Emil Klimo[1]

MAIN ECOLOGICAL PROBLEMS OF CZECH FORESTRY IN FORMER TIMES AND AT PRESENT

HINDSIGHT

Forests on the area of the Czech Republic developed in particular stages including a natural period – without the impact of man which can be dated until the 4th century BC when man was a hunter, fisherman and picker of forest crops and thus he was fully part of the natural environment. Forests developed according to the development of climatic conditions from forests of the tundra character over forests with the high proportion of pine and birch to mixed oak forests with the abundant proportion of hazel. The Atlantic period (8000-6000 BP) was a marked stage for the development of forests in Czech lands. It was a climatic optimum of Holocene (temperature 2-3°C higher than today, precipitation higher by even 70%). While a neolitic man – farmer already occurred at lower locations of Moravia, the uninterrupted development of forest ecosystems continued in the Bohemian-Moravian Upland (mixed piedmont forests with elm, lime, ash and sycamore maple) tending towards the total forestation of the landscape. On more hygric and inverse sites only, spruce or alder occurred more markedly.

In the epiatlantic period (6000-3200 BP), forests were enriched by beech and later on also by silver fir. Thus, the forests are created mainly by Norway spruce, beech and silver fir and the landscape is always without human settlements. For the period 3200-2700 BP (subboreal), the deficit of precipitation is characteristic, however the deficit did not prevent the development of fir/beech forests and particularly spruce forests. The first forts are established in the forest regions – it is the first contact with a prehistoric culture. Until the 5th or the 6th century AD (AD-in the years of Christian era), however, the landscape was not subject to the influence of man and fir/beech and beech/fir forests provided natural character to the landscape.

The first marked impact of man was represented by pasturage and the gradual conversion of forest land to land used for agricultural purposes. The land was cultivated only for a certain time and after the decrease of its fertility it was left as fallow land and thus a gradual deforestation occurred on rather large areas although the number of inhabitants was relatively low.

[1] Institute of Forest Ecology, Faculty of Forestry and Wood Technology, Mendel University of Agriculture and Forestry, Brno, Czech Republic

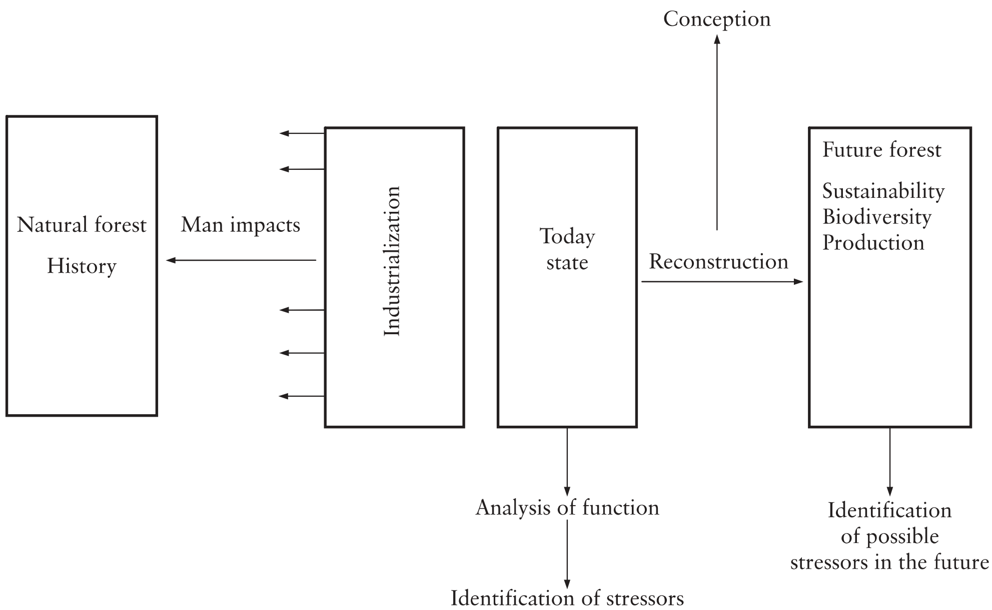

Figure 1 Scheme of the history of forest development

At the beginning of Slavonic settlement (the 6th century AD), it is possible to speak about a natural forest on the majority of the Czech territory although secondary forests were present in abandoned regions of continuous settlement (Blud'ovský et al., 1998).

