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Wood-pastures in a traditional rural region of Eastern Europe: Characteristics, management and status

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ABSTRACT

Wood-pastures are among the oldest land-use types in Europe and have high ecological and cultural importance. They are under rapid decline all over Europe because of changes in land use, tree cutting, and lack of regeneration. In this study we characterized the structure, condition and threats of wood-pastures in a traditional rural region in Romania. Forty-two wood-pastures were surveyed, as well as 15 forest sites for comparison. All wood-pasture sites were described via four groups of variables: condition, management, site, and landscape context. Forest sites were dominated by Hornbeam (*Carpinus betulus*) and Beech (*Fagus sylvatica*), whereas wood-pastures were dominated by Oak (*Quercus* sp.) and various species of fruit trees. Most wood-pastures contained trees classified as 'ancient' but no such trees were found in forests. The proportion of dead trees was positively related to forest cover within 300 m around the wood-pasture. Models that included management, site and landscape-related variables best explained the prelevance of Oak, Beech, Hornbeam and Pear trees in wood-pastures. Large oaks and hornbeams were more likely to be dead or affected by uncontrolled pasture burning than small oaks and other tree species. Our results show that ancient wood-pastures are common in this rural region, and they may be more common in Eastern Europe than previously thought. There is an urgent need for research, legal recognition and conservation management of wood-pastures as distinct landscape elements for their cultural, ecological and agricultural importance.

1. Introduction

Wood-pastures represent an important part of European cultural–natural heritage (Bergmeier et al., 2010), and are one of the oldest land-use types in Europe, being known since the Neolithic (Luick, 2008). Although the concept of wood-pastures is broad (Spencer and Kirby, 1992; Caledonian Partnership, 2003; Goldberg et al., 2007), it characteristically refers to environments that are defined by trees scattered through an open area, generally grassland. Appropriate livestock grazing regimes applied through centuries have been crucial for the formation of wood-pastures and will be important for their further persistence (Quelch, 2002).

Ancient wood-pastures bring together several important components that make them attractive for ecologists and conservationists. First, wood-pastures contain scattered trees. The age of these trees can reach centuries; such trees are sometimes referred to as 'veteran' or 'ancient' trees (Read, 2000; Quelch, 2002). Old, scattered trees provide a broad range of habitat features such as dead branches or hollows (Gibbons and Lindenmayer, 2003). For this reason, old trees represent local 'biodiversity hotspots' in ecosystems around the world (Fischer et al., 2010; Lindenmayer et al., 2013). Moreover, scattered trees (regardless of their age) significantly influence microclimatic conditions and soil humidity, and consequently vegetation structure (Manning et al., 2006) and may help to facilitate adaptation to anthropogenic climate change in the future (Manning et al., 2009). Second, the open habitat throughout which trees are scattered is managed mostly as pasture (Quelch, 2002; Mountford and Peterken, 2003; Bergmeier et al., 2010). Traditional pasture management has typically been low in

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intensity, thus supporting a rich flora and fauna, including many species of conservation interest (Rosenthal et al., 2012). Low intensity grazing, together with scattered, often old trees, makes many wood-pastures regional hotspots of biodiversity (Bugalho et al., 2011).

Wood-pastures have received increasing scientific attention throughout Europe in recent years. Studies on the biodiversity of wood-pastures and the ecological value of old trees have been conducted in the Czech Republic (Horák and Rebl, 2013; Vojta and Drhovská, 2012), Portugal (Gonçalves et al., 2012) Romania (Moga et al., 2009; Dorresteijn et al., 2013) and Sweden (Paltto et al., 2011; Widerberg et al., 2012). Vegetation dynamics and landscape change related to management regimes are available, for example, from the Swiss Jura Mountains (Buttler et al., 2009), the Italian Alps (Garbarino et al., 2011), Belgium (Uytvanck et al., 2008), the Netherlands (Smit and Ruifrok, 2011; Smit and Verwikmeren, 2011), Spain (Plieninger and Schaar, 2008) and Sweden (Brunet et al., 2011). Studies exploring the recruitment of trees in wood-pastures are available from Spain (Plieninger, 2007); and research about the vegetation structure and conservation status of wood-pastures is available from Romania (Öllerer, 2012, 2013), Turkey (Ugurlu et al., 2012) and Greece (Chaideftou et al., 2011). Finally, the crucial importance of low intensity human use for the maintenance of biodiversity and ecosystem services in Mediterranean wood-pastures and their provisioning ecosystem services was reported by Bugalho et al. (2011).

Existing studies highlight that wood-pastures have been undergoing major changes in the past few decades. These changes threaten the existence of wood-pastures and are mostly driven by changing landuse (e.g. land abandonment and changing farming practices), policies, changing attitudes toward old trees, and lack of tree regeneration (reviewed in Bergmeier et al., 2010).

While until recently Britain was considered as one of the main locations in Europe for large (veteran) trees in wood-pastures (Rackham, 1998; Mountford and Peterken, 2003), information from Central and Eastern European (CEE) countries about ancient wood-pastures is scarce. Some national level evaluations exist for example in Hungary (e.g. Haraszthy et al., 1997), suggesting that wood-pastures are among the most threatened ecosystems in this country.

