Land Change in the Carpathian Region Before and After Major Institutional Changes

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Abstract The Carpathian region represents an ideal showcase of several land change theories and their implications for conservation because this region shares the long geo-political and socio-economic history of Eastern Europe while also being a biodiversity hotspot. With a long history of abrupt socio-economic and institutional shifts, the Carpathians exemplify how ecosystems may or may not be pushed into an

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alternative stable state following shocks such as the collapse of empires, world wars or the collapse of socialism. Furthermore, ecosystem changes may or may not experience time-lags in response to shocks, and over long time periods, historic land-use practices may produce land-use legacies that persist on the landscapes for decades or centuries. Here, we analyze the long-term drivers of land change and their land-use outcomes in the Carpathian region, with a particular focus on forests, agriculture and grasslands, and provide examples of how ecosystems respond to shocks using examples of alternative stable states, time-lags and land-use legacies. Understanding how and why land change patterns vary over time and space is important for balancing land-use decisions, especially in biodiverse regions with a high conservation value.

1 Introduction

The Carpathian region (here defined as the Carpathian Mountains and the surrounding lowlands of the Pannonian plains) has experienced several episodes of drastic land-use change over the past two centuries and is therefore an interesting

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'natural experiment' (Gehlbach and Malesky 2014) for the study of overarching issues at the frontier of land change science: land change following socioeconomic and institutional shocks, the importance of drivers of land change, the time-lag and legacy effects of past changes and the uncertain futures of land cover. Moreover, as the "green backbone of Europe" and a biodiversity hotspot (UNEP 2007; Björnsen-Gurung et al. 2009; Hazeu et al. 2010), the Carpathian region harbors some of the largest old-growth forests on the European continent (Veen et al. 2010), as well as high nature-value grasslands (Akeroyd and Page 2011; Fischer et al. 2012), and provides habitat for a large range of species (Nabuurs et al. 2008; Schulp et al. 2008; Halada et al. 2010; Bálint et al. 2011).

Due to the geo-political context of Eastern Europe and the multiple abrupt shifts in institutions, politics and economics, the ecosystems across the Carpathians are at risk. The underlying driving forces and proximate causes (Lambin et al. 2001; Lambin and Meyfroidt 2010), of which institutional and socio-economic forces are the most important in the Carpathians (Kozak et al. 2013b; Griffiths et al. 2014; Munteanu et al. 2014), heavily affect natural ecosystems. Over the past two centuries, various shocks, such as the fall of empires, the collapse of socialism, and the accession of the EU, have caused several shifts in land management and have drastically affected the type and magnitude of land changes (Munteanu et al. 2015). Economic and institutional drivers have caused land-use intensification, while other socio-demographic and policy changes have resulted in land abandonment. As a consequence, a broad range of patterns of land change have occurred, allowing for a comparison of the effects of the underlying driving forces of change over a relatively short time period and across a small region. The effects of the interplay between drivers reverberate throughout the ecosystem, affecting biodiversity, carbon sequestration, ecosystem services, and rural livelihoods (DeFries et al. 2004; Foley et al. 2005; Ellis et al. 2013).

The drivers of land change and their interactions may cause immediate or delayed responses in ecosystems. Land change can occur immediately following a shift in policy or in economic conditions, or it may take as long as several decades for the effects to become quantifiable. For example, forest harvesting provided a source of immediate income in the period of economic depression following the collapse of the Soviet Union (Griffiths et al. 2012, 2014; Knorn et al. 2012a), and the effects of the loss of tree cover were observed only few years after 1989. However, delays in the legislative framework and the restitution process caused intensified logging to occur only after a time-lag in some regions of the Carpathians (Knorn et al. 2012a; Griffiths et al. 2014). In response to conservation practices and land cover changes in the post-Soviet era, large mammal populations rebounded only after a time lag of approximately 10 years following the collapse of the Soviet Union (Bragina et al. 2015; Rozylowicz et al. 2010; Moura et al. 2013).

Land-use futures are associated with high uncertainty because land changes may or may not persist over long time period: the land system may revert to previous

land-use patterns following a shock event, or it may be pushed into an alternative stable state. The volatile history of Eastern Europe makes the region a valuable case study for examining alternative stable states. The regions attractiveness for development restricts future land-use possibilities because built up areas are unlikely to be reverted to a previous use in the future. Conversely, abandoned fields encroached upon by shrubs may or may not revert to agricultural use (Gerard et al. 2010; Griffiths et al. 2013). Due to their agricultural suitability and fertile soils, the lowlands of the Carpathian region have the potential for agricultural intensification and increased food production (Foley et al. 2011), but once an area has undergone forest succession, the cost of reverting it to agricultural use is high, and the system can stabilize in a state of forest cover. Integration into the EU's common market may entail both agricultural intensification and the abandonment of traditionally farmed areas in this region (Elbakidze and Angelstam 2007), and such changes may be permanent or temporary, depending on future economic or policy incentives, such as those provided by the EU Common Agricultural Policy.

The magnitude of recent land changes is modulated—alongside economic, institutional, and demographic drivers—by centuries of human impact on natural ecosystems. The legacies of past land-use patterns shape recent changes and affect ecosystem structure and function, as well as the type, magnitude and timing of more recent land change processes. Multiple, repeated shifts in land management over a relatively short time span (the collapse of the Habsburg Monarchy and the Austro-Hungarian Empire, two world wars, the effects of socialism, and the transition to market economies and EU accession) have caused repeated changes in land management that have affected land-use practices and have generated several land-use legacies (Munteanu et al. 2015). The rates and magnitude of change are generally higher in areas with shorter land-use histories (e.g., post-Soviet agricultural abandonment is more likely in areas cleared for agriculture during the Soviet era than in areas cleared for agriculture during the Habsburg Empire). The legacies of Soviet industrial pollution affect the recent health of forests (Main-Knorn et al. 2009), and natural disturbances are rooted in past forest management decisions (Falťan et al. 2009).

Overall, the land-use dynamics in the Carpathian Region represent an excellent case study for investigating aspects of land change related to drivers of change, shocks, land-use legacies, and time-lags. In the following we outline the environmental and socio-political background of the Carpathian region and review the past two centuries of land change across the eight countries in the region, with a particular focus on the time period around the collapse of socialist regimes in Eastern Europe. We show that institutional shocks can severely affect land change, but that the magnitude of change differs among regions and that the response to abrupt policy changes can sometimes occur with a substantial time-lag. We show that land-use legacies can persist for decades or even centuries, affecting the current landscape composition, pattern and potential for change. Understanding land change patterns and the potential land-use conflicts arising from these changes are essential for land management in the region.

2 The Carpathian Region

2.1 The Environmental Setting

The Carpathians, often referred to as the ecological backbone of Central and Eastern Europe (Hazeu et al. 2010), are the largest and the most geographically, culturally, and ecologically diverse mountain range in the region. They span 1400 km and cover an area of over 160,000 km^2 (Kozak et al. 2013a). Extending between latitudes 43 and 50°N, the Carpathians are a young mountain range, formed during the Alpine orogenesis, and are composed of five subunits, each with unique geological and environmental characteristics: the Northwestern Carpathians (including the Tatra Mountains); the Northeastern Carpathians (between the Tisza and Cheremosh rivers); the Eastern Romanian Carpathians; the crystalline Southern Carpathians (the Transylvanian Alps); and the lower elevation Southwestern Carpathians (UNEP 2007) (Fig. 1). The mean elevation is 850 m, but the highest peaks reach over 2500 m above sea level in the northwest and south (Kozak et al. 2013a). Elevations of approximately 400 m are common in valleys. The temperate climate is characterized by precipitation levels between 400 mm in the southeast

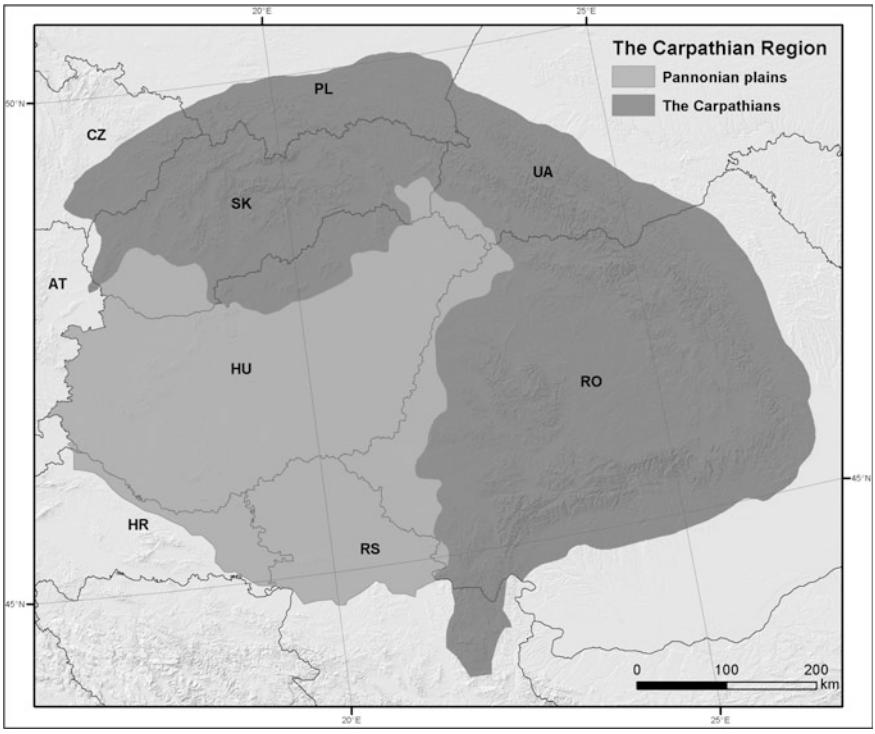

Fig. 1 The Carpathian region: *Graphic*: D. Kaim

and over 2000 mm in the high mountains. Mean annual temperatures range between −2 and 2 °C (UNEP 2007) in high mountains and between 4 and 6 °C at lower elevations. The geological and climatic diversity of the region results in a high level of environmental and biological diversity.

The Carpathians harbor some of the largest areas of continuous forests in Europe, with high conservation value and high biomass production (UNEP 2007; Keeton et al. 2013). Of these, approximately 200,000 ha are old-growth forests found only in Romania (Knorn et al. 2012b). Forests are important for carbon sequestration (Holeksa et al. 2009; Keeton et al. 2010), the provision of habitat and sustaining biodiversity (Knorn et al. 2012a), as well as for aesthetics and providing recreational amenities. Common landscape features consist of a highly diverse mosaic of forests and grasslands intermixed with wetlands along major river valleys. The Carpathian foothills are covered by mixed deciduous forests dominated by oak (Quercus sp.) and hornbeam (*Carpinus betulus*). At higher elevations, beech forests (*Fagus sylvatica*) mixed with silver fir (*Abies alba*) and Norway spruce (Picea abies) are common. Historically, some broadleaved forests have been replaced by Norway spruce (*Picea abies*) that has been introduced outside of its natural range for timber production since the early 20th century (Munteanu et al. 2008, 2016). However, at elevations over approximately 1100 m (with small regional differences), coniferous forests occur naturally, composed mostly of *Abies alba*, *Larix decidua* and *Pinus cembra*. Above the timber line (1400–1900 m), dwarf pine (*Pinus mugo*), and juniper (*Juniperus communis*) shrubs make up the transitional zone leading to alpine landscapes dominated by alpine meadows with high species diversity (Grodzińska et al. 2004). The relatively low elevation of the mountains does not allow glaciers to persist, even at the highest locations (Kozak et al. 2013b).

Semi-natural grasslands with high biodiversity (Bezák and Halada 2010; Akeroyd and Page 2011) and high mountain grasslands (in Ukraine, Poland and Slovakia, also called 'poloniny') are distinctive and typical landscapes of the Carpathians, and they harbor a high number of species that are threatened or endangered due to the overgrazing and shrub encroachment that has occurred over the past 60 years (Baur et al. 2007). Additional grassland communities of the Carpathians include dry and wet meadows, semi-natural mesophilic meadows, and extensively used pastures and fens, all of which have a high diversity and are rich in endemic plant and insect species (Bezák and Halada 2010; Kricsfalusy 2013). The regions forests and grasslands provide habitat for a significant portion of Europe's biodiversity. Large mammals, such as the brown bear (*Ursus arctos*) (Rozylowicz et al. 2010), European bison (*Bison bonasus*) (Perzanowski and Olech 2007; Kuemmerle et al. 2010), lynx (*Lynx lynx*), and wolf (*Canis lupus*), are abundant in this region, unlike in most parts of Western Europe (Kozak et al. 2013b).

