# No country for old trees?

*The future of European wood-pastures*

Doctoral thesis by Marlene Roellig

# No country for old trees?

## *The future of European wood-pastures*

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# Preface

This dissertation is presented as a series of manuscripts and book chapters. The manuscripts are based on empirical research carried out in different regions of Europe. Chapter I provides a general overview of the dissertation. This chapter includes the overarching goal and specific research questions, a summary of all included manuscripts and book chapters, a synthesis of the results in relation to the specific research question and policy recommendations, and highlights pathways for a sustainable future of wood-pastures in Europe. All manuscripts are either published or in revision in international peer reviewed scientific journals. The book chapters have been published (under peer review) in a scientific book.

A reference to the journal each manuscript is submitted to and the contributing co-authors are presented on the title page of each chapter. The chapters are designed to be stand-alone articles; therefore stylistic differences (e.g. U.K or American spelling) and some repetition are possible among the chapters. The content of each chapter is the same as in the published journal article or book chapter with figure and table legends adapted to this dissertation. The style used for citing literature, in the text and for the references at the end of each chapter, represents the formatting requirements of the respective journal or book.

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# Chapter 1

# Chapter 1

## European wood-pastures in a changing world: Status, structure, management & policies

*Marlene Roellig*






## Introduction

Wood-pastures have been present in Europe for thousands of years. This form of grazed landscape, combining herbaceous vegetation with trees and shrubs, has often co-evolved with its human users into complex social-ecological systems (SES). Wood-pastures are associated with high cultural and biodiversity values and are an example of the sustainable use of resources. However, due to their often relatively labour-intensive management and low productivity, large areas of wood-pastures have been lost over the last century. The loss of these areas means not only the loss of biodiversity on both local and landscape scales, but also the loss of traditional farming and cultural heritage in some regions. Across the European Union, wood-pastures are facing different problems and are embedded in different social systems and ecological environments. Yet they are all affected by global change and common European policies. To understand the challenges for wood-pastures in a changing world, a holistic approach combining different disciplines is needed. Therefore, in this dissertation I analyze wood-pastures across Europe as a SES, combining ecology and social science with the aim to identify the barriers and drivers for wood-pastures persistence into the future.

*Human impact on the environment*

Human activity has shaped the natural environment for thousands of years (Smith 2007). Human impacts on the environment can range from hunting-gathering activities to the modification of entire ecosystems, mainly through agriculture (Foley et al. 2005). There are now only few landscapes on earth that are not influenced by human interactions with nature (Bignal and McCracken 2000). Human activities have negatively influenced ecosystems and biodiversity, especially in the last 200 years, due to population growth but also due to new technologies. Especially in the last 50 years, humans have changed the structure of many ecosystem more rapidly than at any other time (Steffen et al. 2007; Vihervaara et al. 2010). Therefore human action can be considered as the main driver of global change (Plieninger and Bieling 2012b), taking us into the geological era of the Anthropocene (Crutzen 2002; Steffen et al. 2011). Nowadays, about one third of primary production is appropriated by humans and more than four-fifths of the earth's land area is human dominated (Plieninger and Bieling 2012b). Consequences of this impact are the loss of ecosystems, biodiversity and ecosystem services all over the world (Pereira et al. 2012). The overall harmful consequences of humanity's influence on global ecosystems in the past decades are beyond doubt. However, there are relatively large areas of Europe that still contain agricultural systems that have not become divorced from their roots in nature —systems that have developed management practices that exploit, but do not over-exploit, natural resources (Bignal and McCracken 2000).

*Cultural landscapes*

Land use systems and practices have shaped highly-valued cultural landscapes all over the world that effectively integrate ecological, economic and cultural needs (Fischer et al. 2012; Plieninger and Bieling 2012b). Such cultural landscapes can allow sustainable use of natural resources, serving as wildlife habitats, providing economic benefits, scenery and open space and being a source of cultural heritage (Pretty 2011). These cultural landscapes are “at the interface between nature and culture, tangible and intangible heritage, biological and cultural diversity” (Schaich et al. 2010). Following Horcea-Milcu et al. (2017), cultural landscapes are “geographic areas where humans and the environment have gradually co-evolved through a variety of land uses over long periods of time” (see also Plieninger et al., 2006). As such, they are increasingly being recognized as worthy of protection not only for their conservation value, but also for providing cultural and ecological services and fostering food security, traditional knowledge and sociocultural values (Plieninger and Bieling 2012b; Horcea-Milcu et al. 2017).

The first cultural landscapes also recognized by the World Cultural Heritage List was the Tongariro National Park in New Zealand, being of cultural and religious significance for the Maori people and symbolizing the spiritual links between the people and their environment (Rössler 2007). More examples of cultural landscapes from across the world were summarized by Fischer et al. (2012): from the Satoyama landscapes in Japan (Takeuchi 2010), to the Western Ghats of India (Ranganathan et al. 2008), the Milpa cultivation systems in Mexico (Robson and Berkes 2011), agroforestry systems in sub-Saharan Africa (McNeely and Schroth 2006), and traditional village systems in parts of Eastern Europe (Palang et al. 2006; Horcea-Milcu et al. 2017).

Despite their cultural and ecological importance, cultural landscapes are under pressure from recent change due to globalization, agricultural expansion, and intensification, land abandonment and urbanization leading to a worldwide decline of these multifunctional landscapes (Fischer et al. 2012; Plieninger and Bieling 2012b).

*Wood-pastures*

Wood-pastures are important elements of cultural landscapes (Bergmeier et al. 2010). Wood-pastures or silvopastoral systems can be found all over the world (Manning et al. 2006; Gibbons et al. 2008; Lindenmayer et al. 2014), for example in Australia (Fischer et al. 2010) or California (Lathrop et al. 1991) as well as in different parts of Europe (Bergmeier et al. 2010). All these systems have in common the combination of permanent pastureland and scattered trees and/or shrubs, often with large old trees functioning as keystone structures and forming ecotones (Bergmeier et al. 2010; Lindenmayer et al. 2014). Through their long history of use, societies have gained not only material benefits (animal and timber products) from wood-pastures, but in many cases have built up complex cultural uses, e.g. as locations for social events or as the basis for resource sharing systems. Due to their specific structure they harbour high biodiversity on local and landscape scales, including many threatened species (Bergmeier et al. 2010; Garbarino and Bergmeier 2014; Hartel et al. 2014). Moreover, wood-pastures can contribute to landscape connectivity (Fischer and Lindenmayer 2002) and adaptation to climate change (Manning et al. 2006; Manning et al. 2009). Despite these common elements, wood-pastures, even within a single region, can differ greatly in their structure, species composition as well in their historical origin.

*Wood-pastures in Europe*

In Europe, wood-pastures evolved thousands of years ago under management according to the needs of humans (Bergmeier et al. 2010; Hartel and Plieninger 2014; Jørgensen and Quelch 2014; Plieninger et al. 2015). Since their origin in Europe in the early Holocene (Mosquera-Losada et al. 2009; Bergmeier et al. 2010; Jørgensen and Quelch 2014), they have developed as multifunctional resources, shaped by local social, economic and environmental factors, grazing intensity, and type of livestock (Chételat et al. 2013; Huber et al. 2013; Hartel and Plieninger 2014). The usually multifunctional management involved typically livestock grazing but also the management of the woody component by extracting goods and services provided by the trees and shrubs (Bergmeier et al. 2010). The type of livestock, the grazing intensity as well as the tree management in wood-pasture could vary not only over geographical regions, but also over time (Hartel and Plieninger 2014). Tree and grazing management were influenced not only by the environmental factors and local needs of humans, but also by external shocks during history (e.g. regime shifts or newly introduced laws). The variations in management as well as geographical conditions created a huge variety of wood-pastures across Europe (Hartel and Plieninger 2014). In contemporary Europe, Bergmeier et al. 2010 identify 13 types of wood-pasture based on a geobotanical classification as well as on regional identifications of these wood-pastures (based on regional names and local management). Figure 1 shows several examples of wood-pastures across Europe.

All types of wood-pastures depend on active management to maintain their semi-open character (Bergmeier et al. 2010; Garbarino and Bergmeier 2014; Hartel and Plieninger 2014; Van Uytvanck and Verheyen 2014). If the management of the wood component is the focus and grazing activities stop, wood-pastures would turn into a forest due to their usually high regeneration potential (Plieninger et al. 2003; Plieninger et al. 2004; Manning et al. 2006; Manning et al. 2009; Hartel and Plieninger 2014). Long-term overgrazing and a neglect of the woody component on the other hand, lead to what Plieninger 2003 calls a treeless pseudo steppe. The grass and tree management of wood-pastures has diverse interdependencies as summarized in a figure by Hartel and Plieninger, (2014) (Fig. 2).

Figure 1: Examples of different wood-pastures in Europe a) from southern Portugal, b) from Western Estonia, c) from Central Germany, d) from Central Romania, e) from Southern England and f) from Southern Sweden.
Note: These pictures do not necessarily show a typical wood-pasture for a region, but give an overview of the variety.

*Source all pictures: Marlene Roellig*

As semi-open landscapes, wood-pastures mimic the ecological conditions in the naturally sparsely wooded areas that are thought to have existed in Europe before human colonization, caused by drought (e.g. forest steppe), flooding or other disturbances in combination with herbivore pressure (Rackham 1998; Vera 2000). Due to their high density of ecotones, wood-pastures support a wide variety of both open habitat and forest species, including several endangered plant and animal species (Bergmeier et al. 2010; Garbarino and Bergmeier 2014; Hartel et al. 2014). Especially species dependent on dead wood need the large old trees, as well as hollow-nesting bird species (Dorresteijn et al. 2013; Horak et al. 2014). Also large mammals such as the Iberian lynx and the European brown bear make use of wood-pastures (Bergmeier et al. 2010; Roellig et al. 2014).

Most of these species benefit from or can tolerate the extensive farming practices of wood-pasture management, making wood-pastures a prime example for high nature value farming (HNV) in Europe (Oppermann 2014). The concept of high nature value farmland was developed in Europe to recognize the importance of low-intensity farming for biodiversity. Oppermann (2014) even calls wood-pastures “archetypes” of HNV farming in Europe, supporting a wide range of species due to their active, but low (chemical) input management. They combine several factors of importance for high nature farming, such as being mosaics of site conditions in space and time, and in many cases supporting the management of rare breeds (Oppermann and Paracchini 2012).

Despite their long and widespread existence throughout Europe, there is relatively little information on the spatial distribution of wood-pastures. “Wood-pasture” is not mapped as a habitat type in systems such as CORINE Land Cover, and although regional estimations on their distribution exist (see Glaser and Hauke 2004; Luick 2008; Garbarino and Bergmeier 2014) none provide a comprehensive quantitative survey of all types of wood-pastures in an internationally consistent way. A recent attempt to map wood-pasture across Europe was made by Plieninger et al. (2015) by gathering information three different categories of grassland with trees using the a georeferenced database from the LUCAS project of the European Union. The study estimates the total area of wood-pasture within the EU at around 203,000 km² (4.7% of EU territory) and confirming the highest proportions of wood-pastures in south and east Europe. The real extent of area covered by wood-pastures is still unknown, which is concerning considering that wood-pastures are facing an uncertain future.

Many of the threats to wood-pastures correspond to the threats for cultural landscapes in general. These are mainly land use change due to abandonment or expansion and intensification of agriculture caused by social and economic change (Plieninger and Bieling 2012a; Hartel and Plieninger 2014; Plieninger et al. 2015). These changes affect wood-pastures in different ways. First, land abandonment will lead to shrub encroachment and tree regeneration, while intensification will cause a decline in woody plants or even their complete removal. Such changes in management will lead to a loss of the specific semi-open character of wood-pastures and a loss of small-scale habitat diversity (Finck et al. 2004; Bergmeier et al. 2010). These effects are further compounded by land fragmentation due to urbanisation and road construction (Bergmeier et al. 2010).

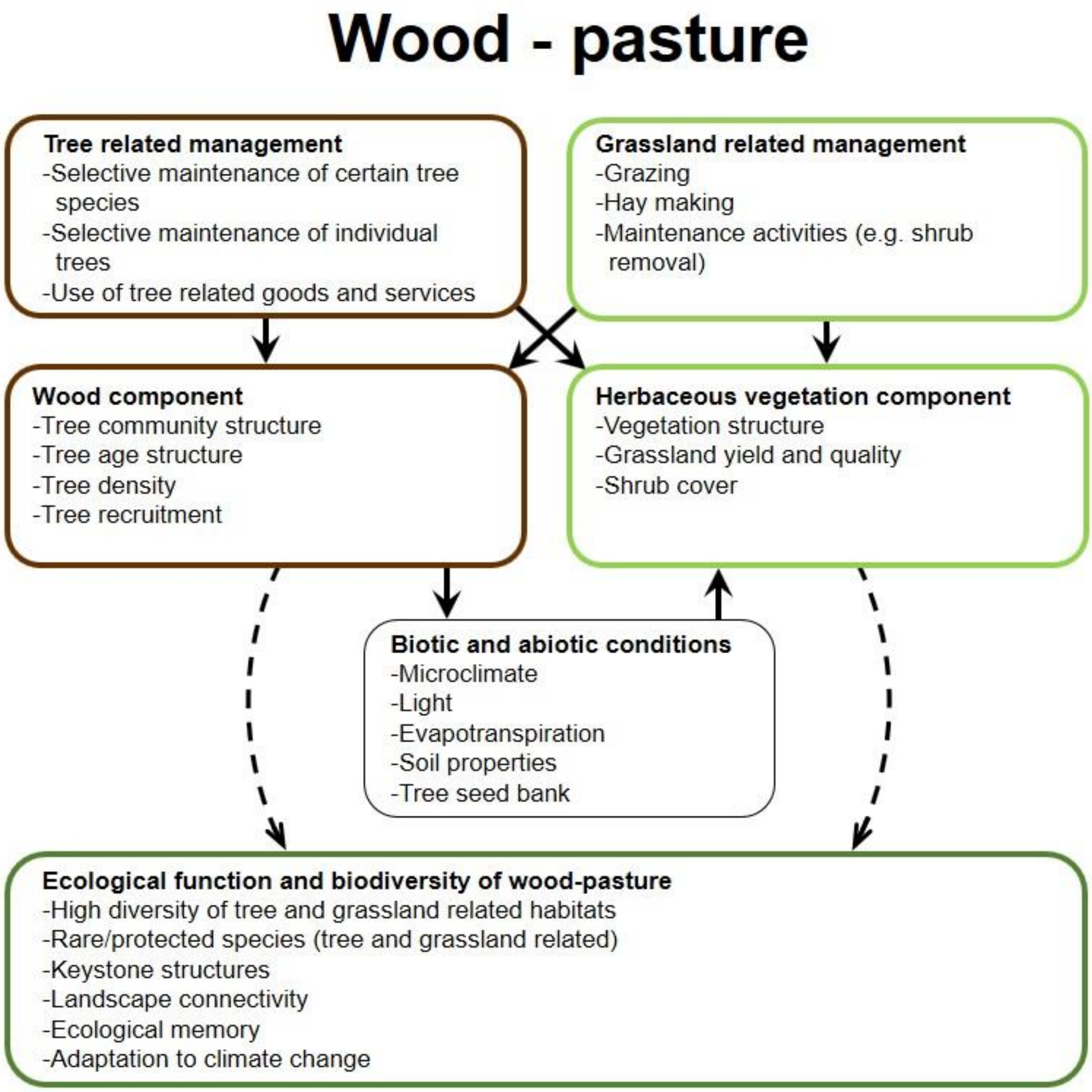


Figure 2: Generalised overview on the management activities interacting with ecological conditions in the creation and maintenance of wood-pasture.

*Source: Modified based on Hartel and Plieninger (2014)*

Being a transitional category of land use between forest and pasture, wood-pastures also receive very little and inconsistent policy support at the European Union (EU) level (Beaufoy et al. 2011; Peeters 2012). In fact, direct payment regulations for pastures from Pillar I of the Common Agricultural Policy (CAP) exclude semi-open habitats with more than 100 trees per ha (Beaufoy 2014; Jakobsson and Lindborg 2015). Concerning nature conservation policy, only four wood-pastures are recognized as distinct types of combinations of pasture and trees by the EU Habitats Directive (5130 *Juniperus communis* formations on heaths or calcareous grasslands, 5210 Arborescent matorral with *Juniperus* spp,, 6310 Dehesas with evergreen oaks, and 9070 Fennoscandian wooded pastures). Other wood-pasture types receive neither formal recognition nor protection at EU level (Bergmeier et al. 2010; Plieninger et al. 2015).

As discussed above, contemporary wood-pastures have often been created through centuries-long interactions between social and ecological systems (see also Huber et al. 2013; Hartel and Plieninger 2014). These underlying mechanism links were often complex and affected by changes in the ecological or social system. Most studies on wood-pasture in the past have been focused on their ecological significance, particularly regarding plant diversity (Bergmeier et al. 2010; Schmucki et al. 2012; Garbarino and Bergmeier 2014; Jakobsson and Lindborg 2015), birds (e.g. Tucker and Evans 1997; Dorresteijn et al. 2013; Hartel et al. 2014; Jakobsson and Lindborg 2017) or insects (e.g. Horák and Rébl 2012; Vojta and Drhovská 2012; Falk 2014; Horak et al. 2014) or their structural development over time(Plieninger et al. 2003; Plieninger et al. 2004; Van Uytvanck and Verheyen 2014; Valipour et al. 2014). Even though several studies in recent years have acknowledged the strong link between the social and the ecological systems of wood-pastures (Huber et al. 2013; Plieninger and Hartel 2014; Plieninger et al. 2015; Moga et al. 2016; Garrido et al. 2017), knowledge about these complex interactions still needs to be improved to better understand the drivers of wood-pasture loss and potential for sustainable development of these systems into the future.

**This dissertation therefore aims to develop a holistic, social-ecological based understanding of wood-pastures across Europe to identify pathways for their sustainable development into the future.**

To achieve this aim, an interdisciplinary approach is needed to understand the interaction between the social and the ecological systems (Berkes and Folke 1998a; Berkes et al. 2003; Folke 2006; Fischer et al. 2012). Therefore in this dissertation, wood-pastures are analyzed through a social-ecological systems lens as proposed by Berkes and Folke (1998a) and adapted and modified by others, including Folke 2006 and Janssen and Ostrom 2006. Social-ecological systems are characterized by their connection between human and nature (Berkes and Folke 1998b; Folke 2006). As Berkes et al. (2003) point out, the ecological system and the social system of socio-ecological systems are not only linked, but the separation between these is systems artificial and arbitrary. Moreover, the social-ecological approach recognizes the tight link between human and nature, considering humans as an integral part of nature (Holling and Gunderson 2002; Berkes et al. 2003; Forbes et al. 2009). This view allows the analysis of numerous complex interactions between the social and the natural system (Milcu 2015). The knowledge about these interactions becomes even more important in periods of change, when human actors in SES need to navigate uncertainties (Holling 2001; Folke 2006; Walker and Salt 2006). The SES concept can also be used synonymously with the terms “coupled human-environment systems” (Turner et al. 2003), “coupled human and natural systems” (Liu et al. 2007) or “human-environment systems” (Vihervaara et al. 2010).

To create an understanding of SES, different variables need to be taken into account describing the ecological system and the social system as well as their subsystems and their interrelations (Anderies et al. 2004; Janssen and Ostrom 2006; Ostrom 2009). For example Ostrom (2009) suggests 4 core subsystems to analyse social-ecological systems: resource systems, resource units, governance systems and users. Each core subsystem consists of multiple second-level variables which are further composed of deeper-level variables (Ostrom 2009).

To describe and explain wood-pastures as a SES in this dissertation, I therefore specifically addressed the following research questions:

1. **What is the current status of European wood-pastures?**
2. **What is the structure of European wood-pastures?**
3. **How does the management influence the structure of wood-pastures?**
4. **How do institutions influence the management of wood-pastures?**

While question 1 mainly addresses the resource system (wood-pastures), questions 2 describes a resource unit within the system (trees). Questions 3 focus on the interaction between the users (farmers) and resource units (trees) and questions 4 addresses the interaction between users (farmers) and the governance system (institutions). Each chapter addresses different second-level variables depending on the specific research questions.

Because wood-pastures in Europe are highly diverse due to the variation in local influences, yet are often affected by common drivers related to global change or EU policies. I therefore use both comparative studies across Europe (chapters 2 and 3) and case studies on local scale (chapters 4, 5 and 6) to describe the status of wood-pastures in Europe. Chapter 2 provides a descriptive overview of wood-pastures across Europe based on existing literature, regarding their history, biodiversity, management as well as theirs threats and different conservations approaches. Chapters 3, 4 and 5 are based on empirical data describing the structure of wood-pastures at a European (chapter 3) and local scale (chapter 4 and 5). Chapter 5 gives insights in the link between the management and structure based on a case study combining ecological (quantitative) and social (qualitative) data. The interactions between institutions and the management of wood-pastures are addressed in chapter 5 based on empirical data and in chapter 6 in a more descriptive way, using a case study of the historical development of the institutions influencing wood-pasture management.

## Summary of chapters

**Chapter 2** gives an overview of wood-pastures in Europe based on the literature to collect existing knowledge about the status of these systems. In this chapter, we outline the geographical variation and functional characteristics of wood-pastures across Europe. Further, we explain their significance for biodiversity conservation, comment on threats to various types of wood-pastures, and address conservation needs and existing conservation approaches at local and European levels.

Grazed wooded landscapes have played a crucial role in the history of the European countryside. From the early Neolithic, wood-pastures have been at the heart of subsistence economies of most rural societies throughout Europe, and they are still locally relevant for the economic integrity of some marginal rural areas. Although the number of wood-pastures has declined significantly over the past century, most countries retain a significant number of these habitats.

Despite sharing the common elements of scattered trees and bushes accompanied by herbaceous vegetation, European wood-pastures exhibit a wide variability of structures and types. In this chapter, we identify 21 different types of wood-pastures based on their geographical distribution, their prevailing trees and natural vegetation, but also their different grazing and tree management. This represents how wood-pastures are not only influenced by biogeography and environmental conditions but also by regional land use history, current management, grazing animals and seasonality of grazing.

Variability at local and regional scale is also one of the main factors contributing to the biodiversity value of wood-pastures, summarized in the second half of the chapter. The semi-open character of wood-pastures contributes to high level of biodiversity on local and on landscape scale, combining species of forest and open landscapes. Although there are no species exclusively linked to wood-pastures, some species may be regionally restricted today to wood-pasture landscapes. Dead wood dependent species such as several insects and birds feeding on these insects, but also those using knotholes and other structures of old and gnarled trees for nesting, are especially related to wood-pastures. In addition, even large mammals such as the Iberian lynx and the European brown bear make use of wood-pastures.

Despite their importance, wood-pastures are threatened throughout Europe. We identified the main threats for wood-pastures discussed in the literature, as well as conservation approaches to maintain them. Among the major threats, we identified forest regrowth due to land abandonment, land-use change and the degradation caused by a reduction in the number of old trees and the lack of regeneration due to overgrazing. Although national or local conservation approaches exist to maintain wood-pastures as important habitats for biodiversity, they are poorly supported by international policies. At the European Union level, wood-pastures are only partially recognised in conservation policies such as the Habitats Directive, while agricultural policy is actively detrimental to the structural integrity of wood-pastures in some areas.

