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Changes and continuity of wood-pastures in the lowland landscape in Czechia

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ABSTRACT

The term wood-pastures is usually applied to areas with trees or other woody vegetation, scattered through a mainly grazed grassland area, and reflects one of the oldest land use types in Europe, which plays important ecological, agricultural and socio-cultural roles. However, a rapid decline in their area due to changes in land use and a lack of tree regeneration has recently been observed all over Europe, which has led to the necessity of a deeper understanding of their behaviour in relation to different factors via a detailed analysis of the history of the changes in their distribution over space and time. Despite the recent increase in the number of related studies, information on historic patterns of wood-pastures in many European locations, such as Czechia, remains incomplete. The goal of this study is to assess the habitat continuity of current wood-pastures and to analyse the land-use/land-cover changes of historical and current wood-pastures in lowlands and warm landscapes of hills and basins of Czechia. To achieve this, nine sites covering a total area of 98.6 km^2 were studied in Czechia. The situation on three time horizons (1820–1840s, the early 1950s and today) was analysed. The results have shown that almost all wood-pastures from the 1st half of the 19th century have now been lost and most of the currently existing ones were formed from the 1950s till today. Most wood-pastures, which were lost by the 1950s, were turned into open habitats, such as arable lands, and the ones lost from 1950 were turned into forest. New wood-pastures are mostly formed from open habitats, often in former military areas.

1. Introduction

Wood-pastures, grazed grasslands with scattered trees or shrubs, are threatened landscape features all over Europe. This is perceived as a negative tendency because wood-pastures are increasingly being recognized for their great ecological, cultural and agricultural importance (Hartel & Plieninger, 2014). The ecological value expressed is given by great structural diversity (Garbarino & Bergmeier, 2014; Jakobsson & Lindborg, 2015), extensive but multiple land use (Opperman, 2014), and the presence of trees serving as keystone structures (Manning, Fischer, & Lindenmayer, 2006). Specifically, old trees are typical for wood-pastures in Britain (Butler, 2014; Read, 2000) and in Romania (Hartel et al., 2013; Moga et al., 2016). Economic use of wood-pastures can be varied. In Europe, trees and grassland in wood-pastures have traditionally served as a source of fodder for grazing animals, the trees also for timber or fuelwood and their crop for pannage (Szabó & Hédl, 2013; Szabó, 2013). Traditional management methods include hay making, berry and fruit picking, which is typical for Germany (Bergmeier, Petermann, & Schröder, 2010; Hartel, Plieninger, & Varga, 2015). Nowadays, the aim is to build new links between wood-pastures and people (Hartel & Plieninger, 2014). Cultural value is explained mainly as the tradition that wood-pastures represent, which is perceived by farmers in Estonia (Roellig et al., 2015) and in Romania (Sutcliffe, Öllerer, & Roellig, 2014). The potential of wood-pasture landscapes for regional development was understood in whole communities in the Black Forest in Germany (Bieling & Konold, 2014). As an example of the value of wood-pastures from the point of view of aesthetical perception, farmers and common inhabitants in the Alentejo region

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in Portugal appreciate complex landscapes, such as the Portuguese type of wood-pasture, *montado,* for their visual qualiies. (Surová, Pinto-Correia, & Marušák, 2014).

We can state that people start to be somewhat aware of the importance of landscapes as soon as they start to be threatened (Antrop, 2005). Bergmeier and Roellig (2014) name as some of the most important threats to wood-pastures the decline of old trees, lack of trees regeneration (Kirby, 2015), overgrowing by woody vegetation, and land-use intensification by transforming a wood-pasture into either a pasture without trees or into different land use. Conversely, Roellig et al. (2015) refer to wood-pastures restoration in Estonia. Van Uytvanck, Maes, Vandenhaute, and Hoffmann (2008) talk about wood-pastures formation on former arable land and grassland in Belgium. Our study deals with land-use and land-cover change (LUCC), describing the processes of persistence, extensification and intensification in the case of past wood-pastures on the one hand, and the formation of new ones on the other.

In recent decades, the number of studies monitoring changes in the landscape have increased, especially accelerated by the emergence of geographic information system (GIS) (Cousins, 2001; Echeverría, Newton, Nahuelhual, Coomes, & Rey-Benayas, 2012; Ihse, 1995; Kienast, 1993; Pino et al., 2010; Munteanu et al., 2014; Plieninger, 2012). The ability to more easily monitor the land use/cover changes (further referred to as LULC) has played a key role (Turner, Lambin, & Reenberg, 2007). There are also many relevant studies focusing on the analysis of spatial changes in the landscape (Khromykh & Khromykh, 2014; Boltižiar, 2001; Hreško & Boltižiar, 2001; Hreško, Boltižiar, & Bugár, 2003; Olah, Boltižiar, & Petrovič, 2006; Seabrook, McAlpine, & Fensham, 2007; Spanò & Pellegrino, 2013). It is especially important is to study landscape persistence (Bürgi, Hersperger, & Schneeberger, 2004).

In relation to pastures, Pătru-Stupariu, Tudor, Stupariu, Buttler, and Peringer (2016) used old maps to study the persistence of pastures, forests and built-up areas in Romania's Carpathians in the periods between 1912, 1980 and 2009. From the studied temporal horizons, the highest proportion of pastures existed in 1980. Pastures showed higher persistence than forests and built-up areas. In reflect of the situation in Czechia, Bičík, Jeleček, and Štěpánek (2001) analysed cadastral evidence from 1845 to 2000. Of all the analysed classes of land use, the sharpest decline between 1845 and 1948 was seen in grasslands. On the other hand, an increase in the share of the same class between 1990 and 1999 was again sharpest in grasslands in comparison to other categories.

Change trajectories of non-forest woody vegetation, which is another topic closely linked to wood-pastures, was analysed by Plieninger, Schleyer, Mantel, and Hostert (2012), who described the spatial-temporal dynamics of trees outside forest in Eastern Germany in the period 1964–2008, which showed a positive net change during the socialist and post-socialist period. Scattered fruit trees were the only declining type of non-forest woody vegetation. Demková and Lipský (2015) described a decline in non-forest woody vegetation in Eastern Czechia during the socialist period and its expansion during the post-socialist period.

It is important to study LUCC and the persistency of wood-pastures to learn about the threats influencing wood-pastures and the drivers underlying the ancient ones. So far, LUCC in silvo-pastoral landscapes has been studied intensively, especially in Iberian Peninsula. The results showed a decline in *montado* and *dehesa* area in the 2nd half of the 20th century (reviewed by Costa, Madeira, Santos, & Plieninger, 2014). If we take into consideration land persistence, in a case study of two areas in south-western Spain, 78% and 89% of the initial wood-pasture area remained persistent between 1956 and 1998. Here, shrub encroachment was the most common cause of losses. The gains occurred in most cases on former grasslands and shrublands (Plieninger, 2006). In southern Portugal, 41%, 42% and 81% of the wood-pasture area respectively in three different areas proved to be persistent between 1958 and 2007 (Costa, Madeira, Lima Santos, & Oliveira, 2011). In Northern Lesvos in Greece, 90% and 55% of wood-pastures in two areas respectively were persistent between 1960 and 2010 (Schaich, Kizos, Schneider, & Plieninger, 2015). In southern Germany, 78% of orchard meadows (regardless of whether grazed or not) between 1968 and 2009 were persistent (Plieninger et al., 2015b). A totally different situation was observed in the case of the Italian Alps, where between 1961 and 2003 there was only 16% and 5% persistence in wood-pasture area in two study areas, respectively, which were defined here by 10–30% tree canopy cover. The wood-pastures were typically transformed into forests (Garbarino, Lingua, Subirà, & Motta, 2011). Varga, Ódor, Molnár, and Bölöni (2015) give evidence about wood-pasture formation in the 19th century in Hungary and their extinction in the post-socialist era. This is the only study focusing explicitly on wood-pasture landscape dynamics in East-Central and Eastern Europe which we found.

