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Ellenberg's indicator in water resources control: The Jizera Mountains, Czech Republic

Josef Krecek[a,*], Jana Novakova[b], Zuzana Horicka[c]

[a] Department of Hydrology, Czech Technical University, Thakurova 7, Prague CZ-166 29, Czech Republic
[b] Department of Landscape Ecology, Czech Agricultural University, Namesti Smirickych 1, Kostelec nad Cernymi lesy CZ-281 63, Czech Republic
[c] Institute for Environmental Studies, Charles University, Benatska 2, Prague CZ-128 01, Czech Republic

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ABSTRACT

Ellenberg's indicator values (simple ordinal classes of plants with a similar realized ecological niche along a gradient) were tested to describe the changing environment and water resources recharge in the upper plateau of the Jizera Mountains. (Czech Republic). In the 1980s, the acid atmospheric deposition led to the decline and clear-cut of spruce plantations (*Picea abies*): *Junco effusi-Calamagrostietum villosae* became a new dominant community there. Ellenberg's indices for light (*L*), moisture (*F*), nitrogen (*N*) and acidity (*R*) were compared with hydrological parameters of a small catchment (soil water content, evapotranspiration, retention, stream-flow pH and nitrate content) in 1982–2008. Ellenberg's indicators *F* and *L* describe well the plant succession related to microclimate and hydrology at clear-cut sites. Also, the indices *N* and *R* follow trends in the atmospheric deposition and water quality; however, with lower sensitivity. Ellenberg's indices reflect the observed changes in water phenomena with a lag period of 3–10 years.

1. Introduction

Ellenberg (Ellenberg, 1979; Ellenberg et al., 1992) summarized environmental characteristics of vascular plants in Central Europe by assigning to each species indicator values for light regime, soil moisture, nitrogen status, soil reaction, temperature, continentality, and salinity. Subsequently, Ellenberg's indices have been widely used as indirect metrics of environmental conditions within Europe (Ter Braak and Gremmen, 1987; Mountford and Chapman, 1993; Diekmann, 1995; Hawkes et al., 1997; Godefroid and Dana, 2006).

In the 1980s, the acid atmospheric deposition in Central Europe has resulted in the decline of spruce plantations (*Picea abies*) and their harvest. Krecek and Horicka (2001) reported the extensive spread of clear-cut in watersheds of the Jizera Mts. (Czech Republic), and Sykora (1983) identified a new dominant community of *Junco effusi-C. villosae* there. The environmental response of acidification and its consequences have been studied in the Jizerka experimental basin since 1982 (Krecek, 1982; Krecek and Horicka, 2006; Novakova and Krecek, 2006). The aim of this paper is to test the significance of Ellenberg's indicator values to assess changes in water phenomena observed at Jizerka in 1982–2009, and their potential use in water resource management.

2. Ecological engineering in watershed management

By the mid-1930s, a group of multipurpose projects were designed together by the Tennessee Valley Authority (TVA, 1972). It was considered the origin of integrated watershed management with first signs of ecological engineering. Since that time, McDonald and Kay (1988) described the watershed management developing from technocratic to eco-centric approach. Ecological characteristics in the catchment considerations extended from the percentage of forest land to a number of more sophisticated parameters (soil-vegetation classes, canopy area, height and roughness, etc.).

The target of ecological design in watershed management is to find a compromise between the regulation of water yield, run-off timing, flood reduction and protecting water quality (water chemistry and biota). However, Karr (1991) reports continuing declines in water resources (both quantity and quality) despite the recent massive regulatory, and calls for a new system of biological integrity in watershed management. The acid atmospheric deposition in Central Europe (culminating in the mid-1980s) changed the

* Corresponding author. Tel.: +420 224354672; fax: +420 224949118.
E-mail address: josef.krecek@fsv.cvut.cz (J. Krecek).

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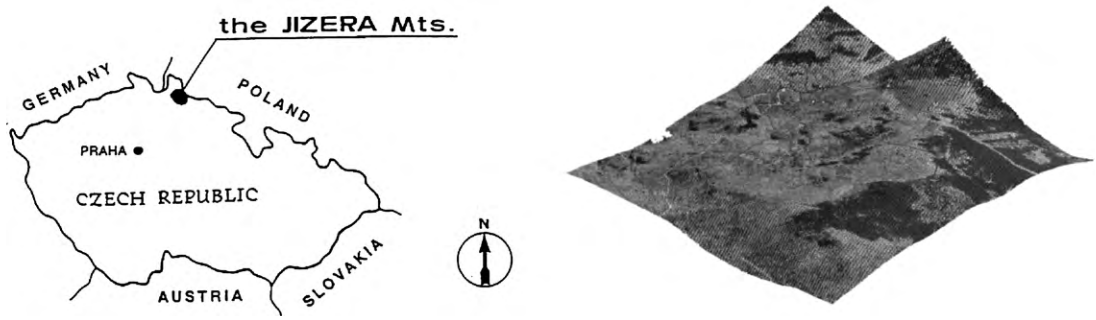

Fig. 1. The Jizerka experimental basin (2003).

general opinion that spruce forests guarantee the high standard of water quality (Krecek and Horicka, 2006; Morgan, 1993). The existing regulatory measures are still not effective in protecting water quality, namely, at distant upland basins.