Building on the literature-based overview of the status of European wood-pastures in chapter 2, **chapter 3** concentrates on the structure of wood-pastures in Europe using empirical data. We

collected a dataset of 13,693 trees from 390 plots in wood-pastures from eight European countries (Estonia, Greece, Germany, Hungary, Italy, Portugal, Romania and Sweden) covering information on diameters at breast height, tree density per plot, tree species composition and the grazing management. We found wood-pastures with only one species present (in Southern Portugal) and wood-pastures with up to 19 species (Hungary). Species occurrence in general appeared to be chiefly related to the geographical range: although we did not explicitly test it, this is suggested by the species occurrence in the surrounding forests. The density of wood-pastures can differ across different regions in Europe, e.g. from 2 trees per ha in Central Romania to almost 5000 trees per ha in Western Estonia. However, we also found a considerable range within a single region (from 4 to 263 trees per ha in Southern Sweden).
Similarly, the structural gradient of wood-pastures varies widely across and within regions. We identified three major structural groups, from very dense wood-pastures with most trees in the lower DBH classes, to very sparse wood-pastures with most trees in the higher DBH classes, while a third group had intermediate density and a balanced range of DBH classes. The dense wood-pastures with small trees (mostly represented in our study by wood-pastures from Western Estonia and Northern Germany) are most at risk of turning into forest due to the difficulty of grazing management here, whilst the sparse wood-pastures with large trees (mostly represented by regions from Eastern Europe) risk turning into treeless pasture due to the large proportion of trees in old and senescent age classes. The structural gradient could not be related to the grazing management, which underlines the importance of social-ecological contexts for wood-pasture condition (history and landscapes perception). We conclude that to prevent the loss of wood-pastures in some regions and to maintain their ecological and cultural values, it is necessary to more comprehensively consider them in European policies, such as the Common Agricultural Policy, taking into account both their structural characteristics and their regional contexts.

To gain a better understanding of wood-pastures at a local scale, **Chapter 4** presents the first case study of this thesis, describing the characteristics, management, and status of wood-pastures in a traditional rural region of Central Romania. For this, we surveyed forty-two wood-pastures, as well as fifteen forest sites for comparison, related to their condition, management, site, and landscape context in Transylvania. We found evidence of tree and shrub removal to fulfill the requirements for subsidy payments in the majority of wood-pastures, and in half of the wood-pastures we also found signs of burning management. Wood-pastures in this region had an average tree density of 7.6 trees per ha, which is low when compared to other European wood-pastures as discussed in chapter 3. The dominant trees were mainly oaks and several species of fruit trees, while in the surrounding forest hornbeam was most dominant. 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. Wood-pastures also contained ancient trees (trees of which the age can reach centuries), which could not be found in the forest.

On the other hand, wood-pastures were relatively low in dead tree abundance and shrub cover compared to forest. These characteristics reflect the traditional management of wood-pastures, which were created from forests by grazing and selective tree removal. Remaining trees were not only valued for their shade, but oaks provided timber and acorns for livestock, while fruit trees provided fruits.

Specific characteristics of wood-pastures were determined by variables such as topography, distance to village, management, and surrounding forest cover. For example, fruit trees were more prevalent close to villages, while many dead trees were found in wood-pastures surrounded by forests. A detailed study on the biodiversity of one specific wood-pasture showed the high potential of wood-pastures to support high levels of biodiversity.

Worryingly, current management of wood-pastures differed from traditional techniques in several aspects, which could potentially threaten their persistence. First, most wood-pastures were grazed by sheep only, whereas mixed livestock grazing used to be the common management type. Second, many large trees suffered from (anthropogenic) burning. Although pasture clearing through controlled burning has been used for centuries, the current trend towards uncontrolled burning is a major threat to wood-pastures. We also found some evidence of (illegal) tree cutting, while historically only branches were cut and the trunk remained (‘pollarding’). Wood-pastures in Central Romania are not consistently formally protected within the EU, and our results show that their persistence in Transylvania is in danger. Therefore, a solid ecological understanding in combination with knowledge on cultural and human livelihood importance of wood-pastures needs to be developed to further their recognition for formal conservation.

**Chapter 5** uses a further case study to gain a deeper understanding of wood-pastures at local scale. In this chapter, we investigated the link between institutions, users and the ecological system in Western Estonia. We compared the structure of wood-pastures under a national subsidy schemes for either restoring or managing wood-pastures, to abandoned wood-pastures and ungrazed forest stands to explore the effects of management. The density of wood-pastures was higher in abandoned wood-pastures than in all other sites, also the shrub density was the highest in forest and abandoned sites. The most common species in all wood-pastures was birch. This was also the most common species in forest, suggesting, that in the Estonian case the natural forest composition has a strong influence over the tree species in wood-pastures. Our results showed a positive effect of subsidies on the habitat value of wood-pastures, as restored sites were not significantly different from old wood-pastures in density and canopy openness, while abandonment rapidly led to a forest-like structure. The significant difference between old/restored and abandoned sites shows that wood-pastures in Estonia are dependent on regular active management.

In addition, we conducted interviews with 24 farmers to understand the history of wood-pasture management and investigate their motivations to join the schemes and carry out the management. The history of wood-pasture management in Western Estonia was diverse and complex due to various regime shift and land reforms. Many had been abandoned during the second half of the twentieth century. Most farmers started farming in or after the end of the Soviet rule in 1991. Only a few of the farmers had farmed independently before that time with a small amount of land, while the others established their farms more recently. The most common livestock in wood-pastures in Western Estonia were cattle for beef production. Dairy cows and sheep as main livestock declined in recent years because of workload and market prices. Like the grazing management, also the tree management was very diverse but in most cases only done for keeping the pastures open. Still almost all wood-pastures in Western Estonia are too dense to receive the single area payment from the first pillar of the common agricultural policy of the European Union and therefore the financial support from the national subsidy schemes was vital for management. We were able to identify five categories of motivations including split into intrinsic and extrinsic motivations, with the financial support being the most important. However, the financial incentives were not the only reasons for farmers to carry out the management: also personal values related to tradition also played an important role. The interviewed farmers differed considerably in their motivations. Nevertheless, almost all farmers confirmed that they would not manage the wood-pastures without the subsidy payments, making this a necessary (albeit not sufficient) condition for farmers to manage wood-pastures. We showed that wood-pastures in western Estonia are social–ecological systems that depend strongly on active management to maintain their habitat value. This management, in turn, is dependent on various factors such as EU and national policies, but also on the extrinsic and intrinsic motivations of farmers. For example, financial incentives play an important role in farmers' decision-making, but also intrinsic motivations such as tradition. When designing policies this combination of motivations should be taken into account.

**Chapter 6** focuses in another case study on the link between formal and informal institutions and users in wood-pasture management in central Romania. In this chapter, we look at wood-pasture governance in the region of Târnava Mare in southern Transylvania (central Romania). We describe the development of wood-pastures in the region, their relatively stable historical communal management by the Saxon community, the destructive impact of the communist era and challenges faced today as Romania is entering a new era of agricultural development. The wood-pastures in Southern Transylvania were formed and maintained over centuries under communal governance, and their status as a community resource is an important part of their historical identity. The governance of common pool resources faces several challenges such as temptation to freeload, i.e. to benefit at the cost of others, or overharvest. However, stable institutions that are monitored and enforced can provide long-term sustainable management of common resources. Analysing the problems and solutions found by commons governance institutions around the world, Elinor Ostrom developed a number of design principles or core factors shared by long sustained commons regimes. Along these principals we compared general characteristics of the historic Saxon grazing regime. Wood-pastures had clear boundaries on spatial and temporal scale, as well as rules where to graze when and even with which type of livestock. The proportional equivalence between benefits and costs was reflected in the work amount of the villagers related to amount of livestock. Collective choice arrangements were made in an annual meeting held by an elected grazing committee and the monitoring of the pastures was secured by peers and formally recoded by the committee. The committee also worked as conflict resolution mechanism, dealing with the problems of users. For not carrying out maintenance work, graduated sanctions were imposed ranging from financial penalties to be excluded from the use of the resources. The minimal recognition of rights to organize was secured through the political, administrative and judicial autonomy that the community had at that time, as well as the by their sole right to control grazing on pasture and oak forest. In contrast to previous views of commons as an ineffective and even damaging form of resource management, it appears that the commons institutions of the Saxons were able to manage wood-pastures in a sustainable way. However, these communities were irrevocably destroyed in the late 20th century, and their institutions damaged by decades of political and social upheaval. Recent developments suggest that the future of the wood-pastures is not assured and unstable governance increases susceptibility to threats such as abandonment and illegal felling. In recent years, grazing associations have been formed in the region to manage the commons. We identified challenges linked to Ostrom’s key threats to sustainable governance systems facing these associations. Blueprint thinking tries to apply universal solutions to often locally specific conditions, in much the same way as current requirements for European agricultural subsidy payments dictate management parameters that associations must fulfil. Also, rapid changes in technology and human populations occurred with the mechanization of agriculture and the changes in farm structures, as well as the dramatic population changes that took place in Romania in the second half of the 20th century. The population changes have also led to transmission failures, in which the principles of an effective community-governed institution were not passed down from one generation to another, due to the interruption of the period of collectivization. The changes in technology and farming systems in general have increased the heterogeneity of participants; villagers with rights to a communal pasture may own 1, 10 or 100 cows, increasing the heterogeneity of interests represented. Finally, corruption and other forms of opportunistic behaviour were rife in the communist era and are encouraged today by the subsidy money available, leading to a decrease in trust in commons institutions and in willingness to cooperate. The current governance seems to be negatively affecting the ecological value of the wood-pastures. Half of all wood-pastures were affected by under or occasionally over-grazing. Potentially more serious, however, is the burning (intentional or unintentional) or felling of trees in wood-pastures. Problems of wood-pastures management in the region cannot be sufficiently addressed by a classical conservation 'reserve' approach. There are not only too many wood-pastures and too little support from the current conservation infrastructure in Romania, but also such an approach would decouple the ecological and social systems. Alternative approaches could include strengthening communal institutions to support sustainable community use.

## Synthesis

This dissertation provides important insights on wood-pastures as social-ecological systems and their sustainable development into the future. First, it demonstrates the ecological and cultural importance of wood-pastures in general, and second calls for an increased recognition of these social-ecological systems for conservation and especially in land use policies. This is urgent, since land-use change and the ongoing erosion of the links between the ecological and the social systems may cause a further decline of wood-pasture all over Europe. By looking at wood-pasture through the lens of social-ecological systems, this dissertation contributes to the knowledge of wood-pastures on European and local scales, as well as from an ecological and a cultural point of view. In the following, I will discuss my findings from this dissertation following the structure of my research questions my research questions. I then derive policy recommendations from my findings, followed by an identification of potential pathways for the sustainable development of these important landscapes in the future.

*Current status and recognition of wood-pastures as land-use type*

All chapters of this dissertation show that European wood-pastures are still a largely forgotten habitat type in European land use policies, and often also at national level. This results in them "falling through the cracks" for example in the EU Habitats Directive (chapter 2) or in the Common Agricultural Policy (chapters 3, 4, 5 and 6). The EU Habitats Directive only recognizes some distinct type of wood-pastures such as the Fennoscandian wood-pastures in Scandinavia or Dehesas and Montados in Spain and Portugal (chapter 2), while the CAP only supports pastures with up to 100 trees per ha (chapters 3 and 5), creating an incentive to abandon (chapter 5) or transform wood-pastures by removing trees and shrubs (chapters 4 and 6). This development has certainly at least partly to do with the relatively small and scattered remaining area of wood-pastures in Europe (Plieninger et al. 2015). However, looking further, this may be also the result of historical traditions during especially the 19th century of dividing grazing and forested land in much of Europe, whereby the combination of the two was largely forbidden (chapter 6). As a result, frameworks and concepts for dealing with land use types usually consider only land for grazing or land for timber production, but rarely the combination of the two (Bergmeier et al. 2010; Beaufoy 2014). Related to this, the large variability in wood-pasture structure as shown in Chapters 2 and 3 meant that it falls foul of the relatively restrictive definitions of land use/land cover that are often used in policy making (Beaufoy 2014; Beaufoy et al. 2015). Even though there are some good approaches to support wood-pastures financially on national or regional scale (chapters 2 and 5), it would make their integration in agricultural land easier if they would be recognized as a specific land use type by EU land use policies but also on national scale.

*Structure of wood-pastures contributes to heterogeneous landscapes*

The definition of wood-pastures as permanent grazed grasslands combined with scattered trees and/or shrubs (Bergmeier et al. 2010) is broad, and my results show across all chapters that the diversity contained within this definition is central to their identity. The structure and species composition of wood-pastures is very diverse across Europe (chapters 2, 3, 4 and 5), sometimes even within regions (chapters 3 and 5). Through selective tree management, e.g. removal or maintaining of trees for different purposes (fruit production, leaf fodder, shade, timber etc.), wood-pastures differ not only in species composition from the surrounding forest, but are often more species-rich than the local forest (chapters 4 and 5), acting as a genetic resources (Plieninger et al. 2015; Garrido et al. 2017). Moreover, the empirical work of this dissertation showed the open environment of wood-pastures allows trees to become bigger (and therefore assumed older) than in forest (chapter 4), thus also increasing their value as habitats for different species (Horák and Rébl 2012; Dorresteijn et al. 2013; Lindenmayer et al. 2014). Heterogeneous landscapes, especially with a high proportion of semi-natural habitats, have been suggested as a major driver of farmland biodiversity (Tscharntke et al. 2012; Tuck et al. 2014) and through their contribution to this heterogeneity on landscape scale wood-pastures are also supporting biodiversity (Bergmeier et al. 2010; Manning et al. 2013). Nevertheless we found across all chapters the main threat to wood-pastures, due to different causes, is the loss of their semi-open structure, which would lead to a loss of heterogeneity and therefore to a loss of biodiversity.

*Tradition maintains structural diversity*

My findings in chapters 4 and 5 suggest that the management of wood-pasture is important for maintaining their semi-open structure. While the history of management had a strong influence on the current structure of wood-pastures (chapters 2, 3, 4, 5 and 6) the current management will shape their structure in the future (chapter 3). Without any management, most wood-pasture will be lost in the future (chapters 3, 4 and 5). Abandonment will lead to forest regrowth (chapter 5), while neglecting the tree component will lead to an open pasture (chapter 4) confirming the findings of Plieninger et al. (2003). Therefore not only active management (chapter 5), but also appropriate (chapters 4 and 6) management is important to maintain the semi-open character of wood-pastures (see also Plieninger and Hartel, 2014). In general also many other species-rich habitats of high nature value in Europe depend on human management (see Halada et al. 2011). Therefore it is important to know what influences farmers to manage semi-natural habitat or high nature value (HNV) farmland such as wood-pastures (de Snoo et al. 2013; Birge and Herzon 2014). In my case study form Western Estonia, I found different factors influencing management decisions. Farmers are not only managing wood-pasture for financial incentives, but also for more intrinsic reasons such as animal welfare, biodiversity and especially tradition (chapter 5). The case study in Central Romania highlights the importance of tradition for a continuous management over centuries (chapter 6). Other studies (e.g., Siebert et al. 2006; Burton and Schwarz 2013) have also shown that financial aspects are not the only, or even the main, motivation for farmers to carry out biodiversity-friendly management. Chapter 6 shows furthermore how management can change when traditions vanish and the traditional knowledge about systems is lost, leading to inappropriate management actions for the system such as uncontrolled fire (chapter 4). Therefore, traditional and local ecological knowledge is considered a valuable for improving management of wood-pastures (Bürgi et al. 2013; Varga and Molnár 2014). Traditions, and thus traditional management, can vary across regions and can create different ideas of how landscapes are perceived, and thus what an ideal landscape should look like (Schaich et al. 2010), and with this contribute to the diversity of wood-pastures within and across regions (see also Moreira et al. 2006).

*Robust institutions safeguarding sustainable management of wood-pastures*

In Chapter 5 and 6 I have shown how institutions can influence the management of wood-pastures. The case study in Western Estonia (chapter 5) exemplifies how formal institutions can support the continuous management of wood-pastures and even their reactivation. The financial support (in this case by the state environmental board providing agri-environment payments) is necessary for the management of wood-pastures in Western Estonia, in a situation where this form of land use is no longer economically competitive to other pastures (chapter 5). In Romania, in contrast, higher level formal institutions (European Union) can even hinder the sustainable management of wood-pastures by providing incentives to clear pastures of trees (chapter 4 and 6). While century-long informal institutions have secured a sustainable management of wood-pastures, the loss of theses informal institutions in Central Romania (chapter 6) has also contributed to an unsustainable management of wood-pastures (chapter 6). Formal institutions (such as the EU or national authorities) play an important role when it comes to the management of wood-pastures (Beaufoy 2014; Kirby and Perry 2014; Plieninger et al. 2015). Nevertheless formal institutions are known to be prone to collapse (Hartel et al. 2016) and existing literature highlights the importance of robust informal institutions for SES such as wood-pastures (e.g. Brondizio et al. 2009; Hartel et al. 2016; Horcea-Milcu et al. 2017). Informal institutions can be seen as a form of social capital formed “through diverse processes involving the development of trust, norms of reciprocity, and networks of civic engagement, including the rules and laws within and between levels of organization” (Brondizio et al. 2009). Social capital is known for playing an important role in the management for SES (Armitage et al. 2009; Ostrom 2009) and is also described by Plieninger and Hartel (2014) as “the glue” local communities and wood-pastures together.

My case studies highlight the importance for both robust formal and informal institutions for the management of wood-pastures. These institutions need to be adaptable to the context, and there is a need for consistency over time to govern long-term social-ecological systems such as wood-pastures. Nevertheless, (Hartel et al. 2016) also suggested that periods of institutional instability can create possibilities for developing a multilevel governance system for social–ecological sustainability, following the idea of Bennett et al. (2015) that only multiple institutions may achieve sustainable results, crafted by the social-ecological system in question.

*Policy recommendations*

Based on my findings on the current status of wood-pastures, I identify the need for a better integration of wood-pastures in international and national policies. That means specifically, that all wood-pastures should be eligible for the Single Area Payments of the European Common Agricultural Policy, independently of the number of trees per ha, to make them equal to other pasture land. This call has been echoed by a wide range of experts in this field in recent years (e.g. Beaufoy, 2014; Garbarino and Bergmeie(Jakobsson and Lindborg 2015)r, 2014; Plieninger et al., 2015). In addition, both CAP regulations and implementation of regulations at national level should use a more flexible about the definition of grazing land not only when it comes to tree density, but also for other structural features such as surface stone, groups of trees or hedges (Beaufoy et al. 2011). This would benefit not only wood-pastures but also the thousands of hectares of ineligible but high nature value grazing land (Beaufoy and Marsden 2010; Peeters 2012).

Also results-based agri-environment measures, promoted at EU level would be an ideal measure to support wood-pastures, as the presence of trees is an excellent indicator for biodiversity and can easily be measured (see Underwood 2014) . This could be an additional source of support for taking specific management actions such as removing or replanting trees to guarantee their semi-open structure. Nevertheless, when designing AES the different motivations of farmers should be considered to guarantee the acceptance of farmers for the measures and therefore their success (see also Schmitzberger et al. 2005; de Snoo et al. 2013; Birge and Herzon 2014).

Nature conservation policies at the EU level, such as the EU Habitats Directive, need to include wood-pastures across Europe as a specific habitat type (or group of habitat types) with land use combining grazing and forestry management. This recognition would allow the special management of wood-pasture as a combination of pasture and trees (Plieninger et al. 2015). Further work describing different wood-pasture habitats (e.g. floristically, on which EUNIS and Habitats Directive definitions can be based) is necessary to help understand the variation in wood-pasture types across Europe and provide an inclusive and workable definition for these policies. It would also help to identify the most valuable habitats, either from a biodiversity or a cultural point of view, which could then be included as priority habitat types for conservation.

*Pathways for a sustainable development of European wood-pastures*

Financial incentives or regulations and sanctions are frequently used in the support of semi-natural habitats such as wood-pastures (Kleijn et al. 2011; Birge and Herzon 2014). Yet as this dissertation has shown, wood-pastures are complex social-ecological systems with long histories of use, and many other factors apart from economics play a role in their continued management. As elements of cultural landscapes, wood-pastures were influenced by changing socio-economic conditions such as regime shifts, changing institutions (chapters 5 and 6) but also industrialization, population growth and market conditions (chapter 2). These changes have caused a loss of the link between the ecological and the social system over time (Plieninger & Hartel 2014). Nevertheless, all empirical studies in this dissertation have shown the ecological and cultural value of wood-pasture in Europe (chapters 3, 4 and 5). The question is therefore how to foster a sustainable future for wood-pastures. Better integration of wood-pastures into EU and national policies as suggested above will play an important role, but it is unlikely to be sufficient to ensure their sustainable future (Beaufoy 2014). The evidence shows that subsidy based systems have had mixed success thus far in conserving the nature values of semi-natural farming systems (Kleijn et al. 2001; Kleijn et al. 2011). In fact, making management dependent on subsidies can weaken the ties between humans and nature (Beaufoy 2014), leading to a decoupling of the ecological and the social system (Fischer et al. 2012). Yet strong links between nature and society are essential for an effective conservation of cultural landscapes (Fischer et al. 2012) including their elements such as wood-pastures. Therefore it is important to strengthening existing links or to create new links between the social and the ecological system, while not trying to preserve the past, but instead finding links that fit into modern context (Fischer et al. 2012; Plieninger and Hartel 2014). Some of these new links are mentioned in this dissertation, such as the production of high quality products under the umbrella of organic farming such as the famous Iberian ham (chapter 2). Chapter 5 also notes options in Western Estonia to sell products from wood-pastures as organic. Another option would be eco-tourism, also shown in chapter 5 as one potential to diversify the use of wood-pastures. Plieninger and Hartel (2014) also mention forest certifications, renewable energy production (also mentioned by Bieling and Konold 2014) and hunting as opportunities for wood-pastures.

My case studies have shown the impact of social capital for the management of wood-pastures. Also other case studies have shown the importance of social capital for wood-pasture management (see Plieninger and Hartel 2014), however it depends on the social background what kind of social capital is needed to support a sustainable management for wood-pastures. For Central Romania building up social capital in the newly formed grazing associations by strengthening the trust between members and the professionalising the framework of the association could benefit the management of the wood-pastures administer. In Western Estonia, networks of farmers managing wood-pastures could be of potential use to share knowledge but also machinery. Overall, the stronger the social capital, the more resilient are systems is in times of change (Plieninger and Bieling, 2013), therefore wood-pasture all over Europe would benefit by increasing features of social captial such as trust, norms, formal support groups and informal networks (Buchmann, 2009)

## Conclusions and further research

Wood-pastures are elements of cultural and natural heritage, but they are under pressure from global change. This leads mainly to land-use intensification or abandonment, whereby the unique semi-open structure of wood-pastures that supports biodiversity on both local and landscape scales is lost. The future of these valuable cultural landscapes depends on the resilience of the social-ecological system that they are part of. Looking at wood-pastures from different scales and across disciplines, this dissertation contributes to the knowledge about this social-ecological system in a holistic way and identifies pathways for sustainable development into the future. These pathways include better integration of wood-pastures in different policies and policy levels (agricultural and environmental, European and national), creation of new links between the social and ecological components of wood-pastures for example by diversifying their use, as well as creating social capital among wood-pasture users and managers. To use these pathways, we need further research on the real extent of wood-pastures across Europe, as well as to understand better the effects of tree density on biodiversity and productive use to inform policy. Market options should be explored to incentivise sustainable use and collaborations between farmers encouraged to increase social capital. By supporting the persistence of these semi-open, extensively used cultural landscapes we could make a significant contribution to the goal of halting biodiversity decline and maintaining cultural heritage in Europe.

