Mendel University in Brno

Faculty of Forestry and Wood Technology

Silviculture

(Instruction and supporting material for practise)

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INVESTICE DO ROZVOJE VZDĚLÁVÁNÍ

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European Forestry

Brief overview of world forests

Forests cover about the one third of the total land area. Thus, total forest area is close to 4 billion hectares. The ten most forest-rich countries account for two-thirds of total forest area (Russia, Brazil, Canada, USA, China, Australia, Democratic Republic of the Congo, Indonesia, Peru, India). Global forests per continents cover: 25.3 % in Europe (with Russia), 21.0 % in South America, 17.1 % in North America, 16.1 % in Africa, 14.5 % in Asia, 5.2 % in Oceania and 0.8% in Central America and Caribbean.

Unfortunately, total forest area continuously decrease. Deforestation, mainly conversion of forests to agricultural land, continues at an alarmingly high rate – about 13 million hectares per year. At the same time, forest planting, landscape restoration and natural expansion of forests have significantly reduced the net loss of forest area. The biggest loss is observed in the South America, Africa, after that in North and Central America and Oceania. Asia shows during the last years increase in forest area, mainly due to afforestation actions in China (western part of Asia still shows a loss). Therefore, net exchange in forest area was estimated at -7.3 million hectares per year. Similarly to Asia, forest areas in the Europe continuously expanded.

Not only economical profit or different land use to full fill society demands, but also forest disturbances leads to deforestations. About 104 million hectares of forest are reported to be significantly affected each year by forest fires, pests (insects and disease) or climatic events such as drought, wind, snow, ice and floods (*see* actual FAO reports).

Ecological stability of forests (predisposition to forest disintegration and dysfunction) highly depends on its type, or by other words, on its affection by human, as natural forest can be presumed close to equilibrium or high stability due to long time adaptation to local site condition including both the biotic and abiotic factors. In these consequences, primary forests create about 36.4 %, modified natural forest 52.7 %, semi-natural forests 7.1 %, productive forest plantation 3.0 % and protective forest plantation 0.8 %.

Forest low as well as forest management is vice versa subordinated by forest ownerships (ca 84% of the world's forests is public owned – but private ownership is increasing). About 11% (around 96 mill. ha) of the world's forests are under of some type of protection (mostly designated for the conservation of biological diversity). About 30% of forests are used primarily for production of wood and non-wood forest products. Global wood removals were forecast to amount ca 3 billion m3. While Asia reported a decrease in wood removals in recent years, Africa reported a steady increase. It is estimated that nearly half of the removed wood was fuel-wood. The value of wood removals is decreasing, while the value of Non-Wood Forest Products is increasing. About 9% (above 300 mil. ha) of forests are designated for soil and water conservation. Protective functions of forests range from soil and water conservation and avalanche control to sand-dune stabilization, desertification control and coastal protection. Use of forests for recreation and education is increasing – but it is difficult to quantify them.

Some 10 million people are employed in forest conservation and management activities.

Forests in Europe

As mentioned above, forest resources in Europe are likely to continue expanding. Fellings will probably remain below increment, and the provision of environmental services will continue as a primary concern, especially in Western Europe. Rules and regulation in this regard will make wood production less competitive in comparison with other regions.

Forest management will continue to serve a wide variety of demands. Economic viability is likely to remain a challenge, especially for small-scale forest owners, but the increased demand for woodfuel could change this. While the forest industry, especially in Western Europe, may continue to lose competitiveness against other regions in labour-intensive segments, it is likely to retain leadership in the production of technologically advanced products, with much of the forest industry shifting to the production of "green" products.

Within the region, the differences in forestry between Eastern and Western Europe are likely to diminish as Eastern Europe catches up (Fig. 1, 2). The impacts of recent development in Russian Federation and in promoting wood energy are difficult to predict, and at present are mainly addressed for the short term.

Fig. 1. Sub-regionalization of forests in Europe.

Fig. 2. Extend of forests and wood land across Europe.

This textbook brings the examples of silviculture (similarly structured) in chosen countries, which belongs to Eastern or Western Europe (Fig. 1) to identify what are the differences as an instruction for seminar work.

Silviculture in the Czech Republic (East Europe)

Content:

1. History of silviculture in the Czech Republic

1.1. Forests development in the Central Europe

The current form of the Central European forests is strongly affected by long-term human activities, which permanently settled as farmers already in the 4th millennium B.C in the Czech basin. Their presence, however, was still a long time for the overall development of forests irrelevant, only affecting their local area, rather than species composition.

If humans would not act on forests, they would look roughly the same today as 3000 years ago (i.e. around 1000 BC). In this age, the climate has been stabilized, which in its essential characteristics unchanged until today, and depending on it were forest stabilized and formed.

This undisturbed evolution ended in Central Europe in the 7th century A.D., when were greatly intensified agricultural activities of man, and which gradually caused many changes in the size and structure of forests. However, the development of vegetation, which is now called forests, began much earlier, about 12 000 years ago, after the end of the last ice age and glaciers retreat to the north when the climate began to warm.

Although the use of pollen analysis, which can reconstruct fairly accurately the natural species composition of our forests from the period 3000 years ago, it would be a mistake to believe that it is sufficient only to restore the original, or close to nature state of forests. Just the simple fact, that in the Czech basin live about 1000 times more people than the was the number of people of previous (Unětická) culture, it is clear that this isn’t possible, because this demographic shift, accompanied by intense processes of civilization, brought lasting permanent changes.

The Paleobotany offers interesting stories about individual trees travels. Based on pollen analysis indicated how its place in the forests of Central Europe gradually took up some of the main wood species - spruce, fir, beech, oak, hornbeam, linden, elm. (www.mezistromy.cz, 2011)

1.2. Historical epochs of forest using by humans in Central Europe

Natural forests of different species composition were in the climatic conditions of the Czech Republic completely dominant natural ecosystem. Natural forest cover at the time of penetration of the first numerically significant population of people approached 100%, but still in the early 10th century is estimated at more than 70%, as was the case in most countries of Central Europe. The development of an absolute majority of forests in the history of man has been somehow intervened. The relationship of man to be forests, with some simplification, can be divided into three historical phases (sbornikjh.sweb.cz, 2011):

I. The period of use of natural forest by "natural" man

This period coincides with the beginnings of human history. Wood was used in conjunction with stone or reed or bones the first material that prehistoric people began to use it. Man initially kept in the forest ecosystem as well as other animals. Forests was in this historical period of natural creation. Man obviously influenced development of the ecosystem, which was itself a part. In principle, however, could not become a limiting factor in forests' development. (cs.wikipedia.org, 2011)

II. The period of exploitation use of forests by man

The Neolithic period began (about 2500 BC) and in the Europe lasted until natural forests were relatively accessible in a sufficient extent. Forests were used as "inexhaustible" source of raw materials without any care from side of humans. This change in relation to the forest at the beginning was caused by transformation of humans to farmers who cut down the forest and succeeded in his place and founded the fields and pastures.

Colonization proceeded from the most fertile and best farming locations (vales River floodplain). After depletion of soil fertility (in central Europe, 2-3 years), had to create new fields, thus destroying an important area of natural forest. Some abandoned fields overgrown with woods again spontaneously. Primary farmers grazed cattle in forests

Grazing of livestock made it difficult, sometimes impossible to completely, restore sensitive tree species (spruce, beech, maple, ash, elm). In the context of medieval mining and ore development mining and processing of metals were extracted and large border forests in mountain range, from which the wood was floated on rivers.

Wood was used to ensure the mining tunnels, by charcoal were roasted and melted ores and the metal. Additional firewood was consumed by glass works. Glass works even for timber moved higher and higher into the mountains. Versatile usability of wood for making tools, such as building materials and fuel led to the intensive exploitation of forests that were not be able to renew themselves, and therefore close to human settlements waned markedly in the Middle Ages. In modern times the pace of deforestation further escalated in proportion to population growth, the emergence and expansion of large-scale industrial uses of wood. The dismal state of forests responded enlightened rulers, trying to prevent the devastation of their legal protection and penalties for illegal logging. But history has shown that the passive protection of forests, though enforced by draconian punishments, does not the goal, if not the demand for wood is no substitute. Only the discovery and subsequent development of widespread use of hard coal in industry and transport partially mitigate the devastation of forests. (cs.wikipedia.org, 2011)

III. Period of economic exploitation of the forest – Establishment of forestry

Forests were threatened with devastation and extinction, which would probably also caused the collapse of human society, which was then in the stage of development depends on the wood as energy (fuel) and material (crafts, construction, industry). The emergence of forestry was a logical response in a period when natural forests were also able to meet the constant demand for wood. Felling volume easily exceeded the rate of spontaneous reforestation. The aim of forestry was therefore to achieve a balance between production and consumption of wood. In the terminology of that time was to ensure continuity of production and yield balance in maximizing revenues (today we would have called sustainable development). These objectives of our predecessors have achieved a real increase in timber production and the active protection of forests as natural resources. Forest must be protected in order to provide timber and other products.

Passage of Ministry of tillage of 3 July 1873 No. 6953 - the devastation of forests: "forests rises devastation little indeed when suddenly because only one act of planting forest goes against, but it happens little by little by trees in the woods again and again excessively trimming, soil reveals that in the great extent and are disproportionately making the burrows, grass mowing, cattle passport, collecting bad luck, etc. So be the owner of forests in the direction should be supervised, should not be treated with their forests and do not use them in such a way that is contrary to the principles of sound forest management regulations and the forest Act .

At the same time a significant portion of revenues from the forest has been constantly reinvested in forest protection, restoration and enhancement of their (amelioration of forest soils, road building construction, torrent control, establishment of forest nurseries ...). (cs.wikipedia.org, 2011)

1.3. The (brief) history of forestry in Bohemia and Moravia

The first surviving document relating to the current area of the Czech Republic (and Central Europe), which shows the existing public interest in state forests, their protection, and efforts to limit their use, was prepared in 1350 and called Code of Charles IV.. Although never entered into force, but became a model for forest orders issued by a number of large forest owners - especially some of the cities and towns. Already in the 16th Century was established in the Czech Kingdom office of the highest hunter, as a state body overseeing the state of forests. Yet until the mid-18th century, it was left the care of state forests to their owners wholeheartedly. As the beginning of systematic management in the Czech, Moravian and Silesian forests is considered issue of Land Forest Orders (Bohemia and Moravia in 1754, Silesia in 1756). Their compliance was problematic because it lacked trained foresters - forest managers. Therefore, in 1850 was created regulation on state tests for forest managers and test people to protect forests. At that time also led to the development of forestry education. The milestone-opening history of modern forest management became the Austro-Hungarian Act No. 250 / 1852, which enshrined economic processes in the concept of forestry, which then led to the creation of forestry as a separate economic sector (in the present Czech Republic, this law was applied until the year 1960).

