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https://doi.org/10.5109/4555

出版情報：九州大学大学院農学研究院紀要. 48 (1/2), pp.375-403, 2003-10-01. Faculty of Agriculture, Kyushu University
バージョン：

J. Fac. Agr., Kyushu Univ., **48** (1・2), 375–403 (2003)

Changes in the Species Composition in the Forests of the Czech Republic in Response to Changing Policies and Their Consequences

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(Received June 25, 2003 and accepted July 15, 2003)

The species composition in the forests of the Czech Republic has been changed from its original natural state. Today's species composition is often referred to as "unsuitable", forming unstable forest stands with high risks of abiotic and biotic damage. The aim of this study was to analyze available sources of adequate information about the natural species composition in the forests of the Czech Republic in order to compare the results with today's situation. The historical developments in Czech forest policy and forest management affecting the changes in species composition were analyzed as well. Based on the analyses, the necessary objectives and methods were suggested. The methodology of Forestry and Game Management Research Institute was used. Possible future characteristics were analyzed. Based on necessary change and reconstruction of species composition proposed by the Government, the future forestation requirements were calculated. These numbers were compared with currently available sources. Inevitable economical consequences affecting forest owners were also calculated. Based on the analyses, the forest policy tools were suggested

INTRODUCTION

In the Czech Republic, the forests cover 2,634,000 ha, i.e. one third of total land area. In international com–parison it means that the Czech Republic has the 8th largest forest coverage and the 4th largest growing stock volume (254 m^3/ha) in Europe. Total growing stock is nearly 600 mil m^3 and mean increment 7.15 m^3/ha. This results from previous forest policies.

Society expects that forests will provide not only timber but also satisfy the everlasting requirements for non–wood–producing services, i.e. water management, soil conservation, recreation, land use, climate etc. This led in the past to differentiation in forest management and its distribution into categories. There are currently the following categories: commercial forests (61.5%), protective forests (3.0%) and forests for special purposes (35.5%). The main objective in commercial forests is timber production while in protective forests and forests for special purposes, non–wood producing benefits predominate over production functions and forests enjoy the legal protection.

There is disproportional predominance of coniferous tree species, particularly spruce

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and pine over broadleaves in the Czech forests. Being aware of risk of this status for total stability of forest ecosystems, foresters are aiming to change the species composition for the benefit of soil–improving and stabilizing species. Target composition starts from analyses of current soil and climate conditions and the structure of original natural stands. When determining species composition as functionally optimum, it is about to reach a compromise between natural and productive–oriented composition.

HISTORICAL DEVELOPMENT OF SPECIES COMPOSITION IN THE FOREST STANDS OF THE CZECH REPUBLIC

It is very difficult to specify original species composition of the Czech Republic forests because forest has evolved together with species evolution. Individuals from one species were continuously establishing communities, modifying relations to site conditions, and constantly developing these communities. Therefore, it is necessary, when using the term "autochthonous" species composition, to mention the dates, to which the species composition is being expressed.

Prehistorical era

According to Poleno (1995), forest type ecosystems with very complicated inter–relations have been established in this geographical area by the end of "Tertiary period". It is supposed that formation of tropical and subtropical forests very different from today's tropics existed at that time. The evolution of Earth's flora and so of forests was not continuous but it has often been interrupted, especially by several ice ages.

Apart from these distant–in–time forest formations, there have been attempts to study the evolution of forests since the last ice age, i.e. in last 15 000 years, using pollen analyses. Even this period is characterized by several important climatic changes, which resulted in many changes in species composition of the forests covering most of the area. In the "Preboreal period", the last ice age was dying out with air temperatures approximately 5 *°C* lower than today's temperatures. At that time, there was taiga vegetation type with birch and Scots pine at the Hercynian Czech Massif region, and mixtures of larch and *Pinus cembra* at the Carpathian region (eastern part of the country). In the "Boreal period" (8000–6000 years BC), with temperatures approximately 2 *°C* higher than today's, most of the area was covered by pine stands with a hazel understorey. Associated species were oak at lower altitudes and Norway spruce at higher altitudes. At the lowest altitudes, there was a majority of steppe or forest steppe vegetation type. The next moderate warming happened in the "Atlantic period" (6000–4000 years BC), when temperatures were 3 *°C* higher than today and the climate was oceanic. These conditions favourited mixed broadleaved forests, with mixtures of oak, lime, ash, elm, and others. This mixed broadleaved forest pushed away the pine to the relict sites, mainly to poor sites with sandy soils and rocks. In the mountains, where the tree line was approximately 300–400 *m* higher than today, the major species was Norway spruce. In the mid altitudes, the oak was meeting the Norway spruce. In the "Epiatlantic period" (4000–2000 years BC), the colder seasons were alternating the warmer periods in short intervals, and wet seasons with dry ones. Temperatures changed moderately (aprox. 1–2 *°C* above today's average), and climate began to be subcontinental.

Therefore immigration of European beech, silver fir, and at lower altitudes hornbeam occurred. In the following period of the "Subboreal period" (2000–1000 years BC), temperatures remained the same, but humidity was getting lower. In the "Subatlantic period" (1000 years BC–1000 AD), moderate cooling appeared (to today's level), and climate was therefore more humid. This allowed massive accession of beech and silver fir, both at higher and lower altitudes.

Historical era

At the end of the 1st millennium (the historical era), humidity decreased and climate became continental. Human activities were becoming more influential: colonisation, slash–burning of forests, pasture, and others. The cleared areas were being again colonised by oak, pine, birch, and aspen, as documented in the oldest written documents. For example, the name of town "Bukovsko" (came from beech) reflects the fact, that there were mostly beech forests around that area when the area was colonised, but chronicle from the year 1374 documents present of oak forests with large oaks. Similar cases can be found in Netolice. Also in Sedlcansko region, the chronicle from the end of 14th century documents oak and Scots pine forests. In the region east of Prague (Sestajovice), on the site called "Dubovy" (came from oak), there was a mixture of Scots pine and lime. There are mentioned "black forests of fir" in Trebonsko region, which is mainly pine region. Chronicle of Radnicko region describes different mixtures of larger numbers of species. Interesting data are documented from area around town Libejovice (in Vodnansko region), where in the forest called "Bukovy" (came from beech) there are assortments of oak and Scots pine. There are often found references about birch and aspen forests, for example in Radnice, Strasice, Pacov, and elsewhere. It is therefore obvious that changes in species composition, most probably under the influence of Man, had already occurred by the end of medieval time (in 13th, 14th, and 15th century).

There were even more human interventions in forests in the 16th century, when in many places, the forests were clearfelled, or at least the stands density strongly decreased in order to supply enough wood to Kutna Hora. There are historical data records that inhabitants of some towns (e.g. Lysa nad Labem, Brandys nad Labem, Podebrady, and others) were suffering with lack of wood that they were not even able to cook food or bake bread. Of course on newly cleared areas, there was succession of more primitive communities, in which the birch and aspen, and thanks to stump sprouting ability also hornbeam, lime, alder, and oak were dominant to the prejudice of beech.

Despite the undeniable progressive change of the species composition in the Czech forests, there was a majority of broadleaved forests in their abundant representation until the 18th century. Until the 18th century, there were no undesirable or uneconomic woody species, which would need removing from the forests. In those days, when woodworking professions counted for more than twenty different specializations, every species had use for its specific properties. Some of the trees were evaluated even for agriculture production, such as oak and beech for animal feed, lime and willow for honey production, which used to be much more important before the beginning of sugar production than today.

It has been estimated (Poleno, 1995) that broadleaved forests covered approximately 65% of forested area of the Czech Republic in the 18th century. The principal species remained the beech, despite the large reductions, with approx. 40% composition. The second main species was oak, with approx. 20% and other broadleaves had 5%. Amongst conifers, the main species was silver fir with approx. 20% valued especially for good properties to make shingles and the frames. Norway spruce covered 20% of the forested area, mostly in the mountainous regions, and 4% was Scots pine. Other conifers had exiguous proportion (larch, common yew, and common juniper).

Only after publication of provincial rules, which are seen as a positive step from a forest conditions point of view, significant changes occured in species composition in the forests. The creaming, when single trees were selected if needed and reachable, gradually decreased. Therefore negative selection and decreasing density stopped, and the pasture and collection of forest bedding has been regulated. The old cleared areas, fields and pastures in erosion risk were afforested step by step. The long decrease in forest land had stopped, and a new model of same–aged forest with different age classes of monocultures established by planting the most valuable species (Norway spruce and Scots pine), which were clear–cut at the end of rotation. The philosophical model based on this principle had become a successful base for reconstruction of devastated forests in the whole of Central Europe.

During less than one hundred years, most of the originally mixed, mostly broadleaved forests were converted to large–scale coniferous monocultures. Remnants of natural or at least close–to–natural forests survived only on inaccessible sites. Only thanks to a few wise foresters and forest owners the few remaining original forests had been left unchanged on purpose in the first half of the 19th century–Zofin, Hojna Voda, Boubin. In the second half of the 19th century, when it was becoming obvious that the new system was having problems, a few other forest reservations were added to the list–Zlatesovicka obora, Cernicka obora, Buky u Vysokeho Chvojna, and others.

