



## Forest and agricultural land change in the Carpathian region— A meta-analysis of long-term patterns and drivers of change



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### ABSTRACT

Humans have altered land cover for centuries, and land-cover change is a main component of global change. Land use transition trajectories, such as the forest transition theory (i.e. switch from deforestation to stable or increasing forest cover), relate long term changes in land use to gradual changes in underlying drivers, such as economic development, demographic change, and urbanization. However, because only few studies examined land change over centuries, it is not clear how land cover changes during very long time-periods which are punctuated by shifts in socio-economics and policies, such as wars. Our goal here was to examine broad land change patterns and processes, and their main driving forces in Central and Eastern Europe during distinct periods of the past 250 years. We conducted a meta-analysis of 66 publications describing 102 case study locations and quantified the main forest and agricultural changes in the Carpathian region since the 18th century. These studies captured gradual changes since the peak of the Austro-Hungarian Empire up to the accession to the European Union of most of the formerly socialist countries in the study region. Agricultural land-use increased during the Austro-Hungarian Empire in 70% of the case studies, but dropped sharply during and especially after the collapse of the Socialism (over 70% of the cases). The highest rates of abandonment occurred between 1990 and 2000. The Carpathian region experienced forest transition during the Interwar period (93% of the cases), and the forest expansion trend persisted after the collapse of Socialism (70% of the cases). In terms of the drivers, institutional and economic factors were most influential in shaping deforestation and agricultural expansion, while socio-demographics and institutional shifts were the key drivers of land abandonment. Our study highlights the drastic effects that socio-economic and institutional changes can have on land-use and land-cover change, and the value of longitudinal studies of land change to uncover these effects.

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### Introduction

Land-cover change is a main component of global environmental change (Foley et al., 2005), affecting climate, biodiversity and

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ecosystem services, which in turn, affect land-use decisions (Ojima et al., 1994). Humans have altered land cover for centuries, but recent rates of change are higher than ever (Foley et al., 2005; Goldewijk, 2001; Hansen et al., 2010). The temporal dimension of change is particularly interesting because land-use legacies may persist for centuries (Foster et al., 2003). Over long time periods though, land-use transition theories predict gradual changes, primarily as a function of demographic and economic factors (DeFries et al., 2004; Foley et al., 2005). For example, forest transition theory postulates that gradual economic and demographic change leads to agricultural specialization and reforestation of marginal lands, and defines the transition point as the time of the lowest forest cover in a given country or region (Mather, 1992; Meyfroidt and Lambin, 2011). Different regions may experience these transitions at different points in time, depending on economic, political or institutional condition (Meyfroidt and Lambin, 2011) or go through multiple transition phases (Yeo and Huang, 2013), as land systems respond to institutional and economic changes (Lambin et al., 2001). Shifts in political systems, and the related socio-economic adaptations, such as those following the collapse of the Soviet Union, greatly affect land trends (Hostert et al., 2011). The question is though first, how land cover changes over long time periods, and how these changes vary depending on economic, institutional and social factors. Regional land change patterns are the combined result of changes at much finer scale, that are driven by complex economic, policy and institutional, demographic and market forces (Lambin and Meyfroidt, 2010; Verburg et al., 2009). These localized changes, in turn, are constrained by interacting broad- and local-scale driving forces, especially in crisis situations (Cioroianu, 2007). While, the local-scale drivers of land-use change can be understood from case-studies (Foley et al., 2005), the variation of these drivers across regions can only be understood from a broader perspective.