Here, we present research on wood-pastures in a traditional rural region of Central Romania. Our study had three aims: (i) to compare the structure of tree communities and tree sizes between forests and wood-pastures, (ii) to describe the main characteristics and current management of wood-pastures and (iii) to model wood-pasture condition using a number of site, landscape and management related variables. Although our study has a regional focus and is partly descriptive in nature, we discuss our findings broadly in the context of international wood-pasture conservation. Drawing on our findings, we argue that some Eastern European wood-pastures have particularly high, but largely unrecognised, conservation values.

2. Methods

2.1. Study area

The study was conducted in Southern Transylvania, Romania and covered *ca* 3600 km^2, of which *ca* 860 km^2 were covered by Natura 2000 regulations (Site of Community Importance, hereafter SCI) (Fig. 1). The region is dominated by traditional land use practices and has low levels of infrastructure development. The most important landcover types based on CORINE landcover classes (see Table 1 for reference) are forest (*ca.* 30%), pasture (*ca.* 26%), heterogeneous agricultural areas (including agro-forestry areas) (*ca.* 15%) and arable fields (*ca.* 14%). The urban area cover is low (*ca.* 3%). Other minor land covers include wetlands and vineyards. The climate in the region is continental and moderate. Annual temperature averages 8.2 °C, with an average temperature of −4.3 °C in January and 18.6 °C in July. The yearly mean amount of precipitation is between 650 and 700 mm (Hartel and Moga, 2010).

2.2. Field methods and variables

Data were collected in 2012. Forty-two wood-pastures and 15 forest sites were studied (see Appendices 1 and 2 in Supplementary material). We sampled a larger number of wood-pastures than forests because forests are relatively homogenous, whereas wood-pastures differ substantially in structural elements and adjacent forest cover. Furthermore, we were especially interested in the description of wood-pastures and thus chose more sites to comprehensively cover existing gradients within wood-pastures.

We used five groups of variables to characterize wood-pastures: condition variables (tree density per ha, number of scattered trees per ha, proportion of dead trees per, tee size, scrub cover and woody vegetation cover), composition variables (prevalence of oak, hornbeam, beech and pear), site (area, elevation and ruggedness) and landscape (forest cover and distance to nearest village) related variables and management (evidence for scrub cleaning related to Agency for Payments and Intervention in Agriculture (hereafter APIA), livestock and burning) related variables. Descriptions of these variables and their units of measurement and sources (for data other than field data) are summarized in Table 1. The tree diameter at breast height (DBH) was calculated from the circumference, which we measured with a tape for standing trees. Tree measurements were made in February–March (2012) in the following way: (1) all trees in wood-pastures were measured within a radius of 80 m around a central survey point (i.e. within a 2 ha site). In forest sites, 50 trees were selected randomly in a spiral from the centre of the site to the edge of the 2 ha, to obtain a representative sample of trees. (2) Additional trees were measured within four strip transects of *ca.* 10 m width between 80 m and 300 m from the central survey point in the four cardinal directions (N, S, E, W). In the case that three or fewer trees were found within the wood-pasture transects we measured up to five trees close to the transect. The resulting data provided indications of the diameter distribution within 2 ha around a central point and in the immediate surroundings. We used the DBH of trees as a proxy for their age categorization and conservation value (i.e. 'truly ancient', 'ancient', 'of conservation value', and 'potentially interesting', following Read (2000) and Farm Environment Plan Guide (2006)). We also recorded if the measured trees were burned (i.e. the tree showed signs of fire but was alive), dead (for standing dead trees), healthy (no visible injury on the trunk of the tree) and injured (when the trunk was injured by cutting – coppicing and pollarding were not considered as injuries).

Tree density within 2 ha was assessed in wood-pastures as the count of all trees within 80 m of the central survey point. All dead trees from the two hectare sites were counted, both in wood-pastures and forests. Trees were identified to genus level. According to a previous study (Hartel and Moga, 2010), the vast majority of the Oaks in wood-pastures in this region belong to the species *Quercus robur* (90% out of 339 Oaks measured), or to *Q. petraea* and hybrids between the two species. Due to the similarities of the ecology and habit of these two oaks, we believe that considering them together was reasonable and facilitated meaningful comparison with the other dominant tree genera.

Scrub cover was assessed for the entire wood-pasture using 400 m long and 6 m wide transects which were placed subjectively so that they covered all representative locations of the wood-pasture. This assessment was made in the period of May–July.

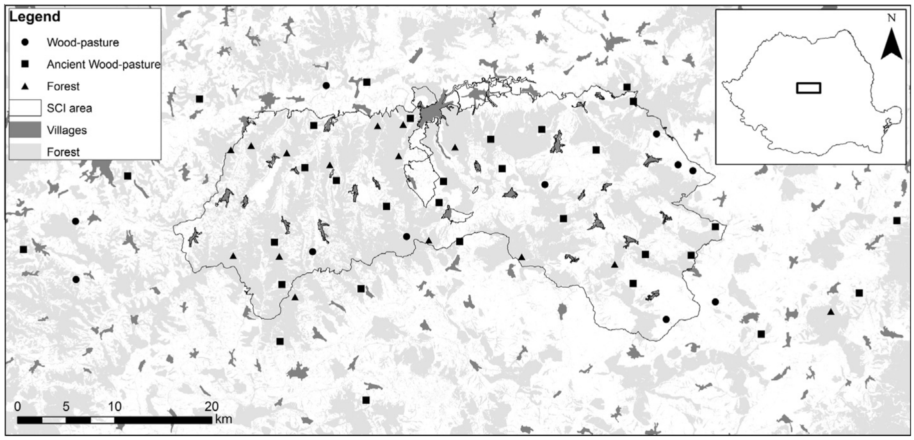

Fig. 1. Map of the study area. All survey sites, including wood-pastures, ancient wood-pastures, and forests are shown. The Natura 2000 site (SCI) is delineated (see study area in Central Romania description).