By the establishment of Scots pine, and later on mainly Norway spruce monocultures, the production of wood increased in central European forests, but also the calamities of all kinds increased (windblow, snowfall, frost, bark beetles, and other insects). Wind mostly damaged the Norway spruce stands on sites affected by ground water (gley, pseudogley, and others). The enormous expansion of snowbreak disasters was due both to the spread of Norway spruce at lower altitudes, and planting of unsuitable ecotypes of Norway spruce at higher altitudes. Amongst the worst disasters of the 19th century was the windbreak disaster in Sumava (in October 1870), when in two days, 2.3 mil m^3 of forest were uprooted in an area of 3,800 *ha* (600 m^3ha^{-1} on average). As a result of delays in wood processing of the fallen trees, the population of barkbeetles increased enormously and turned into an outbreak. All together, 6.25 mil m^3 was processed, and most of the remaining virgin forests stands in Sumava were damaged.

Similar disasters all over Central Europe could not remain unnoticed, and were put down to establishing of Norway spruce monocultures far from natural range of Norway spruce. The most distinguished forester, who already in 19th century called attention to the negative consequences of only economically motivated changes in the species composition was Karel Gayer.

These ideas appeared in the historical Czech lands as well. During the Foresters' Convention in Jihlava (1856), there was discussion about unreasonable spread of Scots pine monocultures and the first university professor of forest science at the Prague Technical University, Kystof Liebich reminded that he had warned against the negative effects of excessive afforestation with monocultures more than twenty years before. Since the second half of 19th century, more foresters had urged to desist from planting monocultures and clearfelling system. They promoted mixed plantations of broadleaves with the use of natural regeneration, especially of beech and silver fir. Silviculture of mixed forests stands was discussed also during the meetings of Moravian and Silesian foresters in Odry (in 1867), in Velke Mezirici (in 1868), and in Bystrice pod Hostynem (in 1883). Josef Vrbata, the chief forester in Kout u Domazlic, wrote in 1870 and published in journal Haj article "Primary forest and artificially cultivated forest", in which he proclaimed principle of silviculture methods derived from the observation of natural processes. In 1880, A. Rosmanith delivered a written essay for the examination of professional forest managers with the title: "Die gemischten Bestände und ihre Vorzüge gegenüber den reinen" ("The mixed stands and their advantages over the pure stands"), (Poleno, 1995).

Also forest managers from the young Czech Republic reflected Gayer's ideas concerning species composition in the forests. After the Second World War, it was mainly the shelterwood silvicultural system, which was quickly developing since the beginning of 1950s. This system was officially supported by the Forest Act 1960, chapter 166 Coll., which significantly restricted the size of felling coupes, and established a system of small felling areas (shelterwood) as one of the main silvicultural systems.

This system had three fundamental principles:

- Establishment of optimal, site conditions and forestry objectives related composition of the forest stands (species, age, and space)
- Restriction of clearfelling system, especially with large felling coupes
- Encouraging individual selection and natural regeneration, wherever suitable conditions occur

The main ideas were very similar to close–to–nature silviculture methods used by German foresters after World War Two, which were following the Möller's ideas of forest with sustainable production, and Krutzschov's "naturgemässe Waldwirtschaft" ("nature oriented forest management"), (Poleno, 1995).

The small–area felling variant of this system affected especially at its beginning more the species composition rather than spatial composition of the stands. During 1950s, the broadleaved species reached almost 50% of the overall forest regeneration. Despite the larger mortality of broadleaves than conifers, this investment from the 1950s caused the high proportion of broadleaves in the 50 years old stands (33%). This proportion is higher only in the oldest stands (150 years old stands and older), caused by the undercutting of broadleaves (for lesser interest of wood–processing industry, and higher tolerance to emissions). In 1950s, the proportion of Norway spruce in forest regeneration decreased to 20–30% of the regenerated area, while the beech reached 7–12%. There already had been difficulties with providing enough seed stock and seedlings for beech at that time. Therefore other broadleaved species were planted instead, mainly oak and lime, both having proportion of approximately 8%. A significant proportion had birch

(6%), alder (6%), and also poplar (4%). More areas were regenerated naturally (6–8%).

DEVELOPMENTS IN THE FOREST SPECIES COMPOSITION FROM 1950

Instructive information about the developments in species composition in the forests is summarized in the Table 1 (Zatloukal, 1991). According to this table, proportions of most of the forest species went through relatively small changes during the 40 years period (1950–1990).

Table 1. Development of percentage forestation in Czech forests in the period 1950–1990

Forest invent.	spruce	fir	pine	larch	Other conif.	Total conif.	oak	beech	birch	Other hard broadl.	alder	Other soft broadl.	Total broadl.	Total
1950	58.9	2.8	20.8	1.6	0.2	84.3	4.4	4.5	5.3		1.5		15.7	100
1970	56	2.1	19.2	2.3	0.6	80.2	5.5	5.1	2.6	3.5	1.4	1.7	19.8	100
1980	56.1	1.8	18.6	2.7	0.6	79.8	5.8	5.4	2.5	3.3	1.4	1.8	20.2	100
1990	55.6	1.3	18.3	3.2	0.5	78.9	6.1	5.5	2.9	3.4	1.4	1.8	21.1	100

Source: Zatloukal (1991)

The proportion of Norway spruce decreased from 58.9% to 55.6%, i.e. change of 3%. However this change was to certain extent caused by dieback of the spruce forests in air polluted regions, namely in Krusne hory, Jizerske hory, and others. In the region of the forest enterprise Janov, Litvinov, partially Klasterec nad Ohri, and in other places, the dead stands were replaced with other tree species, mainly birch. Considering all these facts, which to lesser extent apply to some other mountain regions, it is possible to say that the necessary major decrease in the proportion of spruce in the prejudice of other species, mainly original broadleaves (which would help the stability o forest stands), practically was not achieved. Similar situation was with the relatively small decrease in the overall proportion of the second most important commercial species–Scots pine.

The overall proportion of silver fir decreased drastically, to less than a half (today practically less than a third) of its original proportion. The previous approach of the forest management and forestry operational practice is still deepening this process. Recent development of silver fir damage does not entitle nor justify this approach at all. Recent progress of this type of damage has been stopped, and in certain cases signs of regeneration are apparent even on the trees of middle age. Many cases of successful natural regeneration of silver fir are known when the game damage in natural seeding and advance regeneration has been eliminated.

The overall proportions of larch more than doubled since 1950, up to 3.2% of the area. There are many reasons for such development, amongst the others for example the seedstock availability, successful growth of seedlings, success of the cultures, mainly good speed of growth in early stages, relatively small risk of game damage compare with other species (esp. broadleaves), relative tolerance to air pollution, which gave the possibility to use larch as the substitute tree species in air polluted regions. At the same time, the fast growth and the satisfying production (especially value production during average rotation from 120 to 140 years) play important role too. The proportion of other conifers has increased more than twice. The reasons for this increase are plantations of introduced species, such as Douglas fir, Grand fir, and some exotic spruces.

In case of oak, there was an increase of 1.7% (from 4.4% to 6.6%). Beech increased only of 1% (from 4.5 to 5.5%). The proportion of other broadleaves changed insignificantly. According to this summary, the necessary change of the species composition of the forest stands, which is needed mainly to improve the stability, has not been executed very well. During the period of forty years, only insignificant changes, which cannot greatly affect the overall conditions of species composition dependent stability, appeared.

More information about the species composition in forests can be obtained from Table 2–Afforestation according to individual tree species in CR (Perina *et al.*, 1987). The information reflects the trends in forestry policy and changes in forest management.

Table 2. Afforestation according to the particular tree species in the CR

Tree species	1950		1960		1970		1980		1984		Optimal species composition
	(ha)	%	(ha)	%	(ha)	%	(ha)	%	(ha)	%	%
Spruce	9,426	27	18,586	34	12,946	50	15,074	56	17,898	59	40
Fir	1,373	4	1,840	3	1,373	5	160	1	186	1	2
Pine	6,281	18	6,939	13	4,471	17	5,678	21	5,464	18	11
Larch			4,536	8	978	4	1,628	6	1,571	6	15
Oak	6,764	19	4,539	8	2,217	9	721	3	1,349	4	9
Beech	3,989	12	3,851	7	1,744	7	927	3	530	2	11
Other species	6,974	20	14,937	27	2,175	8	2,845	10	3,158	10	12
Total	34,780	100	55,228	100	25,904	100	27,033	100	30,156	100	100

Source: (Perina et al., 1987)

Right after the war, and in the first half of 1950s, forestry practice reflected the tendency to return to the stable and healthy forests, natural regeneration, supporting the forests managed under different silvicultural systems involving both system of coupes with form of shelterwood system and regeneration by border felling, and selection systems with mostly group and seldom individual form (selection). This period of forest management in the CR is represented by the work of excellent foresters (silviculturalists), such as H. Konias, B. Polansky, F. Kratochvil, F. Sixta, and others. However, these trends were supported not only by the individual foresters but they were also recognized and promoted by the institutions, i.e. in legislation, and state forest administration. Besides the directive documents of all levels, decrees, and regulations, these tendencies were also documented for example by the special seminars, organized for forest workers in former forest enterprise Opocno, which later led to establishment of research station for silviculture in Opocno.

The percentage of Norway spruce in establishment of forest plantations and reforestation strongly decreased in 1950s, down to 27% from the total number of seedlings.

However, this percentage gradually grew during the next years and reached 59% in 1984. While the percentage of silver fir was strongly decreasing since 1980, possibly as a result of the decision to leave the silver fir out of commercial forestry, and use it only to minimal extent for conservation purposes. It was a tendency coming from some ideas published at that time (Poleno, 1977), and from the decisions of the forest management offices, probably promoted by the central offices. The percentage of Scots pine was persisting almost on the same level as in 1950, which was around 20%, except in the year 1960, when it dropped down to 13%.