Capturing land change under successive distinct economic periods and documenting change processes over large areas and long time periods (e.g., centuries) is often impossible due to the lack of consistent, broad-scale and long-term data. When that is the case, a meta-analysis can be a valuable tool for synthesizing knowledge and extracting broader scale patterns and drivers of change (Poteete and Ostrom, 2008; Rudel, 2008). Meta-analyses have been applied to assess, for example, long-term urban growth across the globe (Seto et al., 2011), desertification (Geist and Lambin, 2004), deforestation (Geist and Lambin, 2002), and tropical agriculture (Keys and McConnell, 2005). In regard to forest change, such a meta-analysis showed that tropical deforestation is a result of interacting proximate causes and underlying driving forces, which vary geographically and with historical context (Geist and Lambin, 2002). Another meta-analysis focusing on forest cover in Mexico showed that cattle ranching and outmigration cause deforestation in low-land areas, while highland regions with outmigration experience forest cover increase (Rudel, 2008). Dryland degradation globally has been attributed to the combined effects of climate, economies and institutions which drive cropland expansion, overgrazing and infrastructure development (Geist and Lambin, 2004). In Central Eastern Europe, Kozak (2010) analyzed land change across a number of local case studies to describe forest transition in the Polish Carpathian Mountains as occurring between the two World Wars (WW). However, while most meta-analyses examined broad spatial extents and explain spatial variation, their temporal scale has been limited to decades, which limits the ability to isolate effects and legacies of major socio-economic shifts across time and space. Furthermore, most meta-analyses of land change processes included only case studies that were published in English (Geist and Lambin, 2004; McConnell and Keys, 2005; Seto et al., 2011), thus not including local research and knowledge.

Broad scale, long term comparative studies across countries of Eastern Europe are still lacking (Bjørnsen-Gurung et al., 2009),

despite the availability of a high number of local, regionally published studies. Given its long land-use history and multiple social, political and economic shocks, the Carpathian region represents a “natural experiment” (Gehlbach and Malesky, 2010) to examine long-term land-use change and to develop a broader synthesis of land-use histories.

Our overall goal was to identify and quantify broad-scale and long-term land change patterns and processes during times of shocks, and the main driving forces of these changes. To do so, we conducted a meta-analysis of historical land change studies for the Carpathian region, reaching as far back as 1790s.

Specifically, our objectives were to:

- (1) Assess and quantify the main forest and agricultural changes in the Carpathian region for politically and economically distinct time periods over the past 250 years;
- (2) Assess the heterogeneity of the local-scale studies across the region;
- (3) Identify the main drivers of long-term land-use change and the impact of major socio-economic shocks on forest and agricultural change.

## Methods

### Study area

We studied the 350,000 km<sup>2</sup> Carpathian region in Eastern Europe, which comprises two major eco-regions: the Carpathian Mountains and the Pannonian Plains. The study area includes parts of the Czech Republic, Poland, Ukraine and Romania, and all of Hungary and Slovakia (Fig. 1), has a temperate climate, and landscapes consisting mostly of a mosaic of forests, pastures, and agricultural fields. The region harbors some of the largest contiguous temperate forests in Europe (Knorn et al., 2009; Kuemmerle et al., 2007) alongside high nature conservation value farmland (Paracchini et al., 2008). The Pannonian plains also represent one of the most fertile regions in Europe (Schiller et al., 2010). The Carpathian eco-region is a global biodiversity hotspot, particularly regarding plant diversity, and harbors rare old-growth and alpine meadow ecosystems and many wildlife species of conservation concern (e.g., brown bear, wolf, lynx, European bison (Salvatori et al., 2002)).

The region has a long land-use history, with centuries of agricultural and forest land use being influenced by changes in political, economic and demographic dynamics (Verburg et al., 2009). Land-cover changes during recent decades (since 1980s), have been captured by remote sensing analyses of the entire region, and showed overall increases in forest cover and agricultural abandonment (Griffiths et al., 2014; Kuemmerle et al., 2008). However, our understanding of long-term land-use trends remains scattered across numerous local-scale case-studies dispersed across the region (e.g., Feranec and Ot'ahel, 2009; Kaim, 2009; Ostafin, 2009) and a synthesis of these studies is lacking.

### Theoretical land change predictions

In order to understand land-use trends in the region, we examined agricultural and forest change during five historical periods with distinctive socio-economic, political, technological and cultural characteristics, that were demarcated by several large-scale shocks: (1) the Habsburg and Austro-Hungarian Empires (K.u.K. Monarchy), a time of agricultural modernization and the beginning of the industrial revolution, which ended with World War I (WW I), (2) the Interwar period, characterized by the emergence of several nation-states, industrialization and intensification up to World War II (WW II), (3) the Socialist period,

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