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# Chapter 2

# Chapter 2

## Diversity, threats and conservation of European wood-pastures

Erwin Bergmeier, Marlene Roellig

*European Wood-Pastures in Transition: A Social-Ecological Approach (2014) Eds. T. Hartel & T. Plieninger. Routledge, London, 19-38*






## Introduction

Grazed wooded landscapes have played a crucial role in the history of the European countryside. From the Neolithic, wood-pastures have been at the heart of subsistence economies of most rural societies throughout Europe, and they are still locally relevant for the economic integrity of some marginal rural areas. Various, often complex, forms of agro-silvopastoral systems evolved and became part of the regional cultural history. Although the number of wood-pastures has declined significantly over the past century, most countries retain a significant number of these habitats. Sharing the common elements of scattered trees and bushes accompanied by herbaceous vegetation, European wood-pastures nevertheless exhibit a wide range of structures and types, due to the variety of biogeographic and environmental conditions (climate, soil, topography, geology) as well as social contexts in which they develop. Wood-pastures are also influenced by the regional land use history, current management, grazing animals and seasonality. Also the uses of wood-pastures vary widely over space and time. Remarkable in their multifunctionality, wood-pastures can provide a variety of products and services, such as building materials, fuel, forage, food, cork, shelter and recreation, the importance of which depends on the local context (see also Oppermann, 2014). Agricultural and industrial developments have affected the economic value of wood-pastures, which is now very low in most parts of Europe. Although still in active use in many parts of Southern and Eastern Europe, in Western and Northern Europe they are mostly relicts or new achievements primarily maintained for biodiversity conservation purposes (Bergmeier *et al*., 2010). Wood-pastures are vulnerable across Europe. Among the major threats are forest regrowth due to land abandonment, land-use change and the degradation caused by a reduction in the number of old trees and the lack of regeneration due to overgrazing. Although national or local conservation approaches exist to maintain wood-pastures as important habitats for biodiversity (Finck *et al*., 2002), they are poorly supported by international policies. At the European Union level, wood-pastures are only partially recognised in conservation policies such as the Habitats Directive (Bergmeier *et al*., 2010), while agricultural policy is actively detrimental to wood-pastures in some areas (Peeters and Warda, 2012).

In this chapter, we attempt to outline the geographical variation and functional characteristics of wood-pastures across Europe. Further, we comment on threats to various types of wood-pastures, exemplify their significance for biodiversity conservation, and address conservation needs and approaches at local and European levels.

## Wood-pastures in Europe – geographical diversity and variation in management

Wood-pastures still in use can be found especially in southern and south-eastern Europe, in parts of boreal and subarctic Europe and in the central European mountains. Active wood-pastures are easily recognizable by the co-occurrence of both trees and grazing animals; former wood-pastures may be identified by the presence of ancient trees overgrown by forest or scattered in an agricultural land- scape, often revealing signs of former management such as pollarding and lopping. The essential purpose of wood-pastures is to provide fodder, including grass, leaves and buds, acorns and other fruits, for a variety of domestic animals. Closely connected is the collection of leafy hay from deciduous trees. Leaf-fodder was indispensable in areas of sedentary animal husbandry where livestock had to be kept and fed in stables during harsh winters, particularly in areas without stubble fields and other pasture resources to be used for grazing in the cold season. Machatschek (2002) illustrates the diversity of historical tools and techniques and manners of use around farming systems using leafy hay in Southern central Europe. Halstead and Tierney (1998) exemplify the significance of leaf- and twig-fodder cut from trees for animal husbandry until the late 20th century in the mountains of northwest Greece. During the 20th century, together with silvopastoralism, the use of arboreal fodder has declined dramatically to the point of nearly total abandonment in almost all European countries. It should be kept in mind, though, that leaf-fodder was not only essential to livestock but also shaped the cultural landscape together with wood-pasture from Norway to the Mediterranean over millennia.

Multipurpose grazed woodlands provided a variety of additional products of major local importance, such as firewood, brushwood, timber and wood to carve tools and for furniture, bark, bast fibre for textiles and rope, cork, also litter, fruits, mushrooms and honey. Different tree species serve different purposes, and each region of Europe has a set of tree species at disposal that fulfilled local demands of sustenance, craft, trade and industry. One well-known contemporary supplementary use of wood-pastures is cork harvesting, practised in the southern Iberian Peninsula, southern Italy and northwest Africa. The thick cork cambium layer of the cork oak (*Quercus suber*) is harvested every 8–12 years to produce cork. Cork oak forests are an important part of the Iberian wood-pastures called dehesa and montado and an important habitat for many threatened plants and animals. Bergmeier *et al.* (2010) classify European wood-pasture types using geobotanical criteria such as overall distribution, vegetation structure, elevation and prevailing trees. Following this survey, Table 2.1 shows the wide spectrum of traditional wood-pasture types from the subarctic to the Mediterranean, and Figure 2.1 shows an example of abandoned riparian oak-ash wood-pasture. Some types are still managed and are of local or regional economic significance, while other types have largely vanished or are still extant as relict of a former period in land-use history.

Several names of wooded pastures or grazed woodlands in local or regional use have become internationally recognised to describe regional variants of wood- pastures (Bergmeier *et al.*, 2010). Commonly, the regional term for ‘pasture’ is used to comprise ‘wood-pasture’, with the implicit understanding of the presence of trees in any decent pasture. Dehesa and montado are Spanish and Portuguese equivalents of open pastoral woodlands, often savannah-like, chiefly with old- growth evergreen holm oak (*Quercus rotundifolia*) and cork oak, used as grazing grounds for hogs, cattle, sheep and sometimes deer. Forest, hutewald (Hutewald), weidfeld, wytfeld and löväng denote wooded grasslands or grazed open woodlands with old-growth deciduous trees in England, north and south Germany, Switzerland and Sweden, respectively. This type of wood-pasture can be found in much of Europe, although there might be no specific traditional names in some regions.

**Figure 2.1** Abandoned riparian oak-ash wood-pasture (Hudewald-type with veteran trees of Quercus robur and Fraxinus pallisae), Chilia Dendra, Doiran, Central Macedonia, Greece, May 2013.

*Source: U. Bergmeier*

Open wooded commons (viehweiden, viehwoadt) in the northern Alps foreland, until the 19th century multipurpose wood-pasture where leaf-hay and litter was collected and trees cut for timber and firewood, are still locally used as pasture for cattle and horses. Shibljak is semi-deciduous shrubland of the Balkan and Black Sea regions resulting from forest degradation and long-term grazing (Figure 2.2). Macchia (maquis), garrigue and matorral are Mediterranean evergreen bushland and scrub formations of heights mostly between 1 and 3meters. They are composed of ericaceous and cistaceous species, but junipers, brooms and many others co-occur. Pseudomacchia is an ‘artificial’ geobotanical term used for South Balkan browsed or cut formations dominated by shrubby Kermes oak (*Quercus coccifera*), frequently as patches in grasslands and replacing sub Mediterranean woodlands. Kratt (krattwald, krattskog, stühbusch) indicate deciduous coppiced oak woodland, in former times frequently used as wood-pasture, in northern central Europe and in southern Fennoscandia. Rotational historical agro-silvopastoral wood-pastures such as the Hauberg (‘Hackberg’) system in oak-birch coppice woods in the

Siegerland and Westerwald in north-western Germany provided in a 20-year rotation charcoal, fodder for cattle, litter, tanbark ('Gerblohe') and firewood after the debarking and coppicing of the trees, and eventually buckwheat or rye and straw in an intercropping year after the wood harvest (Becker and Fasel, 2007).

From its medieval origin, the Hauberg wood rotation as a sustainable and cooperative systemlasted several centuries until it declined in themiddle of the 20th century. Similar multipurpose coppice woodlands existed in south Germany, such as the Reutberg and the Birkenberg system in the central Black Forest and the Bavarian Forest, respectively (Abetz, 1955; Reif and Oberdorfer, 1990).

**Figure 2.2** Sheep- and goat-grazed deciduous shrubland (shibljak) with Paliurus spina-christi and low-ground pasture rich in annuals, Central Macedonia, Greece, May 2013.

*Source: U. Bergmeier*

### Biodiversity of wood-pastures

Depending on the density and age of the trees as well as grazing management, wood-pastures can vary in structure, with different environmental conditions and gradients even within a wood-pasture. This provides a high density of ecotones, i.e. borderline areas of different habitats with short-distance gradients of light and nutrient availability, humidity, soil moisture and browsing impact. Through grazing and browsing, unpalatable, small or seasonal plants gain competitive strength. Domestic grazing animals trample trackways, dig the ground, seek shelter underneath tree canopies and produce faecal sites that are commonly ungrazed. Such daily and yearly routines result in spatially and temporally very different degrees of disturbance of the ground. Grazing animals distribute propagules and create open soil, thereby providing safe sites for seedlings of uncompetitive plants. The impact of different grazing animals on the vegetation structure is significant (see Uytvanck and Verheyen, 2014). Nurse effects of shrubs or shrubby trees may be vital for the rejuvenation of other woody plants or herbs (see also Garbarino and Bergmeier, 2014). A large number of plants, animals and fungi benefit from the varied structure of wood-pastures. Although there are no species exclusively linked to wood- pastures, some species may be regionally restricted today to wood-pasture landscapes. Among vascular plants, shade-tolerant unpalatable geophytes such as peonies (*Paeonia* sp.) and hellebores (*Helleborus* sp.) belong to this group. *Helleborus odorus subsp. cyclophyllus* was found to remain as virtually the last living herbaceous plant in a heavily overgrazed game enclosure in oak woodland in the region of Epirus (northwest Greece) (Chaideftou *et al.*, 2009). The richness of rare epiphytic bryophytes and lichens on solitary trees in wood-pastures, as observed in several studies, is chiefly based on habitat continuity associated with the presence of ancient trees and deadwood.

A considerable number of hypogean fungi such as truffles (*Tuber* sp.) prefer thermophilous open woodlands, especially in sub Mediterranean regions of Europe such as in Spain, France and Italy (Reyna-Domenech and García-Barreda, 2009). In Greece, open pine woods, deciduous and evergreen oak woodlands, as well as woods with hornbeam (*Carpinus betulus*, *C. orientalis*) and hazel (*Corylus avellana*) have recently been identified as principal habitats for truffles (Tuber sp.) and other hypogean truffle-like fungi (*Elaphomyces*, *Melanogaster* and other genera) (Diamandis and Perlerou, 2008). As truffle habitats, grazed oak and hornbeam woodlands are currently gaining attention in Greece as possible economic alternatives to more intensive forms of land use, or to abandonment.

Ancient trees – similar to senescent primeval forest, but in contrast to commercial forests – are a characteristic element of many types of wood-pasture. Old wood and deadwood, continuously present through centuries, is a precondition also for many other rare and specialist organisms, including saproxylic fungi and wood-dwelling beetles (Desender *et al.*, 1999; Taboada *et al*., 2006; see also Falk, 2014). Populations of large insects to feed on as well as knotholes and other structures of old and gnarled trees for nesting make old-growth wood-pastures an attractive habitat for insectivorous birds such as shrikes (*Lanius* sp.), hoopoe (*Upupa epops*), roller (*Coracius garrulus*), scops and little owl (*Otus scops*, *Athene noctua*), wryneck (*Jynx torquilla*) and middle spotted woodpecker (*Dendrocopus medius*), which all prefer stands with old trees, particularly oaks. Nine out of ten species of woodpeckers of Romania were identified in the ancient wood-pastures of southern Transylvania, some listed in the EU Birds Directive. The extensive Iberian cork oak dehesas are the primary habitat of Spanish imperial eagles (*Aquila adalberti*), also listed in the EU Birds Directive Annex I, which nests in tall solitary trees (Tucker and Evans, 1997; BirdLife International, 2004). The rarest European felid, the Spanish lynx (*Lynx pardinus*), listed as Annex II priority species in the EU Habitats Directive, prefers wood-pasture landscapes, in particular cork oak dehesas. Also the European genet (*Genetta genetta*) and Egyptian mongoose (*Herpestes ichneumon*) occur in Iberian dehesas. Recent studies in Romania have shown that the European brown bear (*Ursus arctos*), also priority-listed in the EU Habitats Directive, uses wood-pastures for foraging activities. Several large-scale conservation projects are making use of wood-pastures as suitable habitat to reintroduce large herbivores such as European bison (*Bison bonasus*), Eurasian elk (*Alces alces*), wild boar (*Sus scrofa*) and semi-feral domestic animals such as the konik, Exmoor ponies and the heck cattle (Finck *et al*., 2004).

### Threats to wood-pastures

Threats to wood-pasture habitats are primarily the result of changes in traditional land use caused by overall social and economic change in rural landscapes. Such changes may affect wood-pastures in two different ways: intensification of animal husbandry and thus higher livestock densities on the one hand, and land abandonment followed by shrub encroachment, wood succession and loss of small- scale habitat diversity on the other hand. As for other non-intensively used habitats, agricultural expansion and intensification, urbanisation and road construction have fragmented wood-pasture habitats (Bergmeier *et al*., 2010). The major threats are highlighted below.

*Decline of old trees*

Much of the biodiversity of pastoral woodlands depends on the presence and abundance of old-growth, tall broad-canopy trees, in particular veteran trees, chiefly oaks, and locally beeches, chestnuts, ashes or others. If the natural loss of senescent trees is not compensated by rejuvenation, the result will be open grassland; or if the wood-pasture is neglected, dynamic processes will lead to more- or less-dense forest (Bergmeier *et al*., 2010). Reduction of old trees may be caused by natural decay, but also triggered by unusual climatic events (late winter frost, dry and warm spring and summer, lightning strike). Further causes, especially in east and southeast Europe, are cutting of old trees (legal or illegal) and uncontrolled burning to reduce the dead grassy vegetation.

*Lack of regeneration*

The dieback of old trees in wood-pastures is particularly problematic if there is a lack of tree regeneration (Díaz *et al*., 1997; Plieninger *et al*., 2003;Dimopoulos and Bergmeier, 2004; Hartel *et al*., 2013). Regeneration failure may be an inherent problem for wood-pastures, requiring replanting of the key tree species. It can additionally occur through too long periods of overgrazing, such as has regionally occurred in the Mediterranean over recent decades (Bauer and Bergmeier, 2011). Lack of seedlings and juvenile trees can be observed chiefly in pastoral woodlands with goat grazing. Goats are known to selectively browse young trees and shrubs. Overgrazing in general also reduces the understorey, including shrubby nurse plants that would otherwise provide shelter for shade-demanding tree seedlings (Vera, 2000). The effects of grazing on regeneration are complex and summarised in by Ujtvanck and Verheyen (2014). In some areas, numbers of sheep and other livestock increased towards the end of the 20th century due to the EU Common Agricultural Policy per capita subsidies (Lyrintzis, 1996). EUsubsidies are currently no longer paid per livestock unit, but instead decoupled from production. The present requirements for the payments (for detailed information see Beaufoy, 2014) can, however, also pose a threat to regeneration. For instance, in Romania and other east European countries, farmers commonly remove all kind of shrubs and young trees to fulfil the obligations. Similar problems occur in other parts of Europe (Beaufoy *et al*., 2011).

*Forest regrowth*

Most lowland pastoral woodlands of the Hutewald type in western and central Europe were abandoned in the 19th century and converted to ungrazed forest. This was partly a result of decreasing economic viability of this land use type, but also because of the legal prohibition of grazing in forest due to increasing timber and fuelwood scarcity (Vera, 2000; Ellenberg and Leuschner, 2010). In southern and eastern Europe, rural depopulation and land abandonment took place in particular in the second half of the 20th century. The abandonment of wood- pasture and low-intensity farming systems leads to scrub encroachment and denser woodlands, which may increase fire hazards especially in Mediterranean wood- pastures (Boström *et al*., 2013). As a result of beech forest succession over a century in a former Hutewald in Germany, Schmidt (2010) found that the recent plant species composition on the ground indicates overall darker, drier and more nutrient-rich conditions than 100 years ago, when the landscape still had the appearance of a Hutewald. Several red-listed species disappeared with the loss of the patchiness that is so characteristic of wood-pastures.

*Land-use intensification*

Land-use intensification is a serious threat to wood-pastures, especially in the lowland regions of Europe. The use of wood-pastures can be intensified in two main (and often simultaneously occurring) ways: (1) with the removal of the structural elements (i.e. trees) to enlarge grazing areas and obtain more grass fodder for the livestock and (2) with the use of fertilizer and artificial seeding, thus destroying the semi-natural condition of wood-pastures. In Mediterranean countries, traditional sedentary wood-pasture, commonly including olive orchards sometimes with century-old trees, are threatened by intensification. Groves of old olive trees are a characteristic element of the traditional Mediterranean landscape (Figure 2.3). Ancient olive groves can be very rich in rare bulbous plants such as orchids, tulips, hyacinths and crocuses.

Modern irrigation-dependent olive varieties were introduced in the late 20th century, subsequently replacing low-input orchards by plantations that are irrigated, more frequently tilled or ploughed, and treated with herbicides (Kizos and Koulouri, 2010).

Similarly, in non-Mediterranean Europe, extensive Streuobst grasslands of standard apple, pear and cherry trees, formerly common around villages and eminent for the cultivation of traditional or local fruit varieties, have been abandoned or removed. There has been considerable loss of Streuobstmeadows in Central Europe from the 1960s, chiefly due to reallocation of farming lands and rural development (Bergmeier *et al*., 2010). Another form of intensification is to give up the pasture in total and to convert the area in arable land, which is more efficient in terms of subsidies and brings more yields. Higher yields are likewise the motive for the enormous increase of Eucalyptus plantations in recent decades in south-western Europe. Large quantities of Eucalyptus wood is used for paper production and many such plantations in Portugal and southern Spain have replaced wood-pastures of the dehesa type.

**Figure 2.3.** Old pollarded olives and arable fields used as pasture after harvest. Kambochora, Island of Chios, East Aegean, Greece. March 2013,

*Source: U. Bergmeier*

*Tree disease*

Various species of Phytophthora root fungus have been identified as the pathogen causing dieback in oak trees in central and southern Europe. Mortality rates in mature holm and cork oak stands are high, particularly in the last two decades in Portugal, southwest Spain and Italy. In recent years, moth infestations have occurred in central and southern Europe, chiefly of oak processionary moth (*Thaumetopoea processionea,* Nothodontidae), but also of *Tortrix viridana* (Tortricidae) and species of geometer moths (Geometridae), apparently associated with unusual climatic events (late winter frost, dry and warm spring and summer). Observed 'oak disease' is at the end of a process of vitality loss that may have gone unnoticed for years. Affected weakened trees commonly finally die through the additional effects of drought, fungus and insect attacks, and water shortage (Brasier, 1992, 1996; Brasier *et al*., 1993; Moreira and Martins, 2005; Kaltenbach, 2007). In addition to *Phytophthora* infestation, the chestnut blight fungus *Cryphonectria parasitica* has led to a sharp decline of *Castanea* groves, especially in Italy and southern France, including former and present pastoral woodlands.

## Conservation of wood-pastures in Europe

The conservation status of the different European wood-pasture types is difficult to establish, as in each case a reference point for conservation status would have to be defined. To do this, the environmental and management history should be known (see examples in Jørgensen and Quelch, 2014), and how these were related to the dynamics of the key structural elements of the wood-pastures. These variable factors differ from case to case and, even within a region, change over time. Perhaps the greatest impediment to wood-pasture conservation is that, despite their existence throughout Europe, there is no baseline quantitative or spatial data on their international distribution upon which to base a threat assessment. Wood- pasture is not mapped as a habitat type in systems such as CORINE Land Cover, and although regional estimations on their distribution exist (see Garbarino and Bergmeier, 2014; moreover Glaser and Hauke, 2004 or Luick, 2009 for Germany, and the maps of 'Woodpasture and parkland', a priority habitat in the UK Biodiversity Action Plan, DEFRA, 2011), neither provides a comprehensive quantitative survey of all types of wood-pastures in an internationally consistent way.

Nevertheless, with increasing recognition of the numerous benefits of wood-pastures for biodiversity, but also of their vulnerability, there has been growing interest in recent years in the preservation of wood-pastures (Plachter and Hampicke, 2010). These include approaches for the protection of biodiversity and habitats, but also for sustainable agriculture, rural development through value- added production, and rural tourism (see also Bieling and Konold, 2014). Below, we outline several important policies and approaches supporting their preservation in Europe.

### *Biodiversity policy: The EU Habitats Directive*

The Habitats Directive, together with the Birds Directive, is the major EU legislative instrument for wildlife and nature conservation. Adopted in 1992, the aims of the Directive are to maintain and restore favourable conservation status of natural habitats and of wild fauna and flora of Community interest. The major means of achieving this is through a designated network of conservation areas –Natura 2000 – which host the species and habitat types identified in the annexes of the Directive. Among the 233 European natural habitat types listed in Annex I (European Commission, 2013), no less than 65 are to some extent related to wood-pasture. Of these, only four habitat types are explicitly recognised as grazed woody formations, viz. ‘5130: *Juniperus communis* formations on heaths or calcareous grasslands’, ‘5210: Mediterranean arborescentmatorral’, ‘6310: Sclerophyllous grazed woodlands’ and ‘9070: Fennoscandian wooded pastures’. These habitat types cover merely a fraction of the European wood- pasture habitats as classified by Bergmeier *et al*. (2010) (Table 2.1).Most Annex I habitat types related to wood-pasture refer actually to forest habitats but it seems inappropriate to manage all of these as, or restore them towards, forests as demanded by the definition given in the Interpretation Manual. If criteria and definitions of forest habitats were strictly applied (which they are frequently not), wood-pastures would have to be assessed unfavourable conservation status (Bergmeier *et al*., 2010). Adequate forest management in Natura 2000 sites focuses on natural processes and aims to maintain or restore ungrazed dense and tall forest. In this way, restoration would lead to natural old-growth forest rather than open wood-pasture. In current practice, however, sustainable livestock grazing in forests of Natura 2000 sites is commonly tolerated, at least in south and southeast Europe, although it contradicts natural forest development. The resulting uncertainty in Natura 2000 sites of what should be managed as forest and what as wood-pasture calls for clarification. In general, the problem is that some wood-pastures are seen as forest while others are recognised as pastures, neither providing optimal management prescriptions specifically for wood- pastures. Many excellent wood-pastures, not included under the Natura 2000 network due to poor conservation status as forest, should be included under a new code designation – as wood-pasture.