As for Czechia, we know that wood-pastures covered about 1.6% of the whole area of the country in the 1st half of the 19th century (Krčmářová & Jeleček, 2016) when the general trend of separation of forest and agricultural use on one piece of land was occurring (Jørgensen & Quelch, 2014). According to the point database LUCAS, 1.1% of Czechia in 2012 was covered by wood-pastures (Plieninger et al., 2015a), although it was believed that silvopastoral systems virtually did not exist there (Hartel et al., 2015). Little is known about the history of these habitats or whether there are some potentially ancient wood-pastures. In the current study, which is focused on wood-pastures in lower parts of Czechia, we try to answer the following questions:

1. How long is the continuity of wood-pastures?
2. What are the sinks of wood-pastures from the past?
3. What are the sources of current wood-pastures?

We will answer the questions by analysing change trajectories in GIS using land use maps from the 1st half of the 19th century, orthophotos from the 1950s and 2013/4 complemented by field mapping.

2. Methods

2.1. Study area

The geographical framework of the study is represented by the regionalisation of Romportl, Chuman, and Lipský (2013). The regionalisation combines climatic and geomorphologic characteristics, namely average annual temperature, slope and elevation, and constructs six regions, called “general types of natural landscapes”. We chose the two mildest of them – warm lowland landscapes and moderately warm landscapes of hills and basins. These two types cover 46.6% of Czechia and are generally characterized by a high population density (71% of inhabitants of Czechia) (ČSÚ, 2011), a low cover of forests (20.4%, while 33.3% in all Czechia) and a high cover of agricultural land (67.7%, while 57% in all Czechia) in comparison to the whole country (CENIA., 2014).

Within these two climatic-geomorphic regions we analysed nine historical cadastral districts (Fig. 1). We took the historical cadastral district as the sampling unit because of the consistency and accessibility of data on historical land use. The boundaries of current cadastral districts might differ from the historical ones. To include a district in the analysis, we set a threshold that at least 0.5% of the district's current land cover must be occupied by wood-

pasture land use. We applied this condition and did not use any kind of random sampling as it is generally believed that wood-pastures virtually do not exist in Czechia today (Hartel et al., 2015) and for the aims of our study, it would be useless to consider districts with no wood-pasture. For this reason we used orthophotos (ČÚZK, 2016) to identify suitable areas in various parts of warm and moderately warm landscapes of Czechia where there are patches with scattered trees. Only nine districts were included in the presented analysis, even though we actually verified more districts. The area of separate districts ranges from 3.8 to 28.6 km^2. In total, they cover 98.6 km^2, which represents 0.3% of warm lowland landscapes and moderately warm landscapes of hills and basins in Czechia (Table 1). The studied districts are covered by arable land (45.8 ± 20% = mean ± SE), forests (23.3 ± 16.7%), heterogeneous agricultural areas (12 ± 7.8%) and grasslands (6.7 ± 11%) according to the CORINE land cover database from the year 2012 (CENIA., 2014).

2.2. Data sources

We analysed three temporal horizons using different types of data sources, including old maps, aerial images and orthoimages:

2.2.1. 1st half of the 19th century

The period we are focused on starts with the 1st half of the 19th century because it is the first temporal horizon available with relatively exact map evidence on the extent of wood-pastures in Czechia. We base our analysis on a series of Stable Cadastre maps, covering the whole former Habsburg monarchy; these are widely used to study Land Use Land Cover in Czechia (e.g., Bičík et al., 2001; Lipský, 1995; Raška, Zábranský, Brázdil, & Lamková, 2016). Different parts of Czechia were mapped from 1824 till 1843 and the studied cadastral districts cover different map sheets which were mapped throughout this long period. Due to this we use the dating "1st half of the 19th century" in this paper. Besides ordinary land-use classes, the Stable Cadastre also records those which might be considered agroforestry (Krčmářová & Jeleček, 2016), including pastures, meadows and arable land with various types of trees. We used the so-called Imperial imprints of the Stable Cadastre, which are large scale maps (1:2880). We obtained the Imperial imprints as scanned images from the Czech Office of Surveying Mapping and Cadastre (ČÚZK, 2015) and georeferenced each map sheet in ArcGIS software (ESRI., 2015) to control points identified on the current cadastral map to distinct corners of parcel boundaries or parcel intersections that we considered not to have changed their shape. The total number of map sheets was 71. For 62 of them, 1st order polynomial transformation was used, where the root mean square error (RMSE) was on average 1.4 per map sheet. The rest of the map sheets were transformed by 2nd order polynomial transformation, where RMSE was on average 1.6 per map sheet. The transformation method was chosen to best fit the current cadastral map.

2.2.2. 1953/54

The temporal horizon of the 1950s was chosen as it represents one of the most important breakpoints in Czech cultural landscape history. After this period, huge and systematic changes in the landscape were accomplished, when consolidation of land parcels took place as a means of agricultural intensification. One of the outputs was the abandonment of distant and less productive land. (Lipský, 1995). To capture the landscape composition of this period, historic black-and-white orthophotos from 1953/1954 were used (CENIA., 2012). From these orthophotos we were able to distinguish only land cover as no reliable data source on land use from this period in Czechia is available. For this reason, we did not distinguish the land use class "wood-pasture", only semi-open habitats. Some studies use historical aerial images to distinguish wood-pastures, but it is suitable only in areas where wood-pastures are common and traditional land management is present (Costa et al., 2014; Plieninger, 2006; Schaich et al., 2015). The 1953/1954 period serves us as an indicator of the dynamics and age of woody vegetation, but not of the land use.

2.2.3. 2015/2016

To determine current LULC, we used complementary data sources. The orthophoto was taken as the basis and was supplemented by LPIS (Land Parcel Identification System) to distinguish agricultural land (MZeČR, 2016). As another source a layer of land, treated as a forest, was used (ÚHUL, 2000). The areas where we expected wood-pastures to be found were verified directly in the field in July and August 2015 and then reviewed in October and November 2016.

Because of the variability of types of data sources, we used five categories of LULC based mainly on tree density and tree canopy cover, which was interpreted visually as follows:

- Open habitats with less than 7 trees/ha. For the 1st half of the 19th century, only those parcels depicted as agricultural with no woody vegetation.
- Semi-open habitats with at least 7 trees/ha and maximally 80% tree canopy cover. The threshold was inspired by other studies on sparse woody vegetation development (Garbarino et al., 2011; Grossmann & Mladenoff, 2007). For the 1st half of the 19th century, all parcels with agricultural land use with woody vegetation as subordinate land use.
- Wood-pastures as a subtype of semi-open habitats where grazing is the dominant management of semi-open grassland. These could be identified for the 1st half of the 19th century as pastures with trees and for 2015/2016, but not for the 1950s (for the reasons, see above).
- Closed habitats with at least 80% tree canopy cover. In this class we also include all land evidenced as forest by ÚHUL (2000), although these may be temporarily open but we cannot expect any pastoral management because grazing by domestic animals has been prohibited since 1960 (NSČSSR, 1960) and not practised now. We include in this class all forest parcels of the Stable Cadastre although we cannot know what the actual tree canopy cover on the parcels was.
- Other areas including urban and industrial areas and water streams and bodies.

2.3. Data processing and analysis

On the basis of previously mentioned data sources, we vectorised all wood-pastures in the 1st half of the 19th century and in 2015/2016 in the ArcGIS 10.4 environment (ESRI., 2015). The minimal mapping unit was set to 0.3 ha. We interpreted LULC of current wood-pastures in 1953/1954 and in the 1st half of the 19th century. At the same time, we interpreted LULC of wood-pastures from the 1st half of the 19th century in 1953/54 and in 2015/2016. We did not vectorise all study areas, only areas where wood-pastures exist or existed, similarly to studies on non-forest woody vegetation (Demková & Lipský, 2015; Plieninger et al., 2012).