Human activity has modified the natural landscapes of the region for over 2000 years. Characteristic cultural landscapes in the mountains consist of relatively small fields, scattered settlements, and large tracts of forests. In the lowlands, agriculture is practiced at a larger scale. Mining became an intensive activity in the medieval period and remains an important driver of land change, especially in central Slovakia (Bugár et al. 2010) and in the Western Romanian Carpathians

(Munteanu et al. 2014). Changes in forest structure and composition have resulted from intense natural resource use, especially for timber and pulpwood production. The intensive use of grasslands followed by their recent abandonment has altered their species diversity and composition (Halada et al. 2008, 2010; Kricsfalusy 2013). Urban cover has expanded, especially around larger historic cities. The past and recent land-use dynamics affect more recent aspects of landscape structure, composition, ecosystem functioning, and species diversity (Turnock 2002), posing great challenges to land management in this region.

2.2 Geo-political and Socio-economic Context

The current geo-political setting of Eastern Europe is relatively young. The study region includes a small part of Austria and the Czech Republic, most of Slovakia, southern Poland, Hungary, western Ukraine, most of Romania and a small part of northern Serbia. Administrative boundaries in the area have shifted multiple times during the past two centuries, causing repeated landscape changes. Most of the major land changes in the Carpathians were marked by changes in institutional systems and administrative boundaries (Bideleux and Jeffries 1998). Throughout the 19th century and up to the beginning of the 20th century, most of the Carpathian provinces were under the control of the Habsburg Empire and the Austro-Hungarian Monarchy (Munteanu et al. 2014), with the main mountain ridge in Romania constituting the border with the Ottoman Empire. After World War I, the multi-national Austro-Hungarian Empire broke up, and several national states emerged (Seton-Watson 1945). However, the boundaries of interwar Eastern Europe differed significantly from the present boundaries. Poland and Czechoslovakia included the current Ukrainian Carpathians, while the southern part of the Carpathians was part of the Kingdom of Yugoslavia. The regions of Bukovina, Bessarabia, Moravia, Galicia, and Transylvania were annexed to different states (Seton-Watson 1945; Bideleux and Jeffries 1998) (Fig. 2). With the redefinition of state boundaries, the core-periphery relationships changed, breaking old links between settlements and transportation systems and establishing new ones (Kozak et al. 2013b). The legacies of these repeated political changes still manifest themselves in the current land cover and patterns of land cover change in the region.

Following World War II, most of the Carpathian countries (except Austria and Yugoslavia) fell under the influence of the Soviet Union and established socialist regimes. During this socialist period, land use policies and management became relatively homogenous across the Eastern Block—with exception of Poland and Serbia, where the collectivization of agriculture was not broadly applied. The Carpathian countries became part of the Council for Mutual Economic Assistance (COMECON), and joint enterprises with Soviet partners targeted the exploitation of natural resources (Banu 2004; Kligman and Verdery 2011). Land nationalization and the collectivization of agriculture led to some intensification of land use and in a few instances its expansion, along with logging, in Romania, Hungary, Ukraine,

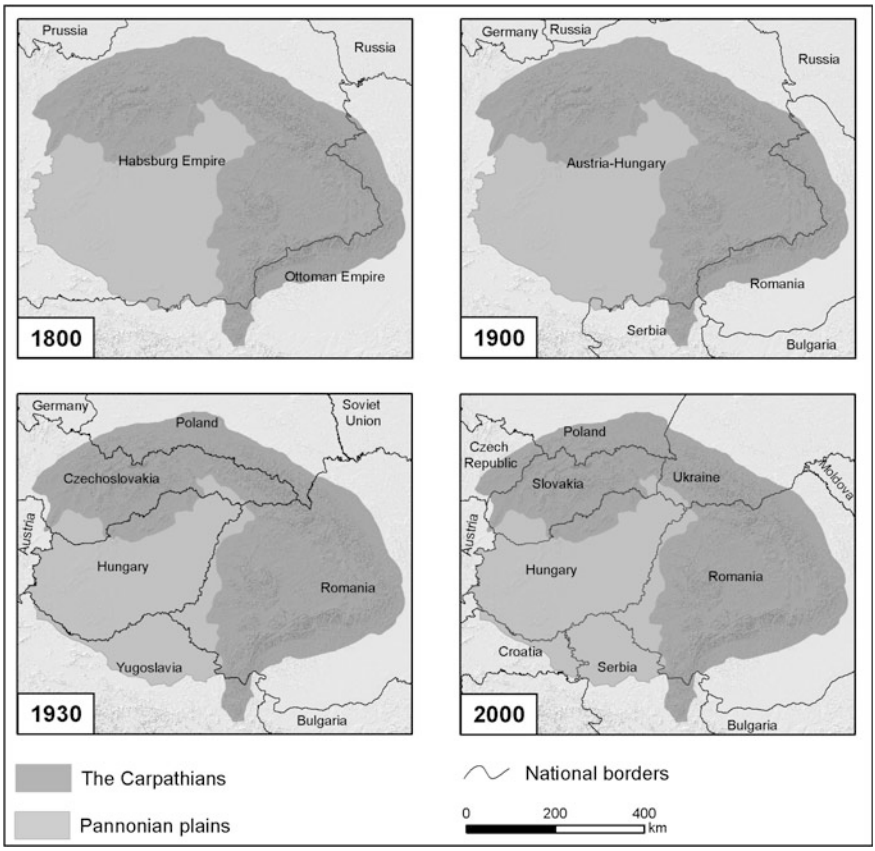

Fig. 2 Historic geo-political boundaries in the Carpathian Region during the Habsburg Empire (1800) Austro-Hungarian Monarchy (1900), interwar period (1930) and post-WWII (2000). *Graphic*: D. Kaim, *Data source*: euratlas.com (1800, 1900)

Slovakia, and the Czech Republic. In the mountainous regions of Eastern Poland, forest expansion was the dominant trend after World War II (Kozak 2010). Changes in Ukraine were particularly drastic because the country was part of the Soviet Union, and it became a main source of timber and agricultural products during Soviet times (Brain 2011).

The transition to market economies started between 1989 and 1991 in the Carpathian countries, when the Iron Curtain lifted and the Soviet Union collapsed. This political shift had major implications for the economies, demographics, and institutions of these countries and ultimately affected land change and conservation. Land reforms occurred in the form of restitution or redistribution of land (Lerman et al. 2004; Hartvigsen 2014), and markets opened up for trade with the Western World. The timing and speed of the transition to market economies varied among the countries, a process partly reflected in the timing of each country's accession

into the European Union. The Czech Republic, Slovakia, Hungary and Poland joined the EU in 2004, while Romania joined three years later, and Serbia and Ukraine remain non-members. However, the Carpathian countries cooperate in regard to nature conservation and sustainable development under the umbrella of the Carpathian Convention, which was established in 2003.

The EU accession of most of the Carpathian countries represents the most recent shift in economics and institutions that have affected land change in this region. EU accession impacted both resource management and nature conservation. Regulations such as the Common Agricultural Policy (CAP) aim to build common markets for agricultural products, remove tariffs, and support environment-friendly agricultural land management. However, the implementation of the CAP and the levels of subsidies differ substantially among countries, affecting in turn the recent rates and extent of change (Young et al. 2007; Knowles 2011). Furthermore, several other EU policies, such as the Water Framework Directive and the Natura 2000 Network, affect the future of land change in the region by encouraging or restricting specific uses, such as wetland restoration and habitat conservation (Kallis 2001; Donald et al. 2002; Maes et al. 2012).

2.3 *Demographic Changes*

Along with institutional and economic forces, socio-demographic processes are important underlying drivers of land change in Eastern Europe (Haase et al. 2007). Across the eight countries, the region was home to approximately 17 million people at the turn of the 21st century (CERI 2001), who mostly lived in rural settlements. A few large cities at the fringe of the Carpathian Mountains experienced substantial population increases during the socialist period, and urban sprawl has increased since 1990. The highest population densities occur in the Czech Republic and the Polish Carpathians (>175 inhabitants/km^2), while the Romanian Carpathians are the least populated (<100 inhabitants/km^2). Supporting and encouraging population growth was one explicit goal during the communist regime, for example, in Romania (Schreiber 2003). The post-war trend of rural depopulation and the marginalization of rural areas led to increases in the populations of urban centers at the edges of the Carpathians. Population aging and a growing inequality between rural and urban areas has become a major concern in the post-Soviet Carpathians (UNEP 2007). The population growth rate since the collapse of the Soviet Union has oscillated between −1 and +0.5 %, with the highest rates since 2005 recorded for the Slovak Republic. In absolute numbers, the population of all Carpathian countries has declined slowly since 1990, except for those of Austria, Poland, and the Slovak Republic (Fig. 3). Due to the opening of borders after 1990, migration to Western Europe and to large cities outside the Carpathians increased substantially. Shifts in employment from the agricultural sector to the service sector continue to foster agricultural abandonment (Schreiber 2003; Kozak 2003). However, the region has recently become more attractive for recreation and tourism. The

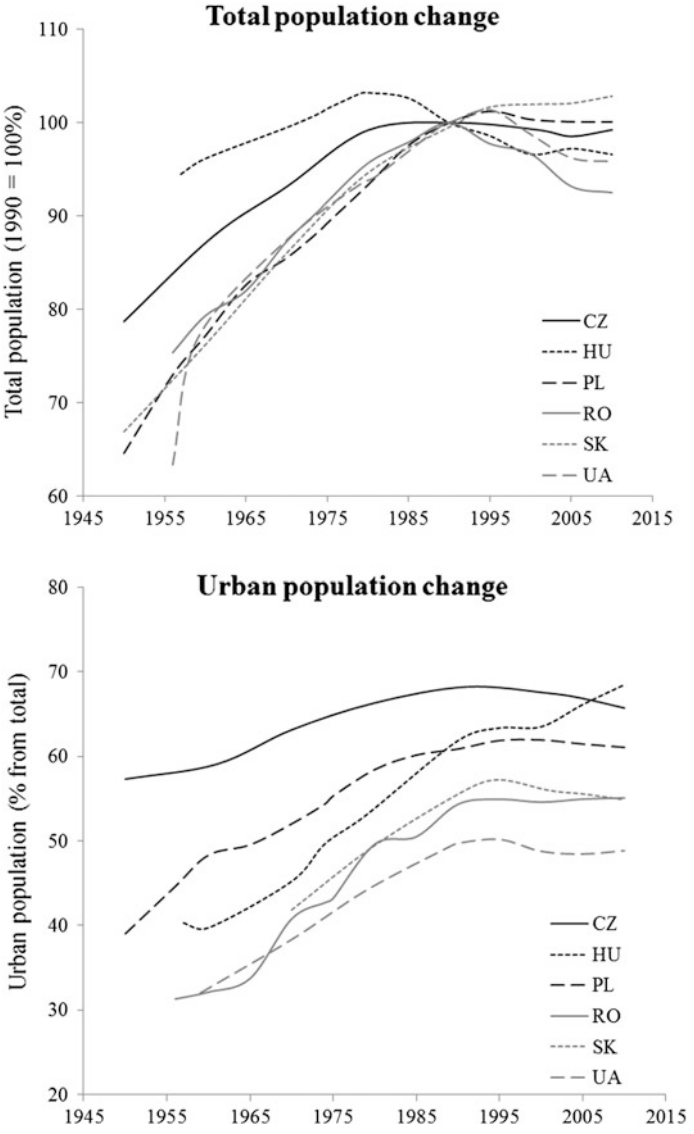

Fig. 3 Population dynamics and changes in the percent of the population in urban areas in the Carpathian countries since 1945. *Country codes CZ* Czech Republic, *HU* Hungary, *PL* Poland, *RO* Romania, *SK* Slovakia, *UA* Ukraine. *CZ and UA* Carpathian district level data (*CZ* Jihomoravský, Moravskoslezský, Olomoucký, Zlínský; *UA* Zakarpatska, Lvivs'ka, Ivano-Frankivska, Chernivets'ka oblasts). HU, PL, SK, RO country level data. *Data source* http://pop-stat.mashke.org/; http://ukrcensus.gov.ua; http://demoscope.ru/; UN demographic yearbooks. *Graphic*: O. Shandra

development of second homes in natural settings (Mika 2013) and employment in the service sector (Süli-Zakar 1998) are recent processes that lead to population increases in both rural and urban areas.