During the 1950s the percentage of the main broadleaved species was relatively high; oak had 19% and beech 12%. It is well known that during 1950s and at the beginning of 1960s broadleaves were used to large extent. Apart from oak and beech, mainly maples and limes were used. Thousands of beech and lime groups were established during that period. These were planted in the frame of popular management of small units and many of them survived until today. They remained in different conditions with regards to late release and stand tending. The proportion than decreased gradually, and in 1970 the proportion of beech and oak in plantations was only 3%, and the others had 10%.

The decrease in the proportion of the main broadleaves was not due to low seed stock availability during the 30 to 40 year period. Although some of the mature and overmatured stands, which represented the base for seed collection, were felled, there were enough other newly maturing stands to collect seed from. With regards to silvicultural systems and tending of newly maturing stands, many of the stands of this age are too dense and do not have the ideal conditions for the fructification. The process of fructification was locally also affected by the changes in the environment, mainly air pollution. However, these negative changes do not drastically affect the overall fertility of the trees. This has been documented by practical experiences from previous years, and positive results of the natural regeneration of broadleaved species, mainly of beech in the stands, where the ideal conditions for the natural seeding and advance regeneration were created (when the game damage regeneration has been eliminated).

Clear but not very strong tendencies towards the planting of oak and beech to improve the species composition can be found in the management models and forest inventory. However the practical result is unsatisfactory, with regards to forest management measures, which could be considered as minimal rather than optimal, and which were not fulfilled in practice.

The reasons for this phenomenon were characterized in many articles, workshops, and conferences. Mainly the changes in the overall conception of the silvicultural system, transition to clear–felling system on larger areas so the rationalization and mechanization would be possible. The mechanized harvesting, which started at the end of 1960s and later became to be a priority, was very often inappropriate. These tendencies appeared in conceptions of the forest management, mostly with giving accent on the species composition of forests with high proportions of high yield species, spruce and pine, which were economically the most effective ones. The reflection of these ideas and tendencies can be seen in the predominate forest stand groups of spruce and pine management, while the forest stand groups with oak and beech management were on the edge of forestry planning. Disproportionate concentration of the seedling production in forest nurseries, establishment of the central nurseries led to the situation, when the forest enterprises were loosing the motivation and responsibility for providing the reproductive material, seeds included. These institutions were to certain extent in many cases exclusively relying on the supply of the reproductive material (seedlings) from other places. This often was, and in some cases still is being done with unsuitable species, unsuitable provenience, and low quality stock. During the inspections no consequences were concluded from the fact that the species composition is uncongenial, and that the coniferous monocultures are at high risk of damaging factors. The management system with orientation on harvesting technology as primary objective was not creating good conditions for plantation of mixed stands with adequate species composition. It was even slowing down the possibilities of natural regeneration (both conifers and broadleaves) by placing the clear–cuts to the places, where it would be possible and relatively easy to induce the process of natural regeneration, or where the natural regeneration had been already established. According to the results of the analyses, which are based on the tables created by Zatloukal (1991), and Perina (1987), developments in species composition of the Czech Republic during the last few decades were not very positive. The necessary decrease of the conifers (Norway spruce and pine) is insignificant, and in relation to this fact there is very slow increase of proportion of broadleaves and mixed stands, which would with higher probability perform better stability. It cannot be stated that the conditions got worse to the point where there would not be possible to secure relatively sufficient amount of reproductive material for broadleaved species. Although not everywhere would be the optimal amount available. Among the others, it is a problem of planning, management, organization, motivation, and stimulation of forestry workers.

NATURAL SPECIES COMPOSITION OF FORESTS IN THE CR BASED ON THE GEOBOTANICAL MAP OF THE CZECH REPUBLIC

The vegetation of the Czech Republic, forests included, is characterized on the Geobotanical map, Czech Lands (Mykyska *et al.*, 1968). According to this work, which contains a number of the sheets with maps at a scale of 1:75,000 (overall the scale is 1:1,000,000); and the text part, the Czech Lands have, from the geobotanical point of view, their own, so called forest climate, which allows development of the most highly organized vegetation cover–forest. There is very little of the country's area, which would be naturally forest–free. Today's forest–free areas of different character are, with a few exceptions, of the anthropogenic origin. The natural forest–free areas in the Czech Republic include the highest peaks of the Krkonose Mountains, Kralicky Sneznik, and Hruby Jesenik, which are above the natural tree line, specified by the alpine climate. In other cases, the natural obstacle for establishing forest could be either wet soils with peat formations, or on other hand extremely dry sites, for example on the slopes with shallow soils and exposure to sun, where the lack of water resulted into establishment of the forest steppe or mountain steppe type of vegetation. Altogether the areas, which could not for any reason be occupied by forest in the past, are insignificant, and therefore most of the units demonstrated in the geobotanical map represent different types of forest communities. The map distinguishes different categories of zonal, non–zonal, extrazonal, and paraclimax forests. This map has a reconstructive character; its content is a theoretical reconstruction of natural vegetation, as it would have evolved in conditions similar to today's conditions at the end of postglacial period. Therefore it encompasses almost the whole of the Czech Republic as the forest communities, even the areas, which are not forested today. When mapping the reconstructed natural vegetation represented in this geobotanical map, the anthropically based changes in vegetation and the impacts of humans on natural environment in the historical period are eliminated. When mapped, the degradation of forest soils caused by unsuitable species in plantations, changes caused by fertilization, and draining of alluvial areas, have not been reflected. The remains of today's natural vegetation and their interactions with the environment have been studied.

The main objects of mapping are groups of moreless related communities. Each of them was chosen in order to indicate the characteristics of its environment (its site sets). The collective of authors was aiming for these units to be used in economy as well. When choosing the groups of communities as mapping units characterized above all by flora, they used floristic system of Currich–Montpellier school (Braun–Blanquet, 1932).

Units used for mapping do not belong to the same taxonomic category, and do not have the same content. Altogether 19 vegetation units are mapped:
wetlands and alder habitat, halophyte communities (only in note, not as independently mapped unit), oak–hornbeam habitat, debris woodland, calciphile oak habitat and calciphile relict pinewood habitat, flowering beechwood habitat, beechwood habitat, acid oakwood habitat, pine–oakwood habitat, wet oak–beechwood habitat, birch–oak habitat and birch habitat on peat, acid pinewood habitat and relict pinewood habitat on silicate parental rock, forest–free communities of sandy soils (only in note, not as independently mapped unit), mountain spruce habitat, wet spruce habitat, high moors and temporary peat bogs, low moors, subalpine and alpine communities.

Each mapped unit is characterized by flora. The characteristic of tree layer is at the first place, main tree species, other tree species forming usually the admixture, and species, which occur in lesser extent only under specific conditions. The spectrum of shrub layer is characterized, if developed, and big attention is paid to herb layer, and in many cases, there are often mentioned the differences, by which it is possible to distinguish the mapped unit from other more or less related units. According to the conditions, the possible existing variants are characterized, and the occurrence or spread of the mapped units throughout the area of the Czech Republic.

Although the units are indicated on the map, there is no indication of approximate area of the unit, nor approximate species composition in tree layer of these communities. Neither for the aims of the global study of species composition in the tree layer of the mapped units, nor for the overall characterization of possible distribution of woody species in natural forests, is not enough necessary information in this map (including the text). The relative richness of the forest ecosystems is obvious, and species variability high. The ecological spectrum of some of the mapped units is very wide.

It is apparent that the units, which compose the geobotanical map of the CR, are not compatible, nor comparable with the typological system of the Forest Management Institute, nor with the system of Zlatnik (1976). Targets of these systems attempting only application in forest management, and methodological principles of production, are in comparison with the geobotanical mapping very different.

CONCEPT OF THE NATURAL SPECIES COMPOSITION OF THE FORESTS BASED ON THE AVAILABLE DATA OF FOREST MANAGEMENT PLANNING

As a foundation of the concept of the original (natural) composition of the forests in the Czech Republic, and for approximate quantitative specification of the proportion of economically important species in the whole spectrum of species of the Czech forests, the only useful study at present is the complex of materials and publications issued by the Forest Management Institute in Brandys nad Labem. The whole list of publications starts with the book from Pliva, Pruša "Typological foundations of silviculture" (1969), work of Pliva "Differentiated methods of management in Czech Republic forests" (1980), anonymous "Models of management" (1985), and work of Pliva, Zlabek "Operational systems in forest planning" (1989). The last publication of Pliva *et al.* "Functionally integrated forest management" (1991), has three parts and represents the final article of the list of related works. In all of them, especially in the latter ones, there are summarized and used the results of the forest site surveys, extensive research of large number of specialists. The results of the research are analytically and synthetically projected to the practice of the forest management, and operational, especially the silvicultural methods. In addition, in all of these publications, the experiences of the long forest taxation practice based on the excellent knowledge of the forest conditions are summarized and generalized. The last publication, "Functionally integrated forest management 1, 2, 3," (1991), in context with publications published earlier, represents work, which is hardly comparable with other European literature, particularly in systematic, detail, and precision of the elaboration. While the first part contains the characteristic of the environmental conditions from the forestry planning point of view, particularly that of silviculture and the second part functions of forestry, the third part contains models of forest management measures. This publication has a major importance for forest management in the Czech Republic, although some parts of the content, particularly those of part three (Models of forest management measures) should be critically discussed.

One of the issues studied and analyzed in these publications is the species composition of forests. This problem is believed to be one of the main tasks for the operational forest management and silviculture.

