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Mid-Holocene vegetation development and herding-related interferences in the Carpathian region

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ABSTRACT

The paper comprises data from 27 case studies to assess large-scale human-vegetation interferences in the Carpathian region during the Mid-Holocene. The main focus is put on herding-related vegetation changes and climate influences are addressed. The publications reviewed are based on sediment sequences which provide C^{14}-dated pollen records, charcoal and geochemical data. Based on a semi-quantitative approach pollen of secondary indicator species and arboreal pollen values were combined in a fuzzy model to assess the intensity of herding-related vegetation changes. The model was applied for 20 selected case studies. The data from the remaining seven sites as well as geochemical and charcoal data were used to validate the results of the standardized evaluation. Speleothem $\delta^{18}O$ and $\delta^{13}C$ records from Hungary and Romania were used as independent proxies to align Holocene climate development. The results were regionalized and trends of herding-related vegetation change are presented for the Southern Carpathians and Apuseni Mountains, for the Eastern Carpathians and for Hungary. Mean distances between included archives and prehistoric settlement sites were calculated as indicator for the marginality of the environmental archives.

In all regions, absolute values for herding indication are low. Phases of changing herding impact on the landscape can be observed for the Southern Carpathians and Apuseni Mountains as well as for Hungary. In the Southern Carpathians and Apuseni Mountains increased herding activities can be traced for the Early Chalcolithic and the Late Bronze Age. The first phase is contemporary with an intensification of the use of secondary products. In Hungary herding impact is in accordance with prehistoric settlement development. Widely increased herding indications date to the Late Chalcolithic and the Early Bronze Age. In the Eastern Carpathians, interference of climate influences and human impacts occurred.

1. Introduction

The Holocene was a period of climatic changes occurring at multiple spatial and temporal scales (Mayewski et al., 2004). At a spatially generalized millennial timescale three periods can be distinguished: a deglaciation period between 11700 and 7000 BP, a warm period between 7000 and 4200 BP and a cool period between 4200 and 250 BP; these periods of relatively stable temperature conditions were interrupted by cold phases at a multi-decadal to multi-centennial timescale (Wanner et al., 2011). However, the Holocene climate development was not uniform across Europe. Davis et al. (2003) show that southern Europe was characterised by cool and moist climate during the Mid-Holocene.

During the Early and the Mid-Holocene, the first farmers spread from the eastern Mediterranean into the Balkans and further towards northwestern Europe introducing agro-pastoral land use practices (Bogucki, 1996). Although the general spatio-temporal trend of this cultural development is northwest oriented, the introduction of Neolithic and post-Neolithic innovations did not uniformly progress but spread with geographic and temporal variability (Bogucki, 1996). Both, climate influences as well as human activities affected landscape development (Bintliff, 2002; Butzer, 2005). In correspondence to the variable nature of these impacts, pace and intensity of landscape development and related sedimentation processes varied though time

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(e.g., Dotterweich, 2008; Dreibrodt et al., 2010; Notebaert and Verstraeten, 2010; Dusar et al., 2011). However, the differentiation between climatically triggered and human-driven landscape changes remains challenging (e.g., Schütt, 2006; Fuchs, 2007; Kalicki et al., 2008; Dusar et al., 2012; Dotterweich, 2013). Phases of erosion processes accelerated due to human impact can most often only be related to settlement activities in general (e.g., Fuchs et al., 2004; Dreibrodt et al., 2014; Notebaert et al., 2014). Furthermore, varying landscape sensitivity as well as time lags between triggering climate events or human impacts and corresponding landscape reactions may induce rather vague cause-effect linkages (Schütt and Krause, 2009; Dusar et al., 2012).

Examining settlement strategies, next to the exploitation of primary products such as cereals and meat, the use of secondary products gained continuously in importance after introduction. The concept of the "Secondary Products Revolution" suggests an increasing use of secondary products from animals such as wool, milk and labour during the Chalcolithic (Sherratt, 1981). While the different secondary products appeared with regional and temporal variations, significant impacts on cultures came with their large scale and contemporary application (Greenfield, 2010). Increasing use of animal products is based on increasing importance of livestock husbandry and implies generally increasing grazing pressure. Furthermore, new subsistence strategies might have triggered changing land use patterns, as formerly unused marginal areas were now exploited by pastoral farmers (Finkelstein and Gophna, 1993). Increasing mobility of pastoral farmers may be connected to the changing economic strategy (Arbuckle, 2012).