Table 1
The description of the environmental variables used to characterize wood-pastures from Southern Transylvania and to model wood-pasture condition and composition. Variables highlighted with asterisk are those that were used in statistical models as explanatory or response variables (see section on Analysis).

Variable name	Description
(a) Condition variables	
Tree density per ha	Calculated from the overall number of standing trees (dead and alive) counted in the 2 ha sites
Number of scattered trees	The overall number of scattered trees in the entire wood-pasture based on counts of trees using Google Earth satellite images
Proportion of dead trees (2 ha)*	The percent of dead trees (standing or fallen) in the 2 ha site
Tree size	Diameter at breast height (DBH) in cm of trees higher than 3 m
Scrub cover*	The percent cover of scrub in the wood-pasture. Scrub was defined in our study as vegetation dominated by woody perennials (shrubs and young trees), usually exceeding the height of the grass layer, and being between 0.2 m and *ca* 3 m in height. Characteristic shrub species were: Hawthorn (*Crataegus monogyna*), Blackthorn (*Prunus spinosa*), Blackberry (*Rubus* sp.) and the Dog Rose (*Rosa canina*). The most common young tree was the Hornbeam (*Carpinus betulus*)
Woody vegetation cover	The percent coverage of woody vegetation (trees and shrubs) in the whole wood-pasture. Source: data derived from a supervised classification of the monochromatic channels of SPOT 5 data (©CNES 2007, Distribution Spot Image SA) using a support vector machine algorithm (Knorn et al., 2009)
(b) Composition variables	
Prevalence of Oak, Hornbeam, Beech and Pear*	Defined as the proportion of Oak, Hornbeam, Beech and Pear in relation to the complete number of trees measured in a given site.
(c) Site related variables	
Area	The size of the wood-pasture (ha). Source: satellite imagery and GIS
Elevation*	In meters (m). *Source*: recorded *in situ* with a Global Positioning System
Ruggedness*	The ruggedness of the terrain for the whole wood-pasture and was calculated as the standard deviation of elevation in a 25 m × 25 m grid (Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) Global Digital Elevation Model Version 2 (GDEM V2))
(d) Landscape related context	
Forest cover*	Percentage of forest cover within a 300 m buffer from the edge of wood-pasture based on CORINE Land Cover classes. Source: European Environmental Agency (2011): (http://www.eea.europa.eu/publications/COR0-landcover)
Distance to nearest village*	The Euclidean distance from the centre of the wood-pasture to the edge of the closest village calculated in GIS (in m).
(e) Management related variables	
Scrub cleaning (APIA)*	The presence of scrub clearance. Cut scrub collected in piles was considered evidence for APIA activities at the site
Livestock*	Cattle, sheep, buffalo, horses or a mixture of these. The percent of wood-pastures grazed by each of these livestock was calculated
Burning	Presence of burning in the wood-pasture

The number of transects in each wood-pasture was chosen according to the size of the wood-pasture: two transects were used in wood-pastures with an area of up to 30 ha, three transects in those measuring 30–80 ha, four transects in those of 80–130 ha area, five transects in those of 130–180 ha area, and six in those measuring more than 180 ha. On average there were 3.7 transects per site. In each transect, the percent of scrub cover was assessed visually every 100 m. Scrub cover values were averaged for the entire wood-pasture to obtain a single representative estimate.

Furthermore we recorded the presence/absence of livestock based on direct observation of the animals and/or their feces. Pasture burning was recorded in March–April period (when this activity usually takes place as management intervention to remove excessive biomass from pastures), and the presence of scrub removal was recorded in March–July (Table 1). We further recorded if we observed tree cutting activities in wood-pastures in 2012.

2.3. Analysis

Raw data were summarized using descriptive statistics. Due to the different scaling of the data the Coefficient of Variation (CV) was used as dimensionless measure of variability, allowing a meaningful comparison among different variables. Illustration of tree communities was based on genera composition from forests versus wood-pastures using detrended correspondence analysis (DCA), using the number of stems belonging to different genera.

The DBH of burned and dead trees was compared against that of healthy trees using *t*-tests. Prior to this, DBH data were *log*-transformed to meet assumptions about the distribution of the data. Density of dead trees per hectare was compared between forests and wood-pastures using a *t*-test.