For the each group of forest types, which are characterized ecologically (climate, orography, soil properties, and species of the herb layer); there is also natural species composition. These data are very important and valuable, considering the fact that the group of the specialists from the Forest Management Institute, who did the research and now continue with site surveys, is a highly qualified team of experts with knowledge and experience for this type of study. The desired target species composition is suggested, the level of production (yield class), and specific possible risk from the detrimental factors of the environment are estimated, on the basis of the natural species composition. The data presented for groups of forest types allow the discussion about problematic of the target species composition. However, it is impossible to calculate average proportions of different species for forests in the Czech Republic, because the areas for each group of forest types are missing.

For the overall estimation of the average natural species composition of the Czech forests, it is therefore necessary to use the "forest stand groups", i.e. synthetic units, which consist of small or large number of the forest types. Also for the forest stand groups, there is referred to the natural species composition at the "Models of the forest management measures" (1991), which in many cases is not distinct but in intervals for each species instead. This approach is logical, considering presence of different groups of forest types in each forest stand group. In framework of natural species composition, there are very often mentioned tree species, which form little admixture of the species composition, and this is without an area description. In relation to these facts, it is clear that the calculation of the average proportion of species in the forests of CR is possible to consider being more or less reliable estimate.

The calculation of the average proportion of species composition is possible with regards to availability of the areas for the forest stand groups. For the purpose management, specified in the "Models of Management Measures", for the average calculation of species composition the same data are used, as are specified for the basic related group of commercial forest (for example for the group 22 the same natural composition will be used as for the group 23, etc.). The data with areas are quoted partly in a publication by Pliva, Žlabek (1989), partly in the Overall forest management plan (1991). For the calculations, data from the latter one were used.

Based on the available data (Models of management measures 1991, Overall forest management plan 1991), it was possible to estimate the proportions of the commercially most important species in the natural composition of forests. From the Table 3, it is obvious that in the original natural conditions in the forests of Czech Republic, the highest proportion had beech (40%), than oaks (18%), silver fir (16%), and Norway spruce (15%). The share of Scots pine was surprisingly small (3%). Although Scots pine was very abundant (according to the geobotanical map for example in calciphile relict pinewoods, pine oakwoods, and acidophile pinewoods), it was pushed away from many sites (except the sites with extreme conditions) by the other species, which performed higher competitive ability on those types of sites. The hypothesis that the proportion of Silver fir in natural forests of CR was high and the proportion of Norway spruce relatively small, was confirmed. Norway spruce in natural conditions was only present in stands of 5th forest vegetation zone (fir beech), and higher. It only played important role in the species composition in higher altitudes of 6th forest vegetation zone, mostly the 7th and 8th (Table). "Other" broadleaved species are not possible to specify by species with relation to insufficient information available. Larch as a natural species, occurres on limited area in eastern Sudety.

It is apparent that there was a majority of broadleaved species in the natural forests, mostly beech and oaks, and the total area of conifers was probably less than 40%. Rapid growth of conifer proportion (especially Norway spruce and pine) is related to the spruce and pine policy, which has begun in the 18th century.

Sindelar (1995) analyzed the proposal of conception of modified species compositions based on forest stand groups and subgroups, prepared by Forest Management Institute. In this proposal, the supposed natural composition of forests in the CR is calculated from the available information from the Forest Management Institute. In comparison with the previous calculations, there are minor differences in the total estimate. For example the Norway spruce is 12%, which is 3% less. The differences in proportion of silver fir, oak, and beech are not exceeding 10%. More significant difference is in the estimate for Scots

Table 3. Estimated natural species composition in the forests of CR

Species	Natural composition (%)
Spruce	15
Fir	16
Pine	3
Larch	1
Oak	18
Beech	40
Other broadleaves	7
Total	100

pine and the group of other broadleaved species. The author is considering higher original proportions of Scots pine in some forest stand groups, for example stands grouped together into the forest stand group number 39–pine management on the wet sites. Those stands are on the poor sites with permanently wet soils on the plateau and depressions of lower and middle altitudes, and sites susceptible to frost damage. The differences in the estimates of the species composition of the other broadleaved species could be of methodological character, and could result from the fact that when the research was carried out in the Forestry and Game Management Research Institute, the species with proportion less than 10% were not included.

It is possible to state that the forests of the Czech Republic are characterized by the high degree of differentiation between the real and natural species composition. In order to increase the stability of forest ecosystems, increase and sustain production, and secure other forest functions (mainly ecological and social), it is therefore necessary to make modifications of the species composition, especially to increase the proportion of broadleaved species to the prejudice of Norway spruce. The knowledge of the natural species composition should be one of the most important bases for creating overall conceptions and realizations of necessary modifications.

PREVIOUS CONCEPTION OF THE SPECIES COMPOSITION IN FOREST STANDS ACCORDING TO FOREST INVENTORY (1991), AND MODELS OF MANAGEMENT MEASURES (1991)

In the last decennial forest inventory carried out by the Forest Management Institute, there are, apart from the real species composition of forest species at that time, also the total numbers for the annual planting plan. It is not quite clear whether this annual planting plan is suppose to be a long term program with regards to models of management measures or data which have been to certain extent modified by the recent situation, for example reliable on the reproductive material available at the forest nurseries, and others.

It is apparent from Table 4 that as far as the proportion of different species in the annual planting plan were considered (especially the main conifers); there were no significant differences from the contemporary species composition. The proportions of spruce and pine were supposed to decrease. The projected decrease of Norway spruce was 7% from the total proportion, which gave 13% from total proportion of spruce in the forests. The Scots pine projected decrease was almost 2%. Despite these facts, the total

Table 4. Species composition according to Forest inventory (1991)

Species	Species composition (%)	Annual planting plan (%)
Spruce	54.6	47.6
Fir	1.0	0.4
Pine	17.8	15.9
Larch	3.2	7.8
Total conifers	**77.5**	**76.3**
Oak	6.0	7.5
Beech	5.4	11.1
Hornbeam	1.2	0.0
Ash	0.9	0.6
Maple	0.7	1.1
Birch	2.9	0.9
Lime	0.9	0.5
Alder	1.4	0.7
Total broadleaves	**22.2**	**23.7**

annual planting of these two coniferous species planned in the annual planting plan (according to the forest inventory), was 64% together (Table 4), which represents almost two thirds of the forested area. This proportion was very high considering the facts that most of the Czech forests were already in air–polluted regions, and these species were not very stable. This reality was documented not only by the recent state of the forests, but also by many new facts, mainly by decline of Norway spruce in some regions. Also the decline and dieback of pines (*Pinus nigra* and *Pinus sylvestris*) had serious consequences in many localities without a possibility of satisfactory explanation for this disease. The effects of early opening up of the middle–age and maturing stands were well known (for example in the forest region number 17–Polabi), the losses on Scots pine plantations and young–growth stands were significant in some regions. The possibility of deformation of root systems and root diseases due to the widely used container–grown and balled plants, were not excluded (Sindelar, 1993).

The proportion of larch, as previously mentioned, almost doubled. However also this species, which used to be considered healthy and stable, was showing problems from local to regional level. Single trees and groups of trees were already declining and dying.

The proportion of silver fir was constantly decreasing. This process was even being supported in forest management plans by annual planting plan of only 0.4%.

The proportion of oak had only a small tendency to increase, according to annual planting plan in forest inventory (real proportions 6.0%, annual planting plan 7.5%). Beech proportion had the trend to increase slightly higher (real 5.4%, plan 11.1%). Other broadleaves were in reforestation plans explicitly omitted, though their role for stabilization was undeniable. Certain increase was planned for maple (proportion 0.7%), when its annual planting plan was only 1.1%. All other species would decrease in comparison with contemporary species composition in that time, despite the fact that some of them could with their influence on structure and stability substitute for beech in certain cases. It could mainly be maple in mid and higher altitudes (forest vegetation zones from 2 to 4), and to certain extent also hornbeam (forest vegetation zones from 1 to 3). Hornbeam although suitable also for the forest understorey in oak stands, sometimes Scots pine, or larch, was not included in the annual planting plan at all. According to Sindelar (1993), it was necessary to evaluate the importance and possible use of hornbeam carefully. It could, on some sites regenerate spontaneously, and therefore depress the main commercially important species, such as oak and beech. On the other hand, it could serve as a nurse for the main crop, mainly in oak stands, designed for production of thick and valuable assortments, or in some promising stands of Scots pine with perspective of roundwood production for veneer or other special purposes. In these cases, it is correct to plant hornbeam as intermixed species during the establishment of forest plantations, or underplanting later.

Following results are based on the analyses of the Forest inventory (1991) and the Models of forest management measures (1991):

The proportions of Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*), which were too high, were supposed to be reduced according to annual planting plan, but only very moderately. This trend could hardly lead to significant changes in species composition in order to strengthen the stability and sustain the productivity in future.

Tendencies to omit Silver fir from the composition of forests were obvious to certain extent, with exceptions considering nature conservation. The fir was endangered not only by the polluted environment but also by the forest management itself, which was deliberately reducing the proportion of this species.

There was a tendency to increase the proportions of two main broadleaved species, small in case of oak but significant in case of beech. These trends should be assessed, especially in case of oak, which can be optimally grown only in altitudinal forest vegetation zones number 1 to 3, eventually 4. On the other hand, beech has a much wider spectrum of sites with optimal conditions for its growth, where it can become important part of the species composition. It includes different forest types and their groups within the altitudinal forest vegetation zones number 2 to 7. The planned proportion of beech in species composition seemed to be low compared with the original composition. However, the most serious problem was the fact that the planned proportion of these species in annual planting plans was not being repeatedly reached.

