



## Legacies of 19th century land use shape contemporary forest cover



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### ABSTRACT

Historic land use can exert strong land-use legacies, i.e., long-lasting effects on ecosystems, but the importance of land-use legacies, alongside other factors, for subsequent forest-cover change is unclear. If past land use affects rates of forest disturbance and afforestation then this may constrain land use planning and land management options, and legacies of current land management may constrain future land use. Our goal was to assess if and how much land-use legacies affect contemporary forest disturbance, and the abundance of different forest types in the Carpathian region in Eastern Europe (265,000 km<sup>2</sup>, encompassing parts of Poland, Slovakia, Ukraine, Romania, Hungary, and Czech Republic). We modeled contemporary forest disturbance (based on satellite image analysis from 1985 to 2010) as a function of historic land use (based on digitized topographic maps from 1860 and 1960). Contemporary forest disturbance was strongly related to historic land use even when controlling for environmental, accessibility and socio-political variation. Across the Carpathian region, the odds of forest disturbance were about 50% higher in areas that were not forested in 1860 (new forests) compared to areas that were forested then (old forests). The forest disturbance in new forests was particularly high in Poland (88% higher odds), Slovakia (69%) and Romania (67%) and persisted across the entire range of environmental, accessibility and socio-political variation. Reasons for the observed legacy effects may include extensive plantations outside forest ranges, predominantly spruce, poplar, and black locust, which are prone to natural disturbances. Furthermore, as plantations reach harvestable age of about 70 years for pulp and 120 year for saw-timber production, these are likely to be clear-cut, producing the observed legacy effects. Across the Carpathians, forest types shifted towards less coniferous cover in 2010 compared to the 1860s and 1960s likely due to extensive historic conifer harvest, and to recent natural disturbance events and clear-cuts of forest plantations. Our results underscore the importance of land-use legacies, and show that past land uses can greatly affect subsequent forest disturbance for centuries. Given rapid land use changes worldwide, it is important to understand how past legacies affect current management and what the impact of current land management decisions may be for future land use.

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### 1. Introduction

Land use and land cover change are major components of global change, causing daunting sustainability challenges (Foley et al.,

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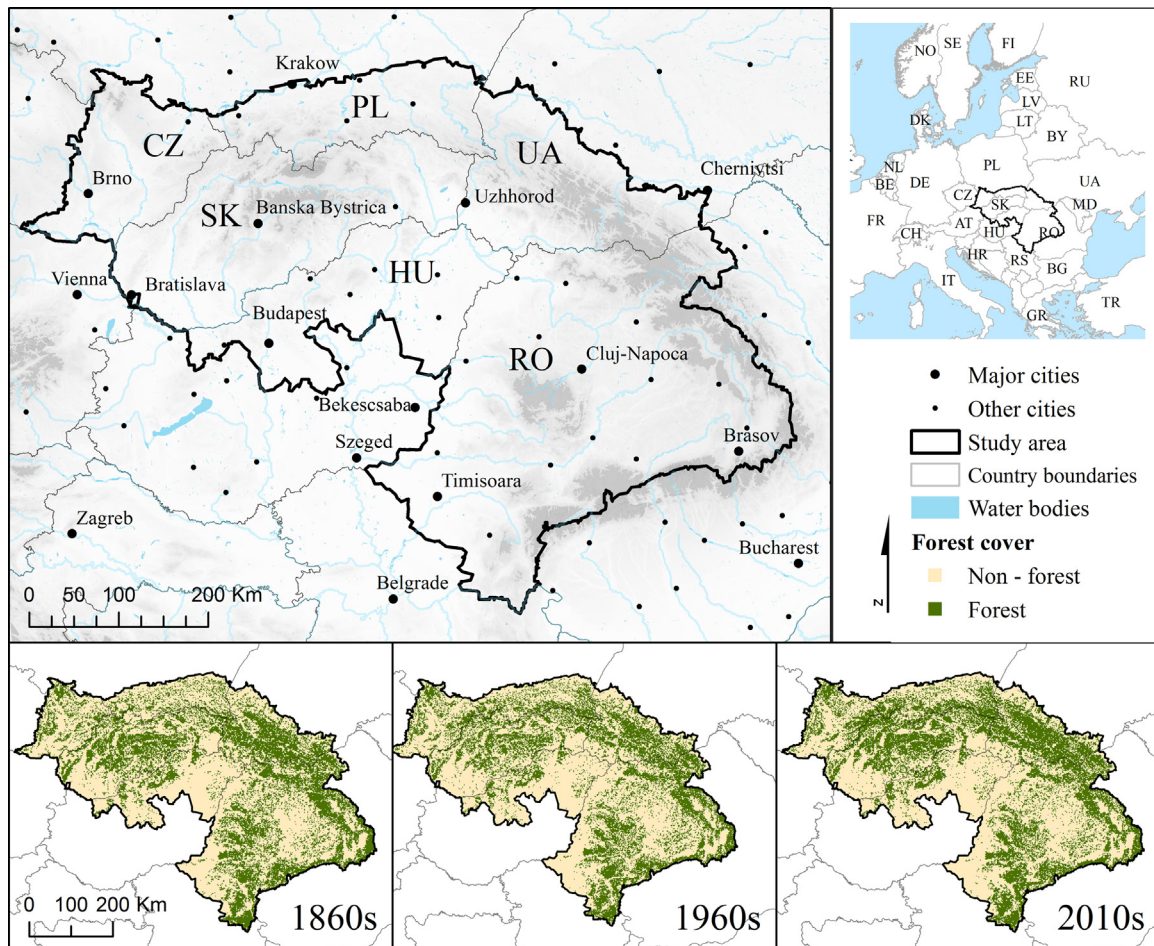
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2005; Lambin and Geist, 2006; Sarukhán and Whyte, 2005). The effects of past land use (hereafter 'land use legacies') on the structure and functioning of current land system can be long-lasting. Legacies manifest themselves in all parts of ecosystems (Foster et al., 2003; Wallin et al., 1994) and can persist for decades (Wallin et al., 1994) or even centuries (Boucher et al., 2013; Thompson et al., 2013). The ecological effects of past land uses on current ecosystem structure are fairly well understood (Boucher et al., 2013; Foster et al., 2003; Rhemtulla and Mladenoff, 2007; Thompson et al., 2013) and path dependency has been conceptually acknowledged in land change science as an uncertainty factor (Brown et al., 2005; Lambin and Geist, 2006; National Research Council, 1998; Verburg et al., 2004), but empirical evidence on how much land use legacies affect contemporary land use change and land management is still scarce.