McDonald and Kay (1988) claim that no effective management of the hydrological cycle exists at the global scale. The main target is to consider the atmosphere and the land surface interactions at a small scale. An effective ecological engineering in water resources recharge still needs to understand detailed processes in the soil-vegetation complex, and use of appropriate characteristics evaluated by long-term (30 years) catchment research.

Recently, more attention has been paid to the role of herbaceous vegetation in watershed studies (Novakova and Krecek, 2006; Schmidtlein, 2005) or dating climate events (herb chronology) (Dietz and von Arx, 2005). Schröder (2006) discusses the view of predictions in un-gauged basins from the data of quantitative landscape ecology.

3. Material and methods

3.1. Study area

The Jizerka experimental basin (50°48′N, 15°21′E, area of 1.0 km^2, elevation from 860 to 980 m, NE slope) is located in the upper plain of the Jizera Mountains (North Bohemia, Czech Republic), Fig. 1. Characteristics of the recent climate normal (1961–1990) are: North temperate zone, Kőppen—Dfc (sub-arctic region), mean annual precipitation 1400 mm and air temperature 4 °C (CHMI, 2005).

Sandy–loamy podsols developed on porfyritic granite show the depth between 0.7 and 1.2 m. The root system dominates in the topsoil occurring up to the depth of 15 cm. The topsoil is created by litter (O_l, depth of 0–2 cm), humus layer ($O_f + O_h$, 2–10 cm), and leached horizon (A_{eh}, 10–15 cm). Mor is the most common humus (2–5 cm) there.

In the early-1980s, the investigated catchment was covered by mature spruce (80–100 years). Between 1984 and 1988, spruce stands were harvested by the clear-cut which extended over large areas in the mountain plateau. Invasive grass communities (namely *Calamagrostis* sp., with dominant *Calamagrostis villosa*) have spread over the studied basin. Although the reforestation followed immediately, there is relatively slow progress in the re-growth.

In 1978, the Czech government proclaimed the Protected Headwater Region of the Jizera Mts. and adopted here limits in clear-cut technology (Krecek and Horicka, 2001). However, the environmentally sound watershed management was still not respected there, in the 1980s (because of the extreme forest dieback).

3.2. Instrumented catchment

The investigated basin at Jizerka (Fig. 2) was instrumented according to recommendations addressed to mountain regions (Shaw, 1991). In 1982, was instrumented by the sharp-crested V-notch weir with the automatic water level recorder at the stream-outlet. Stream water is sampled weekly, and, additionally during extreme events (rain-storms or rapid snow-melts), for chemical analyses.

At the climate station, both standard (500 cm^2) and automatic (200 cm^2) rain-gauges were located in the investigated basin together with three storage rain-gauges (200 cm^2) placed in forest openings at different elevations. Through-fall under the forest canopy was sampled monthly by 10 bulk collectors (200 cm^2); stem-flow was supposed negligible. Five modified storage gauges (200 cm^2) were installed in the soil to collect through-fall under the ground vegetation.

In the vertical profile of the mature spruce stand (mean height of 20.5 m) was installed the micrometeorological observation system. Global and net radiation, air temperature and humidity, as well as the wind velocity, were observed above (at 23 and 28 m), and inside of the canopy. Soil temperature was measured up to 0.5 m.

3.3. Botanical survey

Detailed botanical investigations were carried out at two parallel transects (A and B) in vegetation seasons of 1991, 1998, 2002, and 2005. Phytosociological relevés (4 m × 4 m) were taken at each of the 12-point transect A (clear-cut, main slope of the Jizerka basin), and at the 8-point transect B (neighbouring fragments of mature spruce stands); the focused points at both transects are located in step of 100 m (Fig. 3).

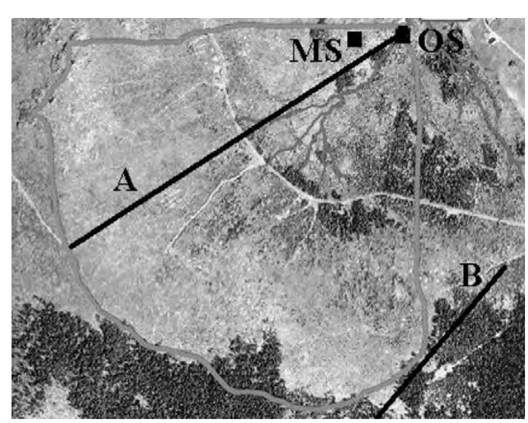

Fig. 2. The Jizerka basin after the harvest (OS – basin outlet, MS – meteorological observations, A and B – investigated transects).