The other broadleaved species, which could add to biological diversity and stability of the forests, were not utilized enough. They are namely: maples, specifically Sycamore maple (*Acer pseudoplatanus*), limes (*Tilia cordata* and *Tilia platyphyllos*), but also ashes, mainly common ash (*Fraxinus excelsior*), and hornbeam (*Carpinus betulus*). Though these species, especially sycamore, both limes, and in some cases hornbeam could in species composition of the forests biologically and ecologically substitute beech in case of significant lack of reproductive material.

It is not quite clear whether the existence of elms was counted for in the future forest management. Although the existence of elms, especially of smooth–leaved elm (*Ulmus carpinifolia*), and wych elm (*Ulmus glabra*) was extremely threatened, there were certain conditions in favour of survivor, for example in the flood plain forest, where it regenerates from the root suckers. This ability is performed by fluttering elm (*Ulmus laevis*), and smooth–leaved elm (*Ulmus carpinifolia*) as well.

According to the analyses of available data based on Forest inventory and from some information provided in Models of management measures (1991), trends oriented towards the changes in the species composition of forest stands in the Czech Republic expressed in the proposal of the annual planting plans were insignificant with regards to real unfavourable and unstable composition of forests. It was mainly relatively small increase in oak proportion, decrease in other broadleaved species (with exception of maple), and factual elimination of some species from the artificial regeneration (hornbeam). These overall trends in forest management could not lead to desirable major changes in species composition. It could not be expected to improve the stability of forests from that development, especially with regards to the fact that the spruce and pine monocultures were still predominant in establishment of new forest stands.

RECENT SPECIES COMPOSITION IN THE FORESTS OF THE CZECH REPUBLIC ACCORDING TO THE REPORT ON THE STATE OF FORESTS AND FORESTRY IN THE CZECH REPUBLIC

From Tables 5 and 6, it is obvious that the species composition of the CR is dominated by the conifers, which cover 77.6% of the total forest area. Of this proportion, Norway spruce makes up 55%, and Scots pine 17.8%. These two species, which to large extent form monocultures with low stability and high risk of calamities, are present on 72.8% in total. The rest (4.8%) is made up by the other coniferous species, particularly by larch, silver fir, Douglas fir, and others.

Table 5. Natural, current, and recommended composition of tree species (According to Report on the state of forests and forestry in the Czech Republic)

Species	Species composition (%)		
	Natural	Current	Recommended
Spruce	11.0	55.1	36.5
Fir	18.0	0.9	4.4
Pine	5.4	17.9	16.8
Larch	0.0	3.7	4.5
Other conifers	0.0	0.2	2.2
Total conifers	**34.4**	**77.8**	**64.4**
Oak	17.2	6.3	9.0
Beech	37.9	5.9	18.0
Hornbeam	1.8	1.2	0.9
Ash	0.7	1.1	0.7
Maple	1.5	0.8	1.5
Elm	0.5	0.0	0.3
Birch	1.1	3.0	0.8
Lime	3.8	1.0	3.2
Alder	0.6	1.4	0.6
Other broadleaves	0.5	1.5	0.6
Total broadleaves	**65.6**	**22.2**	**35.6**

Broadleaved species grow on 22.4% of the forested area. From this share, oak has 6.5%, beech 5.9%. From the other broadleaved species, only birch, alder, and hornbeam have higher proportion than 1%. Birch has 3%, mostly because it partly planted, partly regenerated on the clearcuts induced by air pollution in air–polluted regions of Krusne hory. Alder has 1.5%, and it also appears in the preparatory stands, which are established on former unforested areas, particularly in alternative stands on the clearcuts induced by air pollution in air–polluted regions as well. Hornbeam has 1.2% with regards to more significant occurrence and good reproduction potential in some forested areas or their parts.

Table 6. Species composition of forests

SPECIES	1950	1970	1980	1990	1997	1998
	Area of forest stands ha / %					
Spruce	1,353,203 60.0	1,427,735 55.6	1,437,499 55.7	1,413,893 54.7	1,407,201 54.5	1,402,925 54.3
Fir	64,692 2.9	53,325 2.1	44,786 1.7	27,708 1.1	23,894 0.9	23,576 0.9
Pine	477,627 21.2	491,501 19.2	469,403 18.3	460,481 17.8	457,329 17.7	455,524 17.6
Larch	33,529 1.5	57,410 2.2	68,266 2.7	81,762 3.2	93,019 3.6	94,289 3.7
Other conifers	4,719 0.2	14,885 0.6	19,275 0.8	21,446 0.8	4,487 0.2	4,500 0.2
Oak	81,016 3.6	139,761 5.5	145,817 5.7	155,269 6.0	159,960 6.2	160,900 6.4
Beech	102,243 4.5	129,158 5.0	135,988 5.3	139,533 5.4	148,278 5.7	150,657 5.7
Birch	–	66,926 2.6	65,027 2.5	74,167 2.9	75,809 2.9	75,993 2.9
Other broadleaves	99,778 4.4	167,980 6.5	166,209 6.5	167,959 6.5	176,882 6.9	179,428 7.0
Total conifers	**1,933,770 85.8**	**2,044,856 79.7**	**2,039,229 79.2**	**2,005,290 77.6**	**1,985,930 76.9**	**1,980,814 76.7**
Total broadleaves	**283,037 12.5**	**503,825 19.6**	**513,041 20.0**	**536,928 20.8**	**560,929 21.7**	**566,978 22.0**

FOREST REGENERATION TASKS IN FOREST MANAGEMENT OF THE CZECH REPUBLIC

For regeneration of the forests, it will be necessary constantly to provide sufficient amounts of the reproductive material, i.e. seeds and seedlings. This will require certain measures from forest seed management and nursery management.

To assess the magnitude of these tasks on the long term, it is necessary to estimate the extent of regeneration needed. With regards to this, it is necessary to plan regulations in the species competition in order to differentiate the tasks in seed harvesting and seedling production with relation to suitable use of species and sites.

Amongst the available materials useful for the assessment, there are reports on the state of forests and forestry in the Czech Republic published by the Ministry of Agriculture (1995–1999), statistical information–edition for forestry and game management published by the Czech Statistical Office, and overall forest management plans processed by the Forest Management Institute. The comparable data from these sources are different to a certain extent, which reflect the different methodological approach for data collection and processing. Also the objects studied are sometimes not identical.

Table 7. Unstocked area

Year	Area by Jan. 1st	New unstocked area				Reduction in unstocked area				Area by Dec. 31st
		After cutting	Reforest. losses	Other	Total	Reforest.	Natural reg.	Other	Total	
	ha									
1980	31,961	19,980	6,309	4,866	31,155	26,939	999	1,403	29,341	33,775
1985	39,332	22,706	9,954	5,090	37,750	33,555	594	3,768	37,917	39,165
1990	38,870	19,240	12,178	2,855	34,273	33,615	908	1,080	35,603	37,540
1991	37,540	15,599	13,060	4,925	32,684	31,516	557	1,283	33,356	36,868
1992	36,868	14,651	14,452	3,392	32,495	29,600	575	4,761	34,936	34,427
1993	34,427	12,472	13,437	3,862	29,771	27,698	697	4,010	32,405	31,793
1994	31,793	12,562	14,448	3,767	30,777	26,897	818	1,667	29,382	33,188
1995	33,188	17,016	11,090	3,615	31,721	30,128	1,163	1,189	32,480	32,429
1996	32,429	15,493	7,620	737	25,399	28,426	1,898	879	31,203	26,625
1997	26,625	16,705	6,219	2,537	25,461	24,038	2,538	623	27,199	24,887
1998	24,887	16,870	6,137	3,410	26,417	24,257	2,633	781	27,671	23,633

The information about unstocked area is given in the Table 7. According to this table, the unstocked area during years 1990–1998 changed from 37,540 *ha* in 1990 to 23,633 *ha* in 1998. It means that the average unstocked area for that period was 31,266 *ha*. A large part of the unstocked area originated in fellings during 1990–1994 (12,472–19,240 *ha*). Recently, the unstocked area from fellings decreased significantly with regards to large extent of incidental and salvage fellings, which are scattered around the forests, and therefore the real unstocked areas, which would be possible to reforest, are not actually created. In recent years, there has been a large increase of unstocked area due to plantation establishment failures caused mostly by drought during the growing season. Some of the unstocked areas also contain the forest–free areas, which were not included in the evidence in the past. Significant increases can be observed in unstocked areas, which have been established in less traditional ways. They can be established for example by deforestation for construction purposes, such as communications, power transmission lines, and others, which will later be excluded from the forest land resources.

Natural regeneration had small share (2–3%) of the total forested area in early 1990s but has risen up significantly since 1995 and reached almost 10% of total forested area (Table 8). Although this percentage is supposed to rise, it will not be included in calculations of necessary reproductive material in the near future, and the natural regeneration will form extra reserve for forestation. This approach is justified by the uncertainty of future results in natural regeneration with regards to environmental factors.

Other important information for the estimate of the future average plantation plans is the extent of actual forestation in the past. Results from 1990–1998, and data from 1980 and 1985 are in Tables 19, and 22 (Graph 7, and 9). The annual area afforested during 1990–1998 was 26,576–34,523 *ha*, with the average of 29,774 per year. In 1995–1997, the total area of afforestation decreased. This could be due to different factors, for example high share of incidental fellings, which did not lead to the establishment of forestable areas, or transformation of forest ownership in past few years and problems of forest management within these properties.

