Land-use and water phenomena in the Czech Republic

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Introduction

The territory of the Czech Republic (48-51 N, 12-19 E, and elevation 115-1,602 m, Fig. 1) is situated in the humid temperate zone (including categories Cfb – marine west coast, Dfb – humid continental, and Dfc – sub-arctic of the Kőppen climate classification). Considering the recent climate normal (1961-1990), the country's long-term mean annual precipitation is 693 mm, evapotranspiration 499 mm, and runoff 203 mm. The growing season in most regions of the country extends from April to October.

The country area (78,866 km^2) consists of the agriculture land (54%), forests (34%), and water (2%). Agriculture activities include the arable land (70%), permanent grassland (24%), gardens, vine-yards and hope-yards (5%), and devastated land by open-cast coal mining (1%). About 50% of the agricultural land is exposed to a significant erosion risk. Commercial forests cover 76% of the forested area, and coniferous species (namely plantations of Norway spruce, *Picea abies*) dominate there. About 30 % of all managed forests are in protected headwater areas (Fig. 1). Therefore, the forestry practices dominate in the control of country's water resources (concentrated mainly on surface waters).

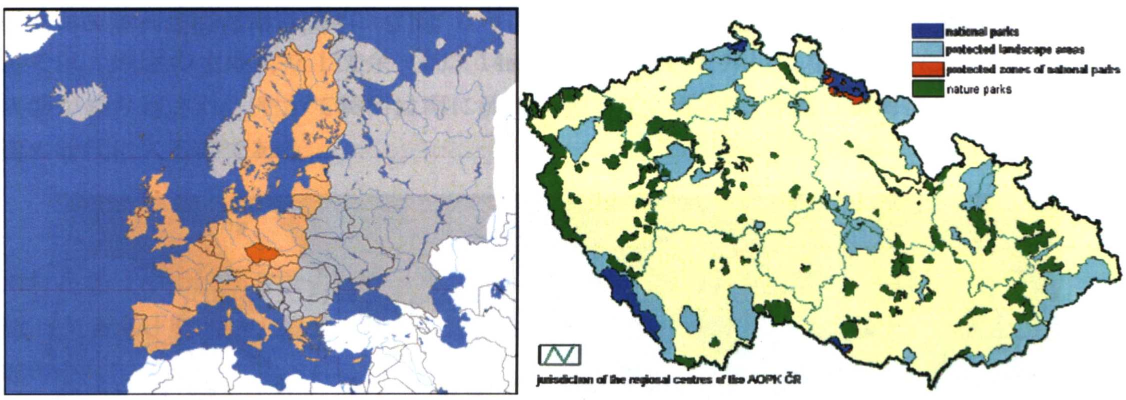

Fig. 1. Czech Republic: Protected areas cover 16% of the territory.

Historical consequences of land-use development

The first significant land-use activities on the country's territory occurred during the Celtic civilization 500 BC-50 BC. The Celtic society was technically well developed (iron instruments, stone mills, ceramics, golden coins) to perform agriculture activities on the deforested land. Finally, this civilization declined by not effective resource management. The Slavonic settlements have been developing there since the 6th century AD. However, the population of the early Celtic society was not exceeded before the end of the 12th century.

In the period of 1526-1918, the country (Bohemian Kingdom) was integrated in the Austrian Empire joining the development of central European regions (principles of sustainable agriculture and timber-yield forestry, or 'industrial revolution' in the second half of the 19th century). After the World War I, the democratic development of Czechoslovakia (included counties of Bohemia, Moravia, and Slovakia, 1918-1938) was broken by German occupation (1939-1945). In the frame of the 'Soviet Block' (1945-1989), serious wrong decisions in the resource management lead to the devastation of the environment. The intensification in agriculture (overuse of chemical fertilizers, collectivization and unification of fields) mobilized soil erosion and declined ground-water resources in the lowland). Large-scale mining and combustion of soft coal (lignite) rapidly increased emission of sulphur into the air; the dieback of mountain spruce plantations occurred. The consequences of the acid atmospheric deposition caused extreme acidification of water resources, reduce in water biota and fish kill. After the political change ("Velvet Revolution" in 1989), and the split between Czechs and Slovaks (1993), the Czech Republic joined the European Union in 2004. Since the 1990s, the new political system is more open to ideas of 'smart resource management', land rehabilitation programmes, or concepts of 'environmentally oriented development'.

