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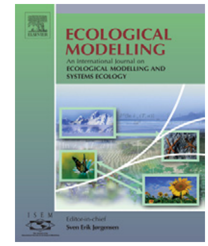


# Modeling radial growth increment of black alder (*Alnus glutionsa* (L.) Gaertn.) tree

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ABSTRACT

Nowadays it is extremely important to understand ecosystem function and its dynamics to predict future changes and consequently to perform appropriate measures. Hydromeliorations and subsequent decrease in groundwater table are thought to be a major reason for a decline in the vitality of black alder (*Alnus glutinosa* (L.) Gaertn.) wetland forests in North-eastern Slovenia. In this study radial increments of trees were used as indicators of black alder forest function and its disturbances. The aim of the study was to build a model of annual radial increments of black alder trees, to use this model to identify environmental attributes that most importantly affect ecosystem's function and to predict changes in the forest function under different scenarios of environmental conditions in the future. The model was induced with a machine learning algorithm CIPER and it was based on the data about site conditions and applied management measures in the past 35 years. Groundwater levels in combination with the duration of sun radiation were identified as the most important environmental attributes affecting annual radial increments. Radial increments were the lowest in very wet and cloudy years. On the other hand, radial increments were decreased under drought stress as well. Changes in groundwater level and in duration of sun radiation, as well as increased oscillations of groundwater level, all cause important increase in oscillations of modeled radial increments, indicating higher stress. Radial increments were further negatively affected by late white frosts in the spring.



## 1. Introduction

The understanding of ecosystem function and reconstruction of ecological niche are especially important in this period in which we have to carefully balance between different needs and interests and in which we expect important changes of climate conditions. An important property of forest ecosystems is that they mark annual radial growth increments. As growth is dependent on ecosystem's well-being and function in individual years, radial increments can be regarded as reliable indicators of ecosystem function.

Black alder (*Alnus glutinosa* (L.) Gaertn.; f. *Betulaceae*) is a deciduous tree species with many special ecological properties as well as of an economical importance. Its most important ecological properties are adaptations to high groundwater level, nitrogen fixation through symbiosis with actinomycetes *Frankia*, fast growth and short lifetime, and light pretentiousness. In the stands under study it is also

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reported to be resistant to white frosts, diseases and herbivores (Nemesszeghy, 1986; Brus, 2005).

Homogenous forests of black alder in the lowlands of northeastern Slovenia are among the last remnants of natural wetland forests of this species in central Europe (Nemesszeghy, 1986). The area of these forests was significantly reduced in the 19th century. Severe decline in the vitality of stands in the studied area was observed in the middle of the last century (Wraber, 1951; Nemesszeghy, 1986; Levanič, 1993) as well as in other black alder floodplain forests in Europe (Pretzell et al., 1997). This decline was attributed to a decrease in groundwater table (Pretzell et al., 1997) and changed hydrological conditions due to extensive hydromeliorations and regulations. The importance of groundwater level and hydrologic regime for wetland trees was also confirmed in the studies of Keeland and Sharitz (1997). Despite the apparently clear causal relationship between the groundwater level and stand vitality, studies performed until now did not succeed to prove changes in groundwater level as a major reason for forest decline (Levanič and Kotar, 1996; Košir, 1987; Levanič, 1993; Čater, 2002). In order to continue with this discussion we conducted a case study research in a black alder floodplain forest of Polanski Log.

Radial growth of trees is influenced by a complex of environmental parameters (attributes) that take place on a particular site. These attributes include water availability, climate conditions and soil fertility (Whitehead, 1998). Radial growth of trees responds very dynamically to a current combination of environmental attributes (Waring, 1987). For that reason we considered radial increments as indicators of function and disturbances of black alder wetland forest ecosystem in individual years.

The main goal of this study was to construct a reliable simulation growth model of black alder forest stand. This model was used to identify the set of the most important attributes that affect growth and development of the stand under study and to predict changes in the function of these stands under future climate change scenarios.

## 2. Materials and methods

### 2.1. Study site

#### 2.1.1. Site description

The forest of Polanski Log covers the area of 414 ha on the left side of the Ledava River. The most common tree species in these stands is black alder (85%), followed by ash (12%) and oak (3%) (Nemesszeghy, 1986). Long-term presence of stable alder forests was proved in a research of subfossil wood (Culiberg, 1989). These stands can be classified as black alder's best sites and as a climax community. Whereas heights up to 30 m are reported for black alder in other countries (McVean, 1953; Dawson and Funk, 1981; Brus, 2005; Krstinič et al., 2002; Featherstone, 2003), they surpassed the height of 34 m in the stand under study (Nemesszeghy, 1986; Laganis, 2007). Trees in individual plots are even-aged.

Black alder represents 95% of trees in the selected stand (Forest Management Plans, 1971–2011). With 69 years it already surpassed its maturity and it was cut down in January 2005. The latitude of the research site is 46,595 and its longitude is 16,358. The area is flat and it is about 190 m above the sea level.

#### 2.1.2. Climate and soil conditions

The selected site lies in a Panonic-type of climate with dry and hot summers and cold winters. Mean annual temperature is 9–10 °C. Important for the vegetation are negative impacts of frequent late frosts in the spring (until April) and early white frosts in the autumn (Wraber, 1951), despite they were not reported to cause important damage in black alder stands (Silvicultural chronicles).

The average amount of precipitation is only about 800 mm (Wraber, 1951), a bit less than 60% of which occurs during the growing period (Žiberna, 1992). Severe droughts during the summer and relatively poor physical and chemical soil properties prevent higher agricultural productivity in this area (Wraber, 1951). The amplitude between the minimum and maximum groundwater level was found to be about 1.5 m between the years 1953 and 1993 in about 7-km distant well (Smolej, 1995), which is of a similar distance from the Ledava River as is the selected stand.

The most important attributes that affect structure and function of these forests are hydrological conditions of soil water and water regime. Soil water is standstill or it flows very slowly through a gravely substrate (Wraber, 1951; Levanič, 1993). In our stand the groundwater level was relatively close to the surface (0–80 cm) during measurements (September 2004–January 2005). In some cases the stand was partly overflown.

This flat area has gravelly to sandy siliceous grounding, covered with fertile, clayey alluvium (intrazonal type of soil, hypogleic eugley; Wraber, 1951; Kalan, 1988). This alluvium varies in depth but in general it is relatively shallow (Wraber, 1951; Levanič, 1993). A shortage of limestone is a reason for poor physical and chemical soil properties (Wraber, 1951). Ascendant groundwater flows toward the surface (upward) are prevailing during the vegetation period and they bring plenty of mineral nutrients to the upper soil layers (Kalan, 1988). Nitrogen is reported to be abundant (Levanič, 1993; Kalan, 1988).

#### 2.1.3. History

According to the Forest Management Plans (1959–1968) and reports of Wraber (1951) large part of the area was uncrossable in the 18th century due to high water levels. The landscape was covered by oak and alder forests. Several meliorations performed after the year 1814 drained the area, large extents of forests were cleared to obtain new agricultural surfaces (Levanič and Kotar, 1996; Nemesszeghy, 1986) and large part of remaining forests was endangered due to a decrease in the groundwater level (Wraber, 1951) and changes in the rhythm of flooding (Levanič, 1993). Smolej (1995) reports that between the years 1953 and 1992 (40 years) groundwater level decreased for 60 cm. The area became less appropriate for black alder (Brus, 2005) and forests remained only on soil, which were inappropriate for agriculture due to high groundwater or low fertility (Nemesszeghy, 1986).

In 1980 a reservoir at Radmožanci was constructed and the riverbed of the Ledava River was deepened. As a result a