Table 8. Forest regeneration

Method of regen.	Reforested [ha]										
	1980	1985	1990	1991	1992	1993	1994	1995	1996	1997	1998
Artificial	26,939	33,555	33,615	31,516	29,600	27,698	26,897	30,128	28,426	24,038	24,257
Of which repeated	6,750	9,569	9,635	12,050	12,702	12,994	14,448	12,760	–	6,219	6,137
Natural	999	594	908	557	575	697	818	1,163	1,163	2,538	2,633
Total	27,938	34,149	34,523	32,073	30,175	28,395	27,715	31,291	30,324	26,576	26,890

The comparison of the average unstocked area (31,266 *ha*), and the average forested area of the same period (29,774 *ha*), gives the result of approximately 5% (1,492 *ha*) difference, where the latter is slightly smaller than the former one. This difference is probably caused by the fact that reforestation tasks of some relatively small areas are being moved to following years for various reasons (work capacity, lack of reproductive material), or because some of the areas are not quite ready for the reforestation. It will be necessary to include these facts in future planning.

For future requirement of forest reproductive material, it is also important to estimate the extent of afforestation of forest–free, mainly former agriculture land. The afforestation of forest–free land culminated in the first half of the fifties, mainly due to changes in settlement by western borders. In recent years, the extent of afforestation stabilized around 1,000 *ha* per year. Although the work connected with the afforestation of agricultural land excluded from the production has not been quite activated yet, it is expected that minimum of 100,000–200,000 *ha* of today's agriculture land should be gradually transferred into the forest land resources, with regards to its low profitability and overproduction of agriculture products. It is possible to calculate the total area, which should be forested every year, from the facts based on these assumptions.

There is no reason to believe in major changes in wood volumes harvested annually in future perspective of 10 to 20 years compared to current numbers, and it is therefore assumed that it will remain on the same level of approximately 13.42 million m^3 per year. This volume of average unstocked area calculated from the total forest area (approximately 2,634,000 *ha*), and average rotation 116 years, represents approximately 23,000 *ha*.

However, the calamities often affect also the younger stands, so there are unstocked areas in the premature stands as well. These incidental fellings are usually compensated by making reductions in the mature fellings. The trends of afforestation of forest–free land in the next 10–20 years are hard to estimate but for the purpose of this study it was counted with the area of approximately 5,000 *ha* per year.

Within the plans for forestation of unstocked areas and forest–free land, it is necessary to add the area of beating up and gapping of new plantations. Under the "normal" favourable circumstances this usually represents 20–30% of forested area. With regards to current conditions, when most of the forests are affected by the air pollution, forest soils are under the influence of depositions of pollutants from the atmosphere, the soil acidity is high, some areas are affected by the nitrogen depositions, and others, it has been suggested for the reasons of this calculation to extend the proportion to 40%. In addition to this, some preventive measures should be taken to deal with possible effects of the global climate changes (greenhouse effect), which can cause higher mortality of established plantations in the future. Total area for beating up and gapping of new plantations on both, the unstocked areas established after fellings, and the forest–free areas, represents roughly 9,000 *ha* per year.

It can be summarized that there will be requirement for the forestation of ca 23,000 *ha* of unstocked areas established after fellings, then ca 5,000 *ha* of forest–free land, and ca 9,000 *ha* for beating up and gapping of new plantations in the conditions of the Czech Republic for the period of next 10–20 years.

The realization of new plantations on the forest land will be in different ways according to site conditions. Planting will be used on unstocked areas, group planting or underplanting inside the forest stands, interplanting where useful natural regeneration will appear, and filling of blanks where necessary.

The average estimate of total area of new plantings required in Czech forestry per year should be ca 37,000 *ha*. This area will be referred to in following calculations, assessments, and conclusions.

The area of natural regeneration is left as a reserve. The share of natural regeneration is suppose to increase in the future, particularly in spruce, larch, beech, partially pine, oak, and some of the other broadleaves. It has been estimated that the natural regeneration could reach 15% of the forested area during next 10–15 years in the conditions of the Czech Republic if deliberately induced and suitable silvicultural methods applied. This would usually be combined with artificial regeneration.

Relatively small will be the proportion of sowing, mainly due to lack of seed material for the species, which used to be widely reproduced by sowing in the past, such as oak, beech, and fir. Sowing of oak and beech was not recently used also because of the high risk of game damage, mainly wild boar and other cloven–hoofed game, rodents, and others. Sowing should be mainly be restricted to certain pioneer species, particularly birch and possibly European mountain ash (*Sorbus aucuparia*) on clearings after salvage felling mostly in air polluted regions. Also plantations of black walnut (*Juglans nigra*) are mostly being established by sowing. These sowings of pioneer species together with the natural regeneration are considered being an extra reserve. It should be considered when calculating the required seed stock. According to the Report of forestry of the Czech Republic (1995), the proportion of forestation by sowing is only 1.5% (Table 9).

Table 9. Artificial regeneration by tree species

Species	1990	1995	1997	1998
			ha	
Total artificial regeneration	33,615	30,128	24,038	24,257
Of which planting	32,846	29,694	23,821	23,889
Of which sowing	769	434	217	368
Spruce	19,467	15,072	10,694	10,646
Fir	215	614	571	602
Pine	5,173	3,716	2,747	2,839
Larch	2,722	2,119	1,443	1,178
Other conifers	671	340	205	241
Total conifers	28,248	21,861	15,660	15,506
Oak	1,415	2,360	2,379	2,617
Beech	1,494	3,445	3,396	3,591
Lime	54	297	344	343
Poplar, aspen	91	46	66	100
Other broadleaves	2,313	2,119	2,193	2,100
Total broadleaves	5,367	8,267	8,378	8,751
% broadleaves	16.0	27.4	34.9	36.1

The area of each species has been calculated from the suggested species composition in the forests of the Czech Republic. For the calculation of required amount of bear–rooted seedlings, the minimal numbers per hectare were used, with reference to attachment number 8 to the Decree of the Ministry of Agriculture of the Czech Republic no. 82/1996, on genetic classification, forest regeneration, plantation establishment, and the evidence of seed and seedling stock of forest species. Though these numbers were used according to official document currently in force, they could be subject of discussion. It is mainly the case when the species is planted in mixtures. There is no reason for lower number of seedlings per hectare on reduced areas, especially in group mixtures, which would be the most common case. Lower numbers of containerized seedlings per hectare could also be questionable. Better root–taking of containerized seedlings is not necessarily always the case. It is necessary to plant enough seedlings for allowing positive selection during young stages of the stand.

It is apparent from the Table 10 that the average calculated requirement for the realization of forestation on the area of 37,000 *ha* is 226,103,300 seedlings, from which the coniferous species have 122,118,500 and broadleaved 103,984,800 of seedlings.

For comparison, the data from publication Statistical Information 13–forestry (published by Czech Statistical Office) were used. These data were calculated proportionally for approximately the same areas as used in the Report of forestry in the CR. The differences in areas and other data are mostly result of different methodology used for data collection for the Czech Statistical Office in one hand, and the Forest Management Institute in the other. Therefore the results can be compared only to certain extent.

According to the Table 11, the amount of seedlings planted in years 1992, 1993, and 1994 compared with the future perspective calculations, is spread in interval between

Table 10. Future perspective of seedlings requirements by species

Species	Share (concept)	Area of forestation	Number of seedlings per ha	Total seedlings
	%	ha	1,000 pieces	1,000 pieces
Spruce	36.5	13,505	3.5	47,267.5
Fir	4.4	1,628	5.0	8,140
Pine	16.8	6,216	9.0	55,944
Larch	4.5	1,665	5.0	8,325
Douglas fir	2.2	814	3.0	2,442
CONIFERS	64.4	23,828		**122,118.5**
Oak	9.0	3,330	9.0	29,970
Beech	18.0	6,660	8.5	56,610
Maple	1.5	555	6.0	3,330
Ash	0.7	259	6.0	1,554
Lime	3.2	1,184	6.0	7,104
Hornbeam	0.9	333	6.0	1,998
Alder	0.6	222	4.0	888
Birch	0.8	296	6.0	1,776
Elm	0.3	111	6.0	666
Poplar	0.6	222	0.4	88.8
BROADLEAVES	35.6	13,172		**103,984.8**
TOTAL	100	37,000		**226,103.3**

Table 11. Comparison of calculation results with information for the years 1992–1994

Calculation results		Forestation	Number of seedlings	Av. Number of seedlings
		ha	1,000 pieces	seedlings/ha
Future perspective	Conifers	23,828	122,118.5	5,125
	Broadleaves	13,172	103,984.8	7,894
	Total	37,000	226,103.3	6,111
1992 planting	Conifers	24,330	–	–
	Broadleaves	5,290	–	–
	Total	29,600	185,831	6,278
1993 planting	Conifers	22,570	134,163	5,944
	Broadleaves	5,128	49,134	9,581
	Total	27,698	181,700	6,562
1994 planting	Conifers	20,470	121,694	5,942
	Broadleaves	6,419	59,824	9,319
	Total	26,897	180,370	6,706

180–186 million of seedlings.

The average amount per hectare is 6,111 seedlings (5,125 are conifers and 7,894 broadleaves), according to future perspective. This means that the total calculated for the future production and usage of seedlings in next 5–20 years is approximately 6% lower in comparison with years 1992–1994. While the average amount of seedlings without special reference to species was 6,516 pieces per *ha* during this three–year period, it has been estimated to drop down to approximately 6,111 seedlings per *ha* in near future. This difference is caused by the changes in species composition to certain extent, mostly by the differences between the old Decree of the Ministry of Agriculture of the Czech Republic No. 248/1993, on plantation establishment and forest regeneration, and the new Decree of the Ministry of Agriculture of the Czech Republic No. 82/1996, on genetic classification, forest regeneration, plantation establishment, and the evidence of seed and seedling stock of forest species.