In the 19th century weren’t known dangers consisting in threat of even-aged monoculture forests by insect pests or extreme weather events (destructive winds, wet snow, dry ...) so that the forests were established mostly as even-aged monocultures. There was thus a fundamental change in species composition of our forests. Pine and spruce plantations were established as a result of the financially yield theories and they were considered most profitable. Clear cutting prevailed and artificially established cultures were tending stereotyped. Habitat survey was developing and also came to the fore the issue of land degradation associated with the cultivation of monocultures.

During the Second World War, although there were increased harvests in Czech forests due to increased demands of war economy, forests have overall weathered this short episode relatively in good condition as well as post-war nationalization and violent collectivization.

In 1960, a new Forest Act (166/1960 Coll.) on forests and forestry was approved and adopted. The shelter wood small-area system was set as basic mode. This Act highlighted the non-productive functions of forest and clearcuts were prohibited to be wider than the height of the stand. The Act however, did not satisfy the socialist farming business of the State Forests. Therefore, it was in 1977 approved a new law on Forests (61/1977 Coll.) which enabled the "rationalization" of forest management (larger bare mowing, abandonment of strictly small-scale farming and shelter wood system). Yet it can not be said that the management of the former State Forests had significantly negative impact on the state of our forests. This were industrial air pollution and acid rain, which during the 70s and 80s of the 20th century caused extensive necrosis and decay of vegetation especially in mountainous areas of northern mountains (Krušné Mountains, Jizerské Mountains, Krkonoše and Orlické mountains, partially also other mountains).

After 1989 (after end of communism era) was probably the most significant change restitution (restoration) about 40% of forest area to the original owners. During the 90s of the last century abruptly increased the powers of the nature protection authorities (the Law 114/92Sb.) and was also adopted new Law on Forests (289/1995 Coll.)

Despite all the legislative somersaults and twists of history occurred gradually (especially since the early 20th century) based on the experience to corrections of management with target to differentiate forest species and spatial distribution. Melioration and reinforcing timber were inserted into forests, forests' production was raised by pruning and thinning, reinforcing strips were set up, and the separation barrier in order to increase their stability. Detailed methods of natural and artificial reforestation, tending models and methods of forest harvesting were elaborated, still with regard to the primary objective (sustainable, revenue-balanced economy ensuring the production of renewable raw materials - wood). (Bezecný P. a kol., 1981; cs.wikipedia.org, 2011)

2. Natural conditions for plant growth in the Czech Republic

The greater part of the Czech Republic Czech occupies Hercynian massif, consisting mainly of hills and highlands. Lowland and flat parts of the board are created by the Czech Cretaceous sediments animated by sandstone rock towns, basalt hills and drained by the river Elbe. The whole area is surrounded by lower mountains: Novohradské mountains Šumava mountains and Czech Forest, Krušné mountains, Lužické a Jizerské Mountains, Krkonoše Mountains and Orlické Mountains. The biggest landscape unit is the Czech-Moravian highlands inland. The eastern part of Moravia is one of the Carpathians. It is separated from the Bohemian Massif by important depressions - Moravian vales and the Moravian gate. Border with neighboring Slovakia are low White Carpathians and Javorniky and the highest Beskydy with Lysa hora (1323 m). The highest mountains in the Czech Republic are Krkonoše mountains with highest point Sněžka (1602 m).

Mild climate is influenced both by oceanic and continental climate influences. It is characterized by westerly winds and high variability. It is heavily influenced by altitude and position. Average January temperatures range from -7 ^{0}C in the mountains to 0 ^{0}C in the lowlands, then from July 7 ^{0}C in the highest parts of mountains to 20 ^{0}C in Prague and South Moravia. The range of absolute temperatures reached -42 ^{0}C to 40 ^{0}C.

It is said that the Czech Republic is located on the "roof of Europe" because its territory is the main European watershed between the North Sea (Elbe), Baltic (Vistula) and Black (Morava, which flows into the Danube). On its territory is only available water, which here falls in the form of precipitation. Precipitations range from 400 to 1500 mm per year. The 2/3rds precipitation fall in the forest. Most of the forests are situated in the mountains (35%) and hilly landscape (60%), totally 95%. From this viewpoint is apparent their water – management and soil - protection importance.

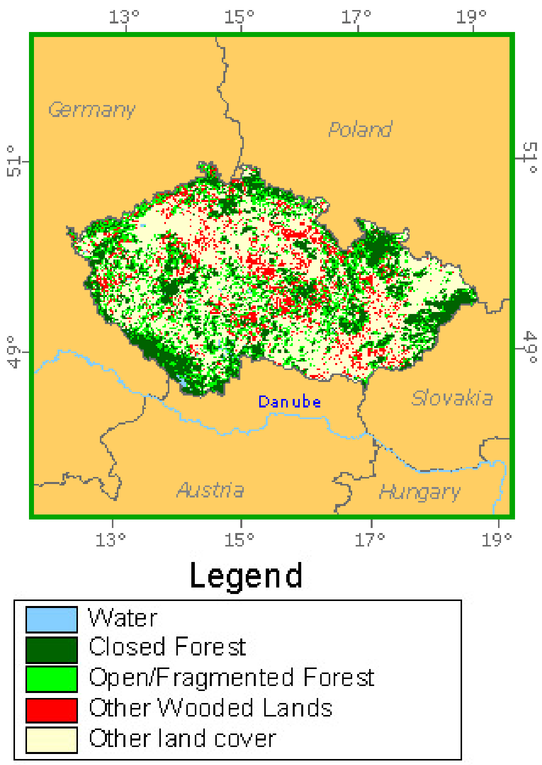
One of the fundamental weaknesses of Czech forests is disproportionate predominance of conifers, especially Spruce and Pine. Because foresters recognize the danger in this state for the overall stability of forest ecosystems, they place as one of fundamental objectives change in species composition of forests in favor of deciduous trees and fir. Target species composition is based on the original composition of natural vegetation and intensive analysis of existing soil and climatic conditions and anthropic influences. During determination of species composition is required to be functionally optimal. This is to achieve a compromise between natural and production composition.

In the years 1950 - 1990 the proportion of deciduous trees increased from 12.5% to 22%. To speed up this process, the proportion of deciduous seedlings increases in afforestation in past years. Since 1990, ratio of deciduous seedlings changed from 19% to 36%, but thanks to substantial State financial assistance. Annually is renewed around 26 thousands ha of forests, which represents about 1% of their total area. The share of natural regeneration gradually increases and reaches an average of about 15%. Representation of tree species is from conifers (76.6 %): 54 % spruce, 0.9 % fir, 17.5 % pine, and 3.5 % larch; from deciduous trees (23.4 %): 5.6 % beech, 6.1 % oak, 3.0 % birch, 1.2 % hornbeam, 1.0 % ash, 0.7 % maple, 0.9 % linden, 1.5% alder and 0.5 % poplar (www.mezistromy.cz, 2011).

3. Basic facts about the Czech forestry

3.1. Introduction to basic facts

The Czech Republic is a country with relatively large amount of woodland. Woodland currently covers 2 651 209 hectares, which is 33.7 % of the total area of the country. The area of forest land has been systematically increased since the mid 20th century (by around 2000 hectares a year) in consequence of the long-term foresting of infertile agricultural land (www.eagri.cz).

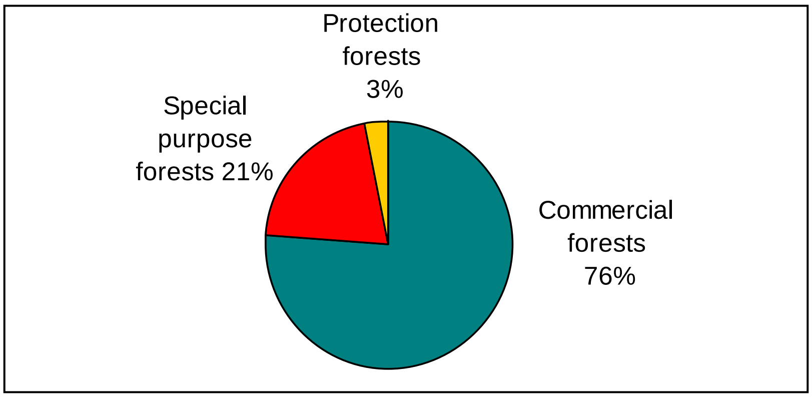


Forested areas in the Czech Republic (www.fao.org)

3.2. Basic facts dealing with forestry in the CR:

Annual fellings	15-16 mil. m^3
Salvage loggig	40%
Volume of annual forest regeneration	25 500 ha
Natural regeneration	18%
Average growing stock	678 m^3/ha (doubled since 1930)
Forest certified by FSC	52 000 ha
Forest certified by PEFC	1 800 000 ha

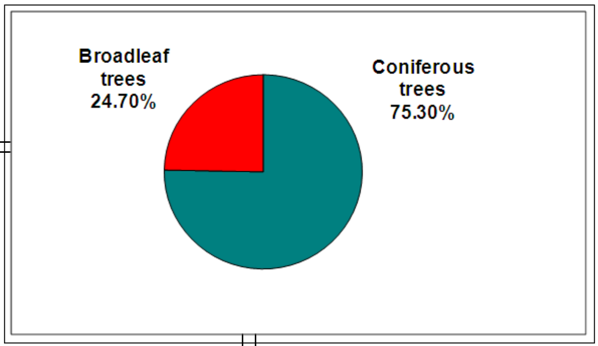
3.3. Forests according to purpose distinguished by Act No. 289/1995 – The forest Act:

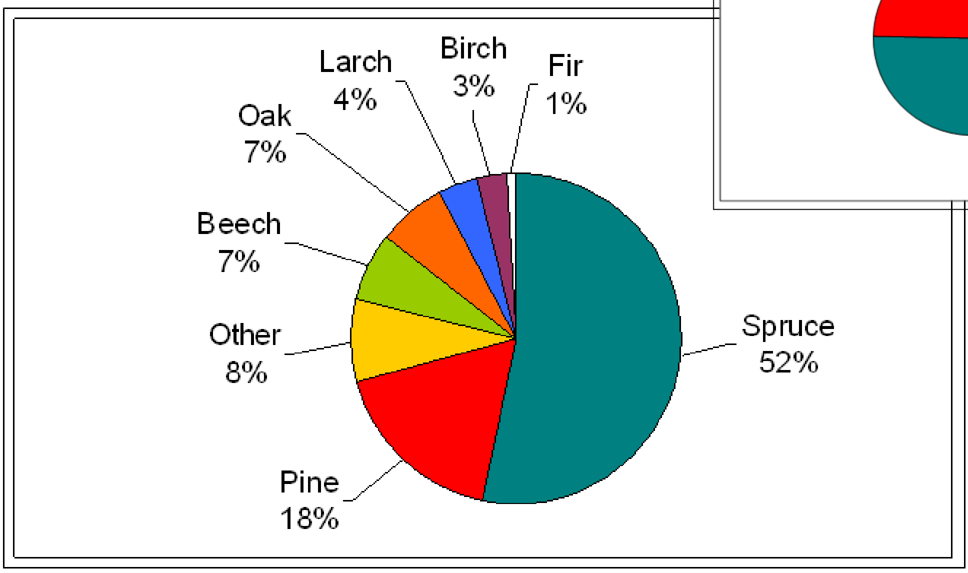


700 000 ha (25,3%) of total forested area is situated in specially protected areas.