2.4 Land Cover and Land-Use Changes

Both the rates and extent of land change in the Carpathians have increased substantially over the past three decades. Most of these changes are due to socio-economic and political shocks related to the Soviet Union's collapse (Kuemmerle et al. 2008, 2011; Baumann et al. 2011). However, many changes are rooted in the regions long land-use history (Kozak 2010), and those land-use legacies may persist for centuries into the future (Bellemare et al. 2002; Foster et al. 2003; Munteanu et al. 2015). Over long time periods, several patterns have emerged for the Carpathians. Forest cover has increased over the past century, with a forest transition—the shift from decreasing to increasing forest area—occurring during the interwar period (Kozak et al. 2004; Kuemmerle et al. 2011; Munteanu et al. 2014). Agricultural land has experienced the opposite process, i.e., agriculture generally expanded up to the early 20th century, followed by the abandonment of marginal areas starting during the socialist period and accompanied by the intensification of existing cropland (Munteanu et al. 2014). Agricultural land abandonment and forest succession accelerated after the collapse of the Soviet Union in most of the Carpathians (Griffiths et al. 2013, 2014). During Soviet times, natural grasslands were converted to arable land (Feranec et al. 2000), especially in lowland and moderately hilly areas. Grazing pressure generally increased in the high mountain grasslands up to the 1990s, but declined thereafter (Sitko and Troll 2008; Shandra et al. 2013). After 1990, many grasslands were abandoned and reforested. However, following EU accession and the nature conservation efforts that accompanied it, extensively managed grasslands (pastures and hayfields) are re-appearing in Carpathian landscapes. Other prominent land changes in the Carpathians include a substantial loss of wetlands and an increase in urban sprawl (Ronnås 1982; Konkoly-Gyuró et al. 2011; Huzui et al. 2012). Wetland drainage peaked during the socialist period, but restoration efforts are being made thanks to EU regulations and incentives (Günther-Diringer 2000; Horváth et al. 2012). Increasing urban sprawl was common for many decades but accelerated substantially after 1990 (Ronnås 1982; Huzui et al. 2012). The regions attractiveness for tourism and second-home development led to the abandonment of fields in the proximity of urban settlements, which have been permanently taken out of agricultural production (Mika 2013).

While the overall trends in land change are strong, local and temporal variation occurs across the Carpathians (Munteanu et al. 2014). For example, in Habsburg times, forest cover decreased in the Romanian, Ukrainian, and Slovakian Carpathians, while it increased in the Polish Carpathians and was stable in the Czech Republic (Munteanu et al. 2014). Following the collapse of socialism, most countries experienced elevated rates of forest disturbance; however, while

disturbances peaked right after 1990 in Ukraine, in Romania, the highest disturbance rates occurred only after 1995 (Griffiths et al. 2012, 2014). Low but positive annual rates of agricultural expansion occurred in Romania and southeast of Hungary during the socialist period, while in Poland, agricultural land decreased by up to 5 % per year (Woś 2005). Overall, the hotspots of land change (i.e., areas that experienced the most change in land cover) occur at the interface of land covers so that the same land change driver is mirrored in multiple processes (e.g., agricultural abandonment/grassland conversion is related to forest cover increase, wetland loss is related to agricultural expansion).

In the following section, we focus on the most important types of land cover in the Carpathians, highlighting their specific characteristics, and discuss land-use history, prominent land cover changes prior to and after the collapse of the Soviet Union, and the drivers of change. The same change processes often affect multiple land cover types, and therefore, they are discussed in the respective sections. While the main focus is on post-socialist land change, the broader historical context is important because past land changes modulate the extent and magnitude of post-Soviet processes. Using these examples, we demonstrate how land change processes exhibit legacies, time lags, alternative stable states, and we highlight some of their effects on biodiversity.

2.5 Forests

Forests represent the dominant land cover type of the Carpathians, making up approximately a quarter of the land cover of the region, with higher values for the mountainous areas (Kozak et al. 2013b; Griffiths et al. 2014), and less forest cover in adjacent lowlands, and they have a long history of human management. As a dynamic system over the past century, forests in this region have experienced multiple changes in terms of total area (Fig. 4), heavy logging related to shifts in composition, natural disturbances and succession over abandoned agricultural areas. The substantial changes in forest cover were driven by socio-economic and institutional shocks, of which the collapse of the Soviet Union was the most complex in terms of interactions between drivers and in terms of the magnitude of the effects on forest management and thus on forest structure and composition (Griffiths et al. 2014; Munteanu et al. 2015).

Over the last 200 years, the overall long-term trend has been an increase of forested areas. On average, forest cover has increased over the entire Carpathian region since the Soviet Union's collapse, with a net increase of 153,000–157,000 km^2 (Griffiths et al. 2014). Romania has experienced an increase of up to 7 % in forest cover since the mid-1980s, largely due to successional encroachment of deciduous species onto abandoned land, while mixed and coniferous forests substantially declined between 1985 and 2010, as was the case in most other countries in the Carpathians (Griffiths et al. 2014). Forest cover has become more continuous, but the habitat structure and the ecosystem services have also changed

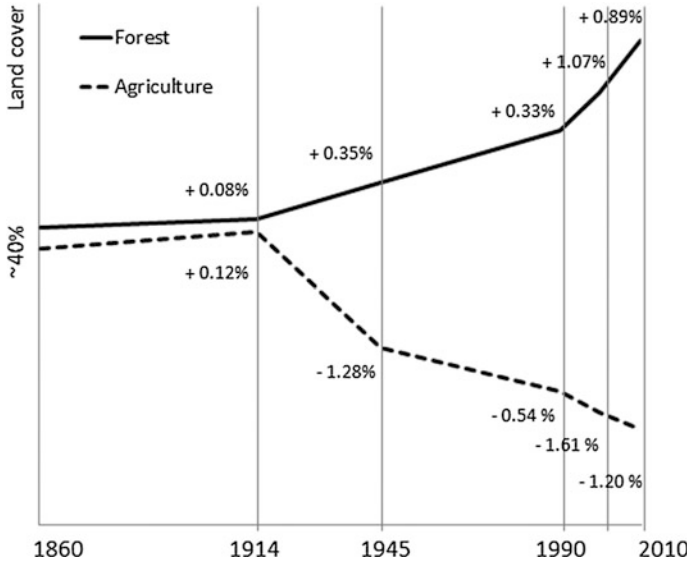

Fig. 4 Conceptual reconstruction of the long term forest and agricultural land cover dynamics in the Carpathians. Mean annual rates of land change based on case studies from Munteanu et al. (2014)

substantially. The smallest increases in forest cover have occurred in the Czech Republic and Austria, where despite similar trends in compositional shifts, forest cover has only increased by approximately 1 % over the past 25 years (Fig. 5). The increase in forest cover began much earlier however, with forest transitions occurring in the interwar period across the Carpathian region (Kozak et al. 2004; Kuemmerle et al. 2011; Munteanu et al. 2014).

A large proportion of the recent increase in forest cover in the Carpathians is due to agricultural abandonment, both in marginal lands (Müller et al. 2009) and on large agricultural fields that were previously owned by state farms (Kozak 2010; Baumann et al. 2011). Additionally, some reforestation of previously degraded forests has contributed to the overall increase in forest cover. During the 20th century, with the decline of transhumance, considerable forest cover increases occurred at the timberline, which was mostly composed of coniferous forest (Shandra et al. 2013). In Soviet times, despite heavy logging, forest cover losses were somewhat compensated for by the planting of trees outside of forest ranges, for example in Hungary (Munteanu et al. 2014). Afforestation also played an important role in marginal areas, such as the border area of Poland, Slovakia and Ukraine (Kozak 2010). Furthermore, local conditions, such as the special case of forced depopulation following WWII in the Bieszczady Mountains of Eastern Poland, also generated a regional hotspot of forest increase in Poland, leading to extensive forest succession on abandoned land across an area including over 50 % of the total landscape (Wolski 2001; Warcholik 2005; Woś 2005).

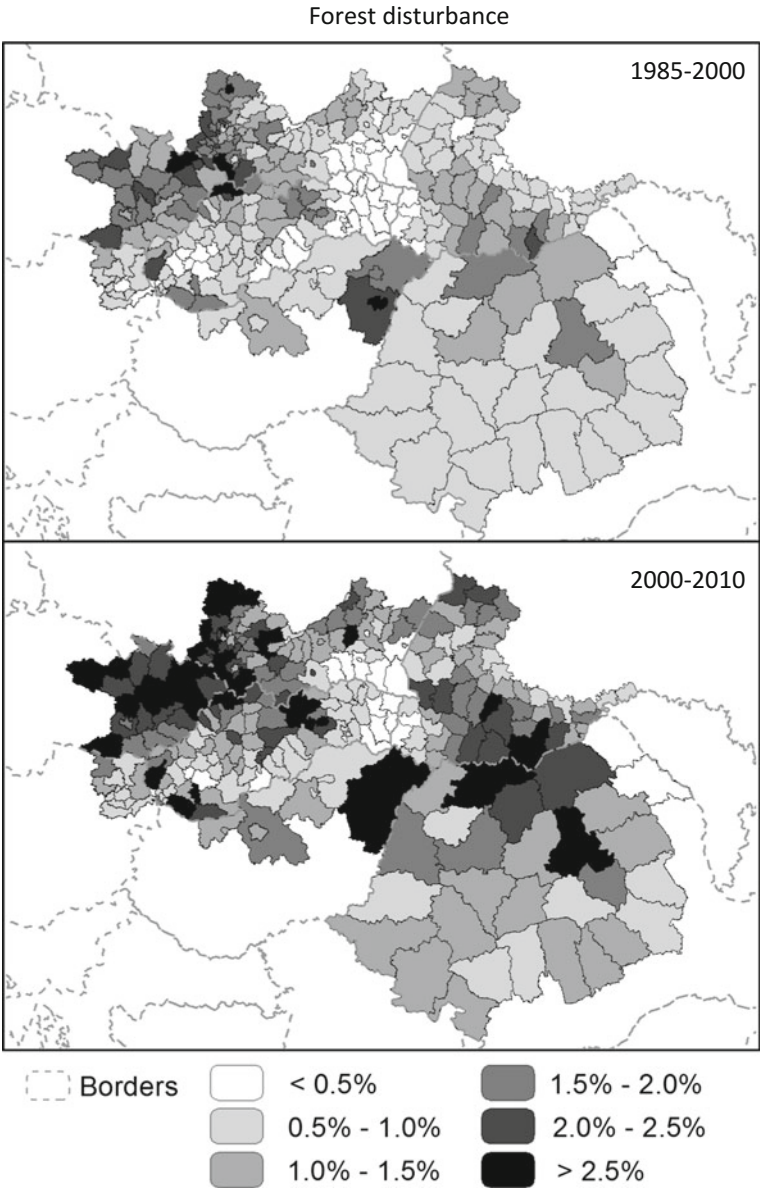

Fig. 5 Annual forest disturbance rates for the periods 1985–2000 and 2000–2010. Disturbance rates consider all stand-replacing disturbances at a 30 m pixel level. Country boundaries are shown in *dashed grey lines*. Disturbance rates are provided at the level of administrative units (district level for Czech Republic, Poland, Slovakia and Ukraine, and county level for Austria, Hungary and Romania). Scale of the maps is 1:8,750,000. Modified from Griffiths et al. (2013)

Despite an overall increase in forest cover, forest management and logging activities affect the structure and health of the Carpathian forests. Forestry as an economic activity developed mostly during the times of the Habsburg Empire and Austro-Hungarian Monarchy due to the high timber demands in the Empire. Mining, a prominent activity since the 13th century, intensified during this period, further raising timber demands and increasing the extent of deforestation (Turnock 2002). Coal and metal mining caused especially widespread deforestation in the Ostrava region of Moravia, the Romanian Banat, Apuseni, and in northern Hungary (Turnock 2002; UNEP 2007). Forest clearing for agriculture and for pastures, especially above the timberline, transformed the Carpathian landscapes in the Middle Ages and up to the 19th century.