Increasing grazing pressure is reflected in the vegetation cover first: species composition reacts sensitively to grazing, while net primary production reacts with a slight time-lag and the soil nutrient pool reacts with a long time-lag to grazing (Milchunas and Lauenroth, 1993). Woodland grazing generally constrains the rejuvenation of trees: this leads to a relative support of species of primary forests that are less light-sensitive and able to grow from the stump (Kalis et al., 2003). Moderate grazing pressure leads to an increase of overall plant species richness (Schütz et al., 2003). Intensified livestock grazing leads to soil compaction and decrease of vegetative cover; subsequently, destabilized soil structure and increasing overland flow enhance soil erosion (Belsky and Blumenthal, 1997). However, the onset of soil erosion processes appears dependent on the magnitude of rainfall events, where the critical threshold is determined by the landscape sensitivity.

While it is hard to retrace the whole cause-effect structure linking certain triggers to landscape forming processes, herding-related changes of the vegetation cover are represented in pollen records (e.g.: Bottema and Woldring, 1990; Magyari et al., 2012; Marinova et al., 2012; Augustsson et al., 2013; Feurdean et al., 2013a). *Polygonum aviculare* and *Plantago major/media* representing ruderal vegetation and *Plantago lanceolata* and *Rumex acetosa/acetosella* representing pasture and meadow communities (Behre, 1981) are commonly interpreted as indicators for animal herding, although it is important to consider the natural vegetation of the investigated site (Magyari et al., 2012). Percentages of arboreal pollen relate to tree canopy (Bradshaw, 1988) and the arboreal/non-arboreal pollen ratio is the most frequently used proxy to trace human impact on the vegetation cover, although it is not the most appropriate one (Kalis et al., 2003). It can be assumed that species composition of a given vegetation community significantly changes due to grazing pressure (Milchunas and Lauenroth, 1993) and that the number of plant species increases (Schütz et al., 2003). In consequence, statistical measures such as rate of change (Huntley, 1992) and palynological richness (Birks and Line, 1992) can be used as indicators for potentially herding-related human impact (Feurdean et al., 2013a). Records of microscopic charcoal represent the importance of regional fires, whereas macroscopic charcoal records indicate the importance of local and extra-local fires (Whitlock and Larsen, 2001). Human induced woodland burning may be distinguished from natural forest fires if independent climate proxies are included in the analysis (e.g. Feurdean et al., 2012).

Holocene vegetation development in the Carpathians is documented by a number of well-dated pollen records. Furthermore, studies on prehistoric settlement history and cultural development in the region have a long research tradition (e.g., Sherratt, 1981, 1982, 1983a,b; Kalicz, 1994; Chapman et al., 2009; Parsons, 2011; Duffy, 2013).

The presented study is based on a review comprising published case studies on Holocene vegetation dynamics in the Carpathian region. Aims of the study are 1) to point out spatio-temporal differences of climate variation and human activity impacting Holocene vegetation dynamics in the region; 2) to characterize herding-related landscape changes within the area and in relation to the southeastern and northwestern adjacent regions, and 3) to relate the vegetation development in the region to the model of cultural development that assumes abruptly increasing animal herding during the Mid-Holocene.

2. Study site

The sites which are comprised in this review are located within a variety of landscape types including the Great Hungarian Plain, the north Hungarian mid-mountains, the Transylvanian Basin as well as different altitude levels of the Carpathian Mountain range. Elevations vary between <100 m a.s.l. in the Great Hungarian Plain and >1900 m a.s.l. in the Eastern Carpathians. These large orographic differences determine the major climatic conditions of the study region: mean annual precipitation ranges from 550 to 600 mm y^{-1} in the Great Hungarian Plain and increases to 1500–1600 mm y^{-1} in the Eastern Carpathians. With increasing altitudes mean annual temperatures decrease from 9.5–11.5 °C in the lowlands of Hungary to 0–2 °C at the high levels of the Eastern Carpathians (Anonymous, 1960a cited in Okołowicz, 1977, p. 108; Stoenescu, 1960a,b). The basin situation and increasing continentality contribute to pronounced dryness and to a marked yearly temperature amplitude in the central lowlands of the Pannonian Plain and towards the east (Okołowicz, 1977, p. 77). However, also different macro weather situations prevail for the different areas of the Carpathian region, with the westerlies controlling rainfall in its northern part from April to November. The oceanic air masses transport moisture and have mitigating effects on the mean temperatures. Towards the south, the sub-tropical high gains importance during summer and causes region-wide temperature maxima in the southeast of the Carpathian region. Especially between October and April, Adriatic lows bring Mediterranean influences to the Pannonian Plain (Weischet and Endlicher, 2000, p. 136).

The research sites included in this review were assigned to four regions: Southern Carpathians including the southern part of the Eastern Carpathians, Apuseni Mountains, Eastern Carpathians and Hungarian low lands and mid-mountain ranges (Fig. 1). Climate, vegetation and relief characteristics of the areas are outlined briefly in the following, and specifications of the included sequences and references are summarized in Table 1.

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