Another important period is žagricultural colonization' which occurred predominantly from the 12th to the 14th century including both the flow of native population and colonization by population from abroad. This colonization changed even to industrial colonization which can be documented eg. in the region of the Bohemian-Moravian Upland.

In the 12th century, a Cistercian cloister was established in Žd'ár nad Sázavou. From this period, however, the stress of man to the landscape increased. A started colonization at lower locations manifested itself (at least in pollen diagrams) already about 1300 AD by the considerable decrease of woody species and increased proportion of herbs, grasses and cereals. In the Middle Ages, felling of forest stands continued, the consequence of which being gully erosion and suspended load sedimentation in river floodplains. Ore mining (at first silver ore and later iron ore) and charcoal burning (beech wood) spread. Since that time, species composition of forests begins to change – Norway spruce comes. At first, a natural process is changed in the 18th century to the purposeful planting of spruce monocultures. The process results in the decrease of species biodiversity of forests and on the other hand the origin of a rich mosaic of biotopes – autochthonous forest biocoenoses, spruce forests, peat bogs, grass communities, open areas of fields, scattered vegetation (Vašátko 2000).

Nowadays, names of many villages demonstrate to a considerable extent the character of a forest in the vicinity in the period of their establishment because they are derived from names of particular tree species (Bukov /beech/, Habří /hornbeam/, Jedlová /fir/, Jívové /goat willow/, Olší /alder/ etc).

In the 16th and 17th century, increased consumption of wood induced certain silvicultural treatments, nevertheless, forests were heavily devastated at the end of the 16th century as demonstrated, eg. by the Krkonoše Mts deforestation mostly for needs of mines of Kutná Hora.

This long time since the 12th century when the impact of man on the forest gradually increases meant an increased erosion in mountains and uplands and a change in the species composition of forest stands mostly in favour of spruce monocultures and the related clear-felling system of forest regeneration.

In this respect, the development of forests in Bohemia was similar as in neighbouring countries. For example, Johann (2004) mentions the development of the species composition of forest stands in Germany from the original proportion of broadleaved forests to coniferous forests 70 : 30% in 1300 to 30 : 70% in 1913. In Austria about the year 1000, the species composition was: spruce 36%, silver fir 26%, larch 2%, pine 4%, beech 20%, oak 8%. At present, the species composition is as follows: spruce 56%, beech 9% and oak 1%.

ECOLOGICAL IMPACTS OF GROWING SPRUCE MONOCULTURES

Before the marked change in the tree distribution caused by man, the original range of Norway spruce in Europe occurred besides a boreal zone also separately in mountain massifs of Alpine, Hercynian, Carpathian, Rhodopian and Illyrian regions. The problem of spruce origin is important for Czech forestry and, therefore, proper attention was paid to it. Through various comparative and archive studies it has been proven that spruce occurred frequently even at lower altitudes on sites with permanent high air humidity and on soils with the high degree of waterlogging or even on peat soils (Mráz 1959). Mráz (1959) tends towards the opinion of Reinhold (1944) (in Mráz 1959) that žrelict' spruce stands of lower locations are relics of the Atlantic period vegetation which has been preserved at certain sites up to the present day.

Extensive introduction of spruce falls particularly into the second half of the 19th century when natural forests were converted to Norway spruce monocultures in order to increase the volume of wood production. These brought both increase in wood and growth of negative phenomena (Nožička 1972).

Long-time discussions were caused mainly by a thesis on the rapid degradation of forest soils related to the formation of podzols as mentioned particularly by Pelíšek (1955). In characterizing marked podzolization he states that the process "occurs under spruce and pine monocultures in forest regions of lowland up to piedmont locations with the shortage of precipitation and with higher temperature conditions”. This statement was based on the involvement of the process of illimerization to the process of podzolization (particularly on loess sediments at lower locations) and also on discounting a fact that the occurrence of podzols on sandstones at lower locations (Bohemian Cretaceous Table) is not related to the present occurrence of spruce monocultures, ie podzols originated far earlier than in the period of growing spruce in the region. This opinion is, however, in contradiction with the opinion of eg. Šály (1978) who states that under a forest stand various soil-forming processes related to the combination of soil-forming factors occur and it is not possible to single out one factor only from the whole context and to attribute absolute effects to it.