3.4. Species composition

The species composition of forests in CZ was altered in the past to the benefit of Norway Spruce in order to increase wood production and to satisfy demand = 75% coniferous trees.





3.5. Forest management

Forest management is the application of appropriate technical forestry principles, practices, and business techniques (e.g., accounting, cost/benefit analysis, etc.) to the management of a forest to achieve the owner's objectives. Stated more simply, forest management is providing a forest the proper care so that it remains healthy and vigorous and provides the products and the amenities the landowner desires.

Main instruments in the CR:

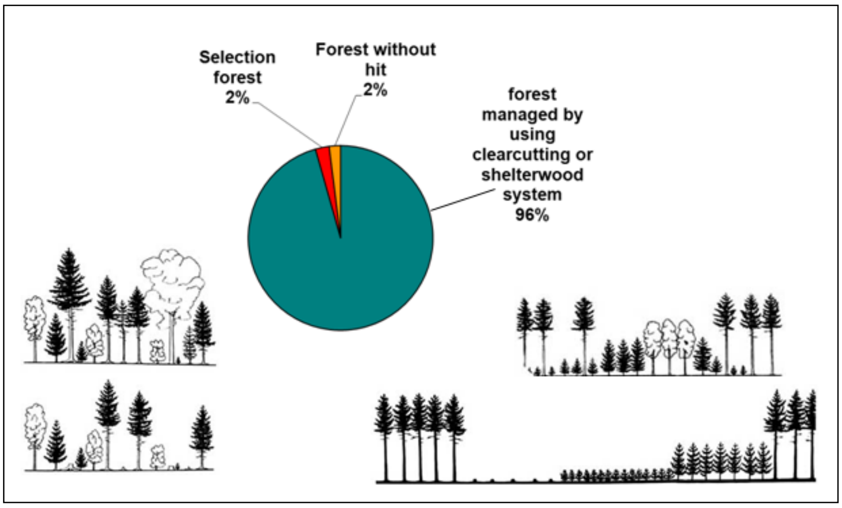
- National forest inventory – NFI (independent survey of the actual state of forest and their development)
- Regional plans of forest development – RPFD (project defining forest management principles in relation to the natural forest regions (41) in the CR)
- Forest management plans – FMP (management instrument for forest owners with area 50–20 000 ha of forest land)
- Forest management guideline – FMG (management instrument for forest owners with area smaller than 50 ha of forest land)

Forest management plans are legally enshrined in forest Act No. 289/1995. It is an instrument for owners in the time horizon of 10 years. They are commissioned by the state forest administration body. Costs for creation are paid by forest owners.

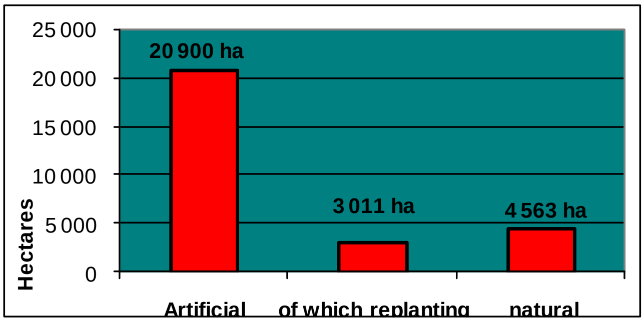
Contains:

- text part (ex. general description, natural conditions, management in previous years)
- forest management book (information on forest stands with plan of harvest and other threatments)
- forest maps

3.6. Management systems



3.7. Regeneration



3.8. Health status of forests in the CR

Commercial forest stands are often vulnerable, susceptible to disturbations. The age structure consists mostly of even-aged forest stands. There is often low ecological stability due to low species heterogenity of stands (Norway Spruce monocultures). On the other hand large area of forests is situated in protected areas, efforts to increase forests managed closer to natureis significant and rules of sustainable management are aplicated.

Damages are mainly caused by:

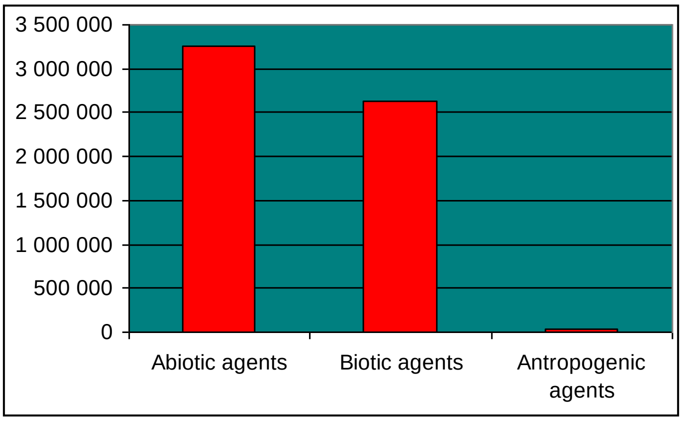
- insect pests attacs (bark beatle) – Šumava Mts.
- wind-throws
- generally overpopulated game
- heavy air pollution in some regions – Krušné Mts.
- fires in summer months

3.9. Damages ratio leading to salvage logging (2009)

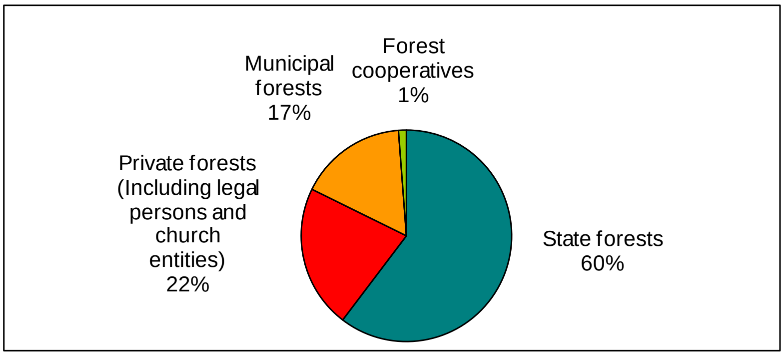
Abiotic agents: 3.25 mil. m^3

Biotic agents: 2.621 mil m^3

Anthropogenic agents: 41 thousand m^3



3.10. Ownership composition



The principal share of forests in the Czech Republic is owned by the state (60 %). Municipalities, their forestry commissions and communities have a 17 % share in woodland ownership and private owners a 22 % share. Of the total area of woodland owned by the Czech Republic (1596.7 thousand hectares) 1340.8 thousand hectares is administered by Czech Forestry Commission, 125 thousand hectares by Army Forests and Estates of the Czech Republic, 6 thousand by the Office of the President of the Republic and 95.6 thousand hectares are administered by National Parks Administration.

3.11. Trends in Czech forestry:

- Increase proportion of shalterwood reproduction method
- Increase proportion of natural regeneration
- Increase of natural species composition (mainly beech and fir)
- Emphasis to non-production function
- Improvement of natural conditions (natural composition, deadwood, suitable technologies)

4. Dominant tree species, their ecological demands for optimal growth

4.1. Norway spruce – *Picea abies*

Spruce is a light-requiring species tolerating shading in its young age. It is also one of reasons why spruce easily infiltrates into stands of other species occupying their position. As a semi-sciophilous species, it occurs sometimes typically in the second storey in commercial forests, for example under Scots pine or European larch. Because in a surface root system spruce is considerably demanding for soil moisture and dry summers can affect it easily. Favourable sites are characterized by uniform moisture. Spruce thickets demonstrate large consumption of water and thus originally wet soils under spruce stands can get dry (land reclamation). Thus, in drier and poorer soils of small water reserves, growth retardation occurs in the certain age of a stand which is particularly evident during dry years. Spruce tolerates well excessive moisture surviving even stagnant water of swamps and peat bogs. However, a moisture deficit becomes a limiting factor of its good growth. Spruce does not show great requirements for soil and a parent rock creating stands on acid igneous rocks, limestones and alluvial soils of various type only when they are not spruce thrives best on moist loamy-sandy soils, however, it grows well also on heavy loamy soils and sands if they are sufficiently moist tolerating chernozems under conditions of admixed moisture. Near the upper forest limit, spruce often grows on stony or even boulder soils too dry or extremely poor in nutrients. On limestone soils, it is evidently replaced by beech. Under conditions of sufficient moisture, it colonizes even rather shallow soils covered by humus. However, on poor siliceous soils and acid peat bogs it grows badly. Insufficient aeration of soils affected its growth very unfavourably. Spruce thrives best on moist loamy-sandy soils, however, it grows well also on heavy loamy soils and sands if they are sufficiently moist tolerating chernozems under conditions of admixed moisture. Near the upper forest limit, spruce often grows on stony or even boulder soils. Spruce stands are heavily affected by soil-forming factors above all the formation of raw humus. Spruce is not demanding for climate. Heavy winter frosts affects its growth only rarely. However, it is much more sensitive to high temperatures and low relative air humidity. In its young age, spruce is less endangered by late frosts than silver fir and, therefore, it is suitable for regeneration on clear-cut areas. However, it suffers more from snow and winter than silver fir. Late autumn frosts can delay the development of young forest plantations through the permanent freeze of shoots for a long time. In mature trees, late frosts damage main lateral buds which results in the origin of narrow crowns. In climatically exposed mountain ranges and peaks, the species forms unilateral flag trees and „bayonet“ tops due to the effect of wind and snow. Spruce is more likely adapted to the short growing season. Short and cold summers are most suitable for its growth. Growing under conditions of a long growing season results in a too early budbreak and easy fungal attack causing decay. A dangerous red rot occurs just at lower climatically temperate locations. In warmer regions, therefore, it is suitable to grow spruce only in deep valleys where moist and cold air is accumulated and excessive moisture occurs. Thus, moisture deficit together with too mild winter and long growing season are another limiting factor for growing Norway spruce. Spruce is sensitive to air pollution and does not suit for parks of larger towns and cities. It is very susceptible to industrial pollutants which was demonstrated by extensive die-back of stands in Central Europe.