To model indicators of condition and composition we used an information-theoretic model selection approach based on the Akaike information criterion (AIC) to identify models best supported by the data (Burnham and Anderson, 2002). We separately considered six different response variables: the proportion of dead trees and the proportion of scrub cover were variables from the 'condition' group (see above and Table 1). The prevalence of Oak, Hornbeam, Beech and Pear were 'compositional' variables (see above and Table 1). We selected the condition variables as responses because (i) they directly influence the quality of the (wood-) pasture (scrub cover, proportion of dead trees); and (ii) they are highly dynamic variables – both increased after the 1989 Romanian revolution, but since the entry of Romania into the European Union (2007 hereafter EU), financial incentives (i.e. APIA payment, see above) have been used to clean pastures of scrubs. We selected the compositional variables because these tree species were abundant and some of them (e.g. Oak, Pear) historically have a strong cultural importance for local communities (Dorner, 1910). Each response variable (see above) was modelled separately as a function of six explanatory variables from the following categories (detailed in Table 1): 'Site related' (*S*) variables (altitude and ruggedness), 'Management related' (*M*) variables (evidence of sheep grazing or not, evidence of 'APIA' related scrub removal) and 'Landscape related' (*L*) variables (forest cover and distance to nearest village).

We constructed seven candidate models arising from all combinations of the groups of explanatory variables listed above (M, S, L, $M + S$, $M + L$, $S + L$, $M + S + L$). All continuous variables were standardized to an average of zero and a standard deviation of one in order to make the effects comparable. For each model, the AIC value was calculated using correction for small samples sizes (AICc, Burnham and Anderson, 2002). The models were ranked according to their AICc, where the best model has the smallest AICc value. Delta AICc (Δ AICc) was calculated to express the difference between each model and the best model. Akaike weights (w) were used to estimate the relative evidence for each model, which could be interpreted as the probability that the model i was the best model for the observed data, given the candidate set of models.

Table 2
Tree genera identified in the forest and wood-pasture sites. The fourth column shows which species are known to occur in our region for each genus (based on Coldea, 1992). A plus denotes presence, minus denotes absence.

Genus	Forest	Wood-pasture	Species from the region
Acer	+	+	*Acer campestre*
			A. platanoides
			A. pseudoplatanus
			A. tataricum
			A. negundo[c]
Betula	+	+	*Betula pendula*
Carpinus	+	+	*Carpinus betulus*
Fagus	+	+	*Fagus sylvatica*
Fraxinus	+	+	*Fraxinus excelsior*
Juglans	–	+	*Juglans regia*
Larix	+	+	*Larix decidua*[a]
Malus	–	+	*Malus domestica*[b]
			M. sylvestris[b]
Pinus	+	+	*Pinus nigra*[c]
Populus	+	+	*P. sylvestris*[c]
			Populus alba
			P. tremula
Prunus	+	+	*Prunus avium,*
			P. spinosa
			P. cerasifera[b]
			P. domestica[b]
Pyrus	–	+	*Pyrus communis*[b]
			P. pyraster[b]
Quercus	+	+	*Quercus petraea*
			Q. pubescens
			Q. robur
			Q. robur × *Q. petraea*
			Quercus rubra[c]
Robinia	+	+	*Robinia pseudoacacia*[a]
Salix	–	+	*Salix alba*
			S. caprea,
			S. cinerea,
			S. fragilis,
			S. purpurea,
			S. triandra
Tilia	+	+	*Tilia cordata*

[a] Species found in wood-pastures in our region but not recorded in our sampling sites.
[b] These fruit trees are not managed in orchards but occur wildly in the wood-pastures.
[c] Introduced in the region.

3. Results

3.1. Tree community composition in wood-pastures and forests

We measured 6739 trees, including 4870 in forests and 1869 in wood-pastures. Twelve tree genera were found in forests and 14 in wood-pastures (Table 2). Tree communities differed between wood-pastures and forests (Fig. 2). Forest sites were dominated by Hornbeam (*Carpinus betulus*) and Beech (*Fagus sylvatica*), while wood-pastures were dominated by Oak (*Quercus* sp.) (Fig. 2).

Smaller (and presumably younger) trees were better represented in forests than in wood-pastures, while larger (presumably older) trees were better represented in wood-pastures (Fig. 3). Wood-pastures contained more ancient trees and more trees of conservation value, while only two individuals of such trees were found in forests (Table 3). Dead trees were observed in every forest site but 64% of wood-pastures contained no dead trees. The average number of dead trees per hectare for the remaining wood-pastures was 2 (min–max: 1–6) while forest sites contained on average 7 (min–max: 1–16) dead trees per hectare, this difference being significant (t-test, $P < 0.05$).

3.2. The characteristics and current management of wood-pastures

The 42 wood-pastures covered a total area of 42.21 km^2. Descriptive statistics describing wood-pastures are presented in Table 4. Sixty percent of wood-pastures were grazed only by sheep, 21% only by cattle and 14% were grazed by a mixture of livestock (i.e. cattle, sheep, buffalo) (Table 4). Evidence for scrub removal (APIA) was found in 88% of wood-pastures (Table 4). Management by burning in 2012 was observed in 50% of the wood-pastures (Table 4). Comparison of the size of burned versus unburned trees was possible only for Oak and Hornbeam due to insufficient sample sizes for other species. Burned Oaks (mean DBH = 123.93, SD = 39.99, $n = 76$) and dead Oaks (mean DBH = 123.28, SD = 48.73, $n = 13$) were significantly larger than healthy Oaks (mean DBH = 83.56, SD = 32.59, $n = 1014$) (t-tests, $P < 0.001$ and $P < 0.05$ respectively; 10 trees injured by humans and struck by lightning were not included). Burned Hornbeams (mean DBH = 70.95, SD = 28,51, $n = 10$) were larger than unburned Hornbeams (mean DBH = 53.03, SD = 26.03, $n = 243$ two dead trees were not included) (t-test, $P < 0.05$). Across all wood-pastures sampled (though not necessarily within our survey sites), we observed that more than 40 ancient Oaks (*sensu* Farm Environment Plan Guide, 2006) collapsed following uncontrolled pasture fires in 2012. In 2012 we recorded tree (Oak and Hornbeam) cutting activities in