Forest management for sawtimber and pulp production increased dramatically during Soviet times (Banu 2004). Large areas were clear-cut and restocked with monocultures. Such intense forest management caused forests to progressively become younger and less dense (Turnock 2002). Stand-replacement disturbances affected forest structure and composition, and were widespread across the Carpathians (Griffiths et al. 2014). In some areas (e.g., Ukraine) forest harvesting increased at surprising rates, especially after the collapse of the Soviet Union. In most cases, disturbances occurred in the decade between 1985 and 1995. Thereafter, disturbance rates dropped but then picked up again after 2005, mostly in Poland, the Czech Republic (due to a combination of natural processes (Main-Knorn et al. 2009)), Slovakia and Romania (mostly driven by changes in institutions and ownership (Griffiths et al. 2012)). However, in Romania and Ukraine, disturbances only peaked 10 years after the institutional shift. This time lag effect may be related to the speed of the restitution process and the speed at which countries transitioned to market economies (Bideleux and Jeffries 1998; Hartvigsen 2014). After the collapse of the Soviet Union and land restitution or redistribution, forest became an immediate source of revenue in many countries (Irimie and Essmann 2009; Mantescu and Vasile 2009), leading to both legal and illegal logging (Kuemmerle et al. 2009; Knorn et al. 2012a). The opening of timber markets, increased exports, shifts in forest ownership and poor regulatory frameworks became the main drivers of forest harvesting for timber production (Ioras and Abrudan 2006; Irimie and Essmann 2009). In Romania and Ukraine, the transition to market economies was slower, and drivers started having effects later than in the Western Carpathian countries. Overall, across the region, the intense use of forests caused forest loss within those areas and resulted in an overall shift to younger forests with shorter rotation cycles (Nijnik and van Kooten 2000; Griffiths et al. 2014).

Intensive and sometimes poorly regulated forest management was, over time, accompanied by substantial shifts in forest composition and patterns. During Habsburg and Soviet times, a shift in forest composition occurred towards a higher proportion of coniferous species (Kozak et al. 2007; Wiezik et al. 2007; Munteanu et al. 2016) due to timber demands and the need to restock with fast-growing species. Since 1985, the trend has reversed, with deciduous forests increasing by

9.0 % in the Carpathians, while mixed forest have decreased by 2.3 % and the coniferous forests by 7.0 % (Fig. 5).

The increase of monocultures for timber and pulp production from the 19th and 20th century had a cascading effect, increasing the occurrence natural disturbances, such as insect attacks or wind throws. Due to the vulnerability of spruce plantations to snow, wind throws, and pest outbreaks, the occurrence and extent of disturbances have increased over the past decades (Main-Knorn et al. 2009). In 2004 in the High Tatra Mountains, approximately 12,000 ha of forest were disturbed by a strong windfall (Falt'an et al. 2009). In 1994, 9000 ha of mostly spruce monoculture was disturbed by wind in South Eastern Transylvania (Turnock 2002). Such events have led to increased forest management awareness. Forest management is currently shifting away from managing monocultures for pulpwood and timber production (Keeton and Crow 2009) and toward mixed forest management. Forest restoration and forest protection plans are being implemented in many areas (Turnock 2002; Keeton et al. 2013; Macicuca and Diaconescu 2013). As a result, forest recovery from disturbance has been more substantial in areas that were disturbed after 1990 than in those harvested prior to 1990. However, the effectiveness of protective and restorative endeavors remains questionable in many Carpathian countries (Knorn et al. 2012a).

Forest changes in the early 19th century were mostly driven by proximate causes, such as infrastructural development and timber harvesting. As the Soviet Union expanded its sphere of influence into Eastern Europe, centralized policies and economies became the most important underlying drivers of forest change (Munteanu et al. 2014). Infrastructure and tourism development were proximate causes of deforestation in Romania (Huzui et al. 2012) and the Tatra Mountains (Gerard et al. 2010). Population displacement, on the other hand, drove reforestation in the Polish-Slovakian-Ukrainian border region (Woś 2005; Kozak 2010). With the collapse of the Soviet Union, a multitude of proximate and underlying drivers interacted at various levels across the Carpathian countries. As countries developed their own policies, redefined property rights, and accessed new markets, a complex suite of underlying drivers become increasingly important for determining patterns of forest change. For example, loopholes in laws related to the use of forests and illegal harvesting caused severe disturbance patterns in Romania and Ukraine (Irland and Kremenetska 2009; Kuemmerle et al. 2009; Knorn et al. 2012a), affecting valuable ecosystems such as old-growth forest (Knorn et al. 2012b). Increasing migration to western Europe reduced the pressure on the land and allowed for forest succession to occur on abandoned grasslands and agricultural areas (Kozak 2003; Munteanu et al. 2008; Smaliychuk 2012). The extent and timing of disturbance patterns differed among countries depending on the time that drivers became active, causing time lags of up to 10 years following the institutional shift to occur in Romania (Griffiths et al. 2012, 2014). Overall, Carpathian forest cover was severely affected by the socio-economic shock caused by the collapse of the Soviet Union. The general trend was a slight overall increase in forest cover accompanied by substantial shifts in forest composition and structure (Shandra et al. 2013; Griffiths et al. 2014). Recent human-induced disturbances are currently affecting ecosystem health, mostly due to selective logging and shorter

rotation cycles (Nijnik and van Kooten 2000). Natural disturbances can be exacerbated by past forest management practices for wood production (e.g., spruce monocultures), but their environmental effects sometimes only became clear decades later (Main-Knorn et al. 2009). All of the changes discussed here were driven by a complex web of proximate causes and underlying forces, whose intensity after the collapse of the Soviet Union increased substantially but at different rates in the various Carpathian countries (Fig. 5).

2.6 Agriculture

Following forestry, agriculture is the second important economic sector influencing the land cover of the Carpathian region and the one that experienced most change over the past three decades. Agricultural land covers approximately a third of the Carpathian Region (Ruffini 2008) with land use patterns ranging from large-scale, intensively used fields in lowlands to small-scale subsistence farming, predominantly in marginal mountain areas. Agricultural land uses include arable land, managed meadows and pastures but our focus here is mostly on arable use, although the reviewed change processes may include land dynamics at the interface of arable land and managed meadows and pastures.

Farm size varies with location and time-period: small-scale subsistence farms in the mountainous areas are typically 1–5 ha in size, while large-scale intensive farms established following collectivization reached over 1000 ha in size, mostly in the lowlands (Jepsen et al. 2013). The main crops in the region are cereals (wheat, corn, barley, rye, and oats) and legumes (potatoes, sugar beets, and peas). In recent years, bioenergy crops such as rapeseed have gained in importance (Griffiths et al. 2013). Fruit orchards, hop fields, and vineyards constitute the majority of the perennial crops, and they are particularly common in the Carpathian foothills and in Slovakia (Špulerová et al. 2011). The dynamics of field size, type of crops, expansion into other land cover types and abandonment have changed over the past two centuries. The overall trends in agricultural land change since the 18th century consist of expansion up to WWI, intensification during Soviet times, widespread abandonment after the collapse of the Soviet Union and recultivation in the past decade.

Traditional agricultural practices, prior to industrialization, included small-scale agriculture based on two-field rotation cropping (Irland and Kremenetska 2009) and livestock farming, including transhumant sheep farming, especially in Romania (Turnock 2002). During the Habsburg and Austro-Hungarian Empires, arable land was expanded into grasslands and wetlands at a rate of approximately 0.1 % annually (Munteanu et al. 2014). In the 19th century and the beginning of the 20th century, Ukrainian smallholders cleared forest patches for agricultural use (Vepryk 2001). Forest clearing for agriculture was also common in Hungary (Konkoly-Gyuró et al. 2011). Agricultural expansion in the Carpathians continued throughout the interwar period, but following the World War II and extensive land reforms, the process gave way to intensification and land abandonment.

The intensification of agriculture was a typical process from the 1950s to the 1970s for the whole of Europe (Young et al. 2007), partly due to efforts to bolster food security after the food shortages caused by WWII. The establishment of socialist regimes after WWII across most of the Carpathian countries represented a major shock for cropland dynamics in the Carpathians. Agricultural land was nationalized in Ukraine and collectivized in the countries outside of the Soviet Union. Agricultural production became highly subsidized, and policies supported the emergence of large collective, state-owned farms at the expense of small family farms (Turnock 1996). The change in field size was particularly striking: the former mosaic of small and narrow patches of land was replaced by large areas of arable land intermixed with intensive grasslands. Large, homogenous, uniformly utilized patches drastically changed the formerly diverse sub-montane landscape (Halada et al. 2008). Agricultural mechanization and the use of mineral fertilizers increased rapidly. Political goals included an increase in agricultural production and caused the expansion of arable land in the Czech Republic (Demek et al. 2008; Skokanová et al. 2009) and Romania (Schreiber 2003). Environmental constrains (e.g., topography and wetlands) were not regarded as a limitation to agricultural use during Soviet times, which often made the allocation of production factors in socialist agricultural systems inefficient (Müller et al. 2013).

Despite the high level of intensification of land use, agricultural abandonment occurred in the Carpathian Mountains soon after WWII (Munteanu et al. 2014). Rural populations increasingly found employment in the industrial sector (Schreiber 2003; Munteanu et al. 2014), abandoning small-scale mountain agriculture. Marginal areas were abandoned in Slovakia (Gerard et al. 2010), while in Poland, private farms persisted during communism, leading to a higher persistence of mosaic landscapes that included small agricultural fields, forest and some tourist-related development (Turnock 2002). The peak of agricultural land abandonment in the Carpathians was reached only after the collapse of the Soviet Union, a trend which is consistent with other post-socialist European countries (Müller and Munroe 2008; Prishchepov et al. 2013).

Most Eastern European countries enacted comprehensive land reforms after the collapse of the socialism, and agricultural markets were liberalized. However, the implementation of the land reforms and agricultural policies and the availability of subsidies varied substantially across countries, which contributed to different patterns of abandonment in the different post-socialist countries (Lerman et al. 2004; Rozelle and Swinnen 2004; Müller et al. 2013). In the Carpathians, approximately 40,000 km^2 of cropland had been abandoned by 2000, and an additional 7100 km^2 by 2010 (Griffiths et al. 2013)—mostly due to cropland-to-grassland conversion (Fig. 6). The highest abandonment rates occurred in Romania and Ukraine, predominantly in marginal areas (45.8 and 58.9 %, respectively, abandoned by 2000). Regional differences depended on the countries' post-Soviet political, institutional and economic situation, as well as on the individual restitution methods (Hartvigsen 2014), resulting in, for example, Slovakia experiencing less abandonment (13.1 %) than Ukraine (58.9 %) (Fig. 6). The highest abandonment rates were associated