4.2. European silver fir – *Abies alba*

Silver fir is a tolerating long-term deep shading without losing vitality. It survives for long decades under the shelter of a parent stand (with the stem diameter of 5 – 8 cm it can reach even 100 years of age) and after cutting down the stand, it begins to grow rapidly. The species shows considerable requirements for moisture and its distribution during the year. It does not grow on dry sites and avoids also waterlogged localities. Silver fir demonstrates higher requirements for the content of nutrients in soils as compared with Norway spruce and requires also deeper soils. Sometimes, its optimum is on limestones while it is missing on peat soils. Soil is used by deep-rooting silver fir rather evenly. Natural distribution of silver fir shows that is a species of oceanic climate. In regions of warmer climate it is related to mountains. The species badly tolerates hot and dry summers and particularly heavy frost. If its biological requirements are neglected it loses resistance to pests being easily attacked by insect or fungi. During recent decades, regeneration of the species occurs and according to the results of research silver fir belongs to the most air pollution resistant coniferous species.

4.3. Scots pine – Pinus sylvestris

Scots pine is a markedly light demanding species unable to regenerate under shading conditions. Therefore, it is very suitable for establishing stands on bare areas. The species is able to cover water consumption from large depth and, therefore, it occurs on extremely dry sites. The pine can germinate even in fissures of bare rocks. Scots pine occurs in areas with large precipitation differences from 400 to more than 1000 mm. The species grows on various soils of different parent rocks. Under natural conditions i tis forced out by shade-tolerating species from better sites. Therefore, extreme sites such as dry sands, peat, limestone rocks where competition of other species doesn´t come on force are typical of Scots pine. Thus, extreme edaphic conditions support the occurrence of Scots pine. Some ecotypes of steppe pine from the south of the European part of Russia able to tolerate saline soils appear to be an interesting edaphic deviation. Within the ecological variability of the species i tis perhaps one of the most marked peculiarities. Experiments indicate that pines growing on different soils are specialized to a great extent and, therefore, they cannot be arbitrarily used elsewhere. The species is demanding for climate. It can tolerate even extreme temperature conditions. It can cope very well with large differences in the growing season – from 90 to 200 days. I tis a species of pioneer properties able to colonize open areas of various type, however, i tis does not suit for the environment of cities and industrial regions.

4.4. European Larch – *Larix decidua*

Larch is markedly a light-demanding species suffering considerably from shading. Stands of larch are always open with large spacing of trees. Due to its sparse crown larch conditions good growth of grass cover enabling thus a suitable connection between the forest and pasture mountains. The species shows medium requirements for water both in soil and atmosphere. Drying up soils do not suit to it. The species avoids regions with the occurrence of low precipitation. Most frequently, it grows on fresh, deep, weathered soils but also on shallow slope debris soils with sufficient moisture. It occurs on various parent rocks preferring soils rich in nutrients. As compared with other ecotypes, Polish larch is better adapted to grow on acid and nutrient-poor soils approaching thus to Siberian larch. Larch is medium-sensitive to air pollution. It is a pioneer species particularly in mountain locations.

4.5. Beech – Fagus sylvatica

It is shade-tolerating species as few of our wood species. Leaves of beech inside a closed stand are adapted to the shortage of light through their differing anatomical structure. Considering its potential to tolerate intense shade even pure beech stands can show several storeys because suppressed trees can survive for a long time in undergrowth. Therefore, on more favorable sites, beech supersedes the majority of other species requiring more light which results in the origin of pure beech stands. Sudden exposure of stems growing in shade to full sun results in bark scorch. Beech demonstrates medium requirements for soil moisture. It avoids extremes missing both on drying out soils and waterlogged soils. Beech doesn´t tolerate floods and, therefore, it doesn´t occur in floodplain forests. The species requires sufficient amounts of precipitation and particularly in summer, sufficient relative air humidity has to be available (north 500mm, south 800-1000 mm). In some parts of its range, beech forest occurs typically in the zone of abundant fogs. In the region of the optimum distribution of beech, it is rather indifferent to a pattern rock. It grows nearly on all types of soils (missing on dry sands, heavy impermeable clays, bog, and peat). Where climate and other factors are not optimal, requirements of beech for soil increase markedly. Therefore, soil requirements can be evaluated only in connection with climatic conditions. Otherwise, beech looks for soils rich in nutrients preferring often limestone if there is sufficient amount of precipitation. Considerable requirements for aeration of soil, on calcareous badly permeate to the deep – endangered by windfall. Thus, is evident that mild oceanic climate satisfies requirements of beech. It does not thrive in frost holes and at localities endangered by late frosts. Young trees can be totally destroyed by late frosts but also mature trees suffer from the frosts and and show crooked burl stems. Due to the susceptibility to late frosts i tis sometimes advantageous to use late-flushing beech from mountain locations for the reforestation of large clear-felled areas. Beech is medium-sensitive to air pollution and, thus, it is not suitable for planting in industrial agglomerations.

4.6. Pedunculate oak – *Quercus robur* L.

Pedunculate oak is a heliophilous species being a little more light-requiring than sessile oak. It is also indicated by the arrangement of leaves. Oak tolerates only light shade and for the purpose of regeneration, heavy opening up is necessary. As for requirements for moisture we have to differentiate two ecotypes in pedunculate oak. An ecotype which is characterized by a possibility to grow on shallow and in summer heavily drying up soils with groundwater table out of the reach of roots is less distributed being economically insignificant. Such conditions occur at forest-steppe localities. A commonly distributed ecotype which is the subject of forest management particularly in floodplain forests exhibits considerable requirements for moisture. Thus, groundwater table has to be within the reach of roots. Pedunculate oak tolerates spring floods before the flushing period taking maximally 21 days. Growing in diverse areas for precipitation (300 mm – 2000 mm). It is a species growing best on deep loamy soils occurring in floodplain forests or on loess. It resists to a certain extent also salts in soil which resulted in its increased use in establishing forest shelterbelts in steppe regions. Pedunculate oak is rather indifferent as for climatic conditions which is related to its considerable range. From the viewpoint of phenology, differences in bud break are most important for growing early-flushing and late-flushing forms can differ in the beginning of flushing even by 3 weeks. The fact is crucial from the viewpoint of damage caused by late frosts. Such forms can be found in any part of its range. The species is rather resistant to air pollution and thrives passably under conditions of large towns. Some results of experiments also indicate a possibility to use the species in the afforestation of waste dumps, slag heaps and spoil banks.

4.7. Sessile oak – Quercus petrea

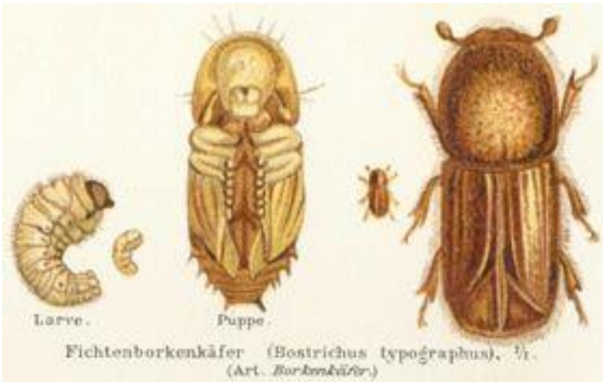
Sessile oak is a helophilous species its requirements for light being a little lower than those of pedunculate oak. It naturally regenerates under a parent stand better than pedunculate oak. As for moisture requirements there are certain differences. Mostly, it is possible to notice that sessile oak grows under conditions of considerable moisture deficit surviving on substrates which become very dry in summer as well as on markedly dry forest-steppe sites on loess or on bedrocks. In addition to this, we can find sessile oak usually with birch on waterlogged sites. In spite of this, it does not tolerate floods. Requirements for soil are exiguous. It grows on nutrient-poor acid and shallow soils of the crystalline complex or on gravel terraces as well as on andesite or limestone. It tolerates bedrocks. As for climatic factors, sessile oak is particularly endangered by heavy frosts causing cracks in wood and damage heartwood and typical frost ribs are formed. In some places, sessile oak crowns are heavily damaged by the mass occurrence of Loranthus. It is a species resistant to air pollution tolerating the urban environment.

5. Problems in forestry

5.1. Bark beetles attacks in Czech Forests

5.1.1. Scientific classification

Kingdom:	Animalia
Phylum:	Arthropoda
Class:	Insecta
Order:	Coleoptera
Family:	Curculionidae
Subfamily:	Scolytinae
Tribe:	Ipini



Ips typographus the European spruce bark beetle has caused many problems in Europe and Asia. Host trees of the European spruce bark beetle include *Picea* (the main host, *Picea abies*), *Abies*, and *Larix* and *Pinus.* It is a pest that mostly infects damaged spruce trees, but can also damage healthy trees as well. The effects of this pest have caused a great deal of economic loss as well as ecosystem change. Populations have increased throughout Asia and Europe, and a possibility of further expansion can exist as a cause of increasing temperature change (www.issg.org).

5.1.2. Ips typographus description

Adult *Ips typographus* beetles range from 4.2 to 5.5 mm in length. They are reddish or dark brown to completely black. The front of the head and the sides of the body are covered with long yellowish hairs (CFIA, 2007). Eggs are pearly white in color. The larvae are white, legless, 'C' shaped grubs with an amber colored head capsule. Mature larvae are about 5 mm long. The pupae are white, mummy-like, and have some adult features, including wings that are folded behind the abdomen (Eglitis, 2006).

Adults are strong fliers and are capable of traveling several kilometers in search of suitable host material. Newly established populations of this species may go undetected for many years due to cryptic nature, concealed activity, slow development of damage symptoms, or misdiagnosis (Eglitis, 2006). A complex system of chemical communication governs the host selection process. Male beetles find suitable hosts, probably in response to tree odors, and then initiate attacks. The males produce pheremones, which aggregate both sexes to the host material. Once the host material is fully colonized, the beetles produce anti-aggregant chemicals, which lead to cessation of further attacks. Male beetles are the principal producers of these chemicals, which are derived from host monoterpenes (Eglitis, 2006).