*State approaches to preserve wood-pastures*

In countries where the economic value of wood-pastures is now almost non- existent, local efforts to maintain the semi-open character of wood-pastures focus on conservation management. Support may come from agricultural subsidies, as implemented for example in Estonia. Estonia introduced national payments to support wooded meadows and wood-pastures in 2001. Now the money is partly extended by agri-environment subsidies from the EU for the management, but support for restoring (cutting out trees and fencing) is still paid by a national support scheme. Every year, €0.15 million have been paid to support wooded meadows and pastures, and between 2001 and 2006, 200 ha of these habitats were restored (Sammul, 2008). Similarly, an agri-environment scheme option in Scotland offers support for the management of ancient wood-pastures, providing a yearly payment per hectare for environmentally sensitive practices and management interventions such as the eradication of exotic rhododendron, creating protection for young trees and the management of old trees. Public agricultural and nature conservation subsidies are essential for wood-pasture preservation. A project on the commons (*Allmende*) in the Alps foreland in southern Bavaria showed that cooperative engagement together with available public means in wood-pastures can provide an economically reasonable alternative to agricultural intensification or abandonment (Lederbogen *et al.*, 2004).

*Rewilding*

Another approach tomaintain wood-pastures is to establish semi-wild large herbi- vores in woodlands with year-round grazing, thus restricting the regrowth of trees and bushes. Such interventions, known as rewilding, have increased in recent years. Robust breeds of farm animals or reintroduced native wild animals may be used (Bunzel-Drüke *et al*., 2008). It is recommendable to employ a suitable combination of herbivores, such as browsers and grazers together. Sufficiently large and heterogeneous areas are necessary that are able to feed the growing popu- lations of animals and to satisfy the specific requirements during all seasons. Rewilding projects focus mainly on the biodiversity benefits of wood-pastures, attempting to increase the area of 'natural' habitats particularly in western Europe. This is not only a time- and cost-efficient approach, but may also attract tourism (McAdam *et al*., 2009).However, by emphasising natural driving forces, rewilding projects may disregard the former productive and cultural functions of wood- pasture. As a result, rewilding has attracted both criticism and support from various stakeholders, and has become a topic of controversy in some areas (see for example Kirby, 2009; Vera, 2009).

Well-known and successful rewilding projects are for instance Oostvaardersplassen in the Netherlands with Konik ponies, red deer and heck cattle, and the New Forest in southern England, UK, with New Forest ponies, cattle and deer. Among the more recent attempts of establishing large-scale wood-pasture are the Höltigbaum in north Germany and the Ennerdale Valley project in the Lake District, UK, both grazed chiefly by Galloway cattle (von Oheimb *et al*., 2006; Browning and Gorst, 2013). Abandoned forme rmilitary training areas are sizable enough to be very suitable for reintroducing wood-pasture, provided that the area of heavily contaminated sites and the pollution risk through ammunition remains and oil spills can be controlled. These projects also require that state and EU funding for landscape development and biodiversity conservation can be combined with local initiatives and agro-economic, farming and scientific expertise. In Germany, many former military training areas, especially in the east of the country, have become property of the German Environment Foundation (DBU). This foundation promotes rewilding as pasturelands, for example in Oranienbaumer Heide, part of the Biosphere Reserve of the Middle Elbe in Saxony-Anhalt (Figure 2.4) (Felinks *et al*., 2012).

**Figure 2.4.** Wood pasture in the Oranienbaumer Heide, Saxony-Anhalt, Germany, with birch (*Betula pendula*) and species-rich perennial grassland with *Peucedanum oreoselinum* on base-rich sands. The former military training area is grazed by Konik horses and Heck cattle. July 2012,

*Source A. Lorenz*

*Value-added production*

The rewilding approach may preserve some of the characteristics of former wood- pastures, but it is not the original meaning of wood-pasture, with the sustenance of the local societies having priority. Just like certain other types of agroforestry systems, wood-pastures may be sustainably used (Mosquera-Losada *et al*., 2009) and due to the absence of chemical fertilizer may be approved as organic farming, which means the products qualify as high-end goods. This applies to a wide range of products and may enhance rural development in some European regions. A well-known such product is Iberian ham – *jamón ibérico*. Large parts of the dehesas are primarily maintained for the production of the ham through the acorn hard mast of the black Iberian pigs. It has even been suggested to increase the area of holm oak dehesa, as this oak species provides acorns most suitable to fatten the pigs (Gaspar *et al*., 2007). While in Spain, Portugal, the Croatian Sava lowlands and elsewhere in southern Europe the farming of pigs in wood-pastures is extant or recent history, in other parts of Europe pig grazing in forests ended chiefly in the 19th century. It is now being rediscovered locally. A wood-pasture in Iphofen, Lower Franconia, Germany, was restored in 2003 for the acornmast of different old pig breeds (Huss, 2013). Through the immediate success of the '*Eichelschwein*' project, the wood- pasture was extended in 2011 to 50 hectares. Traditional cattle breeds such as the small *Hinterwälder* in the southern Black forest, southwest Germany, are well adapted to local diet, weather conditions and steep slopes. As typical dual-purpose cattle it is farmed under suckler cow husbandry and as dairy cows. The *Hinterwälder* cattle is indispensable to maintain the wooded pastures called *Weidfeld* with their impressive solitary beeches (Ludemann and Betting, 2009; see also Bieling and Konold, 2014).

## Conclusion

Wood-pastures are human-made. Even if implemented or revived under a rewilding concept, they cannot be maintained or preserved without human interference. If they are to be accepted by the locals, wood-pastures will have to be accessible and of economic or recreational value. The income generated through tourism and landscape management, but also through animal and plant products is essential and will help to create or renew links between people and 'their' natural environment. European wood-pastures are highly diverse in structure, species composition, land-use history and management. Due to their semi-open and patchy character, as well as to their habitat continuity, they accommodate numerous species, many of which rare and endangered. Traditional wood-pastures express part of the local social and economic history and are therefore of considerable cultural significance. Nevertheless, many types of European wood-pastures are threatened by various factors, most of them related to land-use change. International conservation is difficult due to considerable variation in the status, sustainability and resilience of extant wood-pasture, and the lack of information on a national and pan-European scale. The incomplete and inconsistent coverage of wood- pasture types in the Habitats Directive of the EU reflects this problem. A wood-pasture seen as forest habitat suggests conservation measures that differ greatly from those applicable to pastureland. The diversity of wood-pasture types and its multiple threats clearly require a diverse set of conservation approaches. Due to different pathways of wood-pasture development – by way of succession or degradation – a consistent European monitoring scheme is required. However, management must be flexible and adapted to the local situation. Especially in rewilding areas without a herding tradition, thorough success monitoring and quick adaptation to unforeseen or unwanted developments are essential. Such monitoring should focus on criteria such as old tree numbers, tree densities and composition, tree regeneration, proportion of shrub and ground-plant cover, area, number and kinds of grazing animals and other kinds of impact. A target of the measures will have to be defined and an initial study of the biodiversity and feasibility is necessary. Then, the success of wood-pasture or any specific measure must be tested along the contrasts of before versus after, with versus without and target versus actual. Local studies on biodiversity and land-use history are scarce or the results unpublished or unavailable, in particular in parts of southeast and east Europe. Such studies – they may be biodiversity-, agrarian-, history- or ethnobotany- oriented – should be encouraged and published. By way of case studies, also open questions of sustainability may be solved. Sustainability is a precondition for wood- pasture to be acknowledged as a grant-worthy type of land use. Local approaches of wood-pasture, as well as other types of agroforestry, should make sustainability their primary concern.

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# Chapter 3

# Chapter 3

## Variation of stand structure across European wood-pastures: Implications for land-use policies

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*In revision in Rangeland management and Ecology*






## Abstract

Across Europe, wood-pastures exhibit major differences in structure due to different social-ecological backgrounds. Many European wood-pastures are deteriorating, either because of abandonment and forest regeneration, or because of lack of tree regeneration due to overgrazing or tree and shrub removal. Despite a considerable number of local studies, there has been no comprehensive overview of the stand structure of wood-pastures in Europe showing which systems are most at risk of losing their semi-open character. To provide such an overview, this study aimed to: (I) show differences and similarities of wood-pastures across Europe; and (II) identify threats for wood-pasture persistence in the future. We collated a dataset of 13,693 trees from 390 plots in wood-pastures from eight European countries (Estonia, Greece, Germany, Hungary, Italy, Portugal, Romania and Sweden) covering information on diameters at breast height, tree density per plot, management type, and tree species composition. Based on their structural characteristics we classified wood-pastures using principal component analysis (PCA) and cluster analysis. The PCA showed a gradient from dense wood-pastures with high levels of regeneration (e.g. in Estonia), to sparse wood-pastures with large trees but a lack of regeneration (e.g. in Romania). Along this gradient, we identified five different types of wood pastures. Wood-pastures from Romania constituted a largely separate group, while wood-pastures from Sweden varied in structure, such that they were represented in all five clusters. Our results demonstrate a large structural gradient of wood-pastures across Europe, as well as varying degrees of abandonment and lack of regeneration, which highlights the importance of social-ecological contexts for wood pasture condition. To maintain the ecological and cultural values of European wood-pastures it is necessary to (i) more comprehensively consider them in European policies such as the Common Agricultural Policy, while (ii) taking into account both their structural characteristics and social-ecological background.

## Introduction

Human impact has shaped the structure of wood-pastures for thousands of years all over Europe (Hartel et al., 2015; Hartel and Plieninger, 2014; Jørgensen and Quelch, 2014). Since their origin in the early Holocene (Bergmeier et al. 2010), wood-pastures have developed from forest-based livestock grazing to semi-open landscape elements, shaped not only by biogeographic and environmental conditions, such as climate, altitude and soil, but also by the needs of local people and other social factors such as tradition and economy (Bergmeier and Roellig, 2014; Chételat et al., 2013; Hartel and Plieninger, 2014; Huber et al., 2013). The resulting mosaics of grassland with shrubs and trees of different ages, as well as variable light and shade conditions, provide important semi-open habitats for a wide range of species (Bergmeier and Roellig, 2014; Falk, 2014; Hartel et al., 2014; Roellig et al., 2014).

Despite their shared origin in forest-based livestock grazing, today, wood-pastures across Europe are highly varied because of differences in past and present practices in grazing and tree management (Bergmeier and Roellig, 2014; Hartel et al., 2013; Plieninger et al., 2015). Different grazing management and intensity as well as livestock type fundamentally influence the structure of wood-pastures (Van Uytvanck and Verheyen, 2012). Whereas in Northern Europe, forests were mostly used for cattle grazing, in Central and Eastern Europe, pigs were sent into the forest for mast in autumn, and in Southern Europe, pigs, sheep and goats were herded under trees (Van Uytvanck and Verheyen, 2012). Moreover, historical tree management has also strongly influenced the current structure of wood-pastures (Hartel et al., 2015; Jørgensen and Quelch, 2014). Trees were either managed as high forest or as coppice (Ellenberg and Leuschner, 2010). Pollarding (as a form of coppicing) trees in wood-pastures for firewood or leaf hay was common in many parts of Europe (Bergmeier et al., 2010; Oppermann, 2014). Similarly, the planting of oaks to feed livestock in autumn was widespread in Europe (Bergmeier et al., 2010; Garbarino and Bergmeier, 2014). In contrast, tree management played a less prominent role in some Northern European countries. For example, neither pollarding nor the production of leaf hay was common in Estonia (Roellig et al., 2015). In South-western Europe such as on the Iberian Peninsula and southern Italy, tree management still plays an important role due to bark (cork) harvesting from cork oak (Quercus suber) (Alias et al., 2010; Costa et al., 2014). To ensure an ongoing availability of this still highly valued resource, trees were regularly planted in these systems (Costa et al., 2014). In Central and Eastern Europe on the other hand, wood-pastures often include former orchards or fruit trees, whereas in Greece livestock grazed in olive orchards (Bergmeier et al., 2010; Hartel et al., 2013).

Today the structure of wood-pastures in Europe differs in tree density, tree distribution and the age distribution of trees (represented by the distribution of stem diameter classes) across countries or regions (Garbarino and Bergmeier, 2014; Hartel et al., 2015). Tree density can range from only 4 trees per hectare (ha) in central Romania (Hartel et al., 2013), to 30–60 trees per ha in Iberian cork oak savannahs (Bugalho et al., 2011), to 65 trees per ha in Southern Italy (Alias et al., 2010). Higher densities of up to 200 trees per hectare can be found in wood-pastures in England (222 trees per ha) (Mountford et al., 1999) or Southern Sweden (Jakobsson and Lindborg, 2015). The highest reported densities of trees in wood-pastures were reported in subalpine larch wood-pastures in Northern Italy with 200–500 trees per ha (Garbarino et al., 2011), and in Western Estonian wood-pastures with up 368 trees per ha in an old wood-pasture (Roellig et al., 2015). Abandoned wood-pastures with dense shrub regeneration can reach densities of woody vegetation that are higher by yet another order of magnitude (Roellig et al., 2015; Varga et al., 2015).

The spatial arrangement of trees also differs significantly across Europe (Garbarino and Bergmeier, 2014). In the absence of tree management and low grazing pressure, trees can form a nearly closed canopy. Wood-pastures with long-term traditional management, on the other hand, typically exhibit a relatively sparse distribution of trees, and where trees are planted (e.g. on the Iberian peninsula) the distribution can be close to a regular pattern (Plieninger and Schaar, 2008; Pulido et al., 2001).

The age of wood-pasture establishments, together with the management and the distribution of trees as a result of differences in management, also influence the distribution of stem diameter classes within the pasture (Fischer et al., 2009; Plieninger et al., 2003). Whereas natural and semi-natural forest typically show a high proportion of young trees, the diameter distribution of trees in wood-pastures can be described by a normal bell curve (Fischer et al., 2009; Plieninger et al., 2003; Pulido et al., 2001). That is, there is typically a dominance of medium-diameter classes and a low representation of younger and very old classes (Garbarino and Bergmeier, 2014). Long-term intensive grazing and tree removal lead to a shift towards larger size classes indicating a lack of regeneration (Bauer and Bergmeier, 2011; Plieninger et al., 2011). In abandoned wood-pastures, larger trees surviving from the former land use tend to become overgrown by younger trees, showing a hump on the lower diameter classes of the otherwise normally distributed diameter classes (Plieninger et al., 2003; Rapp and Schmidt, 2006; Varga et al., 2015).

Despite their importance for biodiversity conservation and their multiple cultural values, wood-pastures are facing multiple threats (Bergmeier and Roellig, 2014). A lack of tree regeneration due to overgrazing and the removal of wooded structures, as well as forest regrowth due to abandonment of wood-pastures are two of the main threats to their persistence (Bergmeier and Roellig, 2014). Changes in traditional uses of wood-pastures typically lead to a loss of their semi-open character, either turning into a treeless pasture – referred to by Plieninger (2003) as a "treeless pseudo steppe" – or through succession reverting to forest. Both cases imply a loss of habitat diversity at the scales of individual pastures, but also at the landscape scale (Garbarino and Bergmeier, 2014).

A key challenge is that the management of wood-pastures is often not economically profitable anymore. Traditional management is typically labour intensive, but less productive than other grazing systems (Bergmeier et al., 2010; Roellig et al., 2015). Another major influence on wood-pastures is that of national and European Union (EU) agricultural and nature conservation policies. These policies often do not formally recognize wood-pastures, and if so, very insufficiently or uniformly across Europe, ignoring the actual and historic variability of these habitats (Beaufoy, 2014; Jakobsson and Lindborg, 2015; Peeters, 2012). For example, wood-pastures with more than 100 trees per ha are usually not eligible for the single area support payments (SAP) of the EU's Common Agricultural Policy (CAP) (Beaufoy et al., 2015). Furthermore, nature conservation policies such as the EU Habitat Directive only recognize some European wood-pastures such as the dehesas in Spain and the fennoscandian wooded pastures in Scandinavia (Bergmeier et al., 2010; Comission of the European Communities, 2009), and there are few national policies to protect wood-pastures.

Despite a considerable number of local studies on the stand structure of wood-pastures (Plieninger, 2007; Plieninger et al., 2003; Pulido et al., 2001), there has been no comprehensive overview of the stand structure of wood-pastures in Europe showing which systems are most at risk of losing their semi-open character. To provide such an overview, in this study we aim to (i) show differences and similarities of wood-pastures across Europe in terms of their tree species composition and stand structure, and on this basis (ii) identify threats to wood-pasture persistence in the future. To achieve these aims we compiled data, either already existing or especially collected for this study, on tree structure in wood-pastures from eight different countries in Europe.

## Methods

### *Data collection*

To compare different wood-pasture systems we collected a comprehensive dataset of 13,693 trees from 390 plots located in wood-pastures from eight European countries (Estonia, Germany, Greece, Hungary, Italy, Portugal, Romania and Sweden) covering a wide geographical range (Fig. 1). The dataset included information on plot size, numbers of trees per plot, diameters at breast height (DBH) for all surveyed trees within the plot and management type (grazed or ungrazed). For all countries we collected information on tree species composition (though in some case data were only available at the genus level), as well as coordinates for the plots. Because some datasets also included shrub species, trees were defined for our study as woody plant species usually having one or few self-supporting stems, with a well-defined crown and being part of the canopy layer (>5m total height) when fully grown (Di

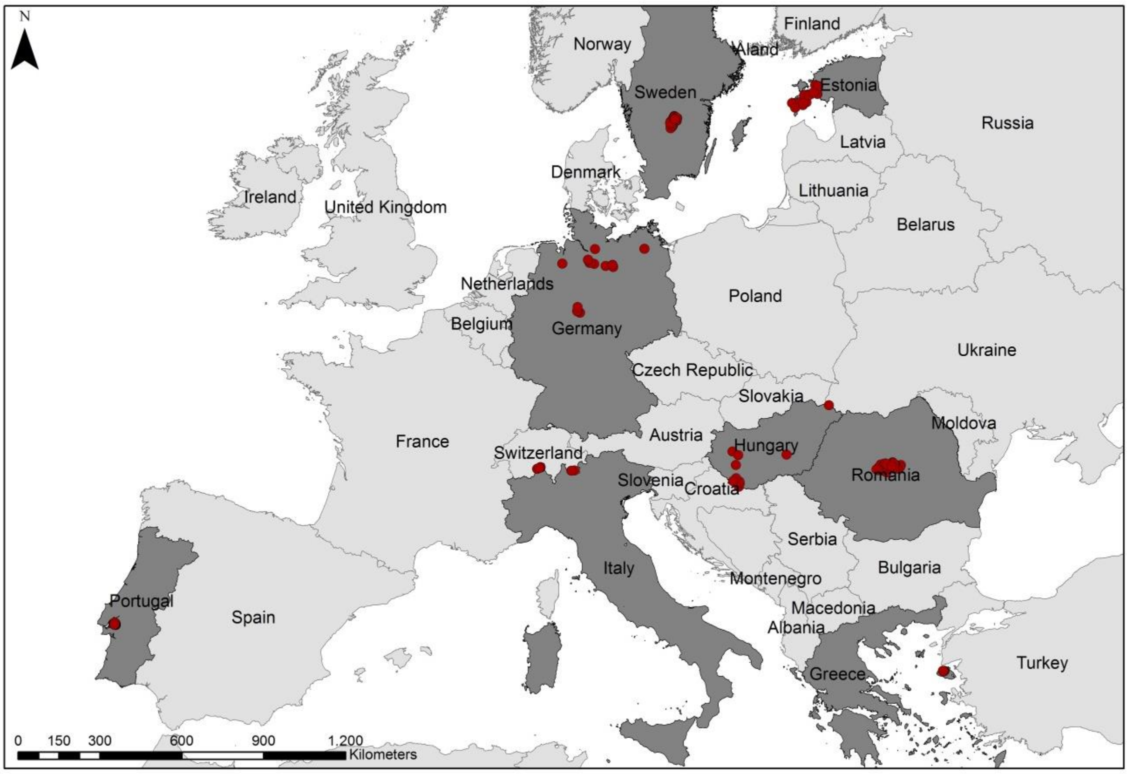


**Fig. 1** Study areas in Europe, showing the study regions for Estonia, Germany, Greece, Hungary, Italy, Portugal, Romania and Sweden

Gregorio, 2005). Under this definition shrub species such as hazel (*Corylus avellana*) and hawthorn (*Crataegus* spp.) were not considered, even when they were present in a given study plot. The sample methods of the collected data differed between plots, and involved random to systematic sampling design in temporary or permanent plots of different sizes (see Table 1 for details). Despite these differences in sampling methodology between countries, we considered the resulting data comparable.

Table 1: Sampling design used to assess wood-pasture structure in eight European countries

| Country | Year of data collection | Plots total | Plots grazed | Plots ungrazed | Plot size (ha) | Sampling design |
|---|---|---|---|---|---|---|
| **Estonia** | 2013 | 30 | 20 | 10 | 0.0625 | Pastures were chosen to cover old, restored and abandoned pastures (10 in each category). Plots were subjectively placed in the centre of each wood-pasture (see Roellig et al., 2015). |
| **Germany** | 2013/ 2014 | 20 | 10 | 10 | 0.0625- 0.5 | Pastures were chosen to cover grazed and not grazed pastures (10 in each category). Plots were subjectively placed in the centre of each wood-pasture (unpublished data). |
| **Romania** | 2012 | 39 | 37 | 2 | 2 | Pastures were chosen to cover average wood-pastures in the region. Plots were subjectively placed in the centre of each wood-pasture (see Hartel et al., 2013). |
| **Sweden** | 2013 | 64 | 64 | 0 | 0.8 – 1.39 | Pastures were chosen to cover a large tree density gradient, from 0 to 214 trees/ha, of grazed wood-pastures. Plots were subjectively placed in a representative area of each pasture, in an area with homogeneous tree density (see Jakobsson and Lindborg, 2015). |
| **Greece** | 2009 | 71 | 65 | 6 | 0.071 | Pastures were chosen through a random-walk procedure, covering five clusters of contrasting site characteristics (distance to village, slope, aspect, and altitude). Plots were subjectively placed in the centre of each pasture (see Plieninger et al., 2010) |
| **Hungary** | 2013- 2014 | 10 | 10 | 0 | 0.1 | Pastures were chosen to cover average grazed pastures. Plots were subjectively placed to include representative area of each pasture and with as homogenous tree density within the plot (unpublished data). |
| **Italy** | 2011 | 11 | 9 | 2 | 0.045- 1 | Temporary circular plots (Garbarino et al., 2013) and permanent quadrat plots (Garbarino et al., 2011) were chosen to cover grazed and abandoned subalpine wood-pastures. |
| **Portugal** | 2007 | 148 | 148 | 0 | 0,2 | Wood-pastures were chosen to cover a large cork oak woodland area with native pasture areas intercropped with grazing areas in a state-owned farm. Plots were placed using a systematic sampling design for cork oak |

forest inventory (see Costa et al., 2010, 2008).