Globally, according to the calculation based on the Decree of the Ministry of Agriculture of the Czech Republic No. 82/1996, it is possible to state that the numbers of seedlings per hectare required for plantations are lower than numbers used in the past.

According to the results of this analysis, the number of total seedlings required for new forest plantations in the Czech Republic will be 226,103.3 pieces, of which 122,118.5 coniferous seedlings, and 103,984.8 broadleaved seedlings. Average number of seedlings per area (*ha*) will be 6,111 pieces. With regards to groups of species, the average number of conifers will be 5,125 seedlings/*ha*, and average number of broadleaves will be 7,894 seedlings/*ha*. The overall average number of seedlings per area (*ha*), based on the Decree of the Ministry of Agriculture of the Czech Republic No. 82/1996, will be approximately 6% lower in comparison with the number derived from the previous Decree of the Ministry of Agriculture of the Czech Republic No. 248/1993.

SEED STOCK REQUIREMENTS IN THE FOREST MENEGEMENT OF THE CZECH REPUBLIC

To provide the bases for the proposed changes in the species composition of the forests in the Czech Republic, it will be necessary to ensure and sustain sufficient seed stock. Therefore the average future seed stock requirements needs be calculated. The calculation is based on the average number of the seeds with good germination ability in weight unit of seed stock. These numbers are taken from the attachment No. 6 of the Decree No. 82/1996–on genetic classification, forest regeneration, plantation establishment, and the evidence of seed and seedling stock of forest species. Content of seeds with good germination ability in weight unit of seed stock theoretically reflects the potential of number of individual seedlings, which could be derived from the seed stock.

According to Sindelar, (1998), the experience with seedling production in forest nurseries suggests much smaller numbers of one–year seedlings derived from weight unit, compared to numbers of seeds with good germination ability. Only available material related to this problem is the Czechoslovakian state norm CSN 48 2111 (1953), where average numbers of seedlings derived from 1 kg of seeds is specified. These numbers of seedlings derived from coniferous seeds account for approximately 50% of seeds with good germination ability. Numbers for broadleaved species with large seeds are more favourable, while for species with very small seeds, such as alder and birch, the numbers are several times smaller. For the calculation of the amount of seed stock required for ensuring future forest plantation it is necessary to estimate the average number of ready–to–plant seedlings, which is possible to derive from 1 kg of seeds. This estimation is difficult to make with regards to variability of seed stock in terms of quality, health conditions, and variability in size, maturity, and health conditions of seedlings produced. There are no suitable studies available at the moment. With regards to these problems, only rough estimation based on practical experiences can be carried out. For the purposes of this analysis, the numbers from VULHM methodology (Sindelar, 1998) were used. The amount of units for spruce was 41,000 seedlings produced from 1 kg of seeds; 54,000 for pine, and 16,500 for larch (Table 12). The number of usable seedlings of spruce is 50% of all seedlings produced. Similar situation is in case of fir and pine. From 1 kg of larch seeds, it is possible to use 12,000 seedlings for plantation, which are almost two thirds of total number of seedlings grown from 1 kg of seeds. When produced using intensive methods with great deal of care and protection, and good quality seed stock, the numbers could be even higher.

According to the methodology of VULHM, for the broadleaved species is possible to use practical experiences from forest nurseries, such as Recany nad Labem, Budisov, and others. The calculation of usable seedlings of beech is problematic with regards to large forestation tasks and difficulties with ensuring sufficient amount of reproductive material. The number used in forestry practice is 800 of usable seedlings derived from 1 kg of seeds. This number is higher than average numbers achieved in forest nurseries (ca. 500 seedlings). However, the numbers attained in the Seed Production Plant Tyniste nad Orlici were significantly higher (ca. 1,000 seedlings). The average number of reproductive material produced by the experts from the VULHM in order to establish research plots was 1,100 usable seedlings derived from 1 kg of seeds. Considering technological progress in some forest nurseries, positive results in seed storage methods, improvement of seedbed preparation, and interest of new forest nurseries owners (mainly private), the number 800 as a national average seems fairly feasible for the future.

In case of oak, the number of usable healthy seedlings is approximately one third less than total number of plants derived from 1 kg of seeds. The main reason is that oak is usually planted as two years old seedling not transplanted, after previous undercutting of root system. With relation to this, there is 100 of healthy seedlings for pedunculate oak, and 150 of seedlings for sessile oak (with higher number of acorns in weight unit) from 1 kg of seeds.

With regards to different ways of growing seedlings of other broadleaved species, the numbers of healthy seedlings vary approximately from 50% to 75% of total seedlings available from 1 kg of seeds. Specific situation is in case of Douglas fir, which is usually planted as two years old seedling (not transplanted), or as three years old transplanted seedling. The number used in VULHM 10,000 healthy seedlings from 1 kg of seeds, which is lower than numbers used in North America. The reason for this is probably the difference in seed quality and technology used.

For some of the species, the average annual seed requirements were transferred into average annual requirement of fruits (raw seed material) with regards to ratio of seeds in fruits. The numbers from the attachment No. 6 of the Decree No. 82/1996 were used for the transfer.

The results shown in the table 12 indicate requirement of 2,363.4 *kg* of seeds, and 78,779.2 *kg* of raw seed material for spruce; 1,864.8 *kg* of seeds, and 124,320 *kg* of raw seed material for pine; and 693.8 *kg* of seeds, and 13,341.4 *kg* of raw seed material for larch. These numbers can be compared with average annual seed requirements in the past, which were for the main species, according to Sindelar (1998), approximately 6,000 *kg* for spruce; 2,000 *kg* for pine; and 2,300 *kg* for larch. Compared to higher plantation share of larch in the past, the future plantation will be reduced to 4.5% of forested area, and the plantation density should be also lower.

Extensive application of important broadleaves (beech and oaks) in the future species composition is reflected in large future seed requirement. Average annual seed requirement for beech is 70,762.5 *kg*. Requirements for both oaks are well–balanced and represent ca. 120 tons for each of them. From other broadleaves, relatively high numbers of seed will be necessary for maple (2,775 *kg/year*), and small–leaved lime (2,273.3 *kg/year*).

Numbers calculated for future average requirements of seeds were also compared with stock of seed and seed raw material in Seed Production Plant Tyniste nad Orlici (Table 13). Although there seems to be enough reproductive material for most of the main species available at the moment, there is likely to be shortage in beech seed material in the future (especially with regards to irregularities in seed years and lower amount of fructification). The stock of beech seeds is 26,281 *kg*, which is significantly lower than in

Table 12. Calculation of the average annual raw seed material requirements for plant cultivation

Species	Average number			Average requirement		Ratio of seeds in fruits	Average requirement of fruits (raw seed material)
	Germination in 1 kg of seeds	Total no. of seedlings in 1 kg of seeds	healthy seedlings from 1 kg of seeds	seedlings per year	seed per year		
				1,000 pieces	kg	%	kg
Spruce	82,000	41,000	20,000	47,267.5	**2,363.4**	3.0	**78,779.2**
Fir	8,000	3,500	2,500	8,140	**3,256.0**	14.0	**23,257.1**
Pine	128,000	54,000	30,000	55,944	**1,864.8**	1.5	**124,320.0**
Larch	54,500	16,500	12,000	8,325	**693.8**	5.2	**13,341.4**
Ped. Oak	168	130	100	11,988	**119,880.0**		
Ses. Oak	254	200	150	17,982	**119,880.0**		
Beech	2,700	1,225	800	56,610	**70,762.5**		
Maple	6,700	2,033	1,200	3,330	**2,775.0**		
Ash	8,600	4,250	2,500	1,554	**621.6**		
Small–leaved lime	17,500	4,250	2,500	5,683.2	**2,273.3**	50	**4,546.6**
Large–leaved lime	6,800	1,500	1,000	1,420.8	**1,420.8**	60	**2,368.0**
Hornbeam	11,200	3,250	2000	1,998	**999.0**	55	**18,163.6**
Alder	250,000	16,500	8,000	888	**111.0**	12	**925.0**
Elm	13,800	3,500	2,000	666	**333.0**		
Birch	700,000	7,750	4,000	1,776	**444.0**	25	**1,776.0**
Douglas fir	49,000	12,500	10,000	2,442	**244.2**	1.5	**16,280.0**

previous years, and less than 50% of required seed stock.

Globally, it is possible to state that the average requirement for seed of spruce should be less than 50% of average requirements in the past. The main reasons for this fact are lower share of spruce in the future species composition in one hand, and lower number of spruce seedlings per area required for plantation establishment in the other. Significant decrease is shown for pine and larch as well. The seed stock of main coniferous species in Seed Production Plant Tyniste nad Orlici is sufficient.

Table 13. Stock of seed and seed raw material in Seed Production Plant Tyniste nad Orlici

Species	Pure seed, kg					Seed raw material, kg				
	1994	1995	1996	1997	1998	1994	1995	1996	1997	1998
Norway spruce	50,300	46,811	42,298	36,660	31,226	230,151	10,465	33,030	32	15,267
Scots pine	4,500	2,038	3,240	2,929	3,208	83,176	96,033	61,663	41,787	14,216
European larch	10,700	6,503	4,748	3,691	2,945	3,182	264	9,024	3,534	144
Silver fir	2,800	1,973	4,589	5,350	8,052	1,152	27,102	91	4,214	2,838
European beech	30,499	40,535	88,155	51,572	26,281	16,237	69,433	81	–	3,256

ECONOMICAL CONSEQUENCES OF FUTURE CHANGES IN SPECIES COMPOSITION

For the modification of species composition in the forests of the Czech Republic new approaches in forest management will be necessary. Decrease of spruce proportion in annual planting plan from current 55% down to ca. 36.5%, and simultaneously increase in broadleaves from 22% up to almost 40% will require higher financial inputs into silvicultural operations. Increase of forest management expenses will be influenced mainly by these factors:

– Non–sufficient seed stock of some species, mainly the most important broadleaved species–beech; to resolve the problem, it will be necessary to import seeds from the Slovak Republic, Ukraine, and Romania;
– More difficult pre–planting preparation of broadleaved seeds, and limited potential use of standard methods of seedlings production in large forest nurseries;
– Higher density of broadleaved seedlings used for forestation;
– Higher requirements for protection of broadleaved species;
– More experienced workforce required for thinning, and low possibility of any use for the material from thinning;
– Higher losses (mortality) in plantations, therefore larger extent of annual beating up.