At present, orientation of forestry in the Czech Republic is, on the one hand, conditioned by catastrophic damage to spruce stands by biotic and abiotic factors and, on the other hand, by accepting objectives of sustainable forest management which is related to the preservation of the production function of forests, maintaining and increasing biodiversity and the use of gene sources of autochthonous quality trees in forest regeneration. A view of the reconstructed natural and recommended composition of forests in some tree species fully supports the trend.

Table 1 Species composition of stands in the Czech Republic – 1999

Forest composition	% of trees in the stand					
	spruce	fir	pine	larch	oak	beech
Natural	11.0	18.0	5.4	0.0	17.2	37.9
Present	54.2	0.9	17.6	3.7	6.3	5.9
Recommended	36.5	4.4	16.8	4.5	9.0	18.0

Changes in the species composition of the forest stands to Norway spruce pure stands resulted in a change in the form of surface humus in the course of one generation. The total mass of the surface humus under the beech stand 80-100 years old was 23 t per hectare with minimum accumulation in the H layer, while the mass in the subsequent Norway spruce stand increased to 50 t per hectare, with maximum accumulation in H layer (Table 2).

Table 2 Change in surface humus mass after the change in the forest stand species composition (t/ha)

Layer	beech stand	Norway spruce stand
L	10.0	11.5
F	12.6	15.8
H	0.5	22.3
Total	23.1	49.6

The change also induced differences in the accumulation of elements and, in particular, slowed down the rate of cycling of some nutrients, especially nitrogen (Table 3).

In connection with the change in surface humus, a change also occurred in the root system distribution, and especially to fine roots, occurring in the spruce stand mainly on the border between H layer and the organomineral horizon A.

Table 3 Supply of elements in surface humus in the beech and Norway spruce

Layer	Forest stand	N	P	K	Ca	Mg	Fe
L	beech	153	11	20	68	4	15
	spruce	155	4	12	37	7	20
F	beech	161	14	59	29	7	40
	spruce	276	16	20	19	13	85
H	beech	7	1	3	0.5	0.2	3
	spruce	350	27	36	14	24	162
Total	beech	321	26	82	97.5	11.2	58
	spruce	780	47	68	70	44	267

In addition to soil changes, growing spruce monocultures conditions other damages both of biotic and abiotic character. It refers particularly to barking damage caused by red deer and mouflon. These damages are naturally related to the number of game. For example, in the year 2000 game damages amounted to CZK 36 374 000 and in 2001 they reached CZK 34 446 000 (Report on the condition of forests and forest management 2001, the CR Ministry of Agriculture, 2002).

As mentioned by Blud'ovský (1998) the condition of forest stands was disturbed by disasters already in last centuries being also significantly influenced by their completely changed character. The largest disasters were caused particularly by abiotic factors such as wind, snow, hard rime, frost deposit and glazed frost. The extent of damage caused by abiotic factors required to fell 90 million m^3 of wood in the period 1963-1990.

In addition to abiotic factors, considerable damages to forest stands were caused by insect pests which often accompanied disasters caused by abiotic agents. As an illustration we give selected data on insect pests.

Insect outbreaks on spruce in 1900-1980 (from Koudela, 1980 – in Blud'ovský, 1998). Damage extent exceeding 1000 ha.

Year	Species	Affected area	Pest
1917-1927	spruce, pine, fir	> 6 000 000 ha	*Lymantria monacha*
1925-1932	spruce	17 000 ha	*Steganoptycha diniana* Gn.
1930-1932	spruce, pine	cca 3 000 ha	*Lymantria monacha*
1937-1942	spruce	cca 6 000 ha	*Lymantria monacha*
1937-1938	spruce	cca 5 000 ha	*Pristiphora abietina* Christ.
1945-1947	spruce	2 000 000 m^3	*Ips typographus*
1953-1955	spruce	200 000 m^3	*Ips typographus*
1959-1960	spruce	120 000 m^3	*Ips typographus*
1966-1978	spruce	5 - 10 000 m^3 per year	*Ips typographus*

Considerable discussions were induced by *Ips typographus* outbreaks in spruce stands of the Šumava National Park. On the one hand, there was an opinion to keep the attacked forest to its natural development and on the other hand, an opinion was promoted to remove attacked trees. The conflict situation resulted in the change of the National park administration.