*Data analysis*

To assess composition of tree species we determined the ten most abundant trees (species or in some cases genus) per wood-pasture in a given country. In order to characterise the structure of each survey plot, we calculated the mean, median, kurtosis, skewness, interquartile range, total range, standard deviation and the 10% and 90% quantile of the DBH distribution. Based on the number of trees per plot and plot size we also calculated tree density per ha for comparison. All variables, except skewness, were not normally distributed and therefore were log-transformed prior to further analysis. In addition, all variables were scaled. With the resulting set of variables we then performed a principal components analysis (PCA) to explore relationships between sites and countries. In the next step we performed a cluster analysis on the same variables, using the "Ward" method with the Euclidean distance as suggested by Dytham (2011), to classify wood-pastures across Europe. Ward's clustering was chosen because it usually produces clear group structures (no problems with chaining), and the resulting clusters were readily interpretable (Legendre and Legendre, 2012). All analyses were performed using the "stats" package in the software R (version 3.0.2) (R Core Team, 2013).

## Results

In general the structure of wood-pastures across Europe shows a wide variety, sometimes even within regions. The density of wood-pastures can differ between 2 trees per ha (central Romania) to almost 5000 tress per ha (Western Estonia) across different regions in Europe, but also from 4 to 263 within a region (Southern Sweden). In Central Romania, followed by wood-pastures from Hungary, we found the highest DBH values, but also the highest range and standard deviation. The lowest DBH values we found in Western Estonia, Northern Germany and Southern Sweden. In Northern Germany the DBH distribution was the most skewed and narrowest. Wood-pastures in Portugal, in contrast, were relatively normally distributed as judged by their skewness and kurtosis values (Appendix 1).

*Species occurrence*

Overall, at least 55 tree species were recorded in wood-pastures across Europe (for full species list see Appendix 2). In Hungary, we found at least 19 species in all wood-pastures across the country; however information on willow species (*Salix* spp.) were only collected at genus level. In Sweden we found 19 species and in Germany 18 species in all wood-pastures. At least 16 species were found in Estonia where we had information on birch (*Betula* spp.) and willow only on genus level. We identified at least eleven species in wood-pastures in Romania, with genus-level data for maple (*Acer* spp.), birch, ash (*Fraxinus* spp.), spruce (*Picea* spp.), willow and lime (*Tilia* spp.). In Greece, ten species were found, in Italy four and in Portugal only one (Fig. 2).

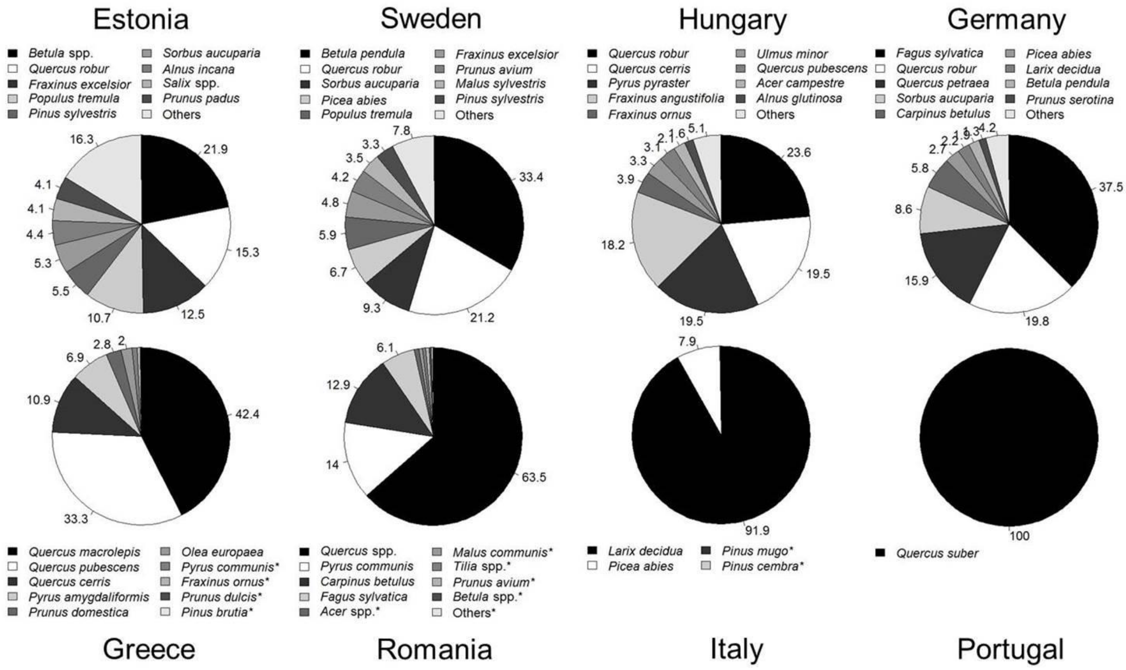


**Fig. 2**: Average proportion of tree species in wood-pastures per country as percentages. If more than ten species were present, only the nine most common are presented. The rest is grouped under "others". Species with a percentage under 1% are marked with a *.

Some regions had many species, but a high percentage of individuals belonged to the three most abundant species. In Hungary we found 19 species, but the three most abundant species formed together 63% of all species (Fig. 2). In Northern Germany (18 tree species), 73% of all tree species were covered by the three most abundant tree species, and in Estonia three out of sixteen tree species accounted for 50% of all tree species. In Eastern Greece and Central Romania we found fewer tree species in total, but the three most abundant ones covered up to 90% of all tree species. In northern Italy the three main abundant tree species were forming almost 100% of all tree species; while in Portugal 100% were covered by only one tree species. In all countries (except Italy), oak species (*Quercus* spp.) were among the three main species. Oak was most abundant in four countries (Hungary, Romania, Greece and Portugal). In Estonia and Sweden, birch species (*Betula* spp.), while in Germany beech (*Fagus sylvatica*) were most abundant (Fig. 2).

*Stand structure of wood-pastures*

Principal components analysis separated wood-pastures based on tree density per ha, tree diameters and the range of diameters within a plot (Fig. 3). The first PCA axis of structural variables explained 52% of the variance and represented a gradient from dense stands with low DBH values (left hand side of ordination; plots from Estonia and Germany), to sparse wood-pastures with a dominance of large trees (right side of ordination; plots from Hungary and Romania). The second axis explained 26% of variance and described wood-pastures with a high variation in stand structure (upper part of ordination), due to a high range of DBH, and a high mean DBH, such as plots from Hungary, to homogenous wood-pastures with a rather low DBH such as plots from Portugal or Greece (lower part of ordination). In terms of countries, there was substantial overlap, with exception of Estonia and Romania (Fig. 3).

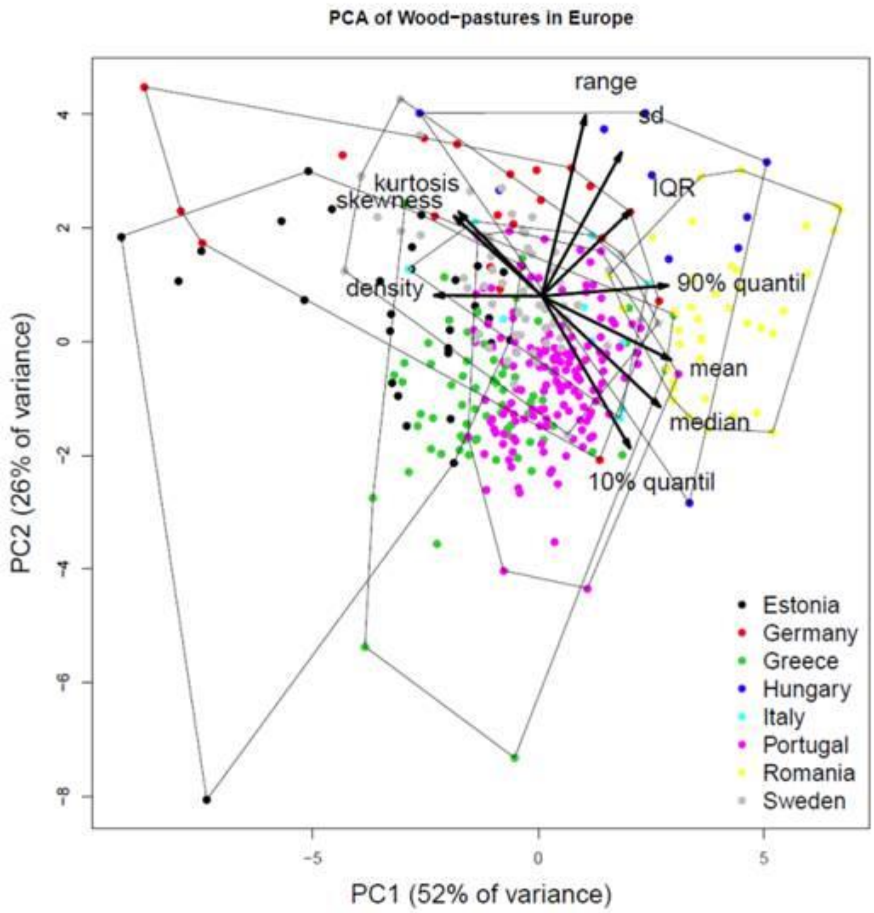


**Fig. 3**. First two axes of the principal component analysis (PCA) of the ten structural variables describing the stand structure of wood-pastures in eight countries across Europe.

Based on a visual inspection of the dendrogram (Appendix 4), we identified five clusters of wood-pastures. These clusters occurred in two large branches, one comprising two and the other comprising three clusters. The first branch contained cluster one and two (Fig. 4). Wood-pastures in the first branch were characterized by a high tree density and low DBH values. Furthermore, they showed a very right skewed DBH distribution. In the first cluster, wood-pastures were even denser and had lower DBH values than in cluster two, while range and standard deviation of the DBH were the lowest of all clusters in cluster two (Appendix 2). In both clusters plots from all countries were represented, except from Romania.

The second branch was formed by clusters three, four and five. These were wood-pastures with lower stem densities and higher values in mean, median and mode of the DBH. Clusters four and five were relatively similar. Both contained plots from homogenous wood-pastures with a low IQR, range and standard deviation, especially in cluster five. DBH followed an approximately normal distribution in both clusters (Fig. 4).

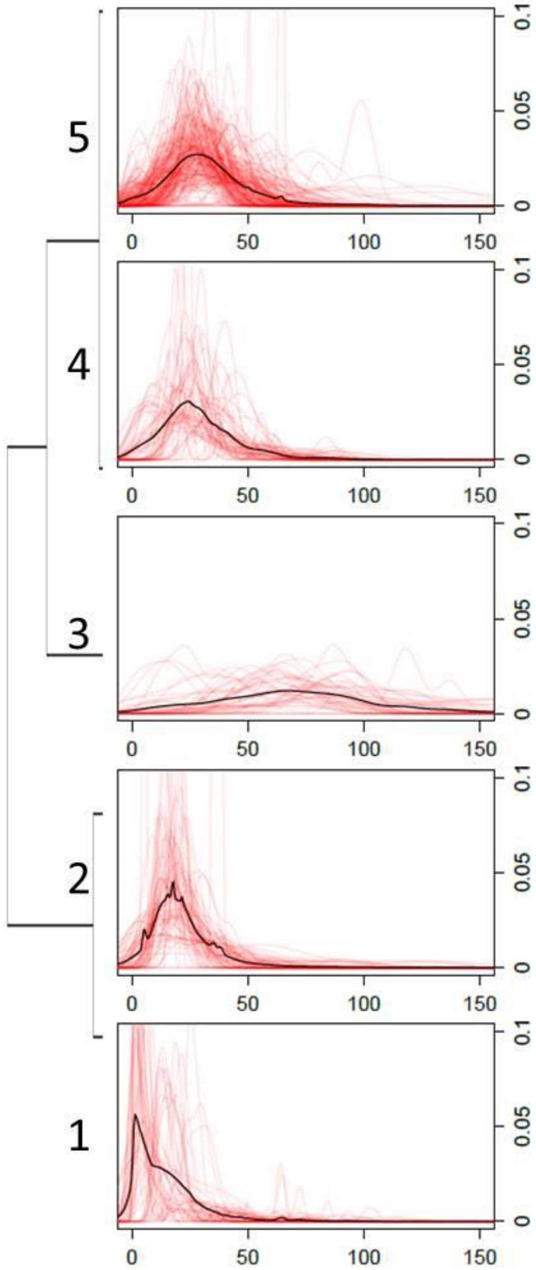


**Fig. 4** Distribution of the DBH structure of wood-pastures for the different clusters (1-5). Each red line denotes the estimated density distribution of the DBH (in cm; x-axes) in a single plot. The black lines indicate the average density distribution for plots in a given cluster.

Cluster four included plots from Germany, Hungary, Sweden and Portugal, while in cluster five plots from all countries were represented except Estonia. In contrast to clusters four and five, in cluster three we found wood-pastures with a very low tree density and trees with a high DBH but also a wide range and standard deviation of the DBH. This cluster contains almost only wood-pastures from Romania, apart from a small number of exceptions from Sweden.

Most of the countries were present in two to four different clusters, except Sweden, which was present in all clusters and Romania, which was almost entirely restricted to a cluster three (Fig. 5). Wood-pastures from Germany occurred mainly in clusters one and two, while Greece, Hungary and Italy were spread between cluster one, two and five. Portugal was mostly represented in clusters four and five.

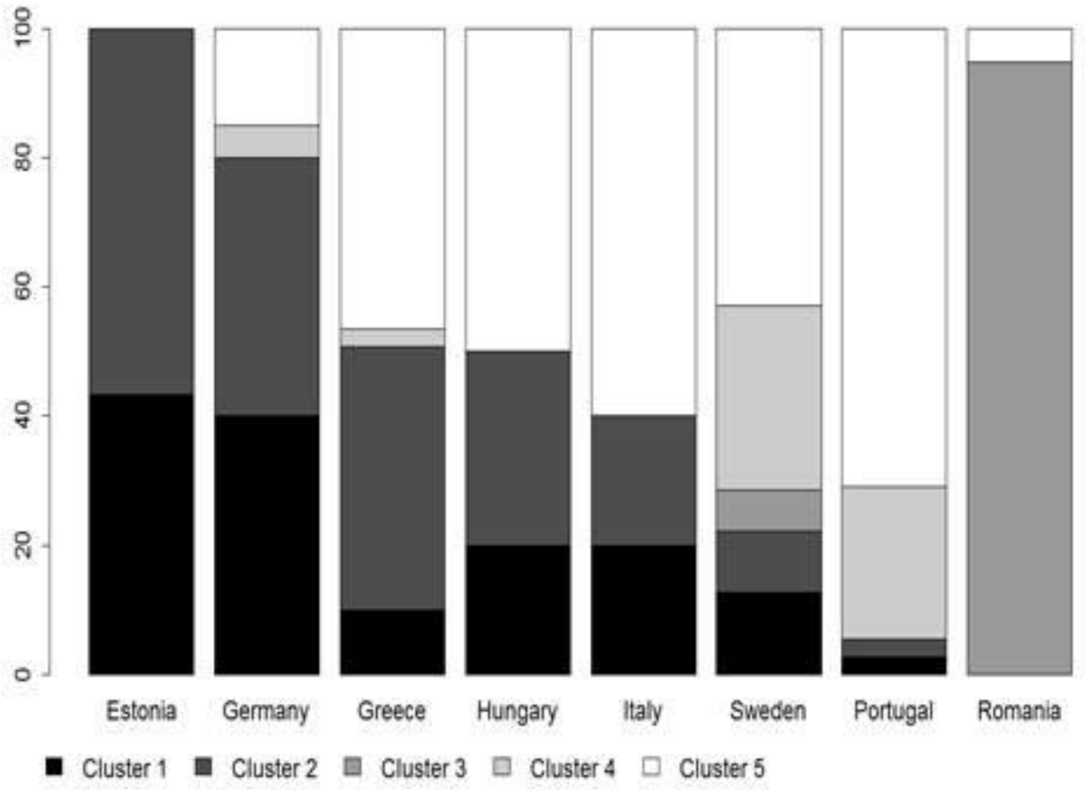


**Fig. 5** Distribution of the five clusters over the different countries

There was no clear pattern regarding grazed versus ungrazed sites. The ungrazed sites of Estonia were split between cluster one (n=6) and cluster two (n=4). Ungrazed sites from Germany were found in cluster one (5), cluster two (4) und cluster five (1). The ungrazed sites from Greece were split half (5) between cluster two and five. Both ungrazed site from Italy was found in cluster one, and one in cluster five. The only ungrazed site from Romania was found in cluster three.

## Discussion

Our results demonstrate a large structural gradient of wood-pastures across Europe, sometimes even within regions. We identified five different clusters along this gradient, showing three major groups of structural differences. The first group (clusters one and two) contained very dense wood-pastures and a high proportion of trees in the lower DBH classes. The second group (cluster three) was formed by very sparse wood-pastures with trees in the higher DBH classes, but only a few trees in the lower DBH classes, while a third group (cluster four and five) had intermediate characteristics. In the following, we discuss these findings in relation to existing knowledge on regeneration patterns, as well as to biogeographical and social-ecological differences, and the current policy environment. We conclude by outlining key implications for the future.

*Patterns of tree regeneration and density*

The distribution of current tree diameters in the three different groups of wood-pastures provides a clear indication of the status of tree regeneration in different regions across Europe (Garbarino and Bergmeier, 2014; Plieninger et al., 2003; Varga et al., 2015). While wood-pastures in the first and second cluster, mostly containing plots from Western Estonia and Northern Germany, show a lot of regeneration but very few old trees, in cluster three with mostly Romanian plots we found the largest trees but a near complete lack of regeneration. With the exception of clusters one and two, regeneration is suppressed in all wood-pastures examined compared to natural forest systems (Hartel et al., 2013; Plieninger et al., 2003).

To date, little is known about the regeneration rate of trees that is needed to secure the persistence of a given wood-pasture. However, drawing on the conceptual model of Plieninger et al. (2003) on changes in diameter distribution following the transformation from forest to dehesas in Spain, the DBH distribution in plots from Central Romania shows a clear trajectory for wood-pastures from that region towards becoming a treeless pasture. In contrast, the wood-pastures in cluster one (mostly plots from Western Estonia and Northern Germany) show clear signs of an abandoned wood-pasture, despite most of the sites being actively managed. Although wood-pastures in cluster four and five showed a normal (or bell-shaped) distribution typically associated with stand structure in wood-pastures (Garbarino and Bergmeier, 2014; Plieninger et al., 2003), it is not clear if regeneration in these wood-pastures is sufficient. A model by Kirby (2015) based on oak regeneration in wood-pastures in England, suggests that at least 32 trees per ha are needed in the age class of 50-100 years to maintain two trees above 400 years based on a loss rate of 0.5 trees per annum. According to this model, more trees are needed in the lower DBH classes to sustain a tree population. This finding, in turn, is consistent with Gibbons et al. (2008) who modelled the regeneration status of scattered tree systems around the world. For most regions, the persistence of trees is questionable – especially in the case of Central Romanian wood-pastures, which had an average tree density of only approximately 8 trees per ha. In combination, our findings suggest that wood-pastures in different regions of Europe face different structural problems. Regions such as Central Romania are at risk of losing their semi-open character from a lack of tree regeneration, whereas regions such as Western Estonia are at risk of losing this character due to too much regeneration.

*Biogeographical differences and social-ecological backgrounds*

Generally speaking, species composition in wood-pastures was broadly similar to expected species composition in the surrounding forest in a given region, apart from a higher occurrence of fruit trees compared to forest in some regions (Bölöni et al., 2011; Drössler, 2010; Garbarino et al., 2013; Hartel et al., 2013; Roellig et al., 2015). Only plots from Central Portugal stood out, with only one species being present. In most regions, oak species were among the most abundant species, except in the Italian system where oaks do not grow due to the high altitude (Ellenberg and Leuschner, 2010).

The structure of wood-pastures, and especially diameter distribution, is influenced by species composition. Some tree species such as birch do not grow to a large DBH (Ellenberg and Leuschner, 2010), and thus wood-pastures with a high percentage of birch evidently have more trees in the lower DBH classes – this may be the case for some wood-pastures in Southern Sweden and Western Estonia. In contrast, in Northern Germany, for example, wood-pastures were dominated by trees that can reach large DBH values, especially when not grown under a closed canopy (Pretzsch et al., 2015). Despite this potential for large DBH values in German wood-pastures, most sites actually were found in clusters with a high number of trees in the lower DBH classes – suggesting that management effects, rather than species composition, kept DBH values low. This difference is clearly apparent when comparing plots in German wood-pastures with those in Romania and Hungary, which are geographically relatively close, both located in hilly areas, and had similar species composition, but a very different structure.

When it comes to the management, one key part of wood-pasture management is the current grazing regime (Van Uytvanck and Verheyen, 2012). In the sample from Estonia, one third of the wood-pastures were ungrazed, while in Germany half of the sampled wood-pastures were ungrazed. We would have expected to find more ungrazed sites in the first cluster than in all other clusters, but there was no clear pattern in our results, suggesting that the current grazing management is part of the persistence of the semi-open character but not the only influence on the structure of wood-pastures. Importantly, our variable describing the status of grazing management related only to the present, but did not contain information on how long a given site had been grazed or ungrazed – this, in turn, may explain why we did not observe systematic differences between grazed and ungrazed sites.

Consistent with this, local history and past management appeared to have an important effect and can partly explain differences in the structure of wood-pastures across Europe. In Estonia, hundreds of years ago livestock was sent into the forest for grazing, but during the last hundred years, due to regime shifts and intensification of agriculture, wood-pasture management almost disappeared (Kukk and Sammul, 2006; Lotman and Lotman, 2011). This partly explains the high tree density and large number of trees in the lower DBH classes. The high tree densities in Northern Germany can be explained by a law which banned forest grazing (including wood-pastures) in the nineteenth century almost everywhere in Germany until today (Luick, 2008). In Central Romania, in contrast, the same prohibition (of grazing in the forest) led to an entirely different structure. Already opened up grazed forests were turned from forests into pastures, and today's sparse wood-pastures with old and large trees developed as a result of ongoing, long-term grazing management (Sutcliffe et al., 2014). In Hungary the same law also separated grazing and forest management, but a decrease in grazing activities in the mid of the 20th century led to an increasing tree regeneration (Varga et al., 2015). Also Italian subalpine wood-pastures were historically maintained sparse through positive selection of larch trees, but the second half of 20th century abandonment caused grazing decline and a subsequent increase of regenerating trees (Garbarino et al., 2011). Wood-pastures in Southern Sweden in contrast are located in a hilly landscape where small scale farming survived over a long period, leaving wood-pastures with a very diverse structure due to different topography and management (Jakobsson and Lindborg, 2014). Similarly, history influenced wood-pasture structure in Portugal. Here, the active tree management from the beginning 18th century, including planting and replanting, fundamentally shaped the stand structure of current wood-pastures (Costa et al., 2014; Joffre et al., 1999). The structure of the Greek wood-pastures is similar to distribution of natural Mediterranean oak forests, suggesting that the traditional land-use system has supported continuous regeneration. However, the almost complete absence of seedlings in the plots indicates that regeneration has been interrupted more recently, probably as a consequence of major intensification of livestock husbandry that took place in the past 20-30 years in the area (Plieninger et al., 2011).