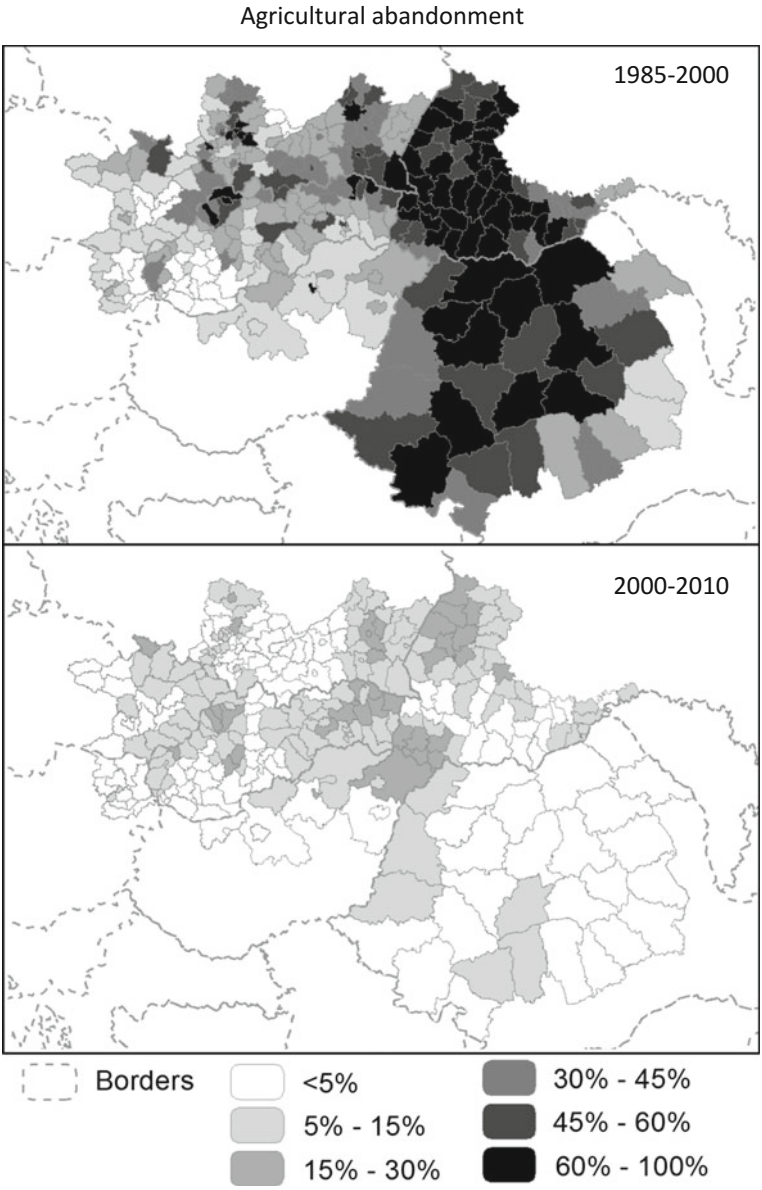

Fig. 6 Agricultural land abandonment for the periods 1985–2000 and 2000–2010. Abandonment is calculated relative to the 1985 and 2000 cropland area per unit. Country boundaries are shown in *dashed grey lines*. Abandonment is calculated on the level of administrative units (district level for Czech Republic, Poland, Slovakia and Ukraine, county level for Austria, Hungary and Romania). Scale of the maps is 1:8,750,000. Modified from Griffiths et al. (2013)

with areas of intermediate and low agricultural suitability (Müller et al. 2013; Griffiths et al. 2013).

Abandonment rates decreased around 2000, and the recultivation of formerly abandoned cropland occurred in agriculturally suitable areas. Of the land that had been abandoned by 2000, 18 % was brought back into production by 2010 (Griffiths et al. 2013). Most of the recultivation occurred in Romania and Hungary, while abandonment and forest succession persisted in Ukraine, parts of Poland and Hungary. With the opening of agricultural markets and access to land, abandoned agricultural land in post-socialist countries represents an attractive target for foreign investors (Deininger 2011; Visser and Spoor 2011). Additionally, the EU CAP includes income subsidies, supporting farmers to increase production efficiency in order to be competitive on the world market (Zanten et al. 2013) and to help manage land in an environmentally friendly way. Although access to subsidies for agricultural production may lead to increased cropping and the re-establishment of large-scale agricultural operations in the lowlands, the access of local, small landowners to CAP subsidies, especially in mountainous areas, remains limited (Bezák and Mitchley 2014). However, the effectiveness of such programs is questionable due to different rates at which farmers apply for subsidies, differences in farmers` attitudes, and a lack of landscape-scale coordination (Zanten et al. 2013) potentially causing issues for the conservation of biodiversity and for the maintenance of traditional agricultural practices (Špulerová 2013).

The reform of institutions, land ownership and agricultural policies following the collapse of the Soviet Union, combined with socio-demographic processes caused by the opening of borders, were major drivers for agricultural land change. The strength of the institutions and the timing of reforms significantly modulated the intensity of agricultural change (Turnock 1996; Hartvigsen 2014) and affected the rates of post-Soviet land abandonment and recultivation. During the Soviet era, institutional and economic factors such as the forced industrialization and intensified production of food supported by state subsidies caused an expansion of agricultural land in the lowlands (Turnock 1996). Following the collapse of the system, the lack of agricultural subsidies, decreased profitability, and the bankruptcy of large agricultural enterprises caused widespread abandonment (Turnock 1996; Lieskovský et al. 2013; Hartvigsen 2014). Providers of agricultural services, such as machinery owners, shifted their activities to the more productive lowlands, further contributing to the abandonment of the marginal mountainous areas (Müller et al. 2013). The underlying drivers of abandonment were related to the land restitution process, which did not take into account the landowners' agricultural activities (Kuemmerle et al. 2008). Migration to Western Europe caused a decrease in employment in agriculture the Carpathian region (Hartvigsen 2014). As the remaining rural population aged, less land was used for agricultural production. Following the bankruptcy of large industrial operations, urban populations moved back to the countryside, but few returned to farming. Many agricultural parcels were taken out of production to the benefit of urban sprawl.

Land abandonment was a short-term process in many areas, which did not necessarily push the land system into a new stable state. For example, areas in

western Romania were abandoned following the collapse of the Soviet Union due to the convoluted restitution process, only to be brought back into production a decade later (Fig. 6). While the land-use future of some abandoned areas is still uncertain, recultivation in others is likely in the future due to the fertility of their soils and their suitability for intensified food production (Foley et al. 2011). However, marginal lands with low agricultural suitability may transition to an alternative state of continuous forest cover, such as the Bieszczady mountains in Eastern Poland (Wolski 2001; Woś 2005). The length of time that areas were used for agriculture before abandonment may influence the speed of abandonment and cause forests to be established faster. The implications of these changes are manifold in terms of habitat provision for key species. Many large mammals, such as European bison (Bison bonasus), benefit from increasing forest cover (Perzanowski and Olech 2007), while forest edge species or generalist species, such as brown bears (*Ursus arctos*) (Gula et al. 1995), generalist birds (Angelstam 1992), and insect species (Magura 2002), may prefer a more fragmented landscape pattern. The future of small-scale farms, extensive agricultural practices and land management for agro-biodiversity is still uncertain in this highly diverse area, and a uniform spatiotemporal land-use future (Aldwaik and Pontius 2012) for the entire Carpathian region seems unlikely.

2.7 Grasslands, Pastures and Hayfields

The grasslands of the Carpathians represent one of the most vulnerable components of the overall land system due to their biological diversity—and the one where changes in species richness and diversity have varied substantially over time. About one third of the Carpathian region is made up of semi-natural habitats, most of which are grasslands (Turnock 2002) whose dynamics are closely related to the other land cover types. In the lowlands, steppe-like grasslands occur predominantly in Hungary, Transylvania, and Western Romania, which are largely remnants of primary steppes or forest steppes (Biró et al. 2012). These grasslands have a high diversity of plants and invertebrates, many of which are endemic, and provide refuge for numerous threatened open-land species (Cremene et al. 2005). Such lowland grasslands were mostly altered due to the intensification of agriculture after the WWII, post-Soviet conversion to urban and agricultural landscapes (Biró et al. 2012), and decreased grazing (Cremene et al. 2005) leading to abandonment and shrub encroachment. In hilly and mountainous areas, meadows of woodland origin, also called ‘poloniny’ (from the old Slavic ‘polonina’), were established in the Middle Ages through deforestation and development for pasture use (Pietrzak 1998; Turnock 2002). Mountain meadows have a remarkably high species richness and contain many endemic species and medicinal plants (Halada et al. 2010). However, the intensified use of these grasslands, with increased human pressure, overgrazing and abandonment, simplified the local agro-biodiversity of their flora and fauna (UNEP 2007). Mountain meadows and grasslands experienced extensive

abandonment due to decreasing livestock numbers (Bezák and Petrovic 2006), but in some regions of the Carpathians, such as Poland, grasslands have been brought back under management following agro-environmental EU policies. Alpine grasslands occur above the timber line, and despite their high species diversity and richness and the amount of endemism, these grasslands experienced conversion to woodlands as the elevation of timberlines tends to increase following a decrease in grazing and mowing.

Grasslands in the Carpathians have a very dynamic history, with a succession of multiple uses over time. They went through periods of intensification, expansion and conversion, all impacting the species diversity and richness of the ecosystem. In mountainous areas, deforestation for pasture and hayfields was common starting in the 14th century and up to the first half of the 20th century when grasslands were used for hay-making and the grazing of domestic animals (Rabbinge and van Diepen 2000). Transhumant sheep grazing is still practiced today as a traditional use of mountain pastures, especially in Romania. Following WWII, not all land was nationalized, and subsistence livestock farming was still practiced in mountainous regions (Turnock 2002). The increased demand for meat and dairy products together with Soviet policies of land-use intensification in the fertile lowlands led to increasing pressures on natural mountain grasslands due to the shift in grazing of privately owned livestock to the higher elevations. Natural pastures were affected by intensive grazing in northern Romania (Munteanu et al. 2008) and in the Southern Romanian Carpathians even after 1990, degrading local biodiversity (Baur et al. 2007). During the socialist period, grasslands in the lowlands were either hayed several times in a year or grazed by large herds of cattle and sheep. As a result of nationalization and collectivization, intensive livestock farming units were developed in the Carpathian lowlands, increasing the pressure on the semi-natural grasslands (Turnock 2002). Overall, grasslands suffered the most degradation through overgrazing under the Communist regimes (Turnock 2002).

Since the collapse of the Soviet Union, grasslands have expanded (Fig. 7), but the nature and composition of these grasslands is different from that of historic grasslands, mostly due to the nature of the underlying land change processes. Post-Soviet grassland expansion is mostly the result of cropland abandonment. Approximately 24 % of the cropland of 1985 had been abandoned by 2010 and subsequently transitioned to grasslands, but the rate increase in grassland cover on abandoned agricultural fields dropped to 9 % by 2010 (Fig. 6). The change from cropland to grassland was most prominent in Romania and Ukraine. However, due to their agricultural history, several decades after abandonment, these fields in the process of converting to grasslands have a different species composition than the historic semi-natural grasslands (Ruprecht 2006). Depending on the length of agricultural use, such agricultural legacies can persist for centuries on the landscape (Foster et al. 2003).

Grassland expansion is only a recent process that is counter-acting the past extensive grassland loss to other land covers. In the lowlands, conversion to arable land and intense grazing affected grasslands before and during the socialist period. Large areas of grasslands were brought into agricultural production by means of

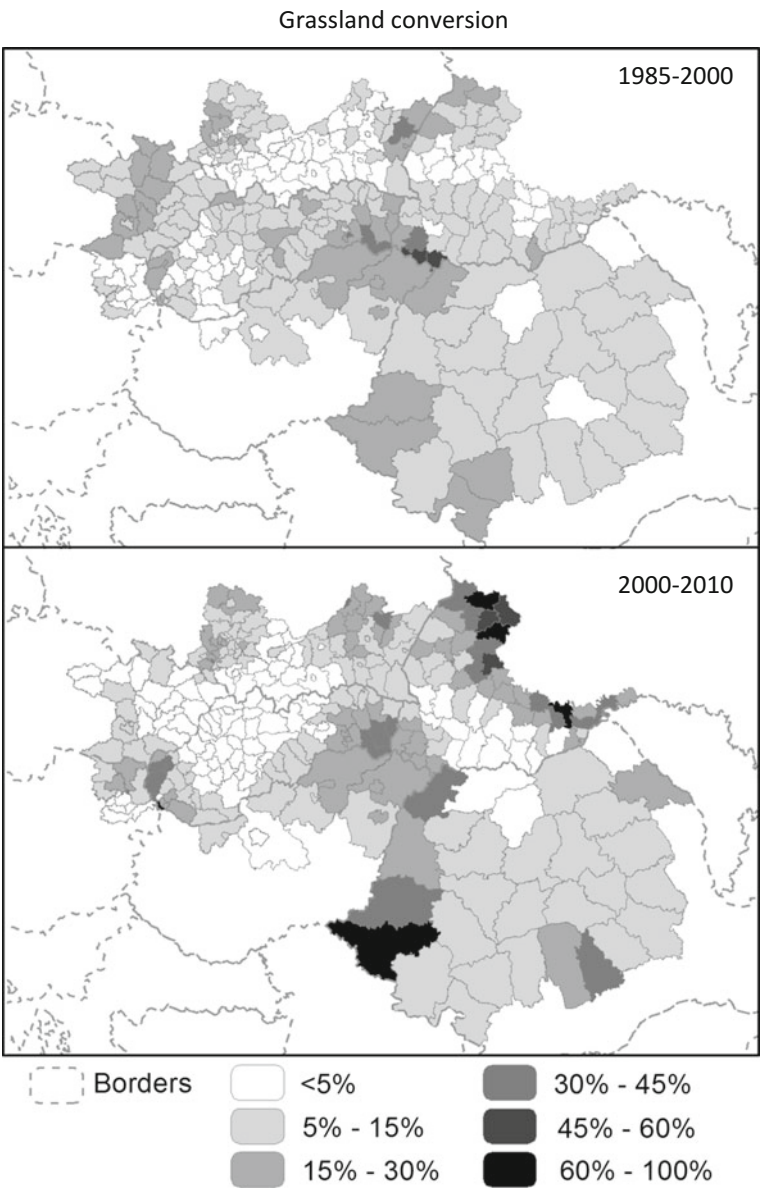

Fig. 7 Grassland conversion for the periods 1985–2000 and 2000–2010. Grassland conversion is calculated relative to the 1985 and 2000 grassland area per administrative unit. Country boundaries are shown in *dashed grey lines*. Grassland conversion is calculated on the level of administrative units (district level for Czech Republic, Poland, Slovakia and Ukraine, county level for Austria, Hungary and Romania). Scale of the maps is 1:8,750,000. Modified from Griffiths et al. (2013)

terrain adjustment, drainage, ploughing, sowing of more productive varieties of grasses and clovers, intensive fertilization, drainage, and the destruction of springs (Biró et al. 2012). Grasslands along river valleys were converted to arable land due to their high soil quality (Halada et al. 2008), leading to an overall substantial reduction of grassland cover: in Romania, steppe grasslands were reduced significantly to expand arable land by 39.2 % (Ioras 2003), and in Slovakia, more than 50 % of extensively used semi-natural grasslands were lost to arable land or to intensive meadows (Halada et al. 2010). In Hungary, wetlands were drained and converted to agricultural lands (Munteanu et al. 2014), although the grassland areas remained unchanged during Soviet times according to Hungarian statistics (Biró et al. 2012). After 1990, the afforestation of grasslands was a common process throughout the region (Griffiths et al. 2013) (Fig. 6).