ECOLOGICAL PROBLEMS RELATED TO AIR POLLUTION

Air pollution as the result of industrial development, particularly of brown coal combustion in power stations and the development of heavy industry in the period after the World War 2 markedly to catastrophically affected the condition of forests in the Czech Republic. Of course, damage to and die-back of forest stands has to be considered in relation to other factors, particularly deviations and changes in climate. Particularly decrease in precipitation resulted in a several-year dry period or a frost shock which occurred during the last day in 1978 when air temperature decreased in the course of several hours even by 25°C. In connection with long-term effects of air pollution eg. in the Beskids, it resulted in the die-back of spruce stands on an area of about 2500 ha.

The largest damages to forest stands were caused by air pollution in the region of a so-called black triangle, ie on the borderline of the Czech Republic, Germany and Poland where SO_2 concentrations reached an annual average of 120 to 150 μg SO_2/m^3, i.e. about 65-80 kg $S.ha^{-1}$. Of course, it refers to dry deposition only. Thus, the region of the Krušné hory Mts became an example of industrial air pollution showing even an international character.

In connection with ecological consequences of air pollution a question was also discussed of direct effects of air pollutants on vegetation organs of forest trees and effects of forest stand decline through changes in soil chemistry due to acid deposits. Particularly the second question caused rather antagonistic opinions. Naturally, in interpreting the forest soil acidity it is necessary to take into account the whole complex of factors.

Parent substrates (soil-forming substrates) appear to be an important factor influencing acidity of forest soils on the area of the CR. Generally, we can state that substrates of acid character predominate. It refers particularly to crystalline rocks such as granite, gneiss, mica schist, Cretaceous sandstones but also sandstones of Carpathian flysch. On these rocks under interaction of climate and plant cover, soils have developed being of acid reaction such as podzols and acid Cambisols. Soils of slightly acid reaction such as Luvisols have been created on loess sediments and soils saturated by basic elements on igneous basic rocks of the České Středohoří Mts. Of special character are soils developed on alluvia of the Labe, Odra, Morava and Dyje rivers which can be primarily of neutral to slightly alkaline reaction. Soils developed on limestone karst rocks are of neutral acidity. Also Mařan (1944, 1948) attributes the importance of natural soil-forming factors for the condition of soil acidity according to particular soil types but the character of surface humus is considered to be the principal factor. The fact is then generalized by Mařan (1948) as follows: (1) humus of closed conifer stands is much more acid than that of closed broadleaved stands of the same region, (2) forest floor layers are more acid than layers of mineral soil.

Similarly Zlatník (1938) studying natural forests of the Trans-Carpathian Ukraine describes sites where soil acidity of upper horizons reaches 4.5-4.8 pH and in some cases even 3.8, 3.6 and 3.4 pH.

Therefore, in studying anthropogenic impacts it is necessary to take into consideration this natural condition affecting also sensitivity of soil to acidification by spruce monocultures and particularly by acid depositions.

Of course, the high input of acid deposits to soil considerably affected the leaching of basic cations (mainly of Ca and Mg) which also induced the requirement of forest soil liming in particularly affected regions. Changes in soil chemistry were also demonstrated in experimental studies (Klimo et al. 1999).

In these experiments studying the movement of calcium, magnesium, potassium, sodium, nitrate nitrogen and sulphate sulphur, calcium and sulphur were washed out most. The addition of sulphur on the soil surface induced increased loss of calcium amounting to 32% at 100 kg $S.ha^{-1}$ (corresponding to 6 keq H^{+}), at a higher rate corresponding to 300 kg S (19 keq), calcium decreased by 122% as compared with the control. The loss of other elements was lower. In magnesium, the addition of 300 kg S per ha increased the loss of the element by 48%, in potassium by 58% during 5 years. The loss of nitrate nitrogen and sulphates was also increased.

Although many serious measures have been accepted, particularly in relation to decreasing harmful air pollutants, forest soil liming, and a trend to change the species composition of forest stands, from monitoring of the health condition of forests it appears that the problem remains in the Czech Republic and its solution requires a long time and further measures.

