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Exploring the role of humans and climate over the Balkan landscape: 500 years of vegetational history of Serbia

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ABSTRACT

We present the first, well-dated, high-resolution record of vegetation and landscape change from Serbia, which spans the past 500 years. Biological proxies (pollen, spores, and charcoal), geochemical analysis through X-ray Fluorescence (XRF), and a detailed chronology based on AMS ^{14}C dating from a western Serbian sinkhole core suggest complex woodland-grassland dynamics and strong erosional signals throughout the Little Ice Age (LIA). An open landscape with prominent steppe vegetation (e.g. Poaceae, Chenopodiaceae) and minor woodland exists during 1540–1720 CE (early LIA), while the late LIA (1720–1850 CE) in this record shows higher tree percentages possibly due to increased moisture availability. The post LIA Era (1850–2012 CE) brings a disturbed type of vegetation with the presence of weedy genera and an increase in regional woodland. Anthropogenic indicators for agricultural, pastoral and fire practices in the region together attest to the dominant role of humans in shaping this Balkan landscape throughout the interval. The changing nature of human interference, potentially as a response to underlying climatic transitions, is evident through large-scale soil depletion resulting from grazing and land clearance during the early LIA and stabilization of arable lands during the late and post-LIA eras.

1. Introduction

Situated at the crossroads of three major continents, the Balkan Peninsula is a region of diverse climate, complex physical geography, and outstanding levels of floral and faunal endemism (Griffiths et al., 2004). It is called a "European biodiversity hotspot" (Petit et al., 2003) as it served as a refugium for many species during past Ice Ages and the region as a whole is surpassed in species richness only by the tropics (Mooney, 1988). Zolitschka et al. (2000) highlight the importance of paleoecological research in this circum-Mediterranean region across three broad fronts; (1) the potential of obtaining very long records of environmental change from basins that have not been over-ridden by extensive glaciations (unlike northern Europe); (2) the fact that the region is a 'frontier zone' where the tropical (monsoonal) climatic system of northern Africa meets and interacts with the North Atlantic climatic system; and (3) the long history of human occupation and civilization in this region (Eastwood, 2004) that makes it a unique setting to study cultural history in relation to evolving landscapes. Moreover, the Balkan landscapes are now part of the most rapidly changing ecological regions of Europe and are very sensitive to dramatic climate change in terms of varying precipitation and temperature patterns (Alcamo et al., 2007; EEA, 2004; IPCC, 2014). This further highlights the need for accumulating more high-resolution ecological records particularly covering the last 2000 years of environmental history where the responses of the terrestrial ecosystems to climatic changes under scenarios similar to the present can help us to better evaluate the interplays and feedbacks of climate variability in the context of human landscapes and activities (Mercuri and Sadori, 2014). Here, we present one such proxy-based reconstruction over the last millennium from Serbia, Central part of the Balkans, which brings important insights for understanding current climate change within a long-term context.

The focus of this study is to describe and interpret the environmental history of a Serbian landscape over the past 500 years, including the 'Little Ice Age' (LIA), which was a major climatic interval that imposed significant changes on landscapes inhabited and cultivated by contemporary societies. From c. 1500 to 1850 CE,

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the LIA followed the 'Medieval Climate Anomaly', and was a time when Northern Hemisphere annual temperatures were cooler, and winters were significantly colder with increased snow when compared with modern day winters (Bradley and Jones, 1993; Jones et al., 1998; Mann et al., 1999). During this interval, European glaciers reached their greatest extent since the late Pleistocene (Matthews and Briffa, 2005). More importantly, this regionally asynchronous cooling is significant in terms of increased variability of the climate (Mann, 2002); many regions of Europe experienced most dramatic climate extremes in terms of large inter-annual as well as inter-decadal temperature and precipitation variability amongst prolonged multiyear periods of cold (Luterbacher et al., 2004; Pauling et al., 2006; Xoplaki et al., 2005). This variability had a profound effect on contemporary human populations and their strategies to manage the landscape (Pfister and Brázdil, 1999; Pfister, 2005). Although deforestation had begun centuries and millennia prior to the onset of the LIA, it was during the LIA when European land surface changed drastically as people cleared pristine areas for agriculture and accelerated the rates of land erosion (Kaplan et al., 2009; Ramankutty and Foley, 1999). Particularly for the Balkans and Serbia, this was a critical period in terms of political, social, economic and demographic changes. After several major conflicts with regional kingdoms in the early 1500s, the Ottoman Empire conquered the Balkans and for almost the next 160–170 years, instituted a number of systems for the management and provisioning of resources for its territories, all the while directing the expansion of the settlement and cultivation across the region (White, 2011). Both 16th and 17th Century Balkans enjoyed a relatively peaceful period with noteworthy commercial progress and significant increase in population (McEvedy and Jones, 1978). However, by the end of the 17th century, the Ottoman Empire started suffering a major crisis with increasing economic turmoil and social unrest from which it never fully recovered (Fine Jr., 1994; White, 2006). In the 17th–18th centuries during the late Ottoman rule, it was in the war zone of the frequent Habsburg–Ottoman confrontations (1683–99, 1714–18, 1736–39, 1788–92) that forced the outmigration of the inhabitants (Palairet, 1997; Stoianovich, 1994). As a result, cultivated lands were abandoned and parts of the Balkans returned to its conventional pastoral economies. Despite their attempts to restore order, the Ottomans completely lost control over their territories and during 1850–70s, Serbia and other Balkan countries came under independent principalities (Ali, 2012). Subsequently, the withdrawal of Ottomans relaxed the region and a significant demographic rise was seen after 1850s (McEvedy and Jones, 1978; Palairet, 1997). This inward and outward flow of people in Serbia (as well as in every part of the Balkans) has left substantial impacts on the landscape under the changing LIA climatic regimes. The LIA climatic migration coincided with the changing nature of human interference that provides an interesting socio-ecological problem. We take the first step to unravel this intricate puzzle by reconstructing the regional vegetational history of Serbia on a multi-decadal temporal scale.