We performed an overlay analysis using the *Intersect* and *Union* tools. The final layer was transformed into raster using the *Feature to raster* tool to eliminate sliver polygons (Grossmann & Mladenoff, 2007). The raster cell size was set to 5 m and the value was

controlled by the value of the largest area in the cell. All wood-pastures were then classified according to their continuity into the following groups: continuous, lost by 1950s, lost by 2015/2016, gained by 1950s, and gained by 2015/2016. We also analysed sinks of lost wood-pastures and sources of current ones.

3. Results

3.1. Overall changes

The total area of wood-pastures in the study area was 163.7 ha in 2015/2016, which makes up 1.7% of the studied districts, as against 78.1 ha in the 1st half of the 19th century, meaning 0.8% of the studied area (Table 1). This is more than twice as much. On the other hand, there are big differences between the districts, e.g., the Milovice district (ID 6 in the Fig. 1) has a large wood pasture now, while there was no large one in the 1st half of the 19th century. On the other hand, in the Bohdalice district (ID 1) there was a decline in wood-pastures of 77%.

3.2. Habitat continuity

Looking at wood-pastures evidenced in the 1st half of the 19th century, one can see that already by the beginning of the socialist era more than half of their area had been lost. 44.1% of wood-pastures area was lost during the second period (Fig. 2). Only 1.9% of those wood-pastures that existed in the 19th century were present on all three horizons. There are two larger patches of continuous wood-pastures, namely in the Rovné and Mšec districts (ID 8 and 7, respectively). When we consider the current situation,

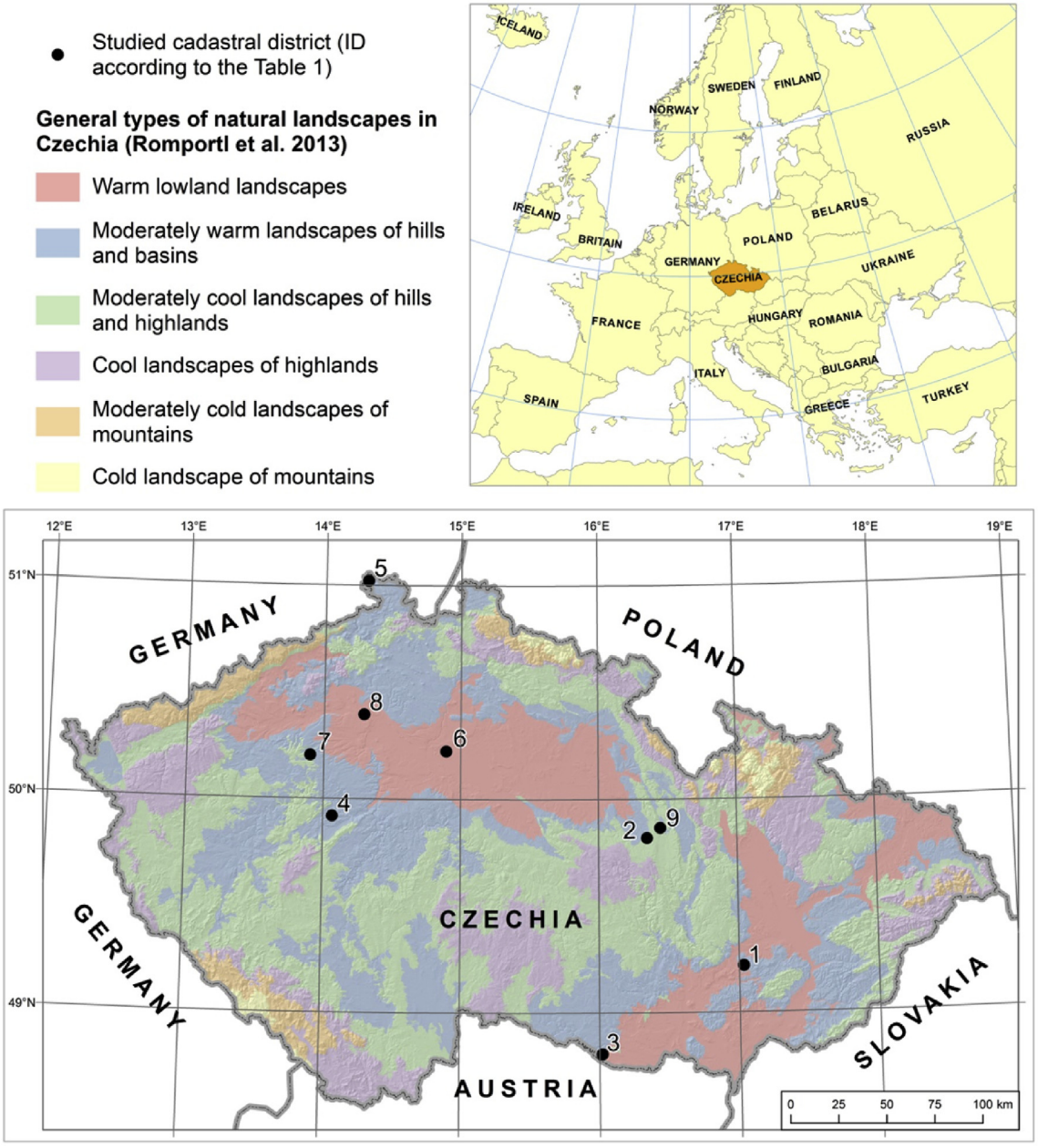

Fig. 1. Localisation of the 9 studied cadastral districts with the context of the general types of natural landscapes in Czechia (Romportl et al., 2013). The number of a district refers to the Table 1.

Table 1
Overall changes of wood-pastures cover in the studied areas between the 1st half of the19th century and 2015/2016.

ID	District	Area (km^2)	Wood-pastures 1824–1843		Wood-pastures 2015		Net change	
			ha	% of district area	ha	% of district area	ha	% of initial area
1	Bohdalice	5,0	12,8	2,6	2,9	0,6	−9,8	−77,0
2	Čistá	28,6	14,4	0,5	30,5	1,1	16,1	111,9
3	Havraníky	11,3	23,2	2,0	28,7	2,5	5,5	23,9
4	Konĕprusy	4,4	1,8	0,4	19,4	4,4	17,6	980,9
5	Lobendava	11,4	4,9	0,4	18,3	1,6	13,4	271,7
6	Milovice	11,8	1,8	0,2	37,5	3,2	35,6	1932,2
7	Mšec	13,8	15,8	1,1	7,4	0,5	−8,4	−53,2
8	Rovné	3,8	1,8	0,5	4,3	1,1	2,5	136,3
9	Semanín	8,6	1,7	0,2	14,8	1,7	13,1	792,7
Total		98,6	78,1	0,8	163,7	1,7	85,6	109,6

more than four-fifths of the wood-pastures in 2015/2016 emerged at a certain time during the last 60 years.

3.3. Sinks of wood-pastures from the past

When we have a look at sinks for wood-pastures lost by 1953/1954 (for an example of such trajectory see the Fig. 5B), most of their area was transformed into land uses with no trees, meaning arable land or grasslands (Fig. 3). Some of these overgrew back in the second period with trees to become semi-open or closed. There are some cases where they were open in 1953/1954 and became wood-pastures again by 2015/2016. Characteristically almost all semi-open areas from 1953/1954 which could have still been wood-pastures at that time had become forests by 2015/2016. Surprisingly, only a small portion of former wood-pastures were transformed into other categories, such as urban areas.

3.4. Sources of current wood-pastures

Concerning wood-pastures present in 2015/2016, the vast majority of them are formed on areas which had been overgrown by woody vegetation during the last 60 years (Figs. 4 and 5A). We can expect the trees there to be very young. An example of such change trajectory is the case of the former military training area in the Milovice and Semanín districts (ID 6 and 9, respectively), where valuable grasslands which are being conserved by grazing have evolved. In fact, 58% of the wood-pasture area is grazed as a management tool of grasslands with high biodiversity, either in state nature reserves or private nature reserves. Almost none of the current wood-pastures have formed in places which were occupied by forests in the 19th century, and in those where wood-pastures do exist, the forest was converted before 1953/1954. If we consider semi-open habitat continuity, only 3.8% (6.3 ha) of the current wood-pasture area has performed such continuity during the last 170 years. An example of such development is a wood-pasture in the Rovné district (ID 8) formed on a historical parcel of arable land with fruit trees.