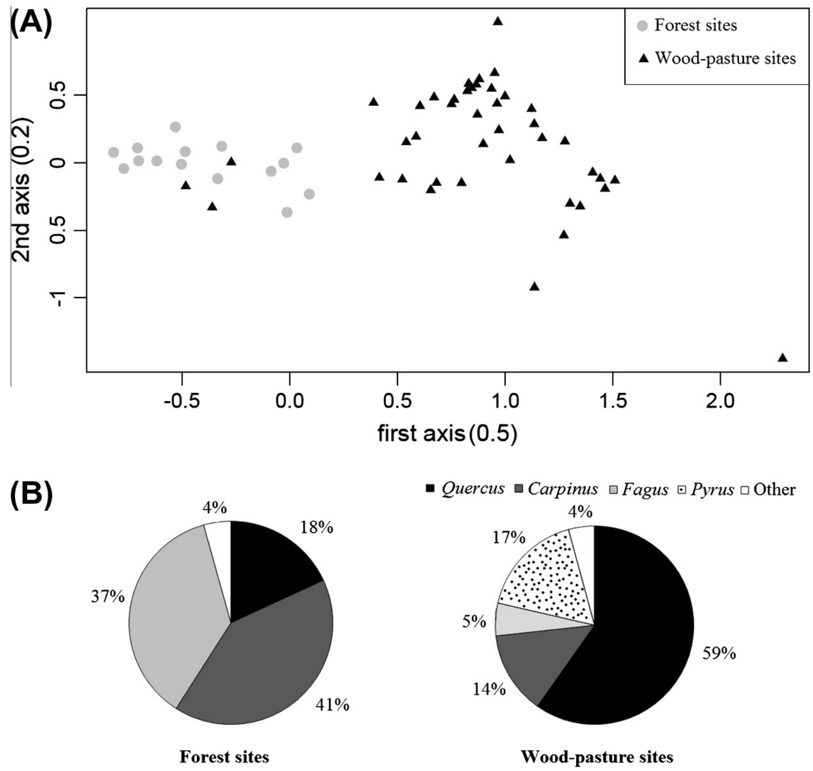

Fig. 2. Tree community composition in forests versus wood-pastures. (A) Illustration of tree communities based on genera composition from forests versus wood-pastures using detrended correspondence analysis. Eigenvalues are given in brackets for each axis. The length of first axis is 3.1 and that of the second axis is 1.7. (B) Percentage of the most common tree genera found in forests and wood-pastures.

five wood-pastures, two of them being ancient (*sensu* Farm Environment Plan Guide, 2006).

3.3. Models of wood-pasture condition and composition

For condition-related response variables, the models best supported by the data contained either management variables (*M*; scrub cover) or variables describing the landscape context (*L*; proportion of dead trees) (Table 5). For the prevalence of particular genera, the best models always included all three groups of variables ($M + S + L$) (Table 5). GLM analysis showed that the proportion of dead trees was positively related to surrounding forest cover (Table 6). Moreover the prevalence of Oak, Hornbeam and Beech was positively and the prevalence of Pear was negatively associated with forest cover (Table 6). Oak prevalence was negatively and Beech prevalence was positively related to ruggedness (Table 6). Distance to the nearest village was related negatively to the prevalence of Pear and positively to the prevalence of Beech (Table 6). Oak prevalence was negatively and Pear prevalence was positively associated with elevation (Table 6).

4. Discussion

In this paper we showed that forests and wood-pastures differed with respect to their tree community structure, typical tree sizes and the prevalence of dead trees. We also showed that sheep grazing dominated wood-pastures while the other livestock (cattle, horse and buffalo) were scarcely used. Burning as a management tool was widely applied, and large trees appeared to be particularly affected by this. Scrub clearance induced by the EU level financial incentives was applied in most wood-pastures. Finally, the prevalence of different species and of dead trees in wood-pastures was related to management, site and landscape related variables.

4.1. Wood-pastures versus forests

While wood-pastures were dominated by Oak and fruit trees (mostly Pear), forests had a more balanced proportion of Beech, Oak and Hornbeam. Differences between the tree communities of forests and wood-pastures can be explained the ecology of the trees (Vera, 2000), natural prerequisites and the traditional preferences of local people for Oak and fruit trees. The potential primary vegetation in the study region is represented by mixed Oak and Hornbeam, and mixed Beech and Hornbeam forests. Mixed Oak and Hornbeam forests (*Quercus petraea*, *Q. robur*, *C. betulus*) were found on shaded and semi shaded hills while mixed Beech and Hornbeam forests (*F. sylvatica*, *C. betulus*), have a more zonal distribution on valley slopes (Coldea, 1992). Historical information suggests that many wood-pastures from Southern Transylvania originate from forest grazing and selective tree removal from forests (Teşculă and Goţa, 2007; Hartel and Moga, 2010). Transylvanian Saxons traditionally valued Oak not only for timber production but also (and especially) for the acorns, which were eaten by domestic pigs and sometimes sheep (Dorner, 1910; Oroszi, 2004). The importance of grazing for wood-pasture formation and their maintenance is well known for other European wood-pastures (Mountford and Peterken, 2003).