2. Study area

The sediment record is derived from a sinkhole located in western Serbia near a locality called Donja Sipulja (44°30′14.33″ N, 19°30′18.46″ E) at an elevation of 250 m a.s.l. (Fig. 1b). This surficially dry sinkhole is oblate in shape with a surface area of roughly 230 m^2. While granites and granodiorites dominate the Cer mountains to the north, the late Cretaceous-Tertiary sequences of limestones and dolomites (Dimitrijević, 1997) give this area a typical karstic topography embedded with numerous sinkholes.

Most parts of Serbia enjoy continental climate with moderate sub-Mediterranean influences - cold, relatively dry winters and warm, humid summers. The mean annual air temperature for altitudes lower than 300 m is about 11 °C with July maximum temperatures ranging between 37 and 42 °C (RHMSS, n.d.). Serbia has a continental precipitation regime with higher rainfall in the warmer part of the year; June is the wettest month with an average of 12–13% of total annual precipitation. In low-lying regions such as the study site, annual precipitation is about 540–820 mm per year that varies with elevation and exposure. Snow cover is characteristic from November to March, and January has the majority of days with snow cover (RHMSS, n.d.).

Serbia presents an "ecosystem mosaic" composed of forests, shrubs, meadows-pastures, swamps, marshes, and lakes with a mixture of many continental and select sub-Mediterranean plant communities (Radović and Kozomara, 2011). Horvat et al. (1974) provide the detailed vegetation classification of the Balkan region (Fig. 1c) characterizing the study area vegetation as part of the deciduous community of Hungarian and Turkey oaks, *Quercus frainetto* and *Quercus cerris*. This oak alliance is extensive in its distribution throughout the region and occurs in several geographic variants; one of them that exists in the study area is a mesophilous community of sessile oak *Quercus petraea*, and hornbeam, very similar to the Illyric *Quercus-Carpinus illyricum* zone (Rakonjac and Nevenic, 2012). The latter occasionally occur with their xerothermic deciduous Submediterranean variants, especially *Carpinus orientalis/Ostrya carpinifolia* in the hilly-mountainous regions. A well-defined and fairly homogeneous submontane-montane community (over 500 m a.m.s.l.) exits throughout Serbia with *Fagus moesiaca* as well as *F. sylvatica* and its associated taxa, *Abies* spp., and *Acer heldreichii*. While sub-alpine coniferous (predominantly *Picea*) belts are rare in this region, some shrubby coniferous taxa exist at tree line above 1800 m.a.s.l. that include *Pinus mugo*, *Juniperus sibiricae*, and *Vaccinium* varieties (Rakonjac and Nevenic, 2012). The Pannonian forest-steppe zone is also quite uncommon in this region, but may be found as smaller stands of xerothermic oak and maple communities such as *Quercus pubesens*, *Q. petraea, Acer tataricum* (Tomic et al., 2011).

The modern vegetation at the study site is mainly composed of grasses (Poaceae), herbs (Polygonaceae, Chenopodiaceae, Asteraceae families and the *Plantago* group), sedges, and minor woodland (Fig. 1b). Trees and shrubs in the area that are characteristic of the lowland Balkan deciduous forest include *Quercus cerris*, *Q. frainetto*, *Carpinus betulus*, *Acer campestre*, *Fraxinus excelsior* (and/or *F. angustifolia* and other variants), and minor occurrence of *Salix* spp. Anthropogenic tree-shrub taxa include *Corylus maxima*, *Juglans regia*, and *Sambucus ebulus* and two *Cornus* varieties, *Cornus mas* and *C. sanguinea*. To a lesser extent, coniferous taxa *Pinus nigra* and *Juniper communis* are also found in the surroundings. Herbs include Polygonaceae (*Polygonum aviculare* and *Rumex* spp.), Asteraceae family (Asteroideae, Cichorioideae, and *Artemisia* groups; the Asteroideae includes *Anthemis*, *Carduus* and *Cirsium* types. The *Plantago* taxa consist of *Plantago lanceolata*, *P. media* and possibly *P. altissima* and/or other *Plantago* varieties. The wetland species mainly include a variety of *Cyperaceae*, predominantly *Carex* and *Scirpus*.

3. Materials and methods

3.1. Core extraction

In the summer of 2012, a 2.1 m sediment core (hereafter, DS) was extracted from the center of a sinkhole using a modified Livingstone piston corer (Wright Jr. et al., 1984). After recovery, the core was described in the field and was refrigerated at 2–3 °C until further processing.