4. Discussion

4.1. Discussion on results

The increase in the area of wood-pastures is related to the fact that we did not locate case study sites randomly in lowland and warm landscapes of hills and basins in Czechia, but situated them purposely in sites where wood-pastures are present so that we can record the change trait of wood-pastures in time. However, that does not mean that since the 1st half of the 19th century the overall area of wood-pastures in lowlands in Czechia increased by more than 100% as in our case study (Krčmářová & Jeleček, 2016; Plieninger et al., 2015a). On the other hand, most of the case studies that analysed historical changes and causes in wood-pastures in Europe generally documented a decrease in the extent of wood-pastures, respecting different natural and cultural conditions (Costa et al., 2011; Garbarino et al., 2011; Plieninger, 2006; Schaich et al., 2015; Varga et al., 2015).

Although we report a positive net change in the overall area covering silvopastoral patches, almost none of the current wood-pastures have had habitat continuity throughout the whole period and only a small portion have had continuity for the last 60 years. This contrast with the studies from Spain (Plieninger, 2006), Portugal (Costa et al., 2011), Germany in case of orchard meadows (Plieninger et al., 2015b) and Lesvos (Schaich et al., 2015), although all of those papers describe much shorter time periods. Only in the Italian Alps was the persistence of wood-pastures similarly low (Garbarino et al., 2011).

We can only speculate about the consequences of wood-pasture dynamics for biodiversity. Ancient wood-pastures are generally considered important biodiversity hot-spots (Falk, 2014; Paltto, Nordberg, Nordén, & Snäll, 2011). Therefore, the losses of wood-pastures with potentially old trees that were documented in our study could be responsible for significant diversity losses in the past at both the local and regional level. However, precise quantification of the losses might be difficult if not impossible. We should consider the possibility that many species could have found alternative habitats in the grasslands and forests which replaced the original wood-pastures. At the same time, newly established wood-pastures would probably mean diversity gains in the landscape. Open grazed shrublands are often richer in species than other habitats, as seen in some examples from Romania (Vojta, Kovář, & Volařík, 2014), regardless of the presence of old trees. Shrubs on a pasture are important for specific bird species (Hartel et al., 2014). A case study from the East Vättern scarp landscape in Sweden shows that γ- and β-diversity in wood-pastures increases along the gradient of tree density on a pasture (Jakobsson & Lindborg, 2015).

Concerning the fate of wood-pastures depicted in the Stable Cadastre from the 1st half of the 19th century, slightly fewer than half of them persisted until at least the 1950s. The former semi-open wood-pastures have turned more into open habitats (be they arable land, meadow or pasture without trees) than into closed canopy habitats, which indicates intensification of agriculture in the period. This could have happened already at the end of the 19th century when a large loss of pasture area and gains in arable land occurred in Czechia (Bičík et al., 2001). The period 1840s–1950s was characterized by a blossoming of private peasant agriculture with a high share of people and working animals. Moreover, new technical equipment and new plants allowed the use of less productive land for more intensive agriculture (Grešlová

Kušková, 2013; Jepsen et al., 2015; Šantrůčková, Dostálek, & Demková, 2015). Our case study reflects a process different from one site in the Bakony hills in Hungary, where a wood-pasture was formed between 1818 and 1880 on the site of a former forest (Varga et al., 2015). On one site in the Romanian Carpathians, large gains in forests in the period 1790–1867 took place at the expense of pastures, which also shows a development different from that reported in the current paper (Pătru-Stupariu, Angelstam, Elbakidze, Huzui, & Andersson, 2013).

Almost all of the wood-pastures from the 1st half of the 19th century in the area of the current study, which remained semi-open until the 1950s, changed into forest land in the second period. This indicates that after the 1950s these areas were subject to more extensive land use. Agriculture after the 1950s was characterized by collectivization, large open fields, and heavy mechanization. On the other hand, less accessible and arable lands were abandoned or reforested (Grešlová Kušková, 2013; Jepsen et al., 2015). The authors studying wood-pasture dynamics in the 2nd half of the 20th century referred to broadly agree in identifying the driving forces which had a major impact towards the decline or to a lesser extent, the emergence of recent wood-pastures. Both suggest a process of intensification and especially intensive grazing (Plieninger, 2006; Schaich et al., 2015; Varga et al., 2015) resulting in the loss of wood-pastures. They also document opposed processes of farming extensification and abandonment, both resulting in tree and shrub encroachment (Plieninger, 2006) which together with the depopulation as well as the abandoning of traditional management techniques play a great role behind the decline in wood-pastures.

Current wood-pastures in lowlands and hilly landscapes in Czechia are have nearly all recently formed on former open habitats. This phenomenon is consistent with the process of abandoning less accessible land in the communist era in Czechia described above (Bičík et al., 2001) and agricultural extensification in the 1990s (Feranec, Jaffrain, Soukup, & Hazeu, 2010). On the other hand, there is a potential to restore wood-pastures (Roellig et al., 2015) from overgrown ones which were converted into closed canopy habitats in case these patches are not registered as forest land in the Czech cadastre. On former agroforestry patches old trees can still be found today (Krčmářová, 2016).

Talking of spatial-temporal changes of wood-pastures in the study sites, they represent rather dynamic landscapes in comparison to the more persistent wood-pasture landscapes of Spain, Portugal and Lesvos. Moreover, in the lowlands and hills in Czechia wood-pastures are not a traditional land use (Krčmářová & Jeleček, 2016). Ironically, land use of wood-pastures, which has a long tradition in Europe (Jørgensen & Quelch, 2014), might be considered allochthonous here. In other words, even though these landscapes did not exist in the past here (Antrop, 2005), we can celebrate them as sustainable landscapes of the future and as an example of integrated landscape management (Manning et al., 2006). However, their sustainability should be further studied especially by means of a land-users' motivation analysis.

4.2. Discussion on the methodology

This study was conducted as a case study, as it was based on 9 specific cadastral districts (sample plots) in warm lowlands and moderately warm landscapes of hills and basins in Czechia (Romportl et al., 2013). The studied area covers 98.6 km^2, which is about 0.3% of all the lower located parts of the country. We selected such districts where wood-pastures cover at least 0.5% of the district's area. Thus, the results are not generalizable in terms of changes in the extent of wood-pastures today and in past but they report about the continuity of current wood-pastures.

In contrast to the current study, most of the other related studies have applied a shorter time perspective, using historical aerial photographs. Thus, Garbarino et al. (2011) documented the loss of wood-pastures in the central part of the Italian Alps in one time period between 1961 and 2003, Schaich et al. (2015) looked at a similar period in Greece on Lesvos island (1961–2010), and Plieninger (2006) made a multitemporal analysis of the development of wood-pastures with three temporal horizons (1956 - 1984–1998) at locations on the Iberian Peninsula. A much longer period was analysed by Varga et al. (2015) in hilly areas in Hungary (1818–2005) in four periods, and in addition to aerial photographs old maps were used.

It is essential to note the specific limits and assets of the different data sources that were used for the studied time horizons (Table 2). The method proposed here may be applied to the entire area which was involved in the Stable Cadastre mapping, which includes most of the former Habsburg Empire. The obstacles in georeferencing and digitising old maps were eliminated by transforming the vector layer into a raster with a 5-m cell size. Old maps of the Stable Cadastre are a solid data source but have their limits as we cannot judge the land cover from them. The threshold defining wood-pastures according to their tree density in the presented study is thus only to a certain limit comparable with the patches defined as pastures with trees or shrubs in the Stable Cadastre.