ECOLOGICAL CONSEQUENCES OF THE CLEAR-FELLED SYSTEM OF FOREST REGENERATION

This questions induces the same discussion as growing spruce monocultures or negative impacts of air pollutants. Unlike these two problems, the question can be dealt with by a relatively fast change in a forest law which was also carried out in the Czech Republic where both the extent of a clear-felled area and conditions when it can be used were modified. The use of a modified clear-felling system is practised particularly in floodplain forests and in case of felling stands on larger areas damaged by biotic or abiotic agents.

Questions induced by the clear-felling system are oriented particularly to the following problems:

1. If the clear-felling system using heavy machines effects unfavourably physical properties of soils.
2. If the nutrient cycle and its total balance is disturbed through the removal of all above-ground biomass from an ecosystem by the single output of elements.
3. If the removal of a plant cover markedly disturbs the hydrological function of a forest and thus soil erosion danger and nutrient leaching from ground waters.
4. If fast mineralization of large amounts of forest litter causes large inputs of $N\text{-}NO_3$ to ground waters.

The clear felling system of forest management and trends to increase the industrial use of tree biomass result in the marked output of organic matter and biogenic elements from the forest ecosystem. If we include the output of elements in the course of tending measures into calculation then the total output of nutrients is as follows:

P	103 $kg.ha^{-1}$
K	510 $kg.ha^{-1}$
Ca	1088 $kg.ha^{-1}$
N	570 $kg.ha^{-1}$

Through the clear-felling system technology considerable destruction of surface humus or even the surface mineral layers of soil occurs. The surface humus under a stand with a relatively homogenous layer of about 50 $t.ha^{-1}$ was differentiated due to logging and transport operations to plots where the supply of surface humus was as follows:

I.	72 868 $kg.ha^{-1}$
II.	83 094 $kg.ha^{-1}$
III.	1 280 $kg.ha^{-1}$

Nevertheless, the total supply of surface humus increased particularly due to the increased litter fall, dry twigs and shoots during logging and skidding whole trees. After the start of plant succession on a clear-felled area and establishment of a new stand, considerable conservation of raw humus occurs, blocking considerable amounts of elements (particularly N) important for the nutrition of the newly established stand.

Using means of mechanization for transport operations considerable changes in physical properties of soils occurred. These changes were particularly marked on skidding and extraction tracks where eg. volume mass increased from 1.27 to 1.70 and porosity decreased from 52 to 32%. Due to the emerging clear-felled area vegetation regeneration, physical properties of soils gradually regenerate. Thus, there is an assumption that substantial regeneration can occur during 8-10 years.

After felling a stand, changes in decomposition processes occur and thus also changes in the soil solution properties. For example, in the initial stage the soil solution (gravitation water) pH was lower on the clear-felled area as compared with a solution in a stand.

The development of herb vegetation on a clear-felled area is of great importance for the development of site on the clear-felled area. The vegetation ensures the cycling of elements and the fact showed itself in the third year after felling. The function of herbs in nutrient cycling decreases with development of a newly established spruce stand on the clearing. However, it can represent competition in nutrition of the newly established stand which was obviously demonstrated in our case particularly in nitrogen, potassium and magnesium.

CONCLUSION

The present view of the forest is changed due to a necessity to maintain the forests in good condition also for future generations. Therefore, the question of forest functions and ways of management has been the subject of discussion on an all-European and worldwide level.

The accepted forest policy of a state company Forests of the Czech Republic (1996) defines as its main task to create optimum relationships between fulfilling all functions of forests and the market economic environment and to ensure the permanent production of quality wood respecting and developing the environmental functions of forests. To fulfil the objectives the Czech Republic government accepted in 2003 a resolution on the National Forestry Programme.