Since the collapse of the Soviet Union, one of the largest threats to natural and semi-natural grasslands is related to land abandonment, followed by forest succession, which reduces the diversity and area of pastures and meadows (Kricsfalusy 2013). As livestock numbers declined in most Carpathian countries, so did the intensity of grazing and pasturing, allowing for forest succession on mountain pastures. The lack of management led to a loss of biodiversity (Cremene et al. 2005). In many cases, the abandonment of mountain meadows lead to a decline in species richness of up to 50 %, with unique grassland communities disappearing entirely (Bezák and Halada 2010). Lowland grasslands were also affected by abandonment: in Hungary, between 1988 and 1999, the annual grassland loss reached 1.3 %, in contrast to relatively static conditions during prior decades (Biró et al. 2012). Grasslands were mostly lost to urban development and forest cover in Hungary (Konkoly-Gyuró et al. 2011; Biró et al. 2012). In Western Ukraine and Western Romania, the rate of grassland loss to other covers has increased since 2000, largely due to agricultural recultivation (28 and 19 % of previously abandoned land in Romania and Ukraine, respectively).

With EU accession and an increased awareness of the importance of conservation, the environmental value of grasslands was recognized, and agro-environmental programs (part of the CAP) now support extensive uses and the conservation of biodiversity. In the Carpathian Mountains, traditional sheep herding is increasingly encouraged for tourism purposes, while maintaining the traditional extensive use of meadows and pastures, and supporting local food production (UNEP 2007). In Romania, subsidies for the management of high nature value grasslands aim to combat the effects of land abandonment and to support traditional agricultural practices (Akeroyd and Page 2011), despite the questionable suitability of the preservation approach of the currently available subsidy systems of the CAP (Fischer et al. 2012).

The underlying drivers of grassland change are closely interwoven with proximate environmental factors such as suitability for agriculture, elevation, and patch size (Biró et al. 2012). While the loss of grasslands in the socialist period was the result of centralized policies, recent grassland loss is mostly the result of the socio-demographic adaptations of individual farmers and land owners to the changing institutional and economic post-Soviet environment. In marginal

mountainous areas, migration and the aging of the population, combined with a decrease in livestock farming, has caused a decrease in grassland management and resulted in conversion to forests (Munteanu et al. 2008, 2014). In Hungary, recultivation and afforestation both caused a decrease in grassland cover, and areas close to settlements and roads were more likely to be converted to other uses (Biró et al. 2012). Increasing foreign investment (Jordan 2013), EU CAP incentives for the recultivation of areas suitable for production, and increased commodity prices are expected to lead to further grassland loss in the Carpathian region (Fig. 6). Recent policy payments increased attention to conservation and support environmental grassland management in the Carpathians (Akeroyd and Page 2011). Management practices that are beneficial for supporting species richness and diversity, such as mowing and the removal of biomass (Galvánek and Lepš 2011) or extensive grazing (Cremene et al. 2005), are encouraged through agro-environmental schemes, a now commonly used instrument for landscape management. These schemes are based on contracts between land managers and public authorities, which provide payments for extensive management of land (especially grasslands and hedgerows). Recent grassland dynamics in the Carpathians indicate that the abandonment trend will not persist and current grassland cover may revert to agriculture or managed meadows and pastures (Griffiths et al. 2013).

2.8 Other Land Cover Dynamics

Two other land cover types in the Carpathians experienced drastic change over the course of history: wetlands and urban areas. Although entirely different, these two land cover types present a common characteristic: their trajectory of change over long periods of time has followed the same direction but with increasing intensity. Urban cover in the Carpathians has increased considerably over the past 250 years. Large urban centers developed in the lowlands and continued to rapidly sprawl after the collapse of the Soviet Union. In mountainous areas, tourism development and the building of second houses (Mika 2013) are the main causes of recent increase in built-up areas. In turn, wetland areas have experienced a continual decline since the middle of the 19th century. Many wetlands were drained and embanked for agricultural development and, in many cases, to support later urban development. The process was most prominent in the lowlands of Hungary.

Urban areas represent approximately 13 % of the Carpathians and are increasing in extent (UNEP 2007; Gerard et al. 2010). The conversion of land to built-up surfaces, including infrastructure development, industries and housing, is one of the six main land cover changes affecting the Carpathians (Gerard et al. 2010). Colonization during the 19th century increased the population of the Carpathians and subsequently caused an increase in built-up areas. The urbanization policies enacted during socialist rule led to the rapid conversion of farmland and grasslands to grow settlements, and increase industrial and infrastructure development. Industrial development pressures correlated with a heavy exploitation of natural

resources that led to urban and industrial development at the edges of the Carpathians, such as Resita and Hunedoara in Romania, Upper Silesia and Krakow in Poland and Kosice in Slovakia. Since the collapse of socialism, many industrial operations have been abandoned, but the land did not revert to past land covers. Furthermore, urban sprawl and suburbanization have increased in magnitude (UNEP 2007). Loopholes in regulations led to unplanned development on recently privatized land (Munteanu et al. 2008). The development of tourism infrastructure, especially in the Tatra Mountains and the Southern Romanian Carpathians, led to additional increases in built-up areas. The Ukrainian Carpathians lag behind in tourism compared to the bordering Maramures (Romania), potentially due to their limited connectivity both by rail and road (Jordan 2013).

Wetland areas are the land cover type that have been changed to largest extent. The mosaic of wetlands and grasslands along the Danube and Tisza rivers have been altered continuously since the middle of the 19th century (UNEP 2007; Biró et al. 2012). River flow control regulations and embankments to extend agricultural production caused dramatic reductions in wetlands, down to less than half of their historic area along the Danube River (Ioras 2003). Most of the embanked areas were converted to agricultural production in Hungary and Romania (Ioras 2003; Konkoly-Gyuró et al. 2011). The straightening and shortening of streams, the construction of dikes and drainage canals, and wetland drainage became common socialist policies from the 1950s to the 1970s, aimed at supporting agricultural production and self-sufficiency (Kligman and Verdery 2011). In many cases in the Hungarian lowlands, the loss of wetlands was nearly total. For example, in Northern Hungary, wetlands made up approximately 17.7 % of the landscape in the 18th century but were reduced to 5.4 % by 1998 (Konkoly-Gyuró et al. 2011). With the adoption of EU regulations, such as the Water Framework Directive, and adherence to international agreements, such as the Ramsar Convention on Wetlands, wetland protection and restoration are becoming more important in conservation practices, yet the efforts required to restore such wetlands have kept the scale of wetland restoration low.

The changes in urban and wetland cover in the Carpathians provide good examples of permanent land cover changes. Once areas have transitioned to an urban landscape or away from wetlands, it is very unlikely that its future use will revert to its historical state. In this context, a sustainable, consistent management of these land covers over time is essential. However, in the Carpathians, most regions have experienced very little or no continuity in land management systems due to the multiple shifts that have occurred in political, economic and socio-demographic conditions. Poor regulations, missing cadastral planning and loopholes in development regulations, as well as shifts in property size and ownership, have all caused chaotic urban sprawl (Björnsen-Gurung et al. 2009; Suditu et al. 2010). Increasing food demands and forced industrialization historically led to massive wetland loss, and although this trend has slowed down in the past years, the effects of past wetland loss on ecosystem diversity are still reverberating. Because the loss of wetlands and urban expansion are mostly permanent changes, adequate planning that considers land as a limited resource is essential for managing these cover types.

3 Conclusions

The Carpathian Mountains, with their long land-use history, are a great showcase of how changes in institutions and land management regimes are reflected in the land cover. The region is suitable for the conceptual study of land-use legacies, alternative stable states and time lags related to the effects of shocks on land change. The truly diverse socio-economic and institutional history and conditions of the Carpathian countries provide a great natural experiment and exemplify how (1) following a shock, land systems may or may not be pushed into an alternative stable state (e.g., agricultural land abandoned following the collapse of the Soviet Union being reverted to agricultural use after EU accession versus agricultural abandonment following World War II resulting in conversion to stable forest cover); (2) effects of institutional changes may or may not experience time-lags (e.g., different rates of forest disturbance following the collapse of the Soviet Union); and (3) land-use legacies may persist for centuries (e.g., past land cover affecting the rate and magnitude of recent land changes).

The establishment and the collapse of the Soviet Union were major events, with long lasting effects on the different types of land cover. Some of the highest rates of land change in the Carpathians occurred after the collapse of the Soviet Union, but often, these changes were rooted in the prior land management history of the area. Forest transitions occurred in the interwar period, mirrored by agricultural abandonment and intensification since the establishment of the Soviet Union. However, many abandoned lands are being brought back into agricultural production following accession to the EU. In the past decade, grassland cover mostly decreased in the Carpathians, and wetland loss and urban expansion have been active processes since the 18th century. In summary, the Carpathians experienced extensive land changes and, thus, offer a wealth of land change lessons related to the effects of shocks, land change trajectories, time-lags and land-use legacies. Land-use trends and patterns in the Carpathians are broadly relevant to land change science as a whole and are applicable to multiple regions that have experienced abrupt transitions due to the collapse of the Soviet Union or to other political and socio-economic events. Land change science is tackling the implications that economic development, globalization, land-use policies, land grabbing, land-use displacement, and resource scarcity may have for future land change trajectories. We show that alongside these factors, socio-economic and political shocks, such as wars or abrupt changes in political regimes, severely affect the magnitude of change. Understanding the diversity of the spatiotemporal patterns of land change is important in balancing land-use decisions regarding intensified production versus extensive use for nature conservation—an issue that is relevant not only for the Carpathians but also for all of the worlds' biodiverse areas.