Aerial photographs, as another data source we used, usually give more precise and detailed information (Herold, Goldstein, & Clarke, 2003) but they do not reflect land use, and sometimes land cover, especially for the 1950s, due to their lower quality. Thus, we are limited in information upon land use for the 1950s time horizon, while for 2015 we are able to get enough related information from additional sources. In historic aerial photos from the 1950s, only the category covering all semi-open habitats could be used. Grasslands

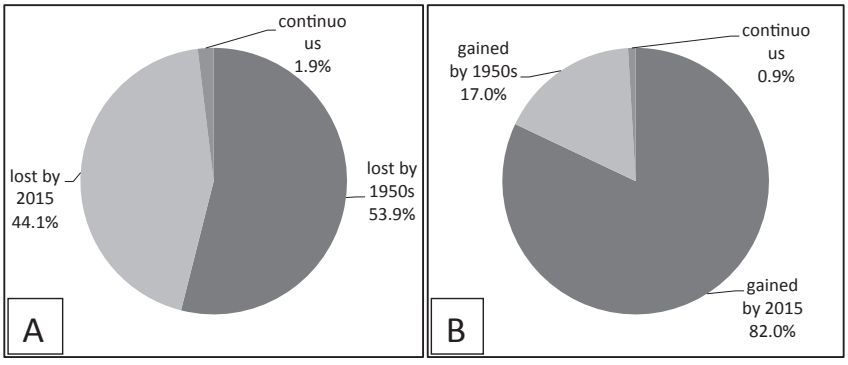

Fig. 2. Continuity of wood-pastures present in 1824–1843 (A) and in 2015 (B).

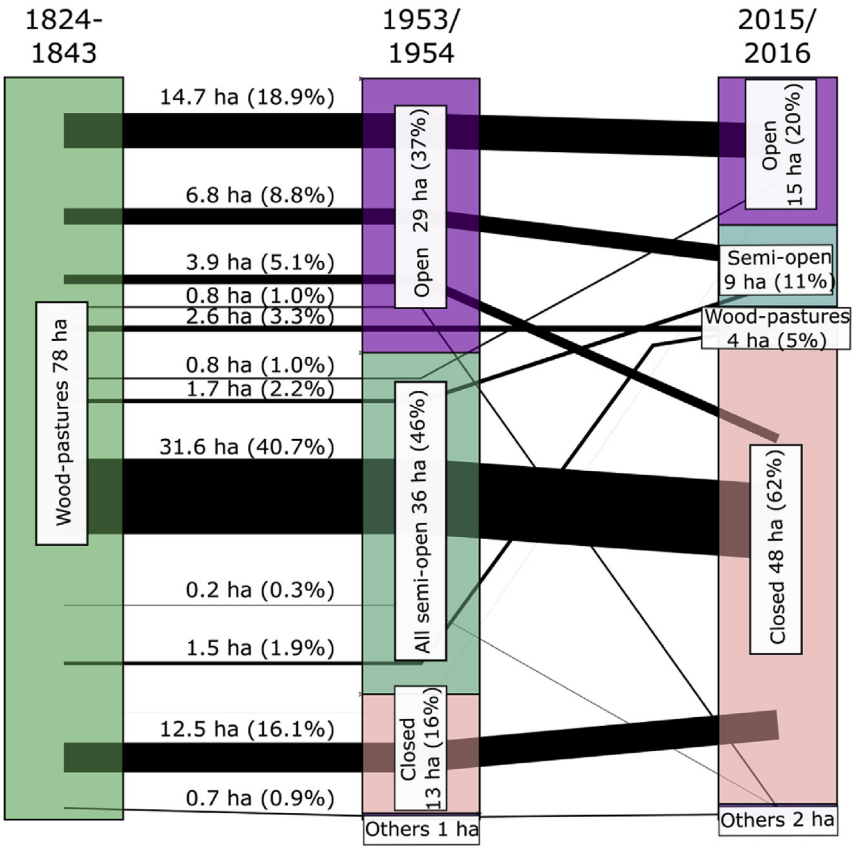

Fig. 3. Change trajectories of wood-pastures present in 1824–1843.

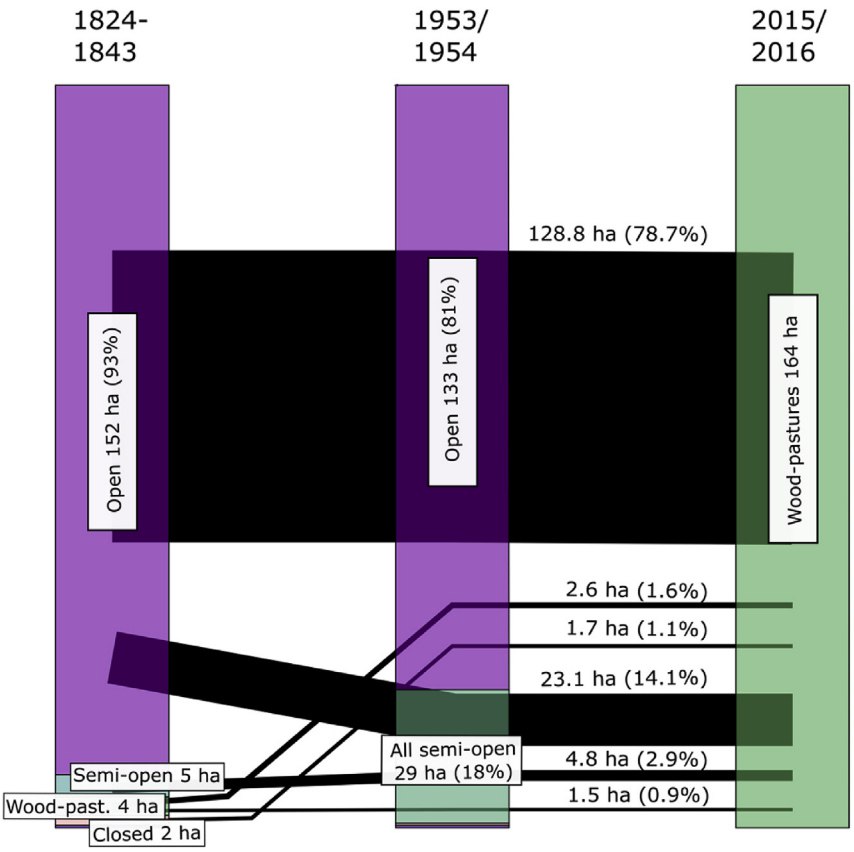

Fig. 4. Change trajectories of wood-pastures present in 2015.