Since the end of the 13th century, the area of forests (34 %) did not change significantly. However, the structure of forests changed rapidly. In the middle ages, forestry focused mainly on the game for land-lords, and military border protection. That time the access into forests was controlled, and timber harvest was limited by selective techniques. In the 17th century, the development of manufactures (glass, iron, etc.) increased the exploitation of timber. In the upper plain of the mountains, the clear-cut technology was introduced, and timber flown downhill. The observed signs of forest devastation lead to some regulations already during the 18th century (limits of forest harvest, prohibited grazing of cattle or harvest of grass from clear-cut sides). The dominant native tree species in mountain regions in the Czech Republic are common beech (*Fagus sylvatica*), Norway spruce (*Picea abies*), and common silver fir (*Abies alba*). Particularly, in the second half of the 19th century, spruce stands were preferred from commercial reasons, and nursery practices established. Thus, forestry produced pure spruce plantations of a low ecological stability (seeds were imported from several different climates of Europe), and more sensitive to an additional stress.

In the 13th century, water engineering in the country originated with water mills. Later, during the 14-16th century, large number of fish ponds (depth of 1-3 m) was constructed mainly in the lowland. At the end of the 19th century, several water reservoirs were constructed in mountain regions to protect growing lowland cities against floods. After the World War II, the demand of drinking water was growing rapidly, and drinking water reservoirs were constructed in headwater catchments covered mainly by forests. The recent need of water resources (2.3 billion m^3 per year) is oriented mainly to exploitation of surface waters (80%).

Forests controlling the hydrological cycle: traditional believes and reality

In the Czech Republic, the idea of forest-water relationship has a long tradition in the country's forestry, water engineering, culture and public believes. During the period 1850-1970, the idea of wide forest benefits dominated across Europe. The society believed that forests protect humans against rainstorms and floods, particularly, and provide them with a good quality of water. The forest percentage in watersheds was considered as the adequate information about hydrological regime.

In central European countries, the scientific discussion on the role of forests in water cycle started in the second half of the 19th century, after several catastrophic floods (observed namely in French, and Swiss Alps) supposed to be related to poor conditions of forests at that time. A new forest law oriented to protect forests against overexploitation and clear-cut was issued (Switzerland, 1876; France, 1882; and Austria, 1884), and national engineering services on torrent control were founded. In 1903, the first experiment on paired catchments originated in Swiss Alps to compare storm runoff produced from "forest" and "non-forest" types of land, and to improve scientific background on the role of the forest in the water cycle. Similar studies started later in other European countries. Engler (1919) presented first results showing that the forest can reduce effectively runoff during short and intensive rainstorms. Burger (1935) already pointed limits if forest benefits to control floods: the forested watershed can store only 10-20 mm more precipitation than the non-forested one.

Later field studies in Europe (summarized by Teller, 1967, and Rodda, 1976) showed that, in general, forest soils have higher infiltration capacities than agricultural or grassland soils. However, where the soil profile is very shallow, the nature of the surface cover may have little influence on hydrology, but is still important in reducing sedimentation and stabilizing slopes. The influence of the forest on flood flows is greatest on deep and permeable soils, where detention and retention capacities can be increased by forest transpiration and where infiltrated water can be held in detention storage. The establishment and later manipulation of a forest influence soil temperatures, snow accumulation and melting. Winter temperatures are higher than in the open and soil freezing is therefore less prevalent so that surface runoff is thus reduced. Snow accumulation in the forest can be increased and spring melting delayed by several cutting techniques. Under some conditions, this could increase the flood danger rather than reduce it. The influence of forest cover on flooding is greatest in valleys of headwater streams, where the distance from the top to the outlet is short. The effect of land-use practices on flooding is largest during storms of short duration and relatively small total rainfall. The effect decreases with increasing length and magnitude of storm rainfall. Major floods are frequently associated with long periods of rainfall during which the soil becomes saturated, or with frozen ground, melting snow or a combination of these conditions. In general, the introduction of a forest cover may reduce the magnitude of flood peaks, but is not likely to affect the total volume of flood runoff.

After the World War II, with rising demand of drinking water, more attention was paid to the impact of forest practices on water yield, and sediment control (Křeček. & Zelený, 1980; Křeček & Balek, 1981). However, the forest was still supposed to guarantee the water quality. In the 1970s and 1980s, the problem of extreme sulphur emissions, and acidification of mountain ecosystems was recognized. The hydrological studies focused on the relationship between forestry practices and water quality (Křeček & Hořická, 2006). Within a forest stand, the atmospheric deposition of sulphur rises with canopy density (leaf area), height and roughness (increasing turbulence of the air mass above the canopy). Thus, the effects of acidification were found to be worse in spruce stands, while deciduous forests have a lower canopy area, particularly in the dormant season when the concentration of sulphur dioxide in the atmosphere culminates (Fig. 2).