References

Akeroyd JR, Page JN (2011) Conservation of High Nature Value (HNV) grassland in a farmed landscape in Transylvania, Romania. Contribuiii Botanice XLVI:57–71

Aldwaik SZ, Pontius RG (2012) Intensity analysis to unify measurements of size and stationarity of land changes by interval, category, and transition. Landscape Urban Plan 106:103–114. doi:10.1016/j.landurbplan.2012.02.010

Angelstam P (1992) Conservation of communities—The importance of edges, surroundings and landscape mosaic structure. In: Hansson L (ed) Ecological principles of nature conservation. Applications in temperate and boreal environments. Elsevier, Uppsala, p 454

Bálint M, Ujvárosi L, Theissinger K et al (2011) The carpathians as a major diversity hotspot in Europe. In: Zachos FE, Habel JC (eds) Biodiversity hotspots. Springer, Berlin, pp 189–205

Banu F (2004) Asalt asupra economiei Romaniei de la Solagra la SOVROM (1936–1956) (in Romanian) 215

Baumann M, Kuemmerle T, Elbakidze M et al (2011) Patterns and drivers of post-socialist farmland abandonment in Western Ukraine. Land Use Policy 28:552–562. doi:10.1016/j.landusepol.2010.11.003

Baur B, Cremene C, Groza G et al (2007) Intensified grazing affects endemic plant and gastropod diversity in alpine grasslands of the Southern Carpathian mountains (Romania). Biologia 62:438–445. doi:10.2478/s11756-007-0086-4

Bellemare J, Motzkin G, Foster DR, Forest H (2002) Legacies of the agricultural past in the forested present: an assessment of historical land-use effects on rich mesic forests. J Biogeorgr 29:1401–1420

Bezák P, Halada L (2010) Sustainable management recommendations to reduce the loss of agricultural biodiversity in the mountain regions of NE Slovakia. Mt Res Dev 30:194–204

Bezák P, Mitchley J (2014) Drivers of change in mountain farming in Slovakia: from socialist collectivisation to the Common Agricultural Policy. Reg Environ Chang 14:1343–1356. doi:10.1007/s10113-013-0580-x

Bezák P, Petrovic F (2006) Agriculture, landscape, biodiversity: scenarios and stakeholder perceptions in the Poloniny National Park (NE Slovakia). Ekologia (Bratislava) 25:82–93

Bideleux R, Jeffries I (1998) A history of Eastern Europe: crisis and change, p 685

Biró M, Czúcz B, Horváth F et al (2012) Drivers of grassland loss in Hungary during the post-socialist transformation (1987–1999). Landscape Ecol 28:789–803. doi:10.1007/s10980-012-9818-0

Björnsen-Gurung A, Bokwa A, Chełmicki W et al (2009) Global change research in the Carpathian Mountain Region. Mt Res Dev 29:282–288. doi:10.1659/mrd.1105

Bragina EV, Ives AR, Pidgeon AM et al (2015) Rapid declines of large mammal populations after the collapse of the Soviet Union. Conservation Biology 29(3):844–853

Brain S (2011) Song of the forest: Russian Forestry and Stalinist Environmentalism, 1905–1953, p 231

Bugár G, Petrovič F, Mojses M (2010) Effects of underground coal mining on the rate of landscape changes. In: Barančoková M, Krajčí J, Kollár J, Belčáková I (eds) Landscape ecology—Methods, applications and interdisciplinary approach. Institute of Landscape Ecology Slovak Academy of Sciences, Bratislava, pp 425–432

CERI (2001) The status of the Carpathians, p 67

Cremene C, Groza G, Rakosy L et al (2005) Alterations of Steppe-Like Grasslands in Eastern Europe: a Threat to regional biodiversity hotspots. Conserv Biol 19:1606–1618. doi:10.1111/j.1523-1739.2005.00084.x

DeFries RS, Foley JA, Asner GP (2004) Land-use choices: balancing human needs and ecosystem function in a nutshell. Frot Ecol 2:249–257

Deininger K (2011) Challenges posed by the new wave of farmland investment. J Peasant Stud 38:217–247. doi:10.1080/03066150.2011.559007

Demek J, Havlíček M, Chrudina Z, Mackovčin P (2008) Changes in land-use and the river network of the Graben Dyjsko-svratecký úval (Czech Republic) in the last 242 years. J Landscape Ecol 1:22–51

Donald PF, Pisano G, Rayment MD, Pain DJ (2002) The Common Agricultural Policy, EU enlargement and the conservation of Europe's farmland birds. Agric Ecosyst Environ 89: 167–182. doi:10.1016/S0167-8809(01)00244-4

Elbakidze M, Angelstam P (2007) Implementing sustainable forest management in Ukraine's Carpathian Mountains: the role of traditional village systems. For Ecol Manage 249:28–38

Ellis EC, Kaplan JO, Fuller DQ et al (2013) Used planet: a global history. Proc Natl Acad Sci USA 110:7978–7985. doi:10.1073/pnas.1217241110

Falťan V, Katina S, Bánovský M, Pazúrová Z (2009) The influence of site conditions on the impact of windstorms on forests: the case of the High Tatras Foothills (Slovakia) in 2004. Moravian Geogr Rep 17:44–52

Feranec J, Šúri M, Oťaheľ J et al (2000) Inventory of major landscape changes in the Czech Republic, Hungary, Romania and Slovak Republic 1970s–1990s. Int J Appl Earth Obs Geoinf 2:129–139. doi:10.1016/S0303-2434(00)85006-0

Fischer J, Hartel T, Kuemmerle T (2012) Conservation policy in traditional farming landscapes. Conserv Lett 5:167–175. doi:10.1111/j.1755-263X.2012.00227.x

Foley JA, DeFries RS, Asner GP et al (2005) Global consequences of land use. Science 309: 570–574. doi:10.1126/science.1111772

Foley JA, Ramankutty N, Brauman KA et al (2011) Solutions for a cultivated planet. Nature 478:337–342. doi:10.1038/nature10452

Foster DR, Swanson FJ, Aber J et al (2003) The importance of land-use legacies to ecology and conservation. Bioscience 53:77–88

Galvánek D, Lepš J (2011) The effect of management on productivity, litter accumulation and seedling recruitment in a Carpathian mountain grassland. Plant Ecol 213:523–533. doi:10.1007/s11258-011-9999-7

Gehlbach S, Malesky EJ (2014) The grand experiment that wasn't? New Institutional Economics and the Postcommunist Experience. Institutions, Property Rights and Economic Growth: The Legacy of Douglass North Washington

Gerard F, Petit S, Smith G et al (2010) Land cover change in Europe between 1950 and 2000 determined employing aerial photography. Prog Phys Geogr 34:183–205. doi:10.1177/0309133309360141

Griffiths P, Kuemmerle T, Kennedy RE et al (2012) Using annual time-series of Landsat images to assess the effects of forest restitution in post-socialist Romania. Remote Sens Environ 118: 199–214

Griffiths P, Müller D, Kuemmerle T, Hostert P (2013) Agricultural land change in the Carpathian ecoregion after the breakdown of socialism and expansion of the European Union. Environ Res Lett 8:045024. doi:10.1088/1748-9326/8/4/045024

Griffiths P, Kuemmerle T, Baumann M et al (2014) Forest disturbances, forest recover, and changes in forest types across the Carpathian ecoregion from 1985 to 2010 based on Landsat image composites. Remote Sens Environ 151:72–88

Grodzińska K, Godzik B, Fraczek W et al (2004) Vegetation of the selected forest stands and land use in the Carpathian Mountains. Environ Pollut (Barking, Essex: 1987) 130:17–32. doi:10.1016/j.envpol.2003.10.031

Gula R, Frackowiak W, Perzanowski K (1995) Current status and conservation needs of brown bears in the Polish Carpathians. Ursus 10:81–86

Günther-Diringer D (2000) Evaluation of wetlands and floodplain areas in the Danube River basin. In: Nijland H, Cals MJ (eds) River restoration in Europe practical approaches. Wagenian, The Netherlands, p 344

Haase D, Seppelt R, Haase A (2007) Land use impacts of demographic change—Lessons from eastern German urban regions. In: Use of landscape sciences for the assessment of environmental security. Springer, Dordrecht, pp 329–344

Halada L, Ružičková H, David S, Halabuk A (2008) Semi-natural grasslands under impact of changing land use during last 30 years: Trollio-Cirsietum community in the Liptov region (N Slovakia). Community Ecol 9:115–123

Halada L, David S, Ružičková H (2010) Biodiversity of Carpathian grasslands under impact of socio-economic changes. In: Forum Carpaticum. Integrating nature and society towards sustainability, pp 35–36

Hartvigsen M (2014) Land reform and land fragmentation in Central and Eastern Europe. Land Use Policy 36:330–341

Hazeu GW, Roupioz LFS, Perez-Soba M (2010) Europe's ecological backbone: recognising the true value of our mountains

Holeksa J, Saniga M, Szwagrzyk J et al (2009) A giant tree stand in the West Carpathians—An exception or a relic of formerly widespread mountain European forests? For Ecol Manage 257:1577–1585. doi:10.1016/j.foreco.2009.01.008

Horváth Z, Ferenczi M, Móra A et al (2012) Invertebrate food sources for waterbirds provided by the reconstructed wetland of Nyirkai-Hany, northwestern Hungary. Hydrobiologia 697:59–72. doi:10.1007/s10750-012-1170-5

Huzui AE, Călin I, Pătru-Stupariu I (2012) Spatial pattern analyses of landscape using multi-temporal data sources. In: 2011 international conference of environment-landscape-european identity. Procedia Environ Sci 14:98–110

Ioras F (2003) Trends in Romanian biodiversity conservation policy. Biodivers Conserv 12:9–23. doi:10.1023/A:1021254615841

Ioras F, Abrudan IV (2006) The Romanian forestry sector: privatisation facts. Int For Rev 8: 361–367. doi:10.1505/ifor.8.3.361

Irimie DL, Essmann HF (2009) Forest property rights in the frame of public policies and societal change. For Policy Econ 11:95–101. doi:10.1016/j.forpol.2008.10.001

Irland LC, Kremenetska E (2009) Practical economics of forest ecosystem management: the case of the Ukrainian Carpathians. In: Soloviy IP, Keeton WS (eds) Ecological economics and sustainable forest management: developing a transdisciplinary approach for the Carpathian Mountains. Ukrainian National Forestry University Press, Lviv, p 432

Jepsen MR, Reenberg A, Kümmerle T et al (2013) Visions of land use transitions in Europe. In: Technological, institutional and economic drivers of land use change, p 226

Jordan P (2013) Transcarpathia—Ukrainian border region at the edge of the EU. Internal and external representations. ISPRS–Int Arch Photogrammetry Remote Sens Spatial Inf Sci XL-4/W3:83–87. doi:10.5194/isprsarchives-XL-4-W3-83-2013

Kallis G (2001) The EU water framework directive: measures and implications. Water Policy 3:125–142. doi:10.1016/S1366-7017(01)00007-1

Keeton WS, Crow SM (2009) Sustainable forest management alternatives for the Carpathian Mountain region: providing a broad array of ecosystem service. In: Soloviy I, Keeton WS (eds) Ecological Economics and Sustainable Forest Management: developing a Trans-disciplinary Approach for the Carpathian Mountains. Ukrainian National Forestry University Press, Lviv, Ukraine, pp 109–126

Keeton WS, Chernyavskyy M, Gratzer G et al (2010) Structural characteristics and aboveground biomass of old-growth spruce–fir stands in the eastern Carpathian mountains, Ukraine. Plant Biosyst Int J Dealing Aspects Plant Biol 144:148–159. doi:10.1080/11263500903560512

Keeton WS, Angelstam P, Baumflek M et al (2013) Sustainable forest management alternatives for the Carpathian Mountain region, with a focus on Ukraine. In: Kozak J, Ostapowicz K, Bytnerowicz A, Wyzga B (eds) The Carpathians: integrating nature and society towards sustainability. Springer, Berlin, pp 331–352

Kligman G, Verdery K (2011) Peasants under siege: the collectivization of Romanian agriculture, 1949–1962. Princeton University Press, Princeton

Knorn J, Kuemmerle T, Radeloff VC et al (2012a) Forest restitution and protected area effectiveness in post-socialist Romania. Biol Conserv 146:204–212. doi:10.1016/j.biocon.2011.12.020

Knorn J, Kuemmerle T, Radeloff VC et al (2012b) Continued loss of temperate old-growth forests in the Romanian Carpathians despite an increasing protected area network. Environ Conserv 40:182–193. doi:10.1017/S0376892912000355

Knowles B (2011) Mountain Hay Meadows: the Romanian context and the effects of policy on high nature value farming, p 8

Konkoly-Gyuró E, Nagy D, Balázs P, Király G (2011) Assessment of land cover change in western Hungarian landscapes. In: Balázs P, Konkoly-Gyuró É (eds) TransEcoNet workshop on landscape history proceedings. University of West Hungary Press, pp 75–89

Kozak J (2003) Forest cover change in the Western Carpathians in the past 180 years. Mt Res Dev 23:369–375. doi:10.1659/0276-4741(2003)023[0369:FCCITW]2.0.CO;2