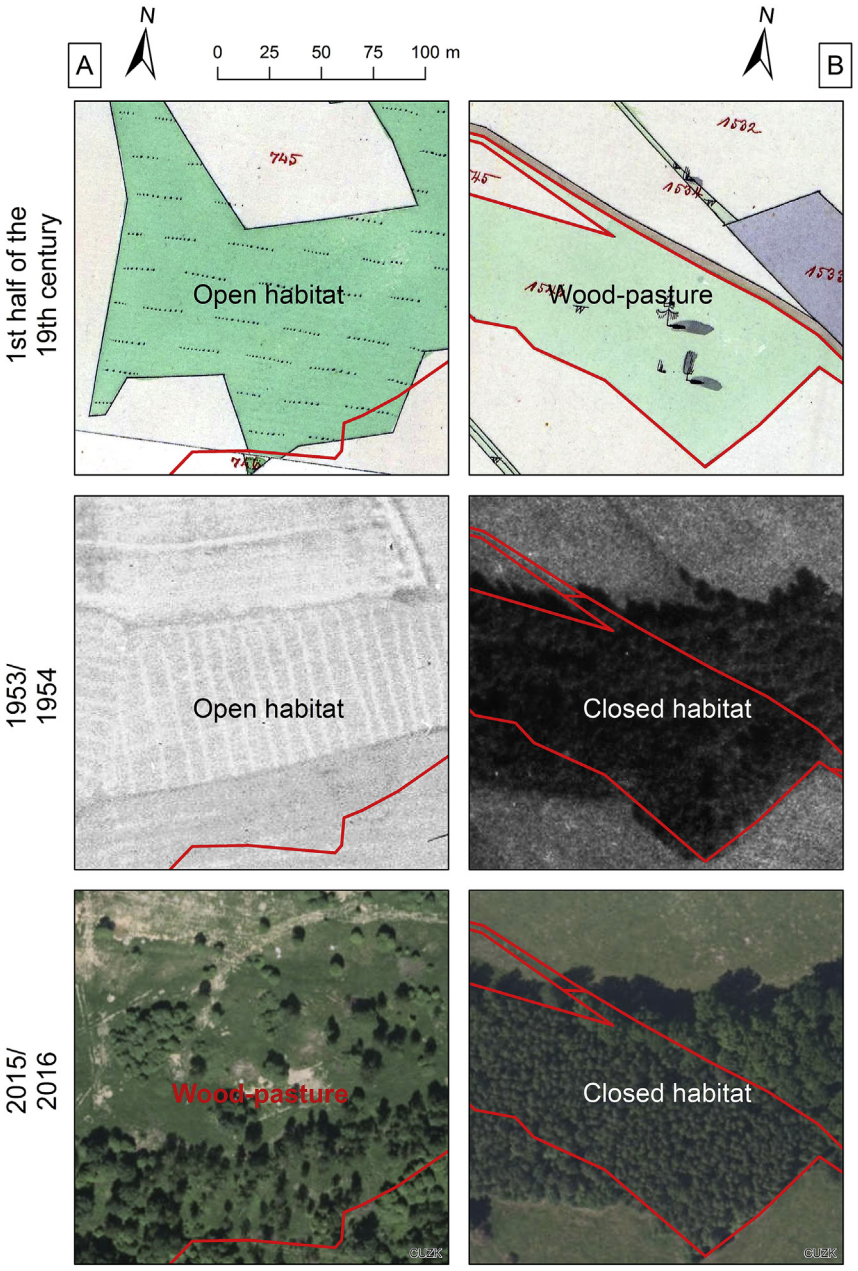

Fig. 5. Examples of typical change trajectories of wood-pastures present in 2016 (A) and wood-pasture present in the 1st half of the 19th century (B).

with shrubs could sometimes be classified as open habitats as the shrubs are not clearly displayed in the orthophoto. This can be confirmed in further studies using archival sources. The major disadvantage of the method of visual interpretation of aerial images consists in its great time demands and sensitivity to the individual manner of work of each particular researcher, which may result in problems in distinguishing between different LULC categories.

Old maps and aerial photographs together with statistical data

Table 2
Limits and assets of the different graphical data sources used for description and analysis of LULC at different temporal horizons.

	1824–1842: Imperial imprints of the Stable Cadastre	1950s: archival orthophoto	2015/2016: orthophoto, field mapping, LPIS, thematic layers
Advantage	Large scale mapping; existing classification of landscape segments	Detectible land cover	Diversity and availability of sources guaranteeing access to any information
Disadvantage	Lack of information upon land cover (abundance and location of trees and shrubs at the plot)	Need of classifying the landscape segments; lack of information upon land-use (grazed/not grazed); low resolution of orthophoto, leading to uncertainty in locating shrubs	Time demanding, need of classifying the landscape segments

about land use are the sole solid data on land use/cover changes, but they should be interpreted carefully. First, the data gained from the sources are related to mapping time horizons, but multiple or repetitive changes between the mapping horizons remain unknown. It is impossible to depict all changes in the model areas, and the interpretation stresses the trends. Secondly, the earliest accurate sources come from the beginning of the 19th century. Information about previous land use changes is scattered and often omitted but the centuries before the 19th century could not be assumed to be unchanging. Finally, the depiction of semi-open habitats on data sources from three temporal horizons does not necessarily imply the existence of wood-pastures with ancient trees in the current landscape. The maps only serve to identify potential habitat continuity and consequent high conservation value (Pătru-Stupariu et al., 2013).

5. Conclusion

The results of the research allow the questions posed in this study to be answered. Firstly, it can be concluded that most wood pastures have not been continuously present in the three studied temporal horizons (1st half of the 19th century, 1953/1954, 2015/2016). Moreover, the wood-pastures present in 2015/2016 were formed mostly in the last 60 years. The source of wood-pastures present now are most often open-habitats, which means that we cannot expect old trees on them.

On the other hand, a little less than half of wood-pastures from the 1st half of the 19th century remained semi-open habitats until the 1950s, which indicates a relatively stable landscape in the first period. However, the process of agricultural intensification was stronger at that time, as more wood-pastures areas were converted into open-habitats than into forests. In the second studied period, rapid transitions of semi-open habitats into forest took place. Indeed, the socialist and post-socialist era was characterized by the abandonment of remnants of wood-pasture land use. Now, wood-pastures are emerging again, although they are valued rather as species rich grasslands which started to be overgrown by woody vegetation and thus need grazing as a conservation management tool.

The overall changes which are presented in the current study, where we described the huge increase in the area of wood-pastures, cannot be generalized for all warm lowlands and moderately warm landscapes of hills and basins. We wanted to study the habitat continuity and change trajectories especially with consequences for current wood-pastures so we chose only those cadastral districts where wood-pastures cover at least 0.5% of the district's area.

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References

Antrop, M. (2005). Why landscapes of the past are important for the future. *Landscape and Urban Planning, 70*(1–2), 21–34. http://dx.doi.org/10.1016/j.landurbplan.2003.10.002.

Bergmeier, E., Petermann, J., & Schröder, E. (2010). Geobotanical survey of wood-pasture habitats in Europe: Diversity, threats and conservation. *Biodiversity and Conservation, 19*(11), 2995–3014. http://doi.org/10.1007/s10531-010-9872-3.

Bergmeier, E., & Roellig, M. (2014). Diversity, threats and conservation of European wood-pastures. In T. Hartel, & T. Plieninger (Eds.), *European wood-pastures in transition: A social-ecological approach* (pp. 19–38). Routledge.

Bičík, I., Jeleček, L., & Štěpánek, V. (2001). Land-use changes and their social driving forces in Czechia in the 19th and 20th centuries. *Land Use Policy, 18*(1), 65–73. http://dx.doi.org/10.1016/S0264-8377(00)00047-8.

Bieling, C., & Konold, W. (2014). Common management of wood-pastures and sustainable regional development in the southern Black Forest (Germany). In *European wood-pastures in transition: A social-ecological approach* (pp. 235–253). Routledge. http://dx.doi.org/10.4324/9780203797082.

Boltižiar, M. (2001). Evaluation of vulnerability of high-mountain landscape on example Velická valley in the High Tatras Mts. *Ekológia (Bratislava), 20*(4), 101–109.

Bürgi, M., Hersperger, A. M., & Schneeberger, N. (2004). Driving forces of landscape change - current and new directions. *Landscape Ecology, 19*(8), 857–868. http://dx.doi.org/10.1007/s10980-005-0245-3.

Butler, J. (2014). Mapping ancient and other trees of special interest: UK citizens' contribution to world tree heritage. In T. Hartel, & T. Plieninger (Eds.), *European wood-pastures in transition: A social-ecological Approach2* (pp. 203–216). Routledge.

CENIA. (2012). *Historická ortofotomapa (50. léta)*.

CENIA. (2014). *CORINE Land Cover 2012 databáze České republiky*.

Costa, A., Madeira, M., Lima Santos, J., & Oliveira, Â. (2011). Change and dynamics in mediterranean evergreen oak woodlands landscapes of southwestern Iberian Peninsula. *Landscape and Urban Planning, 102*(3), 164–176. http://dx.doi.org/10.1016/j.landurbplan.2011.04.002.

Costa, A., Madeira, M., Santos, J. L., & Plieninger, T. (2014). Recent dynamics of evergreen oak wood-pastures in south-western Iberia. In T. Hartel, & T. Plieninger (Eds.), *European wood-pastures in transition: A social-ecological approach* (pp. 70–89). Routledge.

Cousins, S. A. O. (2001). Analysis of land-cover transitions based on 17th and 18th century cadastral maps and aerial photographs. *Landscape Ecology, 16*(1), 41–54. http://dx.doi.org/10.1023/A:1008108704358.