*European and national polices and the challenges for wood-pasture management*

The loss of the semi-open character of wood-pastures is associated with a loss of biodiversity at both the local and landscape level (Bergmeier et al., 2010). Positive effects of trees, especially large old trees, have been reported for numerous groups of organisms (Manning et al., 2006; Söderström et al., 2001). In 2014, the European Union raised the limit of trees per ha from 50 trees per ha to 100 trees per ha (European Commission, 2014) for its financial support (through Single Area Payments – SAP), still leaving denser wood-pasture unsupported (Beaufoy, 2014). So far, recent studies found no specific threshold of tree density to maximise biodiversity benefits in wood-pastures. For example, Aavik et al. (2008) as well as Jakobsson and Lindborg (2015) found no significant difference in diversity of ground vegetation along a gradient of tree density. Similarly, Jakobsson and Lindborg (2017) found no negative impacts of increased tree density on bird diversity in Swedish wood-pastures, although Hartel et al. (2014) found a higher absolute species richness of passerine birds in wood-pastures compared to closed forests and open pastures in Central Romania. In combination, existing work suggests that the semi-open character of wood-pastures in general is more important than a specific threshold of tree density (see also Sammul et al., 2008). Instead of defining tree density limits, wood-pastures thus should be acknowledged as complex systems that are important for biodiversity through their structural heterogeneity. The benefits of such a pluralistic understanding of wood-pastures should be reflected through adequate flexibility in relevant European nature conservation and agricultural policies.

Finally, the current and historical social-ecological context affecting wood-pasture management needs to be taken into account when designing policies for wood-pastures

(Plieninger et al., 2015). Estonian wood-pastures are much denser due to their history and environmental conditions, and their management cannot be directly compared with systems that are environmentally and historically very different, such as wood-pastures in central Romania or Portugal. Nevertheless, where the SAP of the CAP does not cover the additional workload or financial cost to maintain the semi-open character of wood-pastures, such as replanting or cutting trees, national policies need to be established to motivate farmers to carry out the additional management (see also Roellig et al., 2015).

## Implications

The risk of losing the semi-open character of wood-pastures in Europe demonstrated by our results poses a key challenge for biodiversity conservation in these systems. So far management actions and policies are focusing on maintaining wood-pastures as open as possible, but this uniform focus does not adequately account for differences in the threats to persistence across Europe. As demonstrated by our results, wood-pastures in some locations (such as Romania) are at risk of being too open, whereas wood-pastures in other locations are at risk of overgrowing (e.g. in parts of Germany). These differences, as well as the importance of the social-ecological background driving them, need to be taken into account more fully in policies targeting wood-pasture management. Specifically, to maintain wood-pastures: (i) all wood-pastures should be eligible for the Single Area Payments of the European Common Agricultural Policy, independently of the number of trees per ha; (ii) nature conservation policies at the EU level need to include all wood-pastures across Europe as special habitat, while acknowledging regional differences; and (iii) regions with too much or too little tree regeneration should be supported by national policies for specific management actions.

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## Appendix

**Appendix 1**: Minimum, maximum and average values for the structural variables of plots in wood-pastures for each country. Minimum and maximum values for each variable are indicated in bold. (1Inter quarter range, 2Standard deviation, 310% Quantil, 490% Quantil)

| | | Mean | Median | Mode | Kurtosis | Skewness | IQR[1] | Range | SD[2] | Density | 10%[3] | 90%[4] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Minimum | **3.75** | 2.40 | 1.00 | -1.93 | -0.18 | 0.70 | **1.30** | **0.53** | 80.00 | 1.06 | **5.94** |
| **Estonia** | Maximum | 26.80 | 25.50 | 50.00 | 27.36 | 4.85 | 35.30 | 82.89 | 17.13 | **4944.00** | 15.98 | 49.66 |
| | Average | 14.51 | 12.54 | 10.90 | 4.01 | 1.42 | 11.12 | 42.97 | 9.64 | 945.60 | 5.25 | 25.59 |
| | Minimum | 7.17 | **1.00** | 1.00 | -2.17 | -0.89 | 9.00 | 27.00 | 8.80 | 4.00 | 1.00 | 21.00 |
| **Sweden** | Maximum | 46.36 | 50.00 | 57.00 | 8.09 | 2.43 | 41.00 | 125.00 | 26.08 | 263.00 | 26.80 | 67.70 |
| | Average | 22.61 | 21.12 | 15.02 | 0.76 | 0.65 | 18.71 | 64.44 | 14.72 | 83.55 | 5.96 | 40.56 |
| | Minimum | 5.02 | 1.20 | **0.00** | -1.39 | -0.87 | 1.35 | 22.60 | 7.06 | 86.00 | 0.30 | 8.34 |
| **Germany** | Maximum | 60.04 | 63.35 | 60.00 | **55.23** | **7.18** | 42.00 | 125.30 | 31.44 | 3504.00 | 45.80 | 88.32 |
| | Average | 25.37 | 19.81 | 14.75 | 4.96 | 1.65 | 21.74 | 82.03 | 20.02 | 876.86 | 7.56 | 49.82 |
| | Minimum | 17.59 | 8.00 | 5.00 | -1.83 | -0.53 | 8.44 | 21.34 | 9.41 | 40.00 | 5.00 | 54.00 |
| **Hungary** | Maximum | 108.37 | 116.00 | 143.00 | 7.42 | 2.85 | **119.00** | 175.80 | 58.89 | 3980.00 | 84.78 | 155.60 |
| | Average | 62.12 | 58.26 | 53.90 | 0.37 | 0.54 | 45.12 | 126.02 | 35.11 | 687.00 | 27.17 | 108.04 |
| | Minimum | 15.02 | 13.69 | 10.00 | **-2.75** | -0.71 | **0.48** | 2.88 | 2.04 | 28.29 | 9.99 | 18.27 |
| **Greece** | Maximum | 52.15 | 48.70 | 68.00 | 10.65 | 3.35 | 29.76 | 82.97 | 32.68 | 778.04 | 42.27 | 76.27 |
| | Average | 24.29 | 22.78 | 22.47 | -0.28 | 0.58 | 11.04 | 30.62 | 9.63 | 251.60 | 14.92 | 34.68 |
| | Minimum | 28.17 | 15.60 | 8.00 | -1.94 | -1.67 | 11.38 | 35.33 | 11.64 | **2.00** | 8.28 | 64.74 |
| **Romania** | Maximum | **124.24** | **146.10** | **162.00** | 3.98 | 1.82 | 100.75 | **197.35** | **59.38** | 16.00 | **99.95** | **203.50** |
| | Average | 77.29 | 76.28 | 62.44 | -0.74 | 0.11 | 33.71 | 85.07 | 26.24 | 8.09 | 48.09 | 106.21 |
| | Minimum | 14.13 | 7.50 | 10.00 | -2.25 | -1.10 | 3.50 | 25.00 | 11.09 | 88.00 | 4.70 | 26.20 |
| **Italy** | Maximum | 47.87 | 56.00 | 64.00 | 4.76 | 2.23 | 38.88 | 85.50 | 24.63 | 332.00 | 35.40 | 75.50 |
| | Average | 34.02 | 32.02 | 38.64 | -0.37 | 0.44 | 22.58 | 56.55 | 18.10 | 190.09 | 16.82 | 53.25 |
| | Minimum | 15.98 | 12.41 | 0.00 | -2.21 | **-1.91** | 0.96 | 10.82 | 3.20 | 25.00 | **0.00** | 22.54 |
| **Portugal** | Maximum | 61.50 | 64.30 | 83.00 | 8.06 | 2.78 | 33.42 | 86.58 | 27.02 | 265.00 | 55.51 | 70.83 |
| | Average | 31.72 | 30.87 | 30.09 | -0.23 | 0.29 | 13.37 | 40.18 | 11.72 | 76.39 | 19.61 | 44.47 |

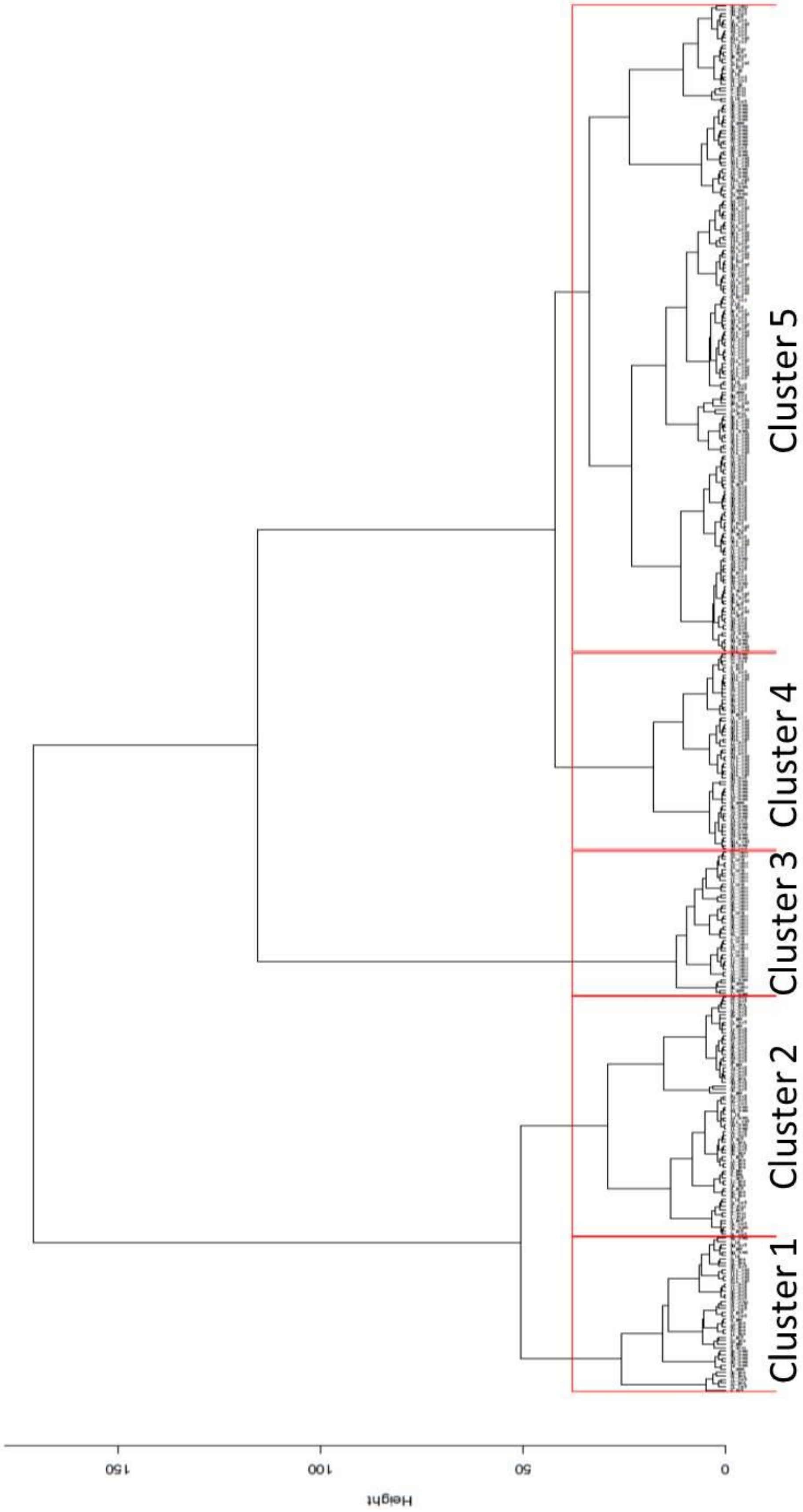
**Appendix 2**: Minimum, maximum and average values for the structural variables of plots in wood-pastures used for the principal component analysis (PCA) in all five clusters.
([1]Inter quarter range, [2]Standard deviation, [3]10% Quantil, [4]90% Quantil)

| | | Mean | Median | Mode | Kurtosis | Skewness | IQR[1] | Range | SD[2] | Density | 10%[3] | 90%[4] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cluster 1 | Minimum | 3.75 | 1.00 | 1.00 | -0.17 | 0.86 | 1.35 | 26.74 | 4.72 | 38.00 | 0.57 | 6.22 |
| | Maximum | 33.48 | 29.60 | 64.00 | 55.23 | 7.18 | 27.00 | 144.00 | 26.78 | 4944.00 | 23.11 | 55.00 |
| | Average | 14.74 | 9.89 | 9.19 | 7.61 | 2.43 | 9.88 | 65.14 | 13.40 | 989.93 | 5.92 | 28.20 |
| Cluster 2 | Minimum | 11.78 | 9.75 | 0.00 | -1.59 | -0.47 | 3.82 | 14.01 | 3.00 | 288.00 | 0.30 | 18.27 |
| | Maximum | 48.57 | 27.37 | 50.00 | 2.25 | 1.53 | 87.00 | 156.00 | 51.24 | 778.04 | 18.59 | 127.00 |
| | Average | 21.11 | 18.12 | 14.72 | -0.13 | 0.67 | 17.56 | 45.29 | 12.46 | 479.67 | 8.49 | 38.67 |
| Cluster 3 | Minimum | 15.33 | 15.50 | 1.00 | -2.17 | -0.69 | 10.50 | 27.00 | 11.27 | 2.00 | 3.00 | 27.50 |
| | Maximum | 124.24 | 146.10 | 162.00 | 2.33 | 1.82 | 100.75 | 197.35 | 59.38 | 16.00 | 99.95 | 203.50 |
| | Average | 73.03 | 72.57 | 59.80 | -0.93 | 0.13 | 31.77 | 80.32 | 25.20 | 7.44 | 44.90 | 100.58 |
| Cluster 4 | Minimum | 15.44 | 10.50 | 1.00 | -1.13 | 0.45 | 2.39 | 20.37 | 6.60 | 20.00 | 1.00 | 26.30 |
| | Maximum | 50.57 | 46.79 | 83.00 | 4.89 | 1.74 | 36.95 | 107.80 | 28.12 | 164.00 | 38.87 | 83.92 |
| | Average | 28.73 | 25.69 | 24.78 | 0.93 | 1.09 | 14.18 | 56.94 | 13.86 | 80.95 | 15.72 | 44.53 |
| Cluster 5 | Minimum | 14.25 | 11.00 | 0.00 | -2.75 | -1.91 | 0.96 | 10.82 | 3.20 | 15.50 | 0.00 | 22.54 |
| | Maximum | 108.37 | 116.00 | 143.00 | 5.58 | 2.03 | 119.00 | 175.80 | 58.89 | 440.00 | 84.78 | 155.60 |
| | Average | 32.77 | 32.63 | 30.30 | -0.84 | 0.00 | 17.04 | 43.02 | 13.11 | 89.72 | 17.97 | 47.30 |

**Appendix 3**: Full species list for all study regions (sometime only on genus level)

| Tree species | Estonia | Germany | Greece | Hungary | Italy | Portugal | Romania | Sweden |
|---|---|---|---|---|---|---|---|---|
| *Acer campestre* | | | | x | | | | |
| *Acer platanoides* | x | | | | | | | x |
| *Acer pseudoplatanus* | | x | | | | | | |
| *Acer* spp. | | | | | | | x | |
| *Alnus glutinosa* | x | x | | x | | | | x |
| *Alnus incana* | x | | | | | | | |
| *Betula pendula* | | x | | x | | | | x |
| *Betula pubescens* | | x | | | | | | |
| *Betula* spp. | x | | | | | | x | |
| *Carpinus betulus* | | x | | x | | | x | |
| *Cerasus mahaleb* | | | | x | | | | |
| *Fagus sylvatica* | | x | | | | | x | |
| *Fraxinus* spp. | | | | | | | x | |
| *Fraxinus angustifolia subsp. pannonica* | | | | x | | | | |
| *Fraxinus excelsior* | x | | | | | | | x |
| *Fraxinus ornus* | | | x | x | | | | |
| *Larix decidua* | | x | | | x | | | |
| *Malus sylvestris* | x | | | | | | x | x |
| *Olea europaea* | | | x | | | | | |
| *Picea abies* | x | x | | | x | | | x |
| *Picea* spp. | | | | x | | | | |
| *Pinus brutia* | | | x | | | | | |
| *Pinus cembra* | | | | | x | | | |
| *Pinus mugo* | | | | | x | | | |
| *Pinus sylvestris* | x | x | | | | | | x |
| *Populus tremula* | x | x | | | | | | x |
| *Prunus avium* | | | | | | | x | x |
| *Prunus domestica* | | | x | | | | | |
| *Prunus dulcis* | | | x | | | | | |
| *Prunus padus* | x | | | | | | | x |
| *Prunus serotina* | | x | | | | | | |
| *Pseudotsuga menziesii* | | x | | | | | | |
| *Pyrus amygdaliformis* | | | x | | | | | |
| *Pyrus communis* | | | x | | | | x | |
| *Pyrus pyraster* | | | | x | | | | |
| *Quercus cerris* | | | x | x | | | | |
| *Quercus macrolepis* | | | x | | | | | |
| *Quercus petraea* | | x | | | | | | |
| *Quercus pubescens* | | | x | x | | | | |
| *Quercus robur* | x | x | | x | | | | x |
| *Quercus rubra* | | x | | | | | | |
| *Quercus suber* | | | | | | x | | |
| *Quercus* spp. | | x | | | | | x | |
| *Robinia pseudo-acacia* | | | | x | | | | |
| *Salix caprea* | | | | x | | | | x |
| *Salix cinerea* | | | | | | | | x |
| *Salix myrsinifolia* | | | | | | | | x |
| *Salix* spp. | x | | | x | | | x | |
| *Sorbus aucuparia* | x | x | | | | | | x |
| *Sorbus intermedia* | x | | | | | | | x |
| *Tilia cordata* | x | | | x | | | | x |
| *Tilia* spp. | | | | | | | x | |
| *Ulmus glabra* | x | | | | | | | x |
| *Ulmus laevis* | | x | | | | | | |
| *Ulmus minor* | | | | x | | | | |

**Appendix 4**: Dendrogram resulting from the cluster analysis based on ten structural variables describing stand structure from eight countries across Europe. Cluster analysis was based on Euclidean distances and Ward's method.



# Chapter 4

# Chapter 4

## 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.

## 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 & 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 & Lindenmayer 2003). For this reason, old trees represent local 'biodiversity hotspots' in ecosystems around the world (Fischer et al. 2010; Lindenmayer et al. 2014). 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 & Peterken 2003; Bergmeier et al. 2010). Traditional pasture management has typically been low in 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 (Vojta & Drhovská 2012; Horák & Rébl 2013), 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. 2008), the Italian Alps (Garbarino et al. 2011), Belgium (Van Uytvanck et al. 2008), the Netherlands (Smit & Ruifrok 2011; Smit & Verwijmeren 2011), Spain (Plieninger & 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 (Uğurlu 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 land-use (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 & 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.

## Methods

### *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. 6.1). The region is dominated by traditional land-use practices and has low levels of infrastructure development. The most important land cover types based on CORINE land cover classes (see Table 6.1 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 ºC, with an average temperature of -4.3 ºC in January and 18.6 ºC in July. The yearly mean amount of precipitation is between 650 and 700 mm (Hartel and Moga, 2010).

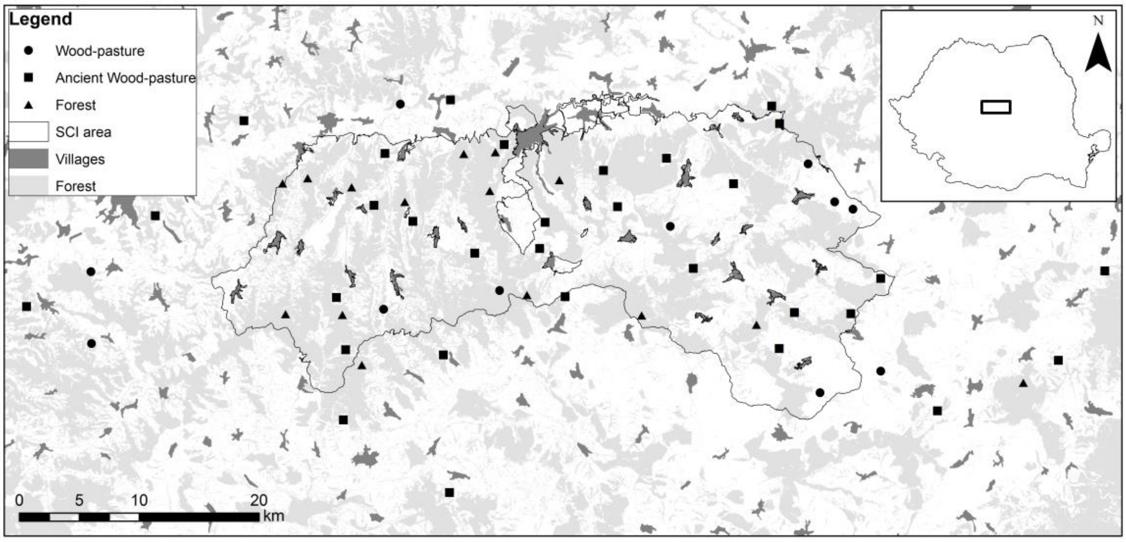


**Figure 6.1** Map of the study area. All survey sites, including wood-pastures, ancient wood-pastures, and forests are shown. The Natura 2000 site (SCI) is delineated (see study area in Central Romania description).

*Field methods and variables*

Data were collected in 2012. Forty-two wood-pastures and 15 forest sites were studied (see Supporting Information 6.1 and 6.2). 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 6.1. 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 & 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. 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 faeces. 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 6.1). We further recorded if we observed tree cutting activities in wood-pastures in 2012.

**Table 6.1** The description of the environmental variables used to characterize wood-pastures from Southern Transylvania and to model wood-pasture condition and composition. Variables highlighted in italics 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 | The median value was computed for each wood-pasture based on the diameter at breast height (DBH) in cm of trees higher than 3 m. These median values across all wood-pastures were then averaged. |
| 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 x 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. |

*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 & 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 6.1). The prevalence of Oak, Hornbeam, Beech and Pear were 'compositional' variables (see above and Table 6.1). 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 6.1): '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 (D 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.

## Results

*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 6.2). Tree communities differed between wood-pastures and forests (Fig. 6.2). Forest sites were dominated by Hornbeam (*Carpinus betulus*) and Beech (*Fagus sylvatica*), while wood-pastures were dominated by Oak (*Quercus* sp.) (Fig. 6.2).