Past land uses can affect all parts of ecosystems (Foster et al., 2003; Wallin et al., 1994). For example, soil composition and nutrient content that were altered in the Eastern US during European settlement, are affecting plant abundances today (Thompson et al., 2013). The vegetation composition of historically ploughed areas has fewer shrubs and a distinct understory vegetation compared to continuously forested areas (Eberhardt et al., 2011; Motzkin and Foster, 2002). Similarly, prior farming in sagebrush ecosystems causes lower shrubs and forb cover today (Foster et al., 2003; Morris et al., 2011) while the high proportion of shrubby vegetation in dry areas, such as Chaco, New Mexico is due to overharvesting by the Anasazi (800 BC) as well as overgrazing and high stocking densities in the 1800s (Brown and Archer, 1989;

Foster et al., 2003; Fredrickson et al., 1998; Gibbens et al., 2005; Swetnam et al., 1999). Past land use decisions affecting possibilities of future change are probably best exemplified by urban area expansion, where path dependence constrains the possibility to revert an urban area to agricultural land (Lambin and Geist, 2006). Although land use legacies are widely acknowledged, the magnitude of their effect on contemporary land use dynamics at broad spatial and temporal scales is rarely quantified. The increasing number of studies and datasets capturing long term land use and land cover change (Başnou et al., 2013; Gerard et al., 2010) offers exciting new opportunities for the quantification of the legacies that past land uses exert on contemporary land change processes.

Forests are particularly likely to exhibit land use legacies, because they are persistent elements in landscapes due to the long lifespan of trees. Land use legacies can affect both forest structure and management decisions. For example, forests that were farmed during Roman times in Western Europe have a different seed bank than those that were always forested, including higher abundance of species that colonize abandoned land, and fewer seeds of poor dispersers (Dupouey et al., 2002; Plue et al., 2009). Historic land use leads to the occurrence of fruit tree species in oak forest systems (Plieninger et al., 2010) and affects both forest structure and composition including basal area, tree density, and woody plant richness (Plieninger et al., 2010; Rhemtulla et al., 2009). Even in cases in which forest composition is similar to that of historic forests, for example after agricultural abandonment in the Northeastern US, the relative importance of tree species is



**Fig. 1.** Study area in Eastern Europe and forest cover maps for the 1860s, 1960s and 2010s. CZ: Czech Republic, HU: Hungary PL: Poland, RO: Romania, SK: Slovakia, UA: Ukraine.

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