ČSÚ. (2011). *Sčítání lidí, domů a bytů*.

ČÚZK. (2015). *Císařské otisky stabilního katastru*.

ČÚZK. (2016). *Ortofoto*.

Demková, K., & Lipský, Z. (2015). Změny nelesní dřevinné vegetace v jihozápadní části Bílých Karpat v leteck 1949-2011. *Geografie, 120*(1), 64–83.

Echeverría, C., Newton, A., Nahuelhual, L., Coomes, D., & Rey-Benayas, J. M. (2012). How landscapes change: Integration of spatial patterns and human processes in temperate landscapes of southern Chile. *Applied Geography, 32*(2), 822–831. http://dx.doi.org/10.1016/j.apgeog.2011.08.014.

ESRI. (2015). *ArcGIS 10.4*. Environmental Systems Research Institute, Inc.

Falk, S. (2014). Wood-pastures as reservoirs for invertebrates. In T. Hartel, & T. Plieninger (Eds.), *European wood-pastures in transition: A social-ecological approach*. Routledge.

Feranec, J., Jaffrain, G., Soukup, T., & Hazeu, G. (2010). Determining changes and flows in European landscapes 1990-2000 using CORINE land cover data. *Applied Geography, 30*(1), 19–35. http://dx.doi.org/10.1016/j.apgeog.2009.07.003.

Garbarino, M., & Bergmeier, E. (2014). Plant and vegetation diversity in Euopean wood-pastures. In T. Hartel, & T. Plieninger (Eds.), *European wood-pastures in transition: A social-ecological approach* (pp. 113–131). Routledge.

Garbarino, M., Lingua, E., Subirà, M. M., & Motta, R. (2011). The larch wood pasture: Structure and dynamics of a cultural landscape. *European Journal of Forest Research, 130*(4), 491–502. http://dx.doi.org/10.1007/s10342-010-0437-5.

Grešlová Kušková, P. (2013). A case study of the Czech agriculture since 1918 in a socio-metabolic perspective - from land reform through nationalisation to privatisation. *Land Use Policy, 30*(1), 592–603. http://dx.doi.org/10.1016/j.landusepol.2012.05.009.

Grossmann, E. B., & Mladenoff, D. J. (2007). Open woodland and savanna decline in a mixed-disturbance landscape (1938 to 1998) in the northwest Wisconsin (USA) sand plain. *Landscape Ecology, 22*(SUPPL. 1), 43–55. http://dx.doi.org/10.1007/s10980-007-9113-7.

Hartel, T., Dorresteijn, I., Klein, C., Máthé, O., Moga, C. I., Öllerer, K., … Fischer, J. (2013). Wood-pastures in a traditional rural region of Eastern Europe: Characteristics, management and status. *Biological Conservation, 166*, 267–275. http://dx.doi.org/10.1016/j.biocon.2013.06.020.

Hartel, T., Hanspach, J., Abson, D. J., Máthé, O., Moga, C. I., & Fischer, J. (2014). Bird communities in traditional wood-pastures with changing management in eastern Europe. *Basic and Applied Ecology, 15*(5), 385–395. http://dx.doi.org/10.1016/j.baae.2014.06.007.

Hartel, T., & Plieninger, T. (2014). The social and ecological dimensions of wood-pastures. In T. Hartel, & T. Plieninger (Eds.), *European wood-pastures in transition: A social-ecological approach* (pp. 3–18). Routledge.

Hartel, T., Plieninger, T., & Varga, A. (2015). Wood-pastures in Europe. In K. Kirby, & C. Watkins (Eds.), *Europe's changing woods and Forests: From wildwood to managed landscapes* (pp. 61–76). http://dx.doi.org/10.1079/9781780643373.0061.

Herold, M., Goldstein, N. C., & Clarke, K. C. (2003). The spatiotemporal form of urban growth: Measurement, analysis and modeling. *Remote Sensing of Environment, 86*(3), 286–302. http://dx.doi.org/10.1016/S0034-4257(03)00075-0.

Hreško, J., & Boltižiar, M. (2001). The influence of the morphodynamic processes to landscape structure in the high mountains (Tatra Mts.). *Ekológia (Bratislava), 20*(3), 141–148.