Our results highlight that the largest trees in Southern Transylvania occurred in wood-pastures: the majority of the surveyed wood-pastures contained ancient Oaks while forest sites contained virtually no such trees. Within the same bioclimatic conditions large trees of a given species are typically older than smaller ones (Gibbons and Lindenmayer, 2003; Holzwarth et al., 2013), and hence the relative proportion of young trees appeared to be higher in forests than in wood-pastures. Age estimations for Oaks from the "Breite" ancient wood-pasture (situated close to the centre of the study region) suggest that a tree with a DBH of $\geqslant 100$ cm

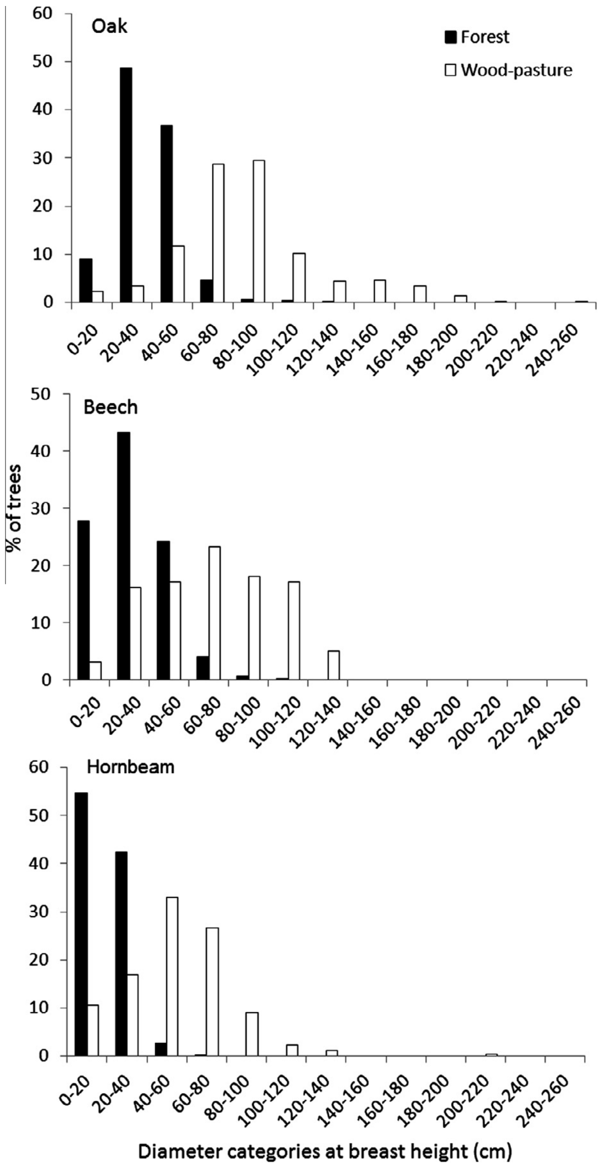

Fig. 3. The percent representation of the tree size categories in forests and wood-pastures. Only Oak, Hornbeam and Beech are shown because these were the most common trees present in both forests and wood-pastures.

may be at least 200 years old, and the largest Oaks may be up to 700–800 years old (Hartel and Moga, 2010; Pătruţ, 2011). The main reason for these size (and age) differences could be the long term management of forests and wood-pastures. In our region trees were maintained on pastures mostly to provide shade for livestock and for their fruit (*TH, unpublished results of 110 semi structured interviews in Southern Transylvania*). Timber extraction occurred also in wood-pastures, but it was done mainly by pollarding (i.e. cutting branches while maintaining the trunk) (Rackham, 1980; Hartel and Moga, 2010). This allowed trees to grow and eventually to become large (old). By contrast, forests were traditionally managed for timber production (see Oroszi, 2004 for an overview of forest management by Transylvanian Saxons), and the economic value (in a monetary sense) of trees was and still is important in determining management actions. Old trees were and are removed from forests because their economic value is decreasing as the amount of dead elements and hollows increase with age. Assuring sustainability of the forests by regeneration (naturally 'from seed' or by replanting the cleared parcels) was important both traditionally (Oroszi, 2004) and continues to be common practice nowadays (Codul Silvic (Forest Code of Romania), Law 46/2008). However, no mechanisms to re-plant trees (or otherwise support their regeneration) occur in the vast majority of wood-pastures.

4.2. Management of wood-pastures

Sixty percent of wood-pastures surveyed in 2012 were grazed only by sheep and 14% by a mixture of livestock (Table 4). This is in sharp contrast with traditional grazing systems: Saxons preferred cattle, horses, buffalo and pigs, and typically each of these had its own pastures with specific management practices around a given village (Dorner, 1910, and also Heinlein et al., 2005 for selected areas of Bavaria, Germany). Pig grazing stopped in the late 1940s and 1950s, and the number of buffalo dropped after the Romanian revolution in 1989, partly because of mass emigration of Saxons and partly for economic reasons. Cattle grazing also declined sharply in many wood-pastures after 1989 (although less so than for buffalo), and the number of sheep is now higher than ever before in the Saxon region of Transylvania (*TH, unpublished results of 110 semi structured interviews in Southern Transylvania*). Changes to the traditional grazing systems also have been reported from many European wood-pastures throughout Europe (Bergmeier et al., 2010) (e.g. the Swiss and Italian Alps – Chételat et al., 2013; Garbarino et al., 2011; Portugal – Costa et al., 2011; Spain – Plieninger and Schaar, 2008).