This species possesses two important traits that are characteristic of aggressive species of bark beetles: effective aggregation pheremones and vectored mutualistic fungi that may help to overcome tree defenses (Grodzki, McManus, Knizek *et al*, 2004). Although bark beetles are able to migrate over long distances, the majority of beetles disperse less than 500 meters (Jönsson, Harding, Bärring *et al*, 2007).

5.1.3. Symptoms of damage by bark beetle

The needles of attacked conifers turn yellow-green to reddish-brown and eventually drop within a few weeks. Other signs of infestation include red-brown frass in bark crevices, the presence of round exit holes, and small pitch tubes extruding from the bark (Kimoto and Duthie-Holt, 2006). Woodpecker damage may also be evident. As with other conifer bark beetle species, *Ips typographus* is a vector for blue-stain fungi (*Ophiostoma* spp., *Ceratocystis polonica*) which hastens the death of trees, discolour the wood and can result in loos of timber grade and value (www.fao.org).

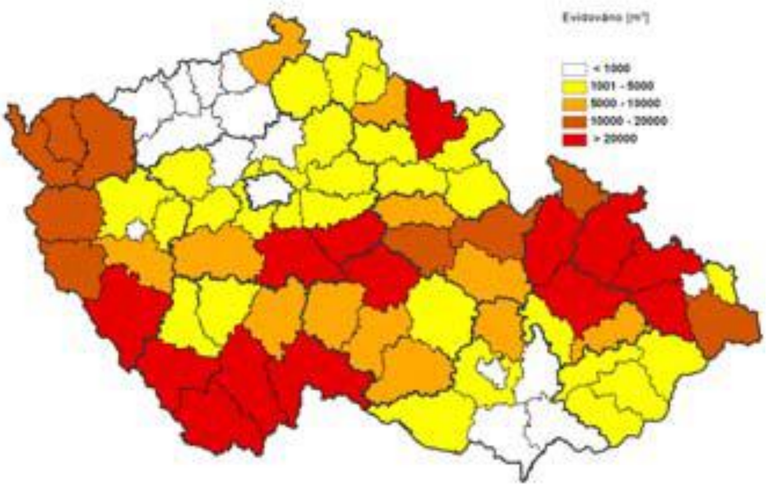
Extensive gallery systems, blue-stained wood and round exit holes (bugwood.org)

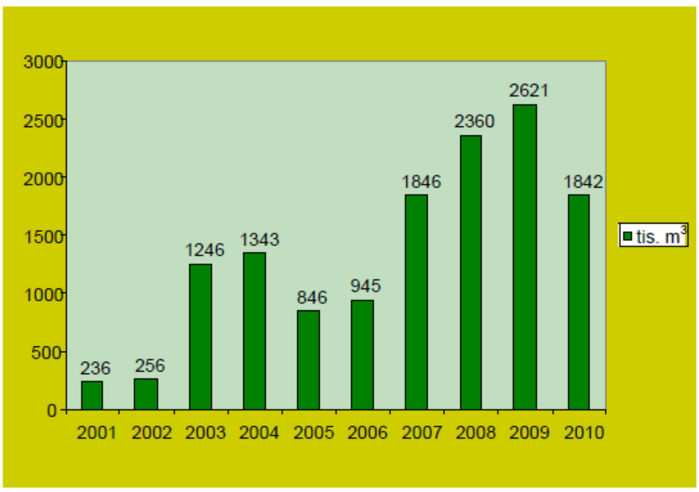
5.1.4. Bark beetle in the Czech Republic

In the most of the area increased a calamity number of bark beetle. Average occurence of bark beetle timber in spruce stands is 1.3 m^3/ha (normal state is 0.2 m^3/ha). One of the biggest calamity areas (in Bohemia) is directly related to windfall in 2007 and 2008. Hurricane Kyrill caused large windbreak in the Žofínský Prales nature reserve, fir–beech primary forest with spruce that without any management. In total, around 2000 m3 of spruce wood was damaged. The population dynamics of bark-beetles was studied by window traps and by studying of damaged trees. No tree wasinfested by bark beetles during summer 2007 but ca. 300–400 m^3 of spruce wood was infested in autumn. The volume of infested damaged wood approximately increased up to ca. 1000–1200 m^3 in 2008 and 500–1000 m^3 of standing spruces were infested additionally. The volume of infested trees has passed many times over the level of bark beetles outbreak possibility (Modlinger *et al*, 2009).

In the Šumava National Park problems with bark beetles have become a heated issue with a political dimension. On one side, some experts (usually with a background in environmental sciences) demanded that nature be left alone and that natural processes be allowed to take their course, even if it meant the bark beetle would destroy most of the forest. On the other side, other experts (usually with a background in forest management) demanded intervention (www.en.wikipedia.org).

Timber damaged by bark beetle recorded in the Norway spruce forest stands (Green report, 2009)





5.1.5. Protection against bark beetle

- Preventative measures - Silvicultural measures such as favouring mixed stands over pure *Picea abies* stands have been reported to reduce risk for *Ips typographus* attack (Netherer and Nopp-Mayer 2005). Prompt salvage or debarking of windthrown material may help to limit population growth, but may be impractical when large areas are involved (Eglitis, 2006). The only chance to stop mass propagation of the European spruce bark beetle is to transport infested wood out of the stands (Feicht, 2004).
- Integrated management - Mass trapping of *Ips typographus* in combination with other measures such as removal of infested trees, have to be included in an integrated control program (Bakke, 1989). In addition, mass trapping with pheromone-baited traps or trap trees has also been successfully used to suppress beetle populations and prevent outbreak conditions (EPPO).
- Biological protection - The entomopathogenic fungus *B. bassiana* is a naturally occurring pathogen of bark beetles, especially the European spruce bark beetle. It can be used for biological control of this species in three possible ways: treatment of fallen trunks, soil treatment around spruce trees against overwintering beetles, or a combination of the fungus with the commercially available and used pheromone traps (Kreutz, Zimmermann & Vaupel, 2004a). When considering the commercial use of this fungus for biocontrol of this species of bark beetle, its efficacy at different temperatures and RH is highly relevant. (Kreutz, Vaupel & Zimmermann, 2004b).
- Chemical protection - Direct controls have included the use of attractant and repellent pheromones to either trap out beetles or reduce attacks on suitable host material. Insecticides have also been used in direct control, but have a number of limitations in their application (Eglitis, 2006).

Examples of traps

5.2. Game (wild animals impact) on silviculture in the Czech Republic

5.2.1. Introduction to problematic

Natural forests' balance has been disrupted by man so that its ideal restoration is not possible. However, it is necessary to strive for proportional representation of all plant and animal species in the wild, where is considered each type of destruction caused by man fault, as cultural barbarism. In the forest should increasingly gain in importance its non-production functions, which also envisages enhancement of species and age diversity of forests. Achieving this goal is not only beneficial for the limitations of various kinds of calamities, but also in terms of damage caused by game in the forests. (www.mzp.cz, 2011)

Damages caused by deer game on forest vegetation especially bud browsing, peeling, chewing and eating bark are still the biggest damaging influences and have been remaining the biggest problem for forest protection in the past 30 years. Because the damage and rot initiated by peeling and eating bark within stands accumulate throughout life, it is possible to estimate the total amount already in the billions of crowns. The highest shares of damages are caused by deer game, sika deer and mouflon. Lesser extent, participates roe deer and fallow deer. Damages caused by wild boars ("the black game") are also not negligible. If foresters want to significantly change the species composition of forests and improve their health, it is imperative to reconcile the numbers of game and trophy sources of the current forest ecosystems. (www.mezistromy.cz, 2011)

Damages caused by game are currently one of the limiting factors, which complicate transition of forests to environment – friendly practices in forests. This means decreasing of stability and endangerment of productive and also non – productive functions of forests. The reason of relatively high damages is inappropriate game management of hunting area users and their unwillingness to reduce population states of hoofed game, but on the other hand also strongly changed species composition in forests and reduced trophy value of forests. (Tuma, 2008, http://90.181.191.228/docs/Skody_zveri_knizek.pdf)

5.2.2. Characteristics of damages in forests

- Browsing – it means eating of terminal and lateral buds (shoots) of self-seeded trees, planted trees, cultures and growths. The result is disposal and elimination of both natural and artificial regeneration, deformation of stems, reduction of increment, reduction of stand vitality and other ecological damages emerging by absence of browsed tree individuals in subsequent stand. The broadleaved species and Fir are browsed most often, but problem with browsing also occur even on Spruce and Pine. Species which have smaller share in given locality are more damaged. Damages caused by browsing occur both in summer and winter.

Examples of browsing damages: damaged young fir, beech and a cultivar of poplar

- <u>Peeling of a bark</u> – this damage arises in summer season, when sap flow in bast part of stem and bark is vulnerable to peeling off, when the whole strips of bark are tore off from stem or from root start. Most often younger age classes of forests are damaged by peeling of bark both coniferous and broadleaved tree species until the coarser bark on stem (strain) is formed.

Examples of peeling off bark damages

- Chew off a bark – it is very similar to “Peeling of bark”, but it occurs in winter season, when there is not sap flow and bark can’t be tear off in whole stripes. The damages are smaller and in the wound are apparent traces of the lower cut-off teeth of game. The result of bark peeling and chewing off is infection of wood caused by wood-decaying fungi (most often *Stereum sanguinolentum)* and as a consequence of rot there is decreased stability, vitality, increment and reducing of possibilities to sell the timber.

Examples of chew off a bark damages

- Knocking the antlers out – these damages are caused by males of antler ungulates, when are damaged narrow trunks and branches by their antlers (when developing antlers). By this behaviour are affected mostly disseminated – weed trees, very popular for game are *Pseudotsuga menziesii* and *Larix decidua.* Damages caused by knocking the antlers out are not so big as in case of browsing, peeling and chewing off a bark

Young pine damaged by knocking the antlers out; roe deer in stage of knocking antlers

- <u>Abrasion of trunks</u> – this kind of damage is caused especially by Red deers and by wild boars in the vicinity of mud grounds. It is minor damage from viewpoint of forestry.

(Tuma, 2008, http://90.181.191.228/docs/Skody_zveri_knizek.pdf)
(Havránek, Bukovjan, Czudek, 2010, http://profimysl.cz)
(www.google.cz, pictures)

5.2.3. Most significant game species causing damages on forests

Most significant damages are caused by hoofed game, only locally (in forest nurseries or in orchards) can *Lepus europaeus* cause bigger damages.