On the basis of assessing present economic and ecological conditions of forest management in the Czech Republic it is possible to summarize main programme measures to ensure sustainable forest management as follows:

To ensure the permanent development of all functions conditioned by the forest existence, it is necessary:

- to maintain the present area of forests through the thorough observance of valid legal directives concerning the protection of land intended for fulfilling forest functions;
- to support the forest land consolidation by purchase, sale, exchange, donation and reallocation of land;
- to increase the area of forests through the afforestation of non-forest land particularly of waste land, fallow land (to support economically afforestation of non-forest land, to simplify relevant directives and to pay attention to suitable species composition of newly established stands);
- to support the present trends in decreasing the environment pollution, particularly of atmosphere, and to mitigate negative impacts of air pollution by available forestry measures;
- to decrease effects of acid depositions on the quality of forest soils and forest stands by biological reclamation and intervention measures;
- to regulate game population, its age structure and sex ratio to a level making successful regeneration and the further development of forest stands possible.

To use silvicultural procedures based on the knowledge of the substance and properties of forest ecosystems and on the useful approach of management to natural processes. It is necessary:

- to create legislative, professional and economic conditions to use the natural regeneration of genetically suitable stands, under conditions where it is effective from biological and economic aspect;
- to pay attention to preserving and increasing biodiversity through care of the gene pool of forest tree taxa;
- to achieve the gradual conversion of the present species composition of forest stands in favour of species characterized by higher tolerance to harmful factors

and better reclamation effects on soil and at the same time providing high wood-producing and non-wood producing functional effects through available tools of forest policy;
- to recommend growing successive stands under the shelter of regenerated stands and reduction of the clear-felling system of management where sustainable forest management is conditioned by such measures.

REFERENCES

Blud'ovský, Z. i dr. 1998. Lesní hospodářství v České republice. Lesy České republiky. 199.

Johann, E. i dr. 2004. History of secondary Norway spruce forests in Europe. In: Spiecker, H., Hansen, J., Klimo, E., Skovsgaard, J.P., Sterba, H. and VonTeuffel, K. (ur.). 2004. Norway spruce Conversion: Options and Consequences - Přeměna smrku ztepilého: alternativy a důsledky. Brill Academic Publishers. EFI. Research Report 18. 269.

Klimo, E. 1992. The Spruce Forest Ecosystems in Czechslovakia. In: Teller, A., Mathy, P., Jeffers, J.N.R. (ur.). Responses of Forest Ecosystems to Environmental changes, Elsevier Applied Scienses. 503-511

Klimo, E., Kulhavý, J., Prietzel, J., Rehfuess, K. E. 1999. Impact of simulated acidification and liming on forest soil and Norway spruce *(Picea abies* Karst.) seedling growth in a container experiment. Ecológia (Bratislava) 18, 4: 413-430.

Mařan, B. 1944. Půda jako základ lesní tvorby (Soil as a basis of forest production). Písek 1944. 544.

Mařan, B., Káš, V. 1948. Biologie lesa (Biology of the forest), Praha: Melantrich. 596.

Mráz, K. 1959. A contribution towards the knowledge of the autochthonous character of Norway spruce and silver fir in the interior of Bohemia (in Czech). Práce VÚL ČSR, VÚLHM ČSAZV Zbraslav-Strnady 17; 137-180.

Ministerstvo zemědělství ČR. 2003. Národní lesnický program. Praha: Ministerstvo zemědělstvì ČR. 15.

Nožička, J. 1972. Původní výskyt smrku v Českých zemích - Original occurrence of Norway spruce in Czech lands. Praha: SZN. 177.

Pelíšek, J. 1955. Nové výzkumy o vzniku podzolovaných půd v lesních oblastech střední Evropy ve vztahu k biologii lesa. Lesnictv, 28, 4: 479-491.

Šály, R. 1978. Pôda jako základ produkcie lesa - Soil as a basis of forest production. Príroda, Bratislava: 235.

Vašátko, J. 2000. The development of the landscape of Bohemian-Moravian Upland in the latest geological history. In: Sborník konference "Žd'árské vrchy v čase a prostoru". Žd'ár n. Sázavou: Environmental Regional Center, Prameny Vysočiny. 179.

Zlatník, A. i dr. 1938. Průzkum přirozených lesů na Podkarpatské Rusi - Research into natural forests in the Trans-Carpathians. Brno: Sborník výzkumných ústavů zemědělských ČSR 152. 524.

Ministerstvo zemědělství ČR. 2002. Zpráva o stavu lesa a lesního hospodářství České republiky 2002. Praha: Ministerstvo zemìdìlství ČR.