Half of the wood-pastures were burned in 2012, and large trees (Oak and Hornbeam) appeared to be most likely to be permanently damaged from this. Fire has been used as a method for pasture clearing in the region since the 16th century (Dorner, 1910). However, uncontrolled pasture burning appears to have increased in recent years, even in protected areas, despite being illegal (*TH, personal observation*).

Table 3
The number of ancient trees and trees of conservation value found in the wood-pastures (n = 42) and forests (n = 15). The most common tree genera are presented. Numbers in brackets are sites (i.e. wood-pastures) where trees from that category were observed.

	Truly ancient[a] (DBH ⩾ 2 m)	Conservation value[a] (DBH ⩾ 1.5 m)	Potentially interesting[a] (DBH ⩾ 1 m)	Ancient[b]
Wood-pastures				
Oak (n = 1113)	3 (2)	73 (11)	175 (32)	251 (32)
Hornbeam (n = 255)	1 (1)	0	9 (4)	37 (16)
Beech (n = 100)	0	0	23 (8)	0
Forests				
Oak (n = 883)	0	0	1	1
Hornbeam (n = 1994)	0	0	0	1
Beech (n = 1782)	0	0	0	0

[a] Read (2000).
[b] Farm Environment Plan Guide (2006): DBH ⩾ 75 cm for Hornbeam, ⩾100 cm for Oak, ⩾150 cm for Beech.

Table 4
Descriptive statistics for variables used to characterize the wood-pastures. CV = coefficient of variation.

Variable	Mean	SD	CV
Condition variables			
Tree density	7.60	4.80	0.63
Proportion of dead trees	0.06	0.10	1.72
Tree size (mean of the medians)	74.25	23.11	0.31
Scrub cover	0.06	0.12	1.90
Number of scattered trees	260.64	230.44	0.88
Woody vegetation cover	0.19	0.14	0.73
Site related variables			
Area	100.50	90.97	0.90
Elevation	543.65	68.21	0.12
Ruggedness	62.75	14.54	0.29
Landscape context			
Forest cover	61	0.23	0.37
Distance to nearest village	1225.17	804.17	0.65
Management related variables			
Scrub cleaning	Observed in 88% of wood-pastures		
Livestock	Cattle: 21%, Buffalo: 7% (always mixed with other livestock), *Sheep*: *60%*, Mixed: 14.28. No grazing: 5%		
Burning	50%		

Table 5
Model selection results for response variables describing different aspects of wood-pasture condition and composition. The best ranked models ($\Delta i \leqslant 2$) are shown. Log(L) = maximised log-likelihood, K = number of estimable parameters, ΔI = difference in AICc compared with the model with the lowest AICc, wi = Akaike weights; S = site variables, M = management variables, L = landscape variables. Variables are defined in the Methods section.

Response variables	Model	Log (L)	K	AICc	Δi	wi
Proportion of dead trees	L	−71.14	4	151.37	0.00	0.60
Scrub cover	M	38.53	4	−67.98	0.00	0.54
Oak prevalence	$M+S+L$	−254.81	7	526.92	0.00	0.66
	$S+L$	−258.34	5	528.36	1.43	0.32
Beech prevalence	$M+S+L$	−114.72	7	246.47	0.00	0.99
Hornbeam prevalence	$M+S+L$	−173.62	7	364.54	0.00	0.98
Pear prevalence	$M+S+L$	−169.81	7	356.92	0.00	1.00

4.3. Wood-pasture condition

Our model selection approach showed that the prevalence of Oak, Beech, Hornbeam and Pear trees in wood-pastures was best explained by models containing management, site and landscape related variables. Oak dominated in wood-pastures with low terrain ruggedness while Beech dominated in areas with high ruggedness. This result can be explained partly by the ecology of these species (see above) and partly by human influence. For example, it is possible that Oak was retained in flatter terrain where accessibility for livestock was high and which contained wet areas often preferred by these animals (especially cattle, domestic pigs and buffalo). Fruit trees (especially Pear) dominated in wood-pastures close to villages (suggesting that accessibility for people was important in creating them) with little forest cover in their surroundings. By contrast, forest cover was an important positive predictor for the abundance of all three forest tree species. A likely explanation is that many, if not most, thinning existing forests created wood-pastures in our region. The Pear prelevance was positively associated with the elevation; this is most likely a result of the slight increase of the average elevation toward the Eastern part of the region, where this tree is more abundant. Our result regarding the significant relationship found between the management related variables and prevalence of different tree genera (Table 5) is not straightforward: the relationship is likely caused by the fact that local conditions shaped human activity (this being recorded in 2012) and not the other way round. For example, it is possible that wood-pastures where beech and hornbeam dominated were less attractive for grazing, possibly because of steeper slopes or higher woody vegetation density. The grazing system in our region is undergoing rapid changes, and therefore this relationship is likely to change in the future.