- <u>Red deer *(Cervus elaphus)*</u> – belongs among food opportunists, most harms by browsing, peeling and chewing out a bark. Smaller damages causes by knocking the antlers out and by abrasion of trunks and stems.

Red deer (Cervus elaphus)

- <u>Sika deer *(Cervus nippon)*</u> – causes the same damages like Red deer, its population dramatically increases and spreading to new localities. Also negative effect is hybridisation with original Red deers.

Sika deer (Cervus nippon)

- <u>Moufflon *(Ovis musimon)*</u> – its food strategy is to be grazer, but most harms by browsing, peeling and chewing out a bark.

Mouflon (Ovis musimon)

- <u>Roe deer *(Capreolus capreolus)*</u> – belongs among browsers and it is most important pest of tree buds (shoots). Considering its numbers and expansion, it significantly influences natural and artificial regeneration of broadleaved species and fir. Locally can be caused significant damages caused by knocking the antlers out, especially on "disseminated trees".

Roe deer (Capreolus capreolus)

- Fallow deer *(Dama dama)* – belongs among food opportunists, most harms by browsing, peeling and chewing out a bark. Smaller, unimportant damages causes by knocking the antlers out.

Fallow deer (Dama dama)

(Tuma, 2008, http://90.181.191.228/docs/Skody_zveri_knizek.pdf)

Chart no.1: Spring stock core states of main game species in pieces (MoA, CSO)

Game	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Red deer	24 004	23 809	23 096	25 012	27 378	26 824
Fallow deer	17 605	17 591	17 727	19 055	20 667	21 676
Moufflon	16 476	15 721	15 572	15 891	17 026	18 201
Roe deer	269 542	261 208	272 864	295 092	302 988	300 811
Wild boars	43 771	43 433	44 705	44 666	49 909	46 193

Source: Jelínek, 2006; http://lesazahrada.cz

Chart no. 2: Hunt of main game species (shooting + trapping) in pieces (MoA, CSO)

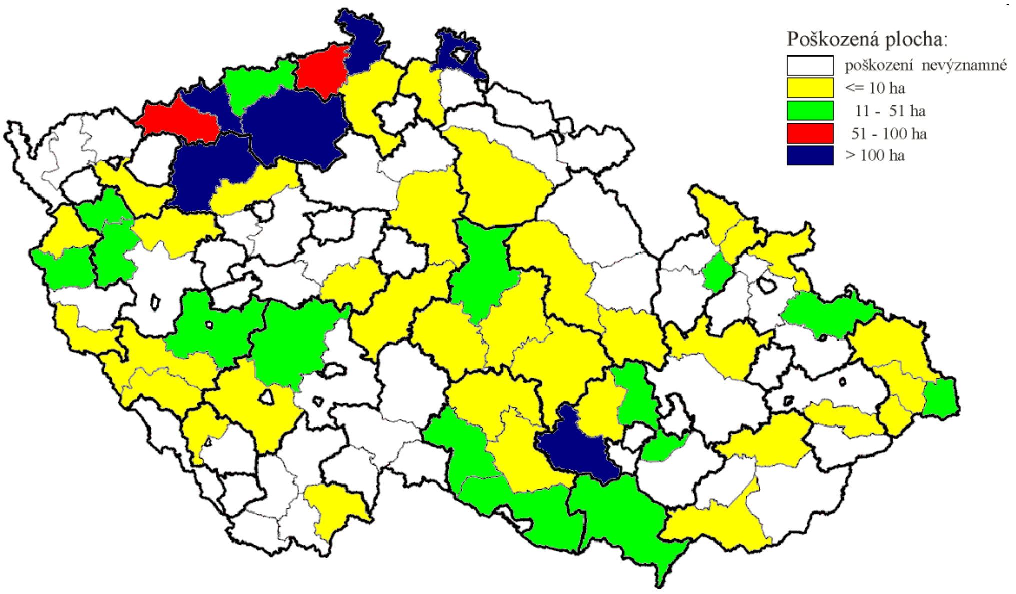
Game	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**
Red deer	19 069	19 366	18 572	18 491	19 531	19 560
Fallow deer	9 651	9 642	8 390	8 647	9 335	10 307
Moufflon	7 974	7 724	6 642	6 265	6 652	7 204
Roe deer	113 320	115 832	112 808	118 795	121 000	123 937
Wild boars	68 571	74 883	82 632	77 955	121 979	100 081

Source: Jelínek, 2006; http://lesazahrada.cz

5.2.4. Main factors causing damages

Damages on forests are caused by many factors. Between the most important belongs especially bellow mentioned. It is necessary to say, that damages caused by herbivores is normal behaviour connected with food intake. It is also necessary to determine limit of tolerable game impact (Tuma, 2008, http://90.181.191.228/docs/Skody_zveri_knizek.pdf; http://lesazahrada.cz;

- The numbers of game – it is logical that amount of food taken is directly proportional to the amount consumers. Currently, the high numbers of game is the most important factor. The number of game should be adequate to capacity of its environment or to amount of damages, which can be tolerated. This factor touches all other concerning factors.
- Structure of game population – altered age, sex, social and spatial structure can also cause increased damages by game.
- Intra and interspecies composition – concerning with numbers of game, both competition between individual of the same species and individuals of other species. Overlaying of food niches.
- Disturbance and stress – concerning with high recreational using of landscape, also with unsuitable ways of hunting, when the game can't enough saturate its need of food intake (pasture cycles(and finding alternative sources of food on more quiet localities (e.g. browsing in very young stands - coppices)
- Capacity of environment – the methods of forest management has changed in past 200 years. The clearcut management system have been used, species composition has changed in favour of Spruce and Pine – the food capacity and offer dramatically decreased. The numbers of game should copy decreased food capacity of its environment until the state of forest will be improved. Game would block or destruct all effort for change in another case.
- Nutrition of game (feeding) – can have positive and also negative influence on amount of damages. If the feeding is unavoidable in certain situations (wintering game preserves), it is necessary to change the technique and technology and selection of feed in comparison with common practice.



Damages in the Czech Republic according to the area of damaged stands

(Tuma, 2008, http://90.181.191.228/docs/Skody_zveri_knizek.pdf)
(http://hnutiduha.cz)

5.2.5. Economical and ecological looses caused by game and financial expression of damages to forests

In landscape live more game than forest are able to support. Actual numbers of damages have been documented by new study performed by the Centre for research of forest ecosystems, Jílové u Prahy. The numbers are warning. The study has shown that excessive population causes:

- enormous damages on new seedlings. In 2005 were damaged 44% of young planted trees.
- enormous damages of broadleaved trees and of Fir. The amount of damaged broadleaved trees and Firs reached 61%. Owners and administrators of forests plant obligatory percentage of these trees, but game damages 2/3 of them. Norway spruce is only one remaining species in forests then.
- damages of higher and bigger trees by peeling and chewing off a bark, thereby way open to pests, diseases. The infections by fungi diseases penetrate to trunk which subjects to rot later. In adult Spruce stands is damaged 16% of trees.

The big financial losses are caused by browsing and by peeling bark. Damages reached amount of 24 millions of CZK during the year 2005. However the real number isn't possible to quantify. The protection against game costs significantly more. Only Czech Forest Enterprise expenditures for protection are more than 100 millions of CZK.

The real losses are much greater. According to the comparisons in Jeseníky mountains, profit from damaged forests can be reduced by more than 250 000 CZK from 1 ha. The newest estimates are nearly 1,5 billion of CZK, whether are included losses on quality and increment.

Among the most affected parts of the Czech Republic belong northern Moravia, Czech – Moravian highlands and Ore mountains. Only in mentioned Ore Mountains damages reach more than 265 millions of CZK actually. Costs for protection are estimated for more than 60 millions of CZK and annual losses on timber are nearly 40 millions of CZK. Real numbers are probably much more higher.
(http://hnutiduha.cz)
(http://aktualne.centrum.cz)

5.2.6. Legislation concerning with game damages on forests

The issue of damages caused by the use of hunting areas, by wildlife and on wildlife is governed by the Game Management Act No. 449/2001 Coll., as amended, in Part Six, § 52 - 56th. According to this law damages caused by game are solved and covers by owner or tenant of agricultural or forest land. It is therefore a relationship among the owner of land and hunting area user. No government game management body is entitled to interfere into this relationship between them.

- §52 Responsibility of hunting area user (describes obligation of hunting area user including payment of damages)
- §53 Harm reduction measures (user of hunting area have to do provisions against damages by game)
- §54 Damages caused by game, which are not paid
- §55 Application of rights and demands (damages to agricultural land and to field crops have to be applied not later than in 20 days from creation of damage)

With regard to the settlement of damages caused by game, Game Management Act prefers mutual agreement between the hunting area user and owner of land. This means that the user and owner can mutually agree on the amount of compensation, but also about a form of mutual settlement. Damages caused by game need not be addressed only in money but also other forms such as:

- Putting land to its original state
- Payment in kind (donating venison, etc.)

The agreement on compensation for damage caused by game is usually treated after the owner claims the right (request) for compensation of damages. The basic assumption is that the damaged land – grounds are situated in hunting area. Damages caused by animals on the non-hunting area aren't paid.
(http://eagri.cz)

5.2.7. Methods of forest protection against game damages

The range of damages caused by animals is possible to alleviate by the systematic protection. Basic ways to protect forests against damage by animals remain in the combination of biological, mechanical and chemical protection. Success can't be achieved, as is often forgotten in forestry practice, by using only one protection measure. It is dependent on a suitable combination of methods of forest protection, if the basic assumptions are failed, which are the achievement of the appropriate numbers of game and manageable way of forestry. Leading position in integrated forest protection has a chemical protection. It makes about 60% of the total protection. Mechanical protection occupies 25% and 15% occupies biological protection. Elaborated according to the:
(Tuma, 2008, http://90.181.191.228/docs/Skody_zveri_knizek.pdf)
(Havránek, Bukovjan, Czudek, 2010, http://profimysl.cz)

- Biological protection – biological protection should be basic method in solution of game damages, because solves nature of the problem, not only its results. It is the cheapest and most efficient way of protection. It lies primarily in game management and in measures like keeping only numbers of game which corresponds with capacity of environment and its food offer and when are concurrently produced only damages in tolerable economical and ecological amount. Keeping of natural game population structure, ratio of sex 1:1, sufficient number of older and oldest individuals, and it is necessary to respect social relationships of game during hunting. It is indisputable that the big predators are the best managers who can maintain optimal spatial structure of game. Theirs return to nature should be supported. The spectrum of species which are kept also concerning with numbers of game, it means significant reduction of non-native species, where their food niche demands overlay with niches of original species, so by this way they increase pressure on their environment. Especially reduction of Sika deer in location of Red deer occurrence should be done. The reduction of game disturbing, directing of recreational using of landscape, changes in ways of hunting (intensive hunts, interval hunts) can significantly contribute to minimizing damages. Increasing capacity of game's environment can be realized by establishing and managing of pastures and meadows, using of small fields with crops for game, by planting of fruitful trees and by total increasing of environment diversity of plant communities. Reduction of damages caused by roe deer knocking of antlers can be achieved by ban of territorial males hunting during intensive defending of their territories – from spring to end of rut. Among biological measures can be included so called biotechnical protection of forest – using of wintering game preserves.

