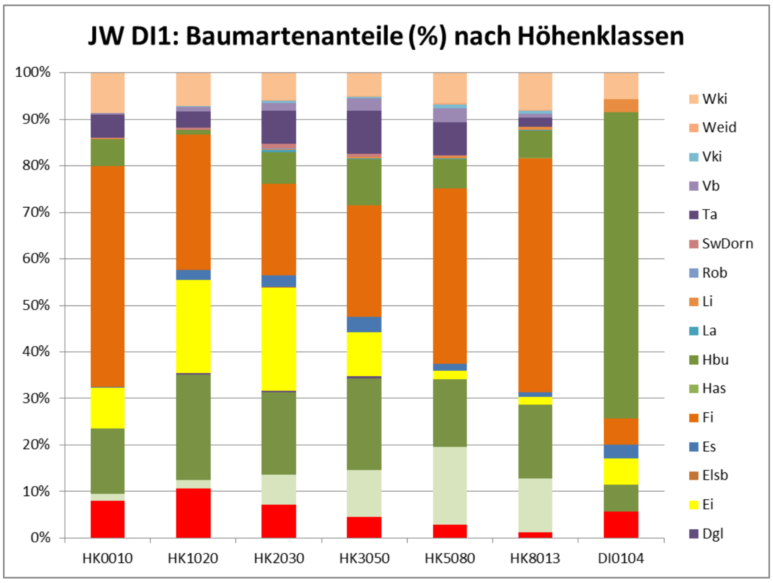


Figure 24: Tree species composition over height classes

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