The percentage of dead trees was significantly related to forest cover around the wood-pasture. Wood-pastures surrounded by forests may be less accessible for people than the wood-pastures from open landscapes. Traditional rural communities from this region carefully cleared the pastures of dead wood and scrub to maintain pasture quality (Dorner, 1910, *TH, unpublished results of 110 semi structured interviews in Southern Transylvania*). Based on this, it is reasonable to assume that wood-pastures in traditional societies contained dead wood only accidentally and if the scrub was present, it was deliberately maintained (e.g. as occasional firewood or as source of fruits). It is possible that the increase of the dead wood on pastures is the result of the abandonment of

Table 6
The relationship between the response variables (first column) and the explanatory variables, separately tested using GLMs.

	Livestock type	APIA clearing	Altitude	Ruggedness	Forest cover	Village distance
Proportion of dead trees	NS	NS	NS	NS	0.47 (0.21)*	NS
Scrub cover	NS	NS	NS	NS	NS	NS
Oak prevalence	NS	−0.50 (0.19)	−0.19 (0.06)*	−0.45 (0.06)**	0.23 (0.06)***	NS
Hornbeam prevalence	−0.92 (0.16)***	0.66 (0.23)**	NS	0.24 (0.06)***	0.67 (0.09)***	NS
Beech prevalence	−1.26 (0.26)***	1.61 (0.53)**	NS	0.56 (0.08)***	0.66 (0.16)***	0.30 (0.13)*
Pear prevalence	0.56 (0.16)***	0.70 (0.28)*	0.39 (0.07)***	NS	−0.61 (0.08)***	−0.17 (0.08)*

NS = non-significant.
* $P \leqslant 0.05$.
** $P < 0.01$.
*** $P < 0.001$.

pastures, which was very pronounced after the 1989 Romanian revolution. As the continuation of use of pastures and hay meadows is promoted by EU agro-environment incentives, it is likely that abundance of dead wood will decline again in the future in most of wood-pastures from this region.

4.4. The biodiversity of the "Breite" ancient wood-pasture

In the context of wood-pasture conservation, it is important to note that some wood-pastures in our study area have been shown to support a very rich diversity of plants and animals. A wide range of studies have been conducted on one of the wood-pastures also surveyed by us for this paper, namely the "Breite" wood-pasture, situated near the centre of our study area, near the town Sighişoara. The Breite measures 133 ha and is completely surrounded by deciduous forest. It is dominated by Oaks (mostly *Q. robur*), many of which are over 200 years old (Pătruţ, 2011). Overall, 476 species of vascular plants (Öllerer, 2012), 121 species of macromycetes (from which over 50 species were found on ancient Oaks – Bucşa, 2007; Bucşa and Tăuşan, 2010), 281 species of Lepidoptera, 40 species of xylophagous beetles (i.e. insects to which wood represents the primary diet), eight species of amphibians, four species of reptiles, 27 species of nesting birds and 38 species of mammals (including Gray Wolf (*Canis lupus* and Brown Brear *Ursus arctos*) have been identified in this wood-pasture (synthesized in Hartel and Moga, 2010; Hartel et al., 2011). The overall number of species considered rare or protected at national (e.g. Red List) and international (e.g. IUCN, Habitats and Birds Directives) level exceeds 50.

5. Conclusions and conservation implications

We showed that there were differences between the tree communities in wood-pastures and forests. Ancient trees were found only in wood-pastures, and most of the surveyed wood-pastures contained ancient trees. Historical and current management, traditional preferences of local people, and natural environmental gradients are likely explanations for these differences. Fire appears to be regularly used in pasture management, but our data suggest that uncontrolled fires can negatively affect (or even kill) trees, especially large ones. Further, our data, in combination with historical records, suggest that major changes are underway regarding patterns of livestock grazing in Southern Transylvania, implying that the management of wood-pastures is shifting from traditional practices. Demographic and economic factors are the likely drivers of these recent shifts. Data from one of the wood-pastures in the centre of our study area suggest that the presence of scattered, old trees, in combination with dead trees, scrub and extensively managed grassland, results in a high biodiversity, with species rich communities of woodland and grassland related organisms. To maintain the ecological value of wood-pastures, at least some of the dead trees and scrub need to be maintained – although this runs counter to both traditional practices and current policy incentives. Wood-pastures are currently managed as pastures (or occasionally as hay meadows) and are formally recognized as such at the national level (Romanian Law No. 214/2011). While tree cutting from wood-pastures without a formal institutional agreement is illegal in Romania (Law 214/2011), there is no legal framework that specifically targets the maintenance and regeneration of wood-pastures and the conservation of old (including ancient and veteran) trees. With very few exceptions, wood-pastures are not recognized in the nature conservation policies of the EU and are not protected as distinct landcover types with special management history, ecological and cultural value. Therefore their maintenance as such is not promoted at policy level. Our study shows that ancient wood-pastures are common in our region, and we suggest that they also may be common in other CEE countries. We urge for more wood-pasture inventories and research in other parts of CEE, to develop the knowledge base that is needed for their formal recognition and legal protection.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.biocon.2013.06.020. These data include Google maps of the most important areas described in this article.

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