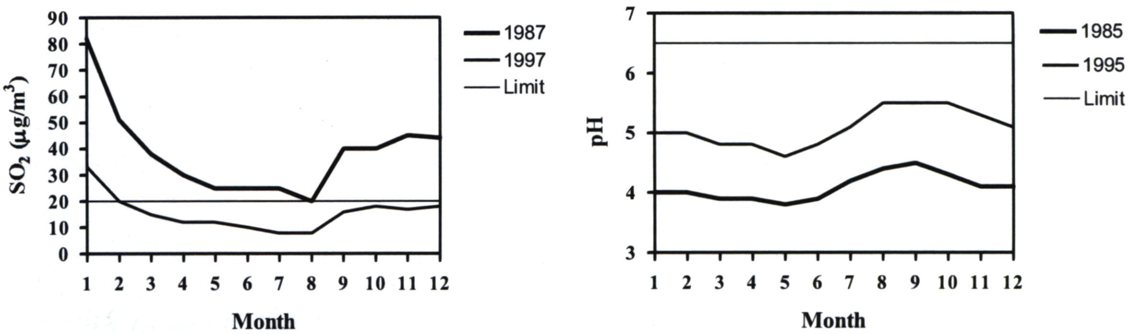

Fig. 2. Sulphur in the atmosphere, and pH of surface water (the Jizerka basin in the Jizera Mts.).

'Fish-killing Forest'

Contrary to the traditional Japanese concept of 'Giant Fish-feeding Forest" (Shiraiwa, 2006), spruce plantations in mountain areas of the Czech Republic showed negative impacts on water biota in surface waters in the last couple of decades. The water quality declined – pH dropped to 4-5, content of aluminium increased to 1-2 mg/l (with a high level of toxic forms: free Al^{3+} or inorganic complexes); and the water biota was reduced. The extinction of fish was documented in reservoirs of the Jizera Mts. since the 1950s, and both zooplankton and phytoplankton were drastically reduced (Křeček & Hořická, 2006).

The recent improvement in quality of mountain waters (observed since the early 1990s) seems to be a consequence of several factors – decreased level of sulphur emissions, reduced canopy density by the clear-cut of dense spruce stands, and massive liming. Therefore, deciduous or mixed forests (near the native composition) are supposed to be more efficient in headwater regions. Furthermore, contrary to the observed dieback of spruce plantations, the native beech stands are more resistant to acidification problems.

Climate change

During the 20th century, in the temperate zone of the northern hemisphere, global temperatures have risen by 0.5°C, precipitation in high elevated areas increased by 0.5-1% per decade, snow cover declined since the late 1960's by around 10%, and the frequency of heavy rainfall increased by 2-4% (Watson, 2001).

Considered scenarios of 'low' and 'high' green gas emissions, by the 2080's, annual average temperatures are supposed to rise by 2-3.5°C. Precipitation in winter might increase by 10-20% for the 'low emissions', and by 15-35% for the 'high emissions' scenario, but reduced snow-pack by 30%. Contrary, less precipitation is expected in the summer: the 'low emissions' scenario predicts the area up to 35% drier, and the 'high emissions' scenario forecasts 50% less rainfall. The forecast includes also increasing wind velocities and evaporation, and more frequent (and intensive) rainstorm events (Houghton *et al.*, 2001). Consequently, at the end of the 21st century, some 45% of country's spruce forests (spruce cover 90% of mountain forests) might be endangered. Therefore, the expected changes in the climate could reduce water yield from headwater catchments by 15-40%, and decline the water quality.

National legislative on headwater control

The forestry sector is responsible for the management of most headwater basins and streams in the Czech Republic. Already in 1741, to support 'sustainable timber yield' the Decree on Forest Regulation included limits of forest harvest, and prohibited grazing or harvest of grass from clear-cut sides. In 1978, the Czech Government established 'Protected Headwater Areas' (Water Act, 2001) covered mainly by 'non-commercial forests' (24% of the country's forest land). The main aim of forestry in headwater basins is to control water yield, runoff timing and water quality; namely clear-cut and soil drainage are controlled there. The services on watershed stabilization or restoration (torrent control, soil amelioration, or a support to the concept of 'ecological stability') are subsidized by the state. In catchments of drinking water reservoirs, some potential point-sources of pollution are prevented by the regime of three categories of buffer zones.

Conclusions

The recent need of water resources in the Czech Republic is oriented to exploitation of surface waters, and headwater catchments are controlled mainly by forestry practices. Since the 1990, the quality of water resources has been improved. The reasons are seen in the decreased level of atmospheric pollution (namely in countries of the 'Black Triangle': Czech Republic, former East Germany, and Poland), numerous successful rehabilitation projects (funded by regional, national or international bodies), and more reasonable forest practices in headwater basins. However, the national action plans on the land-use and water resources are still limited by recent global environmental problems (climate change etc.). One of the recent forestry priorities is to adapt forest stands to new environmental conditions. Therefore, the support of mixed forests near the native composition (to increase the percentage of broadleaved trees from recent 23% to natural 65%) has been highlighted.

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