Bludovsky (1995) calculated the average difference between forest regeneration (establishment) of one hectare of coniferous and broadleaved plantations, which in total amounted in 40,000 CZK/*ha*. The calculation included only the main evincible factors.

According to this calculation, the transition to higher proportion of broadleaves, when current extent of forestation sustained (37,000 *ha/year*), from 8,751 *ha/year* to 13,172 *ha/year* will therefore require additional 176,840,000 CZK/*year*. Average prime costs of forest regeneration will then rise from current 56,300 up to ca. 61,100 CZK/*ha/year*. This increase in forest regeneration costs will result in less interest in necessary modification of species composition from forest owners. Therefore, the system of state subsidies should target concerned forest stands suitable for improvements in species composition, and enable the owners to cover the extra costs from state financial aid.

CONCLUSIONS

From all the different sources of information about the natural species composition in the forests of the Czech Republic used and analyzed in this study. It is apparent that there was a majority of broadleaved species in the natural forests, mostly beech and oaks, and the total area of conifers was much less than today. According to Geobotanical map of CR, the Czech Lands have, their own, so–called forest climate, which allows development of forest, and there is practically very little of the area, which would be naturally forest–free.

Also from the analysis based on available data of forest management planning, it is obvious that in the original natural conditions in the forests of today's Czech Republic, the highest proportion had beech (40%), than oaks (18%), silver fir (16%), and Norway spruce (15%). The share of Scots pine was surprisingly small (3%).

Analysis of forest policy developments shows that rapid growth of conifer proportion (especially Norway spruce and pine) is related to the spruce and pine policy, which has begun in the 18th century. Since then the species composition of the forests in the Czech Republic has undergone major changes under the human influence. Clear but not very strong tendencies towards the planting of oak and beech to improve the species composition can be found in the past management models and forest inventories. However the practical result is unsatisfactory, with regards to forest management measures, which were not fulfilled in practice. According to the analyses of available data based on Forest inventory and from some information provided in Models of management measures (1991), trends oriented towards the changes in the species composition of forest stands in the Czech Republic expressed in the proposal of the annual planting plans were insignificant with regards to real unfavorable and unstable composition of forests.

Today's species composition of the CR is dominated by the conifers, which are on the 77.6% of the total forest area. Norway spruce (55%) and Scots pine (17.8%) to large extent form monocultures with low stability and high risk of calamities. Other coniferous species (larch, silver fir, Douglas fir, and others) take 4.8%. Broadleaved species grow on 22.4% of the forested area. From this share, oak has 6.5%, beech 5.9%. From the other broadleaved species, only birch, alder, and hornbeam have higher proportion than 1%.

With regards to comparison of current and natural species composition, it can be stated that forests of the Czech Republic are characterized by the high degree of differentiation between the two. In order to increase the stability of forest ecosystems, increase and sustain production, and secure other forest functions (mainly ecological and social), it is therefore necessary to make modifications of the species composition, especially to increase the proportion of broadleaved species.

The most appropriate method of species composition modification should be radical change of forestation tasks, which concerns average area of 37,000 *ha* per year. The necessary change and reconstruction of species composition of the forest stands proposed by Government will therefore require 226,103,300 seedlings, from which the coniferous species have 122,118,500 and broadleaved 103,984,800 of seedlings. The area of natural regeneration should be left as a reserve. The number of seedlings per hectare (6,111 pieces) required for plantations is lower than numbers used in the past. This forestation requires 2,363.4 *kg* of seeds, and 78,779.2 *kg* of raw seed material for spruce; 1,864.8 *kg* of seeds, and 124,320 *kg* of raw seed material for pine; and 693.8 *kg* of seeds, and 13,341.4 *kg* of raw seed material for larch. Average annual seed requirement for beech is 70,762.5 *kg*. Requirements for both oaks are well balanced and represent ca. 120 tons for each of them. From other broadleaves, relatively high numbers of seed will be necessary for maple (2,775 *kg/year*), and small–leaved lime (2,273.3 *kg/year*). For most of the main species is enough reproductive material available at the moment but there is likely to be shortage of beech seed material in the future. The stock of beech seeds is 26,281 *kg*, which is significantly lower than in previous years, and less than 50% of required seed stock. Average requirement for seed of spruce should be less than 50% of average requirements in the past. Significant decrease is in case of pine and larch as well. The seed stock of main coniferous species in Seed Production Plant Tyniste nad Orlici is sufficient.

Among other consequences, also higher plantation establishment costs are expected. The transition to higher proportion of broadleaves, when current extent of forestation sustains (37,000 *ha*/year), from 8,751 *ha*/year to 13,172 *ha*/year will require additional 176,840,000 CZK/year. Average prime costs of forest regeneration will then rise from current 56,300 up to ca. 61,100 CZK/*ha*/year. This increase in forest regeneration costs will result in less interest in necessary modification of species composition from forest owners. Therefore, the system of state subsidies should target concerned forest stands suitable for improvements in species composition, and enable the owners to cover the extra costs from state financial aid.

REFERENCES

Anonymous, 1985. *Modely hospodareni*. Lesprojekt, Brandys nad Labem: 144

Bludovsky, Z., 1995. Vliv zmeny druhove skladby na zvyseni nakladu. *Lesnicka prace*, **74** (6): pp. 4–5

Braun–Blanquet, J., 1932. *Plant sociology, the study of plant communities*. London, Fuller and Conrad: 286

Ceskoslovenska statni norma CSN 48 2111 – Plody a semena lesnich drevin, 1953

Mikyska, R. et al., 1968. *Geobotanicka mapa CSSR*. I. Ceske zeme. Praha, Academia: 204

Perina, V. et al., 1987. *Stav a vyvoj lesu CSSR*. Praha, CSAZ: 86

Pliva, K. et al., 1991. *Funkcne integrovane lesni hospodarstvi*. Brandys nad Labem, UHUL: 1: 263, 2: 96, 3: 12 and attachments.

Pliva, K. and Prusa, E., 1969. *Typologicke podklady pestovani lesu*. Praha, SZN: 468

Pliva, K. and Zlabek, I., 1989. *Provozni systemy v lesnim planovani*. Praha, SZN: 208

Poleno, Z., 1995. Vyvoj zastoupeni drevin a porostni skladby lesu Ceske republiky. *Lesnicky pruvodce*, **3**: pp. 18–24

Poleno, Z., 1977. Prognoza dalsiho ustupu jedle. *Prace VULHM*, **51**: pp. 41–52

Sindelar, J., 1993. K otazce zastoupeni drevin ve skladbe lesu Ceske republiky. *Zpravy lesnickeho vyzkumu*, **38** (1): pp. 1–8

Sindelar, J., 1995. Orientacni predstava o puvodni duhove skladbe lesu na uzemi Ceske republiky a jeji vyznam z hlediska moznych uprav. *Lesnicky pruvodce*, **3**: pp. 12–17

Sindelar, J., 1995. Orientacni predstava o puvodnim druhovem slozeni lesu na uzemi Ceske republiky. *Lesnictvi–Forestry*, **41** (6): pp. 293–299

Sindelar, J., 1995. Namety na upravy druhove skladby lesu v Ceske republice. *Lesnictvi–Forestry,* **41** (7): pp. 305–315

Sindelar, J., 1995. Podminky pro dlouhodobe perspektivni planovani druhove skladby lesnich porostu. *Zpravy lesnickeho vyzkumu*, **40** (2): pp. 1–4

Sindelar, J., 1995. Pestebne technicke a organizacni predpoklady pro upravu druhove skladby lesnich porostu. *Zpravy lesnickeho vyzkumu*, **40** (3–4): pp. 40–44

Sindelar, J., 1998. Potreba osiva a sazenic v lesnim hospodarstvi CR. *Zpravy lesnickeho vyzkumu*, **43** (1): pp. 1–10

UHUL, Brandys nad Labem, 1992. *Souhrnny lesni hospodarsky plan 1991*. Stav k 31.12.1991: 520

Zatloukal, V., 1991. Current status and development of forest resources in the Czech Republic derived from forest inventories data. *Lesnictvi*: pp. 843–857

Zlatnik, A., 1976. *Lesnicka fytocenologie*. Praha, SZN: 495

Zprava o stavu lesniho hospodarstvi Ceske republiky, 1995. Ministerstvo zemedelstvi CR, Praha

Zprava o stavu lesniho hospodarstvi Ceske republiky, 1996. Ministerstvo zemedelstvi CR, Praha

Zprava o stavu lesniho hospodarstvi Ceske republiky, 1997. Ministerstvo zemedelstvi CR, Praha

Zprava o stavu lesniho hospodarstvi Ceske republiky, 1998. Ministerstvo zemedelstvi CR, Praha

Zprava o stavu lesa a lesniho hospodarstvi Ceske republiky, 1999. Ministerstvo zemedelstvi CR, Praha