Kozak J (2010) Forest cover changes and their drivers in the Polish Carpathian Mountains since 1800. In: Nagendra H, Southworth J (eds) Reforesting landscapes linking pattern and process. Landscape series 10. Springer, Berlin, pp 253–273

Kozak J, Ostapowicz K, Szablowska-Midor A, Widacki W (2004) Land abandonment in the Western Beskidy Mts and its environmental background. Ekológia Int J Ecol Probl Biosph 23:116–126

Kozak J, Estreguil C, Vogt P (2007) Forest cover and pattern changes in the Carpathians over the last decades. Eur J For Res 126:77–90

Kozak J, Ostapowicz K, Byterowicz A, Wyzga B (2013a) The Carpathian Mountains: challenges for the Central and Eastern European Landmark. In: The Carpathians: integrating nature and society towards sustainability. Springer, Berlin, pp 1–11

Kozak J, Ostapowicz K, Bytnerowicz A, Wyżga B (2013b) The Carpathians: integrating nature and society towards sustainability. doi:10.1007/978-3-642-12725-0

Kricsfalusy VV (2013) Mountain grasslands of high conservation value in the Eastern Carpathians: syntaxonomy, biodiversity, protection and management. Thaiszia J Bot 23: 67–112

Kuemmerle T, Hostert P, Radeloff VC et al (2008) Cross-border comparison of post-socialist Farmland Abandonment in the Carpathians. Ecosystems 11:614–628

Kuemmerle T, Chaskovskyy O, Knorn J et al (2009) Forest cover change and illegal logging in the Ukrainian Carpathians in the transition period from 1988 to 2007. Remote Sens Environ 113:1194–1207

Kuemmerle T, Perzanowski K, Chaskovskyy O et al (2010) European Bison habitat in the Carpathian Mountains. Biol Conserv 143:908–916. doi:10.1016/j.biocon.2009.12.038

Kuemmerle T, Oloffson P, Chaskovskyy O et al (2011) Post-Soviet farmland abandonment, forest recovery, and carbon sequestration in western Ukraine. Glob Change Biol 17:1335–1349. doi:10.1111/j.1365-2486.2010.02333.x

Lambin EF, Meyfroidt P (2010) Land use transitions: socio-ecological feedback versus socio-economic change. Land Use Policy 27:108–118. doi:10.1016/j.landusepol.2009.09.003

Lambin EF, Turner BL, Geist HJ et al (2001) The causes of land-use and land-cover change: moving beyond the myths. Glob Environ Change 11:261–269. doi:10.1016/S0959-3780(01)00007-3

Lerman Z, Csáki C, Feder G (2004) Agriculture in transition: land policies and evolving farm structures in post-soviet countries, p 254

Lieskovský J, Kanka R, Bezák P et al (2013) Driving forces behind vineyard abandonment in Slovakia following the move to a market-oriented economy. Land Use Policy 32:356–365. doi:10.1016/j.landusepol.2012.11.010

Macicuca A, Diaconescu C (2013) Forest certification effects on sustainable management of Romanian forest ecosystems. Present Environ Sustain Dev 7

Maes J, Paracchini ML, Zulian G et al (2012) Synergies and trade-offs between ecosystem service supply, biodiversity, and habitat conservation status in Europe. Biol Conserv 155:1–12. doi:10.1016/j.biocon.2012.06.016

Magura T (2002) Carabids and forest edge: spatial pattern and edge effect. For Ecol Manage 157:23–37. doi:10.1016/S0378-1127(00)00654-X

Main-Knorn M, Hostert P, Kozak J, Kuemmerle T (2009) How pollution legacies and land use histories shape post-communist forest cover trends in the Western Carpathians. For Ecol Manage 258:60–70

Mantescu L, Vasile M (2009) Property reforms in rural Romania and community-based forests. Rom Sociol 7:95–113

Mika M (2013) Spatial patterns of second homes development in the Polish Carpathians. In: The Carpathians: integrating nature and society towards sustainability. Springer, Berlin, pp 497–512

Moura AE, Tsingarska E, Dąbrowski MJ et al (2013) Unregulated hunting and genetic recovery from a severe population decline: the cautionary case of Bulgarian wolves. Conserv Genet. doi:10.1007/s10592-013-0547-y

Müller D, Munroe DK (2008) Changing rural landscapes in Albania: cropland abandonment and forest clearing in the postsocialist transition. Ann Assoc Am Geogr 98:855–876. doi:10.1080/00045600802262323

Müller D, Kuemmerle T, Rusu M, Griffiths P (2009) Lost in transition: determinants of post-socialist cropland abandonment in Romania. J Land Use Sci 4:109–129. doi:10.1080/17474230802645881

Müller D, Leitão PJ, Sikor T (2013) Comparing the determinants of cropland abandonment in Albania and Romania using boosted regression trees. Agric Syst 117:66–77. doi:10.1016/j.agsy.2012.12.010

Munteanu C, Geitner C, Scharr K (2008) Consequences of historical and modern landuse on cultural landscapes and biodiversity of the Maramureş Mountains. In: Gaceu L (ed) Journal of EcoAgriTourism, proceeding of the international conference BIOATLAS 2008. Transilvania University of Brasov, Romania, Brasov, pp 91–98

Munteanu C, Kuemmerle T, Boltiziar M et al (2014) Forest and agricultural land change in the Carpathian region—A meta-analysis of long-term patterns and drivers of change. Land Use Policy 38:685–697. doi:10.1016/j.landusepol.2014.01.012

Munteanu C, Kuemmerle T, Keuler NS et al (2015) Legacies of 19th century land use shape contemporary forest cover Article. Glob Environ Change 34:83–94

Munteanu C, Nita M-D, Abrudan IV, Radeloff VC (2016) Historical forest management in Romania is imposing strong legacies on contemporary forests and their management. For Ecol Manage 361:179–193

Nabuurs GJ, Thürig E, Heidema N et al (2008) Hotspots of the European forests carbon cycle. For Ecol Manage 256:194–200

Nijnik M, van Kooten GC (2000) Forestry in the Ukraine: the road ahead? For Policy Econ 1:139–151

Perzanowski K, Olech W (2007) A future for European Bison *Bison bonasus* in the Carpathian ecoregion? Wildlife Biol 13:108–112

Pietrzak M (1998) Development of settlement and farming from the Neolithic period to date in the marginal zone of the Carpathian foothills between the Raba and Uszwica Rivers. Prace Geograficzne 103:15–53

Prishchepov AV, Müller D, Dubinin M et al (2013) Determinants of agricultural land abandonment in post-Soviet European Russia. Land Use Policy 30:873–884. doi:10.1016/j.landusepol.2012.06.011

Rabbinge R, van Diepen CA (2000) Changes in agriculture and land use in Europe. Eur J Agron 13:85–99

Ronnås P (1982) Centrally planned urbanization: the case of Romania. Geografiska Annaler Seri B, Human Geogr 64:143–151

Rozelle S, Swinnen JFM (2004) Success and failure of reform: insights from the transition of agriculture. J Econ Lit 42:404–456. doi:10.1257/0022051041409048

Rozylowicz L, Popescu VD, Pătroescu M, Chişamera G (2010) The potential of large carnivores as conservation surrogates in the Romanian Carpathians. Biodivers Conserv 20:561–579. doi:10.1007/s10531-010-9967-x

Ruffini V, Hoffmann C, Streifeneder T, Renner K (2008) SARD-M Report for the 941 Carpathian Convention Member States. Assessment of Policies, Institutions and Processes, 942 Regional Synthesis for Czech Republic, Hungary, Poland, Romania, Republic of Serbia, 943 Slovak Republic and Ukraine. In: EURAC (ed) EURAC 944, Bozen, p 63

Ruprecht E (2006) Successfully recovered grassland: a promising example from Romanian old-fields. Restor Ecol 14:473–480. doi:10.1111/j.1526-100X.2006.00155.x

Schreiber W (2003) Analiza peisajelor geografice din partea de vest a Câmpiei Transilvaniei (in Romanian). 135

Schulp CJE, Nabuurs G-J, Verburg PH (2008) Future carbon sequestration in Europe—Effects of land use change. Agric Ecosyst Environ 127:251–264

Seton-Watson H (1945) Eastern Europe between the wars, 1918–1941, p 442

Shandra O, Weisberg P, Martazinova V (2013) Influences of climate and land use history on forest and timberline dynamics in the Carpathian mountains during the twentieth century. In: Ostapowicz K, Bytnerowicz A, Wyżga B, Kozak J (eds) The Carpathians: integrating nature and society towards sustainability. Springer, Berlin, pp 209–223

Sitko I, Troll M (2008) Timberline changes in relation to summer farming in the Western Chornohora (Ukrainian Carpathians). Mt Res Dev 28:263–271. doi:10.1659/mrd.0963

Skokanová H, Stránská T, Havlíček M et al (2009) Land use dynamics of the South Moravan region during last 170 years. Geoscape 4:58–65

Smaliychuk A (2012) Land cover change in low mountain landscapes of Lviv Oblast (Ukrainian Carpathians) during last three decades. In: Conference abstracts of the 2nd forum Carpaticum: From data to knowledge—From knowledge to action, pp 155–156

Špulerová J (2013) Policy instruments and methods for the protection and maintenance of historical agricultural landscapes in Slovakia. The Carpathians: integrating nature and society towards sustainability. Springer, Berlin, pp 429–439

Špulerová J, Dobrovodská M, Lieskovský J et al (2011) Inventory and classification of historical structures of the agricultural landscape in Slovakia. Ekologia 30:157–170. doi:10.4149/ekol_2011_02_157

Suditu B, Ginavar A, Muic A, Iordă C (2010) Urban sprawl characteristics and typologies in Romania. Human Geogr J Stud Res Human Geogr 4.2:79–87

Süli-Zakar I (1998) Socio-geographical transition in the rural areas of the Carpathian Euroregion. GeoJournal 46:193–197. doi:10.1023/A:1006995814365

Turnock D (1996) Agriculture in Eastern Europe: communism, the transition and the future. GeoJournal. doi:10.1007/BF00186661

Turnock D (2002) Ecoregion-based conservation in the Carpathians and the land-use implications. Land Use Policy 19:47–63

UNEP (2007) Carpathians environment outlook. United Nations Publications

Veen P, Fanta J, Raev I et al (2010) Virgin forests in Romania and Bulgaria: results of two national inventory projects and their implications for protection. Biodivers Conserv 19:1805–1819. doi:10.1007/s10531-010-9804-2

Vepryk N (2001) Istoryko-landshaftoznavchiy analiz lisogospodarskogo pryrodokorystuvannya (na prykladi Pivnichnoi Bukoviny u kinci 18 – na pochatku 20 stolittya) (in Ukrainian). Naukoviy Visnyk Chernivetskogo Universitetu, Seria Geografia 120:156–171

Visser O, Spoor M (2011) Land grabbing in post-Soviet Eurasia: the world's largest agricultural land reserves at stake. J Peasant Stud 38:299–323. doi:10.1080/03066150.2011.559010

Warcholik W (2005) Rejestracja różnic w przebiegu granicy rolno-leśnej w Beskidzie Niskim na obszarze Polski i Słowacji (1933-1975) z wykorzystaniem GIS (in Polish). Problemy Zagospododarowania Ziem Górskich 51:59–69

Wiezik M, Svitok M, Dovčiak M (2007) Conifer introductions decrease richness and alter composition of litter-dwelling beetles (Coleoptera) in Carpathian oak forests. For Ecol Manage 247:61–71. doi:10.1016/j.foreco.2007.04.013

Wolski J (2001) Kierunki zmian krajobrazu okolic bieszczadzkiej wsi Caryńskie (in Polish). Prace Geograficzne IGiPZ PAN 179:149–167

Woś B (2005) Zmiany pokrycia terenu w wybranych gminach Beskidów w drugiej połowie XX w. na podstawie analizy zdjęć lotniczych (in Polish). Teledetekcja Środowiska 35:1–114

Young J, Richards C, Fischer A et al (2007) Conflicts between biodiversity conservation and human activities in the Central and Eastern European countries. AMBIO: J Human Environ 36:545–550. doi:10.1579/0044-7447(2007)36[545:CBBCAH]2.0.CO;2

Zanten BT, Verburg PH, Espinosa M et al (2013) European agricultural landscapes, common agricultural policy and ecosystem services: a review. Agron Sustain Dev. doi:10.1007/s13593-013-0183-4