Hreško, J., Boltižiar, M., & Bugár, G. (2003). Spatial structures of geomorphic

processes in high-mountain landscape of the Belianske Tatry Mts. *Ekológia (Bratislava), 22*(3), 341–348.
Ihse, M. (1995). Swedish agricultural landscapes - patterns and changes during the last 50 years, studied by aerial photos. *Landscape and Urban Planning, 31*(1–3), 21–37. http://dx.doi.org/10.1016/0169-2046(94)01033-5.
Jakobsson, S., & Lindborg, R. (2015). Governing nature by numbers - EU subsidy regulations do not capture the unique values of woody pastures. *Biological Conservation, 191*, 1–9. http://dx.doi.org/10.1016/j.biocon.2015.06.007.
Jepsen, M. R., Kuemmerle, T., Müller, D., Erb, K., Verburg, P. H., Haberl, H., … Reenberg, A. (2015). Transitions in European land-management regimes between 1800 and 2010. *Land Use Policy, 49*, 53–64. http://dx.doi.org/10.1016/j.landusepol.2015.07.003.
Jørgensen, D., & Quelch, P. (2014). The origins and history of medieval wood-pastures. In T. Hartel, & T. Plieninger (Eds.), *European wood-pastures in transition: A social-ecological approach* (pp. 55–69). Routledge.
Khromykh, V., & Khromykh, O. (2014). Analysis of spatial structure and dynamics of tom valley landscapes based on GIS, digital elevation model and remote sensing. *Procedia - Social and Behavioral Sciences, 120*, 811–815. http://dx.doi.org/10.1016/j.sbspro.2014.02.165.
Kienast, F. (1993). Analysis of historic landscape patterns with a Geographical Information System? a methodological outline. *Landscape Ecology, 8*(2), 103–118. http://dx.doi.org/10.1007/BF00141590.
Kirby, K. J. (2015). What might a sustainable population of trees in wood-pasture sites look like? *Hacquetia, 14*(1), 43–52. http://dx.doi.org/10.1515/hacq-2015-0010.
Krčmářová, J. (2016). Stromy v horském zemědělství 19. století. Historie a současnost lesozemědělských ploch v katastrálním území Velký Uhřínov. *Orlické Hory a Podorlicko, 22*(1–2), 13–36.
Krčmářová, J., & Jeleček, L. (2016). Czech traditional agroforestry: Historic accounts and current status. *Agroforestry Systems*. http://dx.doi.org/10.1007/s10457-016-9985-0.
Lipský, Z. (1995). The changing face of the Czech rural landscape. *Landscape and Urban Planning, 31*, 39–45.
Manning, A. D., Fischer, J., & Lindenmayer, D. B. (2006). Scattered trees are keystone structures - implications for conservation. *Biological Conservation, 132*(3), 311–321. http://dx.doi.org/10.1016/j.biocon.2006.04.023.
Moga, C. I., Samoilă, C., Öllerer, K., Băncilă, R. I., Réti, K. O., Craioveanu, C., … Hartel, T. (2016). Environmental determinants of the old oaks in wood-pastures from a changing traditional social-ecological system of Romania. *Ambio*, 1–10. http://dx.doi.org/10.1007/s13280-015-0758-1.
Munteanu, C., Kuemmerle, T., Boltiziar, M., Butsic, V., Gimmi, U., Ľuboš Halada, … Radeloff, V. C. (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. http://dx.doi.org/10.1016/j.landusepol.2014.01.012.
MZeČR. (2016). *Land parcel identification system*.
NSČSSR. (1960). *1960/160 Sb. Zákon o lesích a lesním hospodářství (lesní zákon)*.
Olah, B., Boltižiar, M., & Petrovič, F. (2006). Land use changes' relation to georelief and distance in the east Carpathians biosphere reserve. *Ekológia (Bratislava), 25*, 68–81. MARCH.
Opperman, R. (2014). Wood-pastures as examples of European high nature value landscapes. Functions and differentiations according to farming. In T. Hartel, & T. Plieninger (Eds.), *European wood-pastures in transition: A social-ecological approach* (pp. 39–52). Routledge.
Paltto, H., Nordberg, A., Nordén, B., & Snäll, T. (2011). Development of secondary woodland in oak wood pastures reduces the richness of rare epiphytic lichens. *PLoS One, 6*(9), 1–9. http://dx.doi.org/10.1371/journal.pone.0024675.
Pino, J., Smith, G., Thomson, A., Wachowicz, M., Bezák, P., Brown, N., Boltižiar, M., De-Badts, E., Feranec, J., Halabuk, A., Manchester, S., Mojses, M., Petrovič, F., Pons, X., Roda, F., Roscher, M., Sustera, J., Tuominen, S., Wadsworth, R., & Ziese, H. (2010). Determining Europe's land cover changes over the past 50 years using aerial photographs. *Progress in Physical Geography, 34*, 183–205. ISSN 0309-1333.
Plieninger, T. (2006). Habitat loss, fragmentation, and alteration - quantifying the impact of land-use changes on a Spanish dehesa landscape by use of aerial photography and GIS. *Landscape Ecology, 21*(1), 91–105. http://dx.doi.org/10.1007/s10980-005-8294-1.
Plieninger, T. (2012). Monitoring directions and rates of change in trees outside forests through multitemporal analysis of map sequences. *Applied Geography, 32*(2), 566–576. http://dx.doi.org/10.1016/j.apgeog.2011.06.015.
Plieninger, T., Hartel, T., Martín-López, B., Beaufoy, G., Bergmeier, E., Kirby, K., … Van Uytvanck, J. (2015). Wood-pastures of Europe: Geographic coverage, social–ecological values, conservation management, and policy implications. *Biological Conservation, 190*, 70–79. http://dx.doi.org/10.1016/j.biocon.2015.05.014.
Plieninger, T., Levers, C., Mantel, M., Costa, A., Schaich, H., & Kuemmerle, T. (2015b). Patterns and drivers of scattered tree loss in agricultural landscapes: Orchard meadows in Germany (1968-2009). *PloS One, 10*(5), e0126178. http://dx.doi.org/10.1371/journal.pone.0126178.
Plieninger, T., Schleyer, C., Mantel, M., & Hostert, P. (2012). Is there a forest transition outside forests? Trajectories of farm trees and effects on ecosystem services in an agricultural landscape in eastern Germany. *Land Use Policy, 29*(1), 233–243. http://dx.doi.org/10.1016/j.landusepol.2011.06.011.
Pătru-Stupariu, I., Angelstam, P., Elbakidze, M., Huzui, A., & Andersson, K. (2013). Using forest history and spatial patterns to identify potential high conservation value forests in Romania. *Biodiversity and Conservation, 22*(9), 2023–2039. http://dx.doi.org/10.1007/s10531-013-0523-3.
Pătru-Stupariu, I., Tudor, C. A., Stupariu, M. S., Buttler, A., & Peringer, A. (2016). Landscape persistence and stakeholder perspectives: The case of Romania ' s Carpathians. *Applied Geography, 69*, 87–98. http://dx.doi.org/10.1016/j.apgeog.2015.07.015.
Raška, P., Zábranský, V., Brázdil, R., & Lamková, J. (2016). The late Little Ice Age landslide calamity in North Bohemia: Triggers, impacts and post-landslide development reconstructed from documentary data (case study of the Kozí vrch Hill landslide). *Geomorphology, 255*, 95–107. http://dx.doi.org/10.1016/j.geomorph.2015.12.009. September.
Read, H. (2000). Veteran trees: A guide to good management. *Veteran Trees: A Guide to Good Management, 167*. http://dx.doi.org/10.1017/CBO9781107415324.004.
Roellig, M., Sutcliffe, L. M. E., Sammul, M., von Wehrden, H., Newig, J., & Fischer, J. (2015). Reviving wood-pastures for biodiversity and people: A case study from western Estonia. *Ambio, 45*(2), 185–195. http://dx.doi.org/10.1007/s13280-015-0719-8.
Romportl, D., Chuman, T., & Lipský, Z. (2013). Typologie současné krajiny Česka. *Geografie, 118*(1), 16–39.
Šantrůčková, M., Dostálek, J., & Demková, K. (2015). Assessing long-term spatial changes of natural habitats using old maps and archival sources: A case study from central Europe. *Biodiversity and Conservation, 24*(8), 1899–1916. http://dx.doi.org/10.1007/s10531-015-0912-x.
Schaich, H., Kizos, T., Schneider, S., & Plieninger, T. (2015). Land Change in Eastern Mediterranean Wood-Pasture Landscapes: The Case of Deciduous Oak Woodlands in Lesvos (Greece). *Environmental Management*, 110–126. http://dx.doi.org/10.1007/s00267-015-0496-y.
Seabrook, L., McAlpine, C., & Fensham, R. (2007). Spatial and temporal analysis of vegetation change in agricultural landscapes: A case study of two brigalow (Acacia harpophylla) landscapes in Queensland, Australia. *Agriculture, Ecosystems & Environment, 120*(2–4), 211–228. http://dx.doi.org/10.1016/j.agee.2006.09.005.
Spanò, A., & Pellegrino, M. (2013). Craft data mapping and spatial analysis for historical landscape modeling. *Journal of Cultural Heritage, 14*(3), S6–S13. http://dx.doi.org/10.1016/j.culher.2012.11.024.
Surová, D., Pinto-Correia, T., & Marušák, R. (2014). Visual complexity and the montado do matter: Landscape pattern preferences of user groups in Alentejo, Portugal. *Annals of Forest Science, 71*(1), 15–24. http://doi.org/10.1007/s13595-013-0330-8.
Sutcliffe, L., Öllerer, K., & Roellig, M. (2014). Wood-pasture management in southern Transylvania (Romania): From communal to where? In T. Hartel, & T. Plieninger (Eds.), *European wood-pastures in transition: A social-ecological approach* (pp. 219–234). Routledge. http://dx.doi.org/10.4324/9780203797082.
Szabó, P. (2013). Rethinking pannage: Historical interactions between oak and swine. In *Trees, forested landscapes and grazing animals: A European perspective on woodlands and grazed treescapes* (pp. 51–61). http://dx.doi.org/10.4324/9780203102909. May.
Szabó, P., & Hédl, R. (2013). Socio-economic demands, ecological conditions and the power of tradition: Past woodland management decisions in a central European landscape. *Landscape Research, 38*(2), 243–261. http://dx.doi.org/10.1080/01426397.2012.677022.
Turner, B. L., Lambin, E. F., & Reenberg, A. (2007). The emergence of land change science for global environmental change and sustainability. *Proceedings of the National Academy of Sciences of the United States of America, 104*(52), 20666–20671. Retrieved from: http://www.jstor.org/stable/25450958.
ÚHUL. (2000). *Oblastní plány rozvoje lesů*.
Van Uytvanck, J., Maes, D., Vandenhaute, D., & Hoffmann, M. (2008). Restoration of woodpasture on former agricultural land: The importance of safe sites and time gaps before grazing for tree seedlings. *Biological Conservation, 141*(1), 78–88. http://dx.doi.org/10.1016/j.biocon.2007.09.001.
Varga, A., Ódor, P., Molnár, Z., & Bölöni, J. (2015). The history and natural regeneration of a secondary oak-beech woodland on a former wood-pasture in Hungary. *Acta Societatis Botanicorum Poloniae, 84*(2), 215–225. http://dx.doi.org/10.5586/asbp.2015.005.
Vojta, J., Kovář, P., & Volařík, D. (2014). Patterns of grazing and plant species diversity in the pasturelands. In P. Maděra, P. Kovář, D. Romportl, & A. Buček (Eds.), *Czech villages in Romanian Banat: Landscape, nature, and culture* (pp. 153–165). Mendel University in Brno. http://dx.doi.org/10.13140/2.1.3657.1843.