**Table 6.2** 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,*<br>*A. platanoides,*<br>*A. pseudoplatanus,*<br>*A. tataricum,*<br>*A. negundo*[3] |
| *Betula* | + | + | *Betula pendula* |
| *Carpinus* | + | + | *Carpinus betulus* |
| *Fagus* | + | + | *Fagus sylvatica* |
| *Fraxinus* | + | + | *Fraxinus excelsior* |
| *Juglans* | - | + | *Juglans regia* |
| *Larix* | + | + | *Larix decidua*[1] |
| *Malus* | - | + | *Malus domestica*[2]<br>*M. sylvestris*[2] |
| *Pinus* | + | + | *Pinus nigra*[3]<br>*P. sylvestris*[3] |
| *Populus* | + | + | *Populus alba*<br>*P. tremula* |
| *Prunus* | + | + | *Prunus avium,*<br>*P. spinosa*<br>*P. cerasifera* [2]<br>*P. domestica*[2] |
| *Pyrus* | - | + | *Pyrus communis*[2]<br>*P. pyraster*[2] |
| *Quercus* | + | + | *Quercus petraea*<br>*Q. pubescens*<br>*Q. robur*<br>*Q. robur × Q. petraea*<br>*Quercus rubra*[3] |
| *Robinia* | + | + | *Robinia pseudoacacia*[1] |
| *Salix* | - | + | *Salix alba*<br>*S. caprea,*<br>*S. cinerea,*<br>*S. fragilis,*<br>*S. purpurea,*<br>*S. triandra* |
| *Tilia* | + | + | *Tilia cordata* |

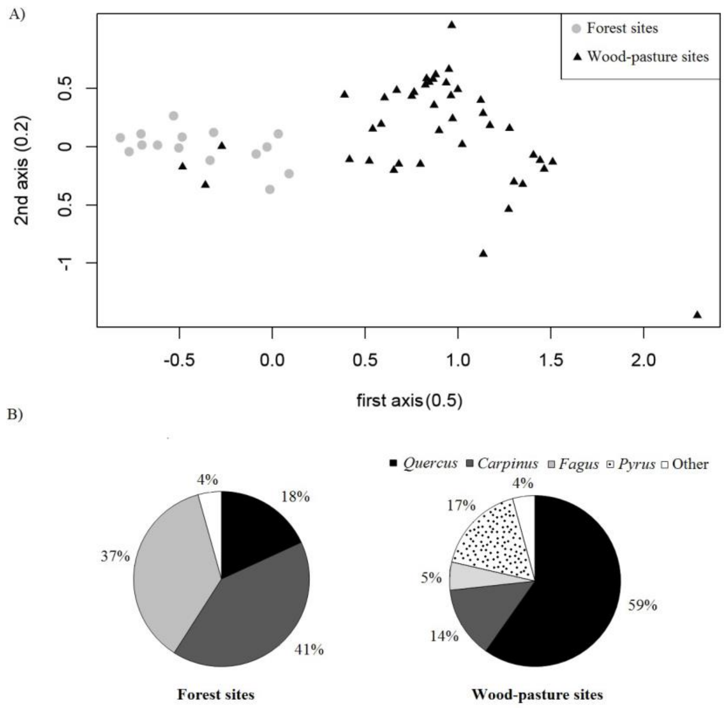


**Figure 6.2** Tree community composition in forests versus wood-pastures. A) Illustration of tree communities based on genera composition from forests versus wood-pastures using detrended correspondence analysis. Eigenvalues are given in brackets for each axis. The length of first axis is 3.1 and that of the second axis is 1.7. B) Percentage of the most common tree genera found in forests and wood-pastures.

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. 6.3). Wood-pastures contained more ancient trees and more trees of conservation value, while only two individuals of such trees were found in forests (Table 6.3). 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, $P < 0.05$).

**Table 6.3** 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 (31) |
| 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

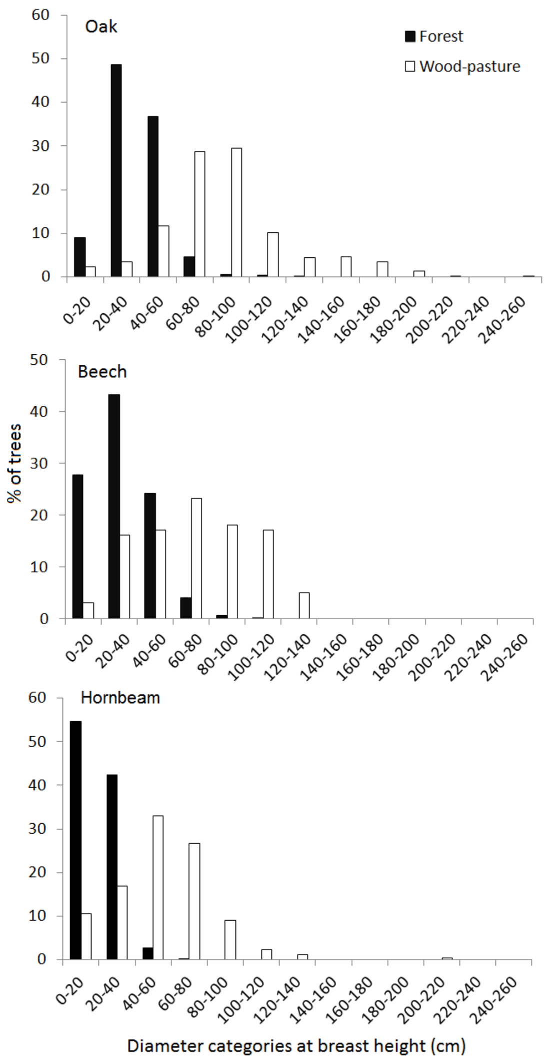


**Figure 6.3** The percent representation of the tree size categories in forests and wood-pastures. Only Oak, Hornbeam and Beech are shown because these were the most common trees present in both forests and wood-pastures.

*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 6.4. 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 6.4). Evidence for scrub removal (APIA) was found in 88% of wood-pastures (Table 6.4). Management by burning in 2012 was observed in 50% of the wood-pastures (Table 6.4). 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 five wood-pastures, two of them being ancient (sensu Farm Environment Plan Guide 2006).

**Table 6.4** 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 |
| Number of scattered trees | 260.64 | 230.44 | 0.88 |
| Proportion of dead trees | 0.06 | 0.10 | 1.72 |
| Tree size | 74.25 | 23.11 | 0.31 |
| Scrub cover | 0.06 | 0.12 | 1.90 |
| 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 (APIA) | 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% | | |

*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 6.5). For the prevalence of particular genera, the best models always included all three groups of variables (M + S + L) (Table 6.5). GLM analysis showed that the proportion of dead trees was positively related to surrounding forest cover (Table 6.6). Moreover the prevalence of Oak, Hornbeam and Beech was positively and the prevalence of Pear was negatively associated with forest cover (Table 6.6). Oak prevalence was negatively and Beech prevalence was positively related to ruggedness (Table 6.6). Distance to the nearest village was related negatively to the prevalence of Pear and positively to the prevalence of Beech (Table 6.6). Oak prevalence was negatively and Pear prevalence was positively associated with elevation (Table 6.6).

**Table 6.5** Model selection results for response variables describing different aspects of wood-pasture condition and composition. The best ranked models ($\Delta i \leq 2$) 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** | **$\Delta_i$** | **$w_i$** |
|---|---|---|---|---|---|---|
| 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 |

**Table 6.6** 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<0.001.
** = P<0.01.
* = P≤0.05.

## 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.

*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 & A. 2007; Hartel & 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 & 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 & 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 ≥100 cm may be at least 200 years old, and the largest Oaks may be up to 700–800 years old (Hartel & Moga 2010; Patrut 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 & 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 and overview of forest managament 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.

*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 6.4). 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 (Plieninger & Schaar 2008; Bergmeier et al. 2010; Costa et al. 2011; Garbarino et al. 2011; Chételat et al. 2013).

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).

*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 prevalence 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 6.5) 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 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.

*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 Sighisoara. 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 (Patrut 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 & 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 & 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.

## 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 land cover 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

Figure 1. KML-file of the surveyed wood-pasture sites shown in Google Earth Map

Figure 2. KML-file of the surveyed forest sites shown in Google Earth Map

# Chapter 5

# Chapter 5

## Reviving wood-pastures for biodiversity and people: A case study from western Estonia

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## Abstract

Wood-pastures are associated with high cultural and biodiversity values in Europe. However, due to their relatively low productivity, large areas of wood-pastures have been lost over the last century. In some areas, incentive schemes have been developed to revive wood-pastures. We investigated the effects of one such scheme in western Estonia. We compared the structure of grazed wood-pastures (old and restored) to those of abandoned wood-pastures and ungrazed forest stands to explore the effects of management, and conducted interviews with 24 farmers to investigate their motivations to carry out the management. We found a positive influence of active management on the semi-open structure of wood-pastures. Financial support was vital for management, but personal values related to tradition also played an important role. The interviewees differed widely in their range of motivations, suggesting that other strategies in addition to financial incentives would further improve the management of wood-pastures in the region.

## Introduction

Wood-pastures are complex social–ecological systems (Huber et al. 2013; Hartel and Plieninger 2014). Since their origin in Europe in the Holocene (Bergmeier et al. 2010), they have developed as multifunctional resources, shaped by the local needs of humans, local social and environmental factors, grazing intensity, and type of livestock (Chetelat et al. 2013; Hartel and Plieninger 2014). The resulting mosaic of grassland with shrubs and trees of different ages as well as variable light and shade conditions provides important semi-open and semi-natural habitats for a wide range of species (Bergmeier and Garbarino 2014; Falk 2014; Hartel et al. 2014).

As social–ecological systems, wood-pastures depend on management to maintain their characteristic structure. The loss of this management due to the changing social and economic context of farming and forestry has led to their decline throughout Europe over the last century (Bergmeier and Roellig 2014). In the European Union (EU), one major recent driver of changes in European wood-pasture management has been the availability of agricultural support payments under the EU common agricultural policy (CAP) (Hartel et al. 2013; Beaufoy 2014). Most wood-pastures are ineligible for single area support payments (SAP) from the first pillar of the CAP because they are too dense (Beaufoy et al. 2011). Nevertheless, some are eligible for payments through agri-environmental schemes (AES) under the second pillar of the CAP, or through national support schemes (Beaufoy 2014). AES and associated financial incentives have often been hailed as potential solutions to stop the decline of semi-natural habitats (Ahnström et al. 2008; de Snoo et al. 2013). Although financial aspects are important (e.g., Siebert et al. 2006; Burton and Schwarz 2013), they are not the only factors motivating land man- agers, and personal norms and values have also been found to play a role (Burton 2004; Siebert et al. 2006; Ahnström et al. 2009). It is therefore important to understand the interplay of different motivations of land managers to design effective conservation incentives (de Snoo et al. 2013; Birge and Herzon 2014).

Like many other countries in Europe, Estonia has a long tradition of wood-pasture management (Talvi and Talvi 2012). In Estonia, grazing in forests was historically wide- spread (Troska 2004), and although this practice was stopped in eastern Estonia in the late 18th century, it continued in the west until the early twentieth century (Meikar 2002a, b). In western Estonia, wood-pastures were mostly used as common land until independence in 1918 (Troska 2004). After this, pastures in Estonia were rapidly divided up among farmers and fenced, leading to an abrupt reduction in forest grazing (Lotman and Lotman 2011). Much land fell out of use during the communist era due to rural depopulation, enforced collectivization, and later due to the industrialization of agri- culture. By the 1970s, a large proportion of natural grassland had been plowed and fertilized, and most of the wood-pastures were abandoned or only grazed very lightly. This situation did not change after the end of the Soviet period in 1990, and by 1999 grazing in wood-pastures had almost completely ceased (Kukk and Sammul 2006). In 1996, the first trials of grazing subsidies for managing and restoring semi-natural grasslands started in Matsalu National Park, which were later expanded to the whole country (Lotman 2004). Currently, Estonia is one of the only countries in the EU providing financial support to maintain intact wood-pastures and restore abandoned ones (Sammul et al. 2008).

Estonian wood-pastures are listed in Annex I of the EU Habitats Directive (type 9070 Fennoscandian wood-pastures) and many are protected within Natura 2000 sites. Most Estonian wood-pastures do not receive SAP (Beaufoy et al. 2011), but are eligible for AES. After a 3-year pilot project, a national subsidy scheme was introduced in 2001 to support the management of semi-natural habitats, including wood-pastures. This included payments to maintain their semi-open structure (e.g., grazing and tree thinning), as well as to restore abandoned wood-pastures (e.g., tree removal and fencing) (Talvi 2010). Since 2007, the payments for wood-pasture maintenance are part of the national AES, while restoration is paid solely by the Estonian government. In the context of the widespread decline of wood-pastures throughout Europe, lessons learnt from Estonia could provide valuable insights for their conservation in other countries.

To date, there is little published information about the management and structure of wood-pastures in Estonia. Wood-pasture maintenance and restoration activities have not been investigated, either in terms of their effects on habitat structure, or concerning the motivations of farmers to carry out these activities. Focusing on western Estonia, we therefore investigated (i) the effects of restoration activities on the structure of wood-pastures and (ii) the motivations of farmers to carry out these activities. We also provide general information about the structure of wood- pastures and their current management in western Estonia. To achieve these aims, we combined ecological surveys of 30 wood-pastures (abandoned, restored, and old), as well as of 10 ungrazed forest sites as reference points, with semi- structured interviews with farmers.

## Materials and methods

### *Study area*

The study was conducted in the counties Saaremaa and Läänemaa in western Estonia in summer 2013. Läänemaa is located on the west coast of mainland Estonia, while Saaremaa consists of the islands Saare and Muhu (as well as many other small islands) in the Baltic Sea (Fig. 1). The proportions of land-use types are similar in both counties, namely (aver- age for both counties) 49%forest (20%broad-leaved forest, 17% coniferous forest, 12% mixed forest) and 28% agri- cultural area (11% arable land, 11% heterogeneous agricultural land areas, 6%open pastures) (CORINE land-cover; European Environmental Agency [EEA] 2006). The counties were chosen because of their relatively high abundance of wood-pastures (Lotman and Lotman 2011).

*Ecological data*

We selected 30 wood-pasture sites based on a map of the habitat type 9070 (Fennoscandian wood-pastures), information about grazing activities from the Estonian Environmental Board, and additional information about the history and the management of the sites from interviews with farmers (see below). We also selected 10 ungrazed forest sites for comparison, which were chosen randomly via ArcGIS based on CORINE land-use cover of deciduous forest and mixed forest (avoiding pine plantations). Active wood-pastures were categorized as *old* (actively used for >10 years with maintenance but no major restoration) or *restored* (used for<12 years with major restoration activity during this period). *Abandoned* wood-pastures had been unused for at least 5 years. Ten sites were surveyed for each of these four categories, seven of which were on Saaremaa and three on Läänemaa (due to the higher frequency of wood-pastures on Saaremaa) (Fig. 1).

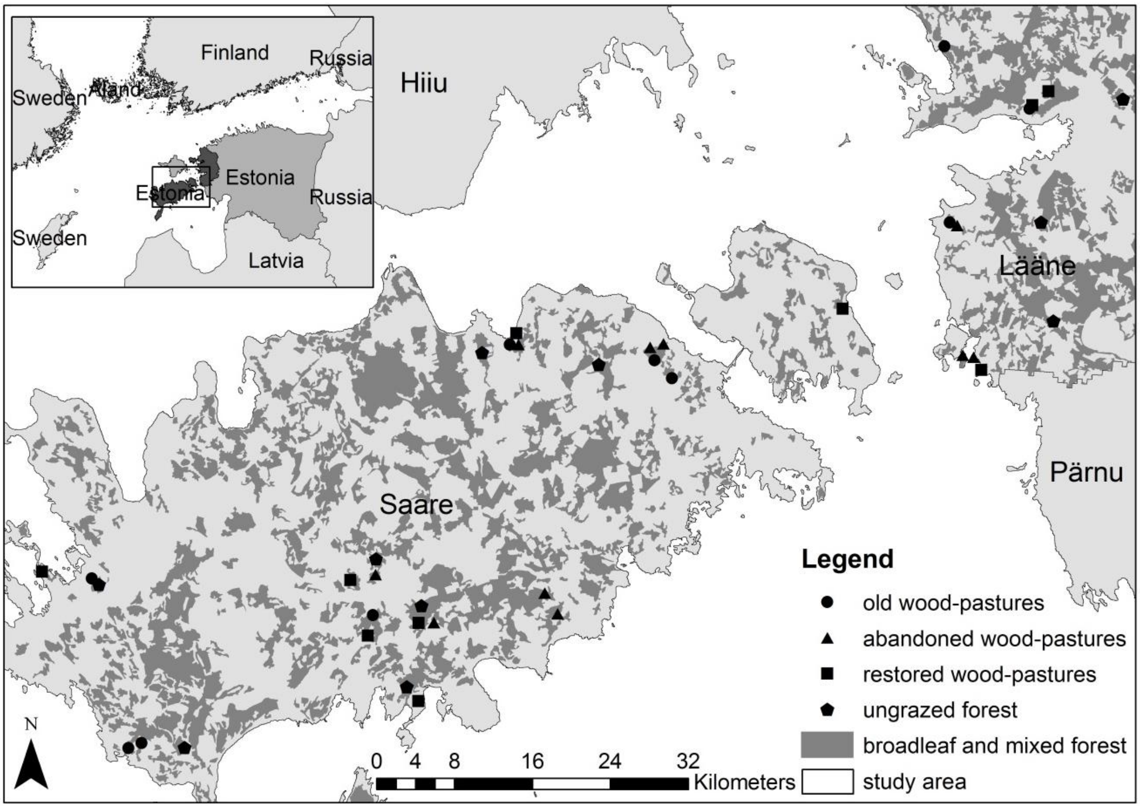


**Figure 1** Study area in western Estonia, with the counties Saaremaa and Läänemaa, showing broadleaf and mixed forest in the study area and all 40 survey sites

To characterize the stands, we surveyed one 25 m x 25 m plot (0.0625 ha) in each site. The plots were placed subjectively in a representative area near the center. We measured the diameter at breast height (DBH) for all living and dead trees within this plot, estimated their height, and identified species. In plots with unusually low tree densities, we also measured trees in the immediate vicinity of the plot perimeter until a minimum of 50 trees per plot was reached, so that the sample sizes for species composition and DBH distribution were statistically robust. The density of each plot was based on the number of trees within the 25 m x


**Figure. 2** Examples of sites from different management categories: **a** old wood-pasture dominated by hazel, ash, and birch; **b** restored wood-pasture with birch, hazel, and ash; **c** bandoned wood-pasture with hazel and lime; and **d** ungrazed forest dominated by hazel and pine

25 m plot. Within each plot, we also recorded shrub cover including tree saplings (visual estimation) and took five pictures with a fish-eye lens to determine canopy openness. The latter were analyzed using the software Gap Light Analyzer 2.0 (Frazer et al. 1999).

We analyzed seven variables (following McElhinny et al. 2005) to describe stand structure: (1) tree density per ha, (2) standard deviation of DBH, (3) standard deviation of height, (4) % shrub cover, (5) % of canopy openness, (6) basal area of dead wood, and (7) species richness within the plot or within the minimum of 50 trees. The variables density, shrub cover, and dead wood were skewed, so we log-transformed them for analysis. No strong correlations (Spearman's rank correlation coefficient\0.6) were found between the habitat variables. To explore relationships between habitat variables and land-use categories, we performed a principal component analysis (PCA) with the set of habitat variables described above. To test for significant differences between the land- use categories, we used a MANOVA with default Pillai statistic. Afterwards, we performed individual ANOVAs with Bonferroni corrections for each single variable. For significant variables, a post hoc test (Tukey HSD, using the R package multcomp; Hothorn et al. 2008) was performed to determine differences between categories. All analyses were performed using the ''stats'' package in the software R (version 3.0.2) (R Core Team 2013).

*Interview data*

To address the motivations of farmers for managing wood- pastures, we conducted 24 semi-structured interviews with farmers (both commercial and hobby farmers, hereafter referred to collectively as farmers). Of these, 17 were conducted on Saaremaa and 7 in Läänemaa. All interview partners actively managed wood-pastures, except one who owned but did not manage a wood-pasture. Because no owners of abandoned wood-pastures could be located, we did not include these in our interview sample. Interviews lasted on average for 30 min (min. 10 min, max. 1 h) and were conducted either in Estonian with the help of a translator (n = 21), or in English or German by the interviewer (n = 3). All interviews were recorded, sometimes only partly (n = 4), and supported by notes. Our questions covered two themes: (i) details on wood-pasture management to provide background information about the system and for further analysis of the interviews, and (ii) motivations for managing wood-pastures and benefits of wood-pastures in general, but also benefits for the farm and livestock in question, as well as participation in and importance of AES and restoration schemes. All interviews were transcribed and translated, and interview notes were added to the transcripts. We used content analysis to identify motivations for farmers to manage wood-pastures, coding the interviews thematically using the software MaxQDA 11 (MAXQDA 2014). We then identified different types of farmers based on the different combinations of motivations.

## Results

*Ecological data*

In total, we measured 4808 trees in 30 wood-pastures and 10 forest sites. The density of wood-pastures ranged from 368 trees per ha (category old) to 6704 trees per ha (abandoned). The standard deviation of diameter per site ranged from 3.27 (old) to 15.51 cm (old), while that of height ranged from 3 m (abandoned) to 20 m (abandoned). Shrub cover ranged from 1% (old and restored) to 50% (forest). We found 3–14 tree species per plot, with maxi- mum and minimum occurring in old sites. Canopy open- ness ranged between 8 % (forest) and 68% (restored), and dead wood ranged from 0 cm2 (old) to 19 718 cm2 (old) (Fig. 2).

We found 25 tree species in total, 24 species in wood-pastures, and 23 species in forest sites. The most common species in wood-pastures was birch (*Betula* spp.), which occurred in 80 % of all wood-pastures and represented 10 % of all recorded individuals. Ash (*Fraxinus excelsior*) was found in 76 % of wood-pastures but represented only 8% of all individuals. Hazel (*Corylus avellana*), on the other hand, was found in 71% of wood-pastures and rep- resented 22 % of all individuals in wood-pastures. Finally, oak (*Quercus robur*) occurred in 73% of wood-pastures and represented 5 % of all individuals (Table S1).

The first PCA axis of habitat variables explained 37% of the variance and represented a gradient from high canopy openness and low amounts of dead wood to low canopy openness and more dead wood (Fig. 3). The second axis (26% of variance) represented the standard deviation of diameter and height. Of all variables, species richness had the lowest effect on the PCA. Old and restored wood- pastures were separated along the first axis from abandoned wood-pastures and forest sites.

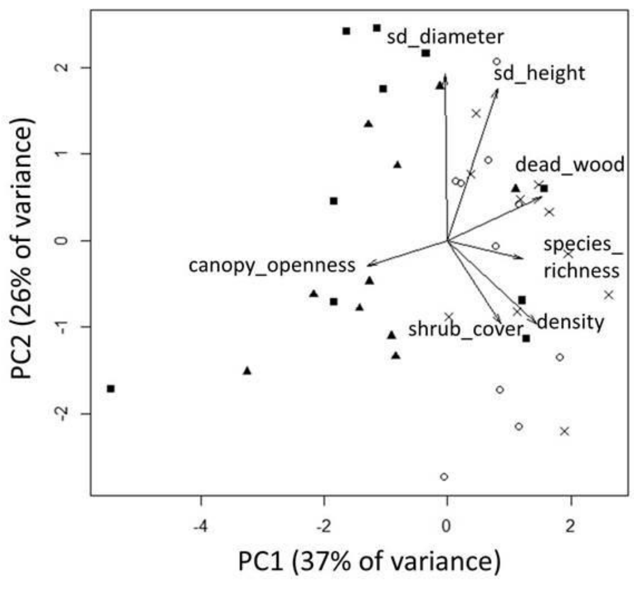


**Figure 3** Principal component analysis (PCA) of seven structural variables in old wood-pastures (squares), restored wood-pastures (triangles), abandoned wood-pastures (circles), and forest sites (crosses)

The MANOVA also showed significant differences between the wood-pasture categories in terms of their structural characteristics (d.f. = 21, F = 2.2, p\0.01). The individual ANOVAs showed only density and canopy openness to be significantly different between categories (Table 1). The post hoc tests showed old and restored wood-pastures to be significantly less dense, with a significantly more open canopy than forest or abandoned wood-pastures (Fig. 4).