Example of small crop field for game

- Mechanical protection – is based on prevention of access to parts of tree, whole tree or to group of trees. Its effectiveness is limited, it is laborious and costly, which don't solve nature of the problem. Costs for mechanical and chemical protection are in order of hundreds millions crowns every year. To protect terminal buds are used different plastic protectors, bonding tows around, human hair etc. These measures are effective only for protection of terminal buds and only for limited number of trees. For individual protection of trees are used plastic tubes, mesh fences, plastic spirals. In protection against browsing and peeling of bark is used binding of brushwood, plastic or metal netting, also bark wounding is possible, especially in case of Spruce. This bark wouldn't be bitten then. This method is laborious, expensive and protects only small number of individual trees until they overgrow the height of tubes or netting. Their removal after fulfilled their function is also relatively problematic. Wooden or mesh fencing is used for protection of trees groups or whole stands. Their advantage is that they protect whole area of forest, even natural regeneration, disseminated, auxiliary and filler trees, herbs. Its disadvantage is the necessity of their permanent control and maintenance, their building is laborious and expensive.

Examples of mechanical protection against game – wire protection, fences, plastic tubes; nettings

- <u>Chemical protecton</u> – is based on the treatment of trees part by different types of repellents, products containing effective and active substances that can repel game. Only chemical treatments listed in “List of registered plant protection products” released annually by the State Phytosanitary Administration or treatments listed in “List of registered treatments for forest protection” released by the Ministry of Agriculture can be used in the Czech Republic. Repellent can be divided into three basic groups – repellents against summer browsing, repellent against winter browsing and repellents against peeling and chewing off a bark. Details for application and dosages, ways of application and terms are written on particular treatments and in “List of registered treatments for forest protection”. These recommendations must be respected for fully efficiency. Increasing of dosages isn’t necessary, it is preferable to change the treatment sometimes to game not get use to. Chemical protection of forest against game is very expensive, laborious and protects only limited numbers of tree individuals. It doesn’t solve reason of damages, but only its consequences. Examples of used repellents: Lavanol, Repenal, Morsuvin, Hukinol, Morsuvin, Nivus, Neoponit, Repentol.

Examples of chemical protection: protection of terminal bud on young spruces, "Morsuvin" – one of the most used chemical treatment preparations

5.2.8. Possible solutions of the problem by change of legislation

Numbers of game should be derived from capability of forest to support it. It means that real states of game would be determined according to the percentage of damaged trees. Some control plots, unfenced and fenced, should serve for this purpose. The proposed rate of damages is up-to 10% between control plots. After limits would be exceeded, state administration body should increase the plan of hunt. The harmony of game numbers and capability of forest to feed them is logical and ensures rational use of ecosystems. Damages of seedlings and trees can be counted more easily and more accurately than animals in forests.
(http://hnutiduha.cz)

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Silviculture in Finland (West Europe)

Content:

1. History of silviculture in Finland

The forest is Finland’s most important natural resource, and throughout history it has been an important part of Finnish life. From the forests we have gotten firewood, building materials and food in the form of berries, mushrooms and game. Usage of forests has differed quite a lot from the current ways. In the old days forests were scorched in to fields, woods was burned in to tar, cut in to lumber and made in to paper.

Slash-and-burning was done in Finland already 4000 years ago, even though it was most widely used from 1500 to 1800. Yields obtained from burned fields could be many times higher than the yield compared to conventional fields. Use of slash-and-burn fields was continued until 1990’s, even though it was understood already 200 years earlier that it was harmful to the forests. As a result of slash-and-burn old spruce forests disappeared and were replaced with mixed birch-pine forests.

First export product from Finnish forests was tar. Tar burning peaked at 1600-1800, when Finland was one of the largest tar producing countries in the world. Tar produced in Finland went mainly to Central Europe, where it was needed for shipbuilding. Finland already had large forest resources and at the same time forest coverage in Europe had declined due to excessive harvesting; these factors among others guaranteed the success of Finnish tar production. The primary wood used in tar burning was pine.

In 1800s when steam sawmills started to become more popular, the monetary value of timber also began to rice. Finland has been using water powered mills since the 1500s, but after that team revolutionized the industry. Saws were especially established on riverbeds, to guarantee easy access to timber by log floating.

In the second half of 1800, timber had become even more important natural resource with the popularity of new mills. Because of this many forestry organizations were started; Metsähallitus and Evo forestry school, which represented highest degree of education in forestry. First forest law was set in 1886, and its most primary goal was to reduce destruction of forests, in other words it meant securing financial sustainability, which even now is important part of Finnish forestry.

Slashing and burning which had continued for hundreds of years along with tar burning, had damaged the Finnish forests badly when arriving to the 1900s. Following the slashing and burning, old spruce forests had disappeared, and replaced with young birch and pine stands. Tar burning caused pine forests with damaged undergrowth. Sawmill industry got most of its timber from elective cutting, which meant taking the best trees from the forest and leaving the poor quality trees. Generally we can consider Finnish forests to have been in really bad condition and underproductive during the start of 1900. The primary goal for the start of the century was to get forests productive again. The change happened gradually and forestry methods didn’t change until 1950. Before 1950 forests had been cut down by selective cutting method, which caused the forest stand quality to decline. For this reason selective cutting method is not currently preferred in Finland Coming to the 1950s new forest management guidelines were given, in which forestry turned to even aged forests. Selective cutting was banned completely. Even aged forestry has remained the single one forest growing method in Finland. Even aged forestry was seen to fit the best for trees growing in Finland. In the start of 1950s, chemical forest industry was a fast growing field of industry and with even aged forestry the demand for raw material was met because even aged forests produce a lot of pulp wood in first thinning.

The 1960s and 1970s were branded, the so called age of intensive forestry, when ditching was started to be done in swamps, which produced more land for forestry growth. Also the use of nutrients was very heavy in addition to the use of pesticides.

To this age it was very common to only think about productivity, without caring for other natures values. In 1970 forestry went through large changes with the introduction of harvesters to tree felling, this also reduced the need for manual labor.

The direction of forest management changed again in 1992 after the environment conference in Rio de Janeiro. After the conference forest management in Finland started to also observe and protect natural values. Alongside economic sustainability, ecological and social sustainability were introduced. The newest forestry law from the year 1997 obliges forests to be handled in a way that is economically, ecologically and socially sustainable.

2. Natural conditions for plant growth in Finland

Finland is located between 60 and 70 latitude, which means that the distance between southern Finland and northern Finland is a bit over 1000 kilometers. Finland is part of the boreal climate, in other words known as northern coniferous zone. The boreal climate can be divided in to southern, middle and northern boreal climate. The northwest and southern coasts are part of the hemi-boreal climate, which is between boreal and temperate climates. Due to the length of the country growing conditions differ between northern and southern parts. Finland is located on the same latitude as Alaska and Siberia, but the climate here is more temperate thanks to the Gulf Stream. Typical characteristic for Finland is also the differences between the four seasons, which are clear. Finland has podsolic soil, which has fairly low nutrients. The climate is cold, which causes the litter to decompose slowly in the humus layer.

2.1. Hemi-boreal climate

Small parts of the Finnish coast in the southwest and southern parts can be considered as hemiboreal climate. Degree days on this area are around 1400, and the period of growth is under 200 days. Thus this coastal area is the only places in Finland where oak, maple, lime grow. The mean temperature on this area was over 6 degrees Celsius in 2011 and the amount of rain was over 725 mm.

2.2. Southern boreal zone

Forests of the southern boreal climate in Finland are the most productive from the viewpoint of the forestry industry. Compared to the north, trees grow faster and larger, meaning the annual profit grows a lot larger. Growing season in this area is around 160-175 days, and degree days is around 1100-1300. Most common growing soil is moist upland forest site and as the climax species there is spruce (*Picea abies*). In the southern zone pine can also be found, mostly on arid soils where spruce doesn’t thrive. Black alder (*Alnus glutinosa*) is a common tree species in the humid southern climate. In the undergrowth there are many species of moss and blueberries. In the year 2011 average temperature was 4 - 6 Celsius and annual precipitation was between 625 and 725 mm.

2.3. Mid boreal zone

Most common soil type in the mid boreal climate is dry upland forest site, so the most common tree species is pine. Also moist upland forest site and spruce are found in the mid boreal climate. Wood production is good in this climate, but doesn't reach the levels of the southern climates. Length of the growing period is 140-160 days and degree days is from 1000 to 1100. Typical undergrowth species are lingonberry, black crowberry and different species of lichen. In the mid boreal climate black alder starts to become rare. In the year 2011 the areas mean temperature was between 3 and 5 Celsius and the annual precipitation was 625 – 725 mm.

2.4. North boreal zone

Forests in north boreal zone grow really slowly, and thus aren't very productive. In the southern parts spruce can be still found, but north of the Arctic Circle it starts to become rare. Typical forest in the northern part of the climate is slowly growing, short pine and tundra birch (*Betula pubescens* subsp. Czerepanovii) mixed forest. Common forest type in this climate is dry upland forest site and as under-growth lingonberry, northern bilberry and mountain bearberry can be found. Growing period in this climate is 100-140 days and degree days in southern parts of the area is 950 and in the north 360. Mean temperature in the area was from +2 Celsius to +1 Celsius in 2011 and the annual precipitation was between 625 and 600 mm.

3. Dominant tree species in Finnish forests and their ecological demands for optimal growth

In Finland there are 30 different tree species, of which most are deciduous trees. Naturally growing coniferous trees are fairly few, only four, which are spruce, pine, juniper and yew. Even though there are 30 different tree species, only spruce, pine and silver birch have economic value, and these species are the ones we renew our forests with and of which forest industry is interested in.

3.1. Spruce (*Picea abies*)

Spruce is the newest arrival of the three main tree species in Finland. It was introduced to Finland around 5000 years ago, after the ice age. Spruce forests cover 27% from all our forests and after pine it is the most common tree species. Spruce grows on nutrient rich soils which have enough of moisture. It is the only tree grown in Finland which can withstand shading, due to this it can be grown as sapling under the primary stand. When young, spruce is vulnerable to damages from frost. Typical growing soil for spruce is moist upland- and herb-rich upland forest sites, even though spruce thrives on moist and nutrient rich soils, it cannot tolerate still water. Spruce can also grow on barren soils, but its yearly productivity is lower than pine.

3.2. Pine (*Pinus sylvestris*)

Pine is the most common tree species in Finland. Pine requires a lot of light grow and thanks to its deep roots it can absorb water fairly deep. It thrives on barren and nutrient rich soils, but when growing on too rich soils the pine becomes low quality, which is evident especially with the large amount of thick branches. Pine is normally grown on dry upland forest sites, but it can also be grown on moist upland forest sites if the grain size of the soils is large enough; pine doesn't stand still water. Pine should be grown fairly tight (at least 2000 saplings per hectar) so that the branches would fall off naturally from the saplings thus increasing the technical quality of the wood. Pine also is the pioneer and climax species on barren soils.

3.3. Silver birch (*Betula pendula*)

The growing soil requirements of birch are fairly similar to spruce, so birch thrives on nutrient rich soils, like moist upland forest sites, herb-rich forest sites and groves. Birch requires a lot of light and water to grow. As a fast grower and short aged it is a pioneer tree species, which in time loses to spruce. Birch regenerates from seeds and sprouts. The best individuals grow from seeds. Birch doesn't thrive on soils with low oxygen values, like clay soils.

4. The main principles of silvic in Finland

The main principle of Finnish forestry is sustainability. The aim of the forestry law is to advance forest management and use in a way that it is considered sustainable, without decreasing biological diversity. In the newest forestry law from 1997 the diversity of forest ecology and biology was taken as equal aim next to economically sustainable forestry. Sustainable forestry can be described with three layers, which are economical, ecological and social sustainability. Economical sustainability means that forests are managed in the way that annual felling is always less than annual increment, which means that the amount of forests in Finland increase every year. This goal has been accomplished fairly well, since annual increment in Finland is around 100 million cubic meters and annual felling is 50 million cubic meters. The total amount of wood in Finnish forests is 2100 million cubic meters. Economical sustainability is advanced for example by demanding forest owners to regenerate their harvest until five years have passed from the felling and by supporting forest management costs with the help of governments money in poor quality young stands. The best way to guarantee economical sustainability is to choose the right tree species for the right soil and by regenerating felled areas right after, according to the guidelines and by taking care of the forest stand with thinning and other forestry tasks when required.

Ecological sustainability means using the forests in a way that doesn't reduce biological diversity. Diversity can be secured by leaving areas decreed in the forestry law as specially important ecosystems outside of the felling and forestry industry. Another way is to sustain a good amount of decaying trees in the forests and by leaving small groups of trees in felling and prescribed burnings. Ecological sustainability goals have been partly completed in Finland. The amount of decaying trees has increased during the last 10 years from 2,8 cubic meters per hectar to 3,2 cubic meters per hectar in southern Finland. In Lapland it is 7,6 cubic meters per hectar, and the average for whole Finland is 5,4 cubic meters per hectar. A research done in 2010 on endangered species in Finland showed that on 81 species the danger of extinction has been greatly reduced and on 108 species the rate of extinction hasn't decreased.

Social sustainability basically means the multi-purpose use of forests, including gathering berries, mushrooms, hiking and trekking, hunting and fishing. Every man's rights guarantee that every person has the right to walk, ski and bike or ride horses in anybody's forest. In the nature you can also make a campsite and gather berries and mushrooms without the landowners permit. Driving a motor vehicle or making a fire in the forest requires the land owners permit. In state owned lands there are many forests considered as areas which combine social sustainability with economical sustainability in mind.

4.1. Certification

Sustainability in forestry can be guaranteed by certification. Finland uses PEFC and FSC certificates. Dominant system currently is the PEFC certification, and 95% of Finnish forests are certificated by PEFC. Third party observes that requirements for the certificates are met in forestry management. Without this certificate the selling of wood can be impossible for the forest owner because largest buyers for timber only buy it from certified forests.

4.2. Forest management and growing

Finland uses even aged forestry method, selective and small area felling are done very rarely. The use of this method has been explained to be the best due to the properties of Finnish tree species. Spruce is the only tree species that can tolerate shading and thus even aged forestry has seen to be the most productive way to grow our forests, even though this method has been criticized during the last few years. In the year 2013 a new law will come in to effect where small area felling are most likely allowed again.

The aim of forest caretaking is to speed up the growth of the forest and thus gain a better yield for it. In effect this is done by regulating the density of trees in the stand during sapling and young stand phase. When the right forestry actions are done during the right time the stand can reach felling maturity in 60-70 years, depending on the soil. In Finland the forest site grading goes from the most barren to the most nutrient rich, Pine is cultivated in Nutrient poor heathland sites, Dry upland and Medium dry upland forest sites; mixture of Pine/Spruce/Birch is common in Moist upland forest site; mixture of Spruce/Birch is common in Herb-rich forest sites.

The pre-commercial thinning is made at DBH (stem diameter at the breast height) bellow 8 cm, and tree height varying within the interval 1.3 m – 7 m (T2 stand development pahse- Mature sapling stand). The first thinning is made in young stands (Stand development class 02) at DBH between 8 and 16 cm and tree height over 7 m. When the DBH is over 16 cm then the second thinning is made (Stand development class 03- Mature stand). Final felling is common in stands with DBH between 24 and 30 cm (Stand development class 04 – Regeneration maturity).

4.2.1. Growing of spruce

Spruce is planted usually by hand and the method of soil preparation is mounding. Recommendation for planting density is 1800 saplings per hectare. Natural regeneration is not really used, because results from past attempts have been poor. In areas with frost danger spruce should be planted under an older stand, if this is possible. The older trees are removed when the saplings are 1-2 meters tall. During the first years grass control should be done to reduce the amount of dying saplings. In T1 stand phase class (i.e. Small sapling stand), around the 5th year the recommended action would be circle cleaning, in which you remove all trees around the sapling in a 1 meter area around. In T2 phase (Mature sapling stand) when the stand is 5-6 meters tall on average the trees interfering with the growth of spruce is removed, if dead saplings are found, other tree species are planted to cover these holes. The aim after sapling phase is to establish the stand to have around 1600-1800 trees per hectare. In 02 phase(Young stand), when the majority height of the trees is between 13 and 15 meters the first thinning can be done, in which the amount of trees is dropped by half. The time for thinning is defined by height and DBH. In the thinning the lowest quality trees are removed. In 03 phase the 2nd thinning is done, in which half of the trees are removed again. In 04 phase the stand is ready for felling. The time for felling is determined by heaviness. After 10 years from the regeneration growth fertilization can be done, which increases the growth rate of trees and the investment can produce a 10-15 % profit. A well-kept planted spruce produces around 8 cubic meters growth per hectare per year.

4.2.2. Pine growing

Pine is regenerated naturally or artificially plating/seeding. About half of Finnish pine forests are regenerated naturally. Natural regeneration and seed planting should be done on arid soils, where there is very little undergrowth. Natural regeneration always also includes soil preparation to increase chances of seeds growing in to saplings. Planting by hand is done on richer soils where there is more undergrowth. Recommended planting density is 2000 saplings per hectare. When pine is regenerated by seed planting, recommended density is 4000 seed planting spots per hectare. On areas where weeds are present they should be removed during the first growing years. Usually pine grows on more barren areas, so removal of weeds isn't needed. In T1 phase trees interfering with the growth of pine are removed. In T2 phase required forestry actions should be done when the stand is 4-7 meters tall, if regeneration was done by seed planting or by natural regeneration and the amount of saplings is very large, the thinning can be done earlier. After these actions the density of the stand should be from 1800 to 2000 trees. The technical quality of pine can be improved by 10 growing it even as dense as 3000 trees per hectare, and by pruning. Pruning is done when the stand is in phase 02. 02 and 03 phase thinning can be done the same way as for spruce. A pine forests in southern Finland grows about 7.5 cubic meters per year per hectare. On barren soils pine is easily the best choice for productivity.

4.2.3. Birch growing

The recommended planting density for birch is 1600 saplings per hectare. Birch can be regenerated naturally or by planting. In planted stands the early management of young stands is not necessarily needed, because birch is a fast growing tree species. When doing natural regeneration for birch, the stand will be very thick. When it reaches 1-2 meters height, it can be thinned to 1600-1800 trees per hectare. First actual thinning is done when the stand is 14-15 meters tall. During thinning half of the trees are removed.

5. Snow damage as a common problem in Finland

Conditions for snow damages are born when wet and dense snow freezes on the tree crowns, when frozen snow mass is accumulated enough, branches or crown will be broken. Highly speed wind can boost these damages. Snow damage occurs throughout the country. In highland areas (more than 250 meter above the sea level) of Northern Finland snow damages are the most common. Unlike Central Europe, avalanches are not problem in Finnish forests because of relatively flat topography. Finnish Forest Research Institution (Metla) has measured snow load of 3197 kilogram from 19 meter high spruce. Snow can damage every tree species. Pine stand which has grown too dense is the most vulnerable, right after thinning is made. In young pine forests snow can break not only the branches, but also the crown. In mature pine forests crown damages are not typical, even though it is possible in cases where snow mass is extremely heavy. In young birch forests snow weight can bend the trunk on the ground. Spruce is the most resistant tree species towards the snow damages, even though crown damages exist sometimes. Snow damages can destroy whole tree or expose them to a fungi and insect damages. In cases where wood are destroyed more than 10 m^3/ha, this wood must be carried away before upcoming summer, in order to prevent insect and fungi damages.

Solution: It is impossible to entirely prevent snow damages, always is risk but it is possible to reduce this risk. In order to prevent snow damages thinning should be made at the correct time and not allowed forest to grow too dense when individual trees become high and thin, thin trunk increases snow damage risk dramatically. Risk of snow damages are highest at this kind of forests where trees are high and thin and where thinning are made too strongly. If forest is not managed well 12 and if it is too dense, thinning should be made carefully. At the young age pre-commercial thinning must be done, in order to prevent forest to become high and thin.