**Table 1** Results of individual ANOVAs showing the significance of the differences between old, restored, and abandoned wood-pastures and forest categories. P values given with Bonferroni correction (**\0.01, ***\0.001). Differences between the site types are shown in Fig. 4

| Variable | Degree of freedom | Sum of square | F | Corrected p-value |
|---|---|---|---|---|
| Density (stems per ha) | 3 | 9.568 | 9.023 | 0.001** |
| Standard deviation of DBH | 3 | 7.490 | 0.226 | 1.000 |
| Standard deviation of height | 3 | 2.607 | 0.281 | 1.000 |
| Shrub cover | 3 | 10.282 | 3.895 | 0.116 |
| Canopy openness (%) | 3 | 3394.40 | 10.237 | <0.001*** |
| Dead wood | 3 | 23.198 | 3.395 | 0.197 |
| Species richness | 3 | 30.600 | 1.671 | 1.000 |

*Interviews*

History and management of wood-pastures

Around half of the interviewees took (back) possession of their current land in or after 1991 (the end of Soviet rule). Only a few of the interviewees had farmed independently before that time with a small amount of land, while the others established their farms more recently. Farming was the main source of income for the majority of the interviewees, but some kept animals as a hobby. Where farming was not the main business, it was often combined with tourism. Where farming was the main business, it mostly focused on livestock. Few farmers also grew crops commercially, while most made hay and grew crops for their own use. The most common livestock in wood-pastures was cattle, mostly for beef. Dairy cattle had been declining in the last 10 years, because of the low price for the milk and/or the workload with the dairy cows. Besides professional farming, livestock also served to keep the land open. Sheep were more common 10 years ago, but for various reasons (e.g., lynx attacks on the mainland) many farmers changed to cattle. Our sample included only one farm where horses and goats were kept in a wood-pasture. The number of animals per farm ranged from 5 to 300.

Over half of the farms practiced organic farming, but not all of them were certified. The main reason for not being certified was that farmers perceived the paperwork and monitoring as excessive: ''*I was organic for 2 years in the beginning. I don't use any fertilizers or chemicals, but the paperwork and requirements are just too much*.''(I3).

Of the wood-pastures we surveyed, the longest continuous use we could confirm (including use by previous owners) was 30 years, the shortest 6 years. Nevertheless, the history of wood-pastures was difficult to reconstruct due to changes in ownership and different land reforms, and previous land use sometimes even varied within a single pasture.

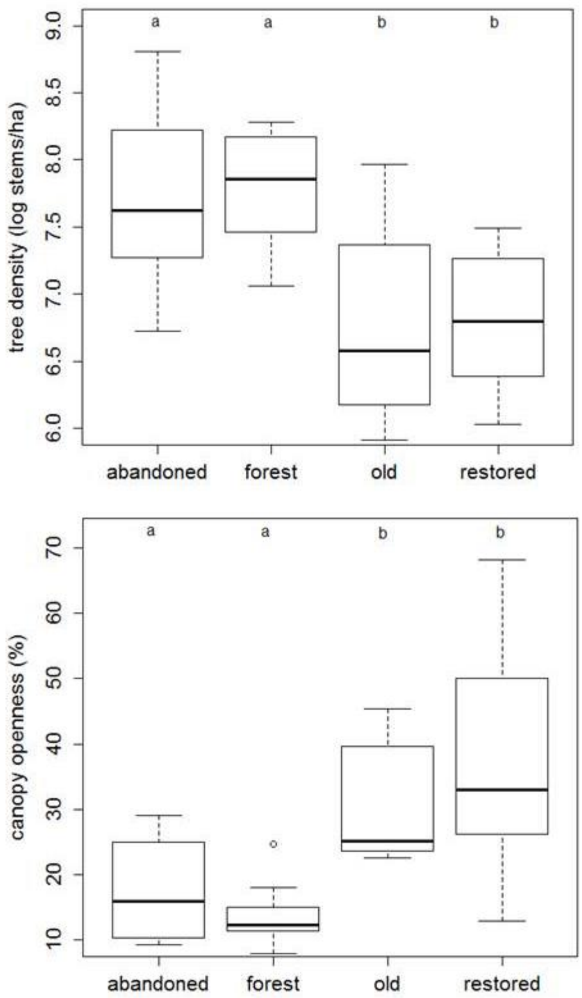


**Figure. 4** Variation in a tree density (shown on log scale) between old, restored, and abandoned wood-pastures and forest sites, and b canopy openness for the different categories. Significant differences (p\0.05) according to the post hoc Tukey HSD are shown with different letters (see Table 1 for ANOVA scores)

Typically, wood-pastures were either grazed at low intensity, mown, or farmed more intensively as part of a collective farm. Many had been abandoned during the second half of the twentieth century. Only eight of the interviewees farmed only their own land. Typically, the majority, if not the whole area of a given wood-pasture, was rented from neighbors or the state. Often wood-pasture areas were adjacent to other semi-natural habitats such as alvars (natural calcareous grasslands) or coastal pastures.

Tree management was also diverse. Most farmers managed trees in some way, mainly to keep the pastures open rather than to produce wood. One farmer did not cut out trees, because his rented land had too many different owners and it was complicated for him to agree on a management regime with the other owners. Farmers often mentioned that it was difficult to manage the trees if the land belonged to the state. Tree management varied from cutting single trees with a chainsaw to removing groups of trees with light machinery (bought from the subsidies). All kinds of trees were cut, but in general farmers preferred to keep broadleaf trees or ''*the good looking trees''* (I8). Oaks would always be kept and were considered typical wood-pasture trees. If there was a lot of wood left (e.g., after first restoration activities), it was typically used as firewood for personal use or sold for woodchips. All interviewees received agricultural subsidies from the state, but only one received SAP from the first pillar of the CAP. All other wood-pastures surveyed were not eligible for area support due to their high density of trees, but participated in the AES for grazing semi-natural habitats; ten of them also participated in the restoration scheme.

Farmers' motivations to manage wood-pastures

Five categories of motivations emerged from the content analysis, which represent extrinsic motivations (two categories) and intrinsic motivations (three categories). Both extrinsic motivations were financially driven, but in different ways. Due to the rapid regrowth of trees and the similarly high labor costs of both management and restoration, the differences in motivation for management and restoration were often blurred. We therefore concentrated primarily on the motivation for management, but refer to the motivation for restoration in the description of different groups of farmers where appropriate (see below). The most frequently mentioned motivation was **financial support**. Farmers could not afford to manage the wood-pastures without subsidies (either SAP or AES): ''*Without the subsidies it would be impossible to buy any kind of machinery. And since the cattle is on semi-natural habitat, their production isn't as good as production-oriented cattle*'' (I8). Without the payments, most interviewees would give up the wood-pastures, keeping them only in some special cases, for example, in combination with other, more profitable land, or as a hobby. One farmer said that he would keep wood-pasture without the payments, if it were his own land.

The second extrinsic motivation was the **scarcity of land**. ''*There was no other land*'' (I24 and I13), especially because wood-pastures were historically common in western Estonia. During the Soviet era, farmers would use wood-pastures because this was the land left for private livestock after collectivization. Newly established or expanding farms recently looking for land only found semi-natural habitats (including wood-pastures) left for rent, which they were not allowed to clear as they were already included in a protected area. The intrinsic motivations were more complex, but in our analysis, three main categories emerged. The most frequently mentioned kind of intrinsic motivation was **tradition**. This included traditional farming methods (''*It has always been like this [with trees and grass]*'' (I17)) and the memory of the landscape (''*When I was little, it was all clean and beautiful*'' (I20)). Keeping tradition alive seemed to be a strong motivation for land owners to maintain or even restore wood-pastures. To keep the landscape open was part of this tradition, and land owners (especially hobby farmers) felt responsible for maintaining the landscapes. The second intrinsic motivation was **animal welfare**, that is, providing ‘‘natural’’ conditions for the animals and healthy fodder in the wood-pastures (and in other semi- natural habitats). People believed that having animals in a wood-pasture was ‘‘*closer to nature*.’’ The animals could find shelter from rain, sun, wind, and snow. They were often out for the whole year and even gave birth in denser parts of the wood-pasture. The animals found more diverse fodder from ground and woody vegetation, with the result that some farmers did not have to medically treat their animals as much (e.g., for worms). The third category, **biodiversity**, was less frequently mentioned. The farmers talked about the diversity of plants and also birds, sometimes even mammals. Some of the pastures were wooded meadows before, and as such had been the subject of scientific research—hence, some farmers were aware of rare species. Where farmers knew about rare species in their pasture, they expressed pride in hosting them.

Types of farmers

Based on the combinations of motivations stated by the interviewees, we identified three groups of farmers. Nota- bly, some farmers did not fit into any of these groups, but rather showed a broad range of motivations. The ‘‘**traditionalists**’’ had a high intrinsic motivation, valuing tradition above other factors. Their main concern was keeping the landscape open, because they ‘‘*…don’t want to live in the jungle’’* (I3). They were not highly dependent on direct profits from the wood-pastures, because they often had only small pastures, sometimes in combination with larger areas elsewhere or non-farming income (e.g., tourism). Biodiversity and animal welfare were also important to this group, but were not the main motivation. Farmers in this group had little to no financial motivation, but still without the payments many would have been unable to manage the pastures. Some of the restored wood-pastures in this group were only reactivated because of tradition. Either ‘‘*it has always been like is*’’ (I17) or farmers wanted to maintain the landscape they remembered from their childhoods. Second, ‘‘**profitable stewards**’’ had both extrinsic and intrinsic motivations. Farming was their main source of income, and often the wood-pastures were combined with other (large) semi-natural habitats such as coastal pastures. Profitable stewards wanted to make profit, but at the same time also had a high intrinsic motivation, mostly relating to animal welfare and biodiversity conservation. Old wood- pastures in this group often belonged to established organic farms, including some of the first organic farms in the region: ‘‘*We have always been organic*’’ (I11 and I19). Farmers participating in the restoration scheme in this group were often looking especially for semi-natural habitat to rent and restore, because it was not only the most frequently available land, but also suitable for meeting organic farming guidelines and perceived as environmentally friendly. Third, ‘‘**opportunists**’’ were mostly motivated by the extrinsic motivation of the scarcity of land, but also by financial aspects. Farmers in this category managed wood- pastures mainly because it was the only land they had. Since the wood-pastures were not eligible for the SAP, they joined the AES to get some additional money. If they took part in the restoration scheme, they often used the restoration subsidy to modify land they were already using so that it would become eligible for management subsidies.

## Discussion

Our results showed a positive effect of subsidies on the habitat value of wood-pastures, as restored sites were not significantly different from old wood-pastures in density and canopy openness, while abandonment rapidly led to a forest-like structure. The significant difference between old/restored and abandoned sites shows that wood-pastures in Estonia are dependent on active management. We identified a variety of motivations for farmers to carry out this management, both extrinsic (e.g., financial support) and intrinsic (e.g., tradition). The interviewed farmers differed considerably in their motivations. Nevertheless, almost all farmers confirmed that they would not manage the wood-pastures without the AES payments, making this a necessary (albeit not sufficient) condition for farmers to manage wood-pastures.

### *Wood-pasture structure*

In general, Estonian wood-pastures appeared to be a lot denser than wood-pastures in other parts of Europe (min. 368 trees per ha). For example, an average of only eight trees per ha was recorded in Romanian wood-pastures (Hartel et al. 2013), while Spanish wood-pastures ranged from *16 trees per ha in old stands and *28 trees per ha in younger stands (Plieninger et al. 2003). Even in central Sweden (which has wood-pastures more similar to those in Estonia), a maximum of 200 trees per ha has been reported (Jakobsson and Lindborg 2014). This high density may have a historical explanation, as most wood-pastures in Estonia originate from grazed forests and have developed without strong conscious thinning efforts (Kukk and Kull 1997;Pa¨rtel et al. 2005). In addition, there was a period of abandonment (1980–2000) during which almost none of the wood-pastures were grazed in Estonia (Kukk and Sammul 2006; Sammul et al. 2008). Higher tree density also logically leads to a faster return to forest conditions, and thus an even greater threat of habitat loss through abandonment here than in other areas of Europe. During the interviews, farmers often mentioned the fast regrowth and the associated workload of cutting out trees in addition to grazing management. This suggests that although the restoration scheme has been successful in terms of its effect on the structure of wood-pastures, these effects may be rapidly reversed should management cease, for example, if subsidies were no longer available.

### *Motivations of farmers*

Understanding farmers' motivations to manage semi-natural habitats such as wood-pastures is an important step in tailoring future incentive schemes, so they have the best outcomes for biodiversity (de Snoo et al. 2013; Birge and Herzon 2014). This is not always straightforward, as farmers are typically quite heterogeneous in their motivations (Busck 2002). Such heterogeneity was also shown by the three main groups of farmers identified in our results, as well as by some farmers that did not fit into any of the groups.

The most common motivation, shared by almost all farmers, was the financial compensation for the management of wood-pastures. This shows that this financially oriented policy instrument plays a key role in the survival of wood-pasture habitats (see also e.g., Beaufoy 2014), which are rarely eligible for the single area payments from the first pillar of the CAP (Beaufoy et al. 2011). However, there is also a threat that farmers will become too dependent on subsidies and grazing will lose its economic value. The second extrinsic motivation was the scarcity of grazing land. This is somewhat in contrast to trends in other parts of Europe, where farming is concentrated in the most productive areas and marginal habitats are abandoned. The use of wood-pastures as extra land brings indirect financial gains due to an increase in productive area and was especially important for the group of opportunists. While there is some debate about the importance of production (independently of profit) in farmer decision making today, it appears to remain at least one of the major factors for European farmers (Busck 2002; Burton and Wilson 2006). However, in addition to this productivist aspect, several farmers mentioned the symbolic importance of the ownership, rather than simply the use of land, suggesting that the need for land as a motivation may also have an intrinsic aspect.

Tradition, in terms of landscape esthetics and farming practices, was the most frequently mentioned intrinsic motivation and the main motivation of the *traditionalists*. It was so strong that it even extended to rented land. The importance of tradition was to some extent unexpected, because there is relatively little information on the effects of tradition on farmer decision making (although in a wider sense, the influence of norms and values has been widely studied, see e.g., Beedell and Rehman 1999, 2000; Burton 2004). The role of tradition may therefore be an aspect that could be capitalized on in other countries in order to promote the use of wood-pastures.

The second and third most frequently mentioned intrinsic motivations were animal welfare and biodiversity benefits of wood-pastures, respectively. Birge and Herzon (2014) also found animal welfare and nature conservation (similar to our category of biodiversity) among the motivations of Finnish farmers to manage semi-natural habitats. Herzon and Mikk (2007) also showed that Estonian farmers were willing to implement simple conservation measures in semi-natural habitats even without financial compensation. Hence, although this motivation was less important than the others, it does appear to play a role for many farmers. Thus, as other studies have shown (e.g., Siebert et al. 2006; Burton and Schwarz 2013), financial support is a necessary prerequisite, but is not the only (or even main) motivation for farmers to carry out biodiversity-friendly management such as wood-pasture maintenance and restoration.

*Groups of farmers and targeting of incentives*

Ideally, different groups of farmers should be addressed with different incentives within AES (Schmitzberger et al. 2005). In our study, three groups of farmers were identified —*the traditionalists, profitable stewards, and opportunists*— with different sets of motivations for managing wood-pastures. Of the farmers, the opportunists appeared to be most strongly motivated by (as opposed to facilitated by) the subsidies in their decision to manage wood-pastures. However, although financial incentives can maintain traditional farming practices in the short term, in the long term they can de-couple social systems from ecological benefits (Fischer et al. 2012). In Estonia, there was still evidence of a tight link between social systems and ecological benefits. The *traditionalists* and *profitable stewards* still had strong links to the past, but also actively sought to diversify their benefits from wood-pastures by adopting organic farming or farm tourism. Instead of, or in addition to, support payments, these farmers may be better supported in their choice to farm wood-pastures by what Fischer et al. (2012) described as a ‘‘transformation strategy’’ for the sustainable development of traditional landscapes. Such a strategy entails the creation of new direct links between nature and social and economic well-being, which are then viable over the longer term and robust to changing conditions. This could happen in Estonia through support of organic farming and farm tourism as well as through developing and supporting local and regional initiatives that create value-added products from wood-pastures.

## Conclusion

We have shown that wood-pastures in western Estonia are social–ecological systems that depend strongly on active management to maintain their habitat value. This management, in turn, is dependent on various factors such as EU and national policies, but also on the extrinsic and intrinsic motivations of farmers. For example, (extrinsic) financial incentives play an important role in farmers’ decision making, but we also found a strong (intrinsic) influence of tradition on our interviewees. Although this was a regional case study, our results also provide insights that may be of use in other countries aiming to revive wood-pasture management. For example, we have shown that national subsidies may be an effective means of restoring and maintaining the habitat value of wood-pastures. If eligibility problems mean that EU funds through the CAP are not available, payments can alternatively be provided by national funds. In addition to financial incentives, land managers have a range of other motivations for the management of wood-pastures, which should be taken into account when designing incentive mechanisms for the management of such semi-natural habitats. Particularly, the role of tradition is rarely focussed on in the agricultural context, but could play an important role in maintaining wood-pastures.

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## Appendix

**Appendix 1**. Species occurrence in different management categories, showing the percentage of sites in which they occur, and the average percentage of the individuals that they make up in the sites. Bold values are the highest per category, underlined are the 3 highest, italic values indicates that 50% of all individuals are only occur in one site

| Species | Old | | Restored | | Abandoned | | Total WP | | Forest | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Site | Individuals | Site | Individuals | Site | Individuals | Site | Individuals | Site | Individuals | Site | Individuals |
| *Acer platanoides* | 30.00 | *0.91* | 0.00 | 0.00 | 70.00 | 2.85 | 33.33 | 1.76 | 10.00 | *0.06* | 27.50 | 1.50 |
| *Alnus glutinosa* | 20.00 | 1.17 | 40.00 | 5.02 | 0.00 | 0.00 | 20.00 | 1.38 | 10.00 | *0.25* | 17.50 | 1.00 |
| *Alnus incana* | 20.00 | *1.43* | 10.00 | *1.15* | 10.00 | *9.18* | 13.33 | 5.55 | 30.00 | *1.48* | 17.50 | 4.18 |
| *Beberis vulgaris* | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | *0.17* | 3.33 | 0.09 | 0.00 | 0.00 | 2.50 | 0.06 |
| *Betuls* spp. | **100.00** | 17.27 | **80.00** | 22.09 | 60.00 | *3.27* | **80.00** | 10.01 | **100.00** | 10.21 | **85.00** | 10.71 |
| *Cornus sanguinea* | 30.00 | *1.82* | 10.00 | *0.14* | 50.00 | *4.24* | 30.00 | 2.76 | 30.00 | *1.30* | 30.00 | 2.27 |
| *Corylus avellana* | 80.00 | **20.13** | 60.00 | **24.25** | 80.00 | **21.91** | 73.33 | **21.99** | 90.00 | **23.52** | 77.50 | **22.50** |
| *Crategus* spp | 20.00 | *0.26* | 10.00 | *1.58* | 20.00 | *0.12* | 16.67 | 0.47 | 20.00 | *0.12* | 17.50 | 0.35 |
| *Frangula alnus* | 30.00 | 6.10 | 30.00 | 0.72 | 30.00 | *14.82* | 30.00 | 9.63 | 60.00 | 10.62 | 37.50 | 9.96 |
| *Fraxinus excelsior* | 80.00 | 12.08 | 70.00 | 7.60 | 80.00 | *5.93* | 76.67 | 7.78 | 70.00 | 6.67 | 75.00 | 7.40 |
| *Juniperus communis* | 60.00 | 4.68 | 60.00 | *10.76* | 30.00 | *2.79* | 50.00 | 4.99 | 20.00 | *1.36* | 42.50 | 3.76 |
| *Lonicera xylosteum* | 20.00 | *0.26* | 10.00 | *0.29* | 30.00 | *0.23* | 20.00 | 0.25 | 0.00 | 0.00 | 15.00 | 0.17 |
| *Malus sylvestris* | 40.00 | *3.38* | 20.00 | *0.57* | 20.00 | *0.17* | 26.67 | 1.04 | 20.00 | *0.56* | 25.00 | 0.87 |
| *Picea abies* | 30.00 | *3.25* | 0.00 | 0.00 | 20.00 | *1.39* | 16.67 | 1.54 | 20.00 | *2.53* | 17.50 | 1.87 |
| *Pinus slvestris* | 20.00 | *1.17* | 50.00 | *8.46* | 30.00 | *0.35* | 33.33 | 2.32 | 30.00 | *2.65* | 32.50 | 2.43 |
| *Populus balsamifera* | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 10.00 | *0.06* | 2.50 | 0.02 |
| *Populus tremula* | 60.00 | *13.51* | 50.00 | 3.44 | 30.00 | 5.23 | 46.67 | 6.84 | 90.00 | 7.10 | 57.50 | 6.93 |
| *Prunus padus* | 20.00 | *0.78* | 20.00 | *1.00* | 30.00 | *6.22* | 23.33 | 3.76 | 70.00 | *11.67* | 35.00 | 6.43 |
| *Quercus robur* | 70.00 | 7.92 | 70.00 | 7.03 | 80.00 | 4.07 | 73.33 | 5.10 | 70.00 | 4.01 | 72.50 | 5.10 |
| *Rahmnus cathartica* | 0.00 | 0.00 | 10.00 | *0.57* | 10.00 | *0.23* | 6.67 | 0.25 | 10.00 | *0.06* | 7.50 | 0.19 |
| *Salix* spp | 30.00 | *1.04* | 10.00 | *3.30* | 20.00 | *11.16* | 20.00 | 6.99 | 20.00 | *1.54* | 20.00 | 5.16 |
| *Sorbus aucuparia* | 60.00 | 2.47 | 60.00 | 1.84 | **90.00** | 1.86 | 70.00 | 2.01 | 80.00 | *5.37* | 72.50 | 3.14 |
| *Sorbus intermedia* | 10.00 | *0.39* | 0.00 | 0.00 | 0.00 | 0.00 | 3.33 | 0.09 | 10.00 | *0.19* | 5.00 | 0.12 |
| *Tillia cordata* | 0.00 | 0.00 | 10.00 | *0.14* | 20.00 | *1.98* | 10.00 | *1.10* | 30.00 | *7.59* | 15.00 | 3.29 |
| *Ulmus glabra* | 0.00 | 0.00 | 0.00 | 0.00 | 30.00 | *1.39* | 10.00 | *0.75* | 10.00 | *0.19* | 10.00 | *0.56* |

# Chapter 6

# Chapter 6

## Wood-pasture management in Southern Transylvania (Romania): from communal to where?

Laura Sutcliffe, Kinga Öllerer and Marlene Roellig

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## Introduction

Wood-pastures developed in many areas of Europe as a shared community resource under the governance of local institutions (e.g. Vera 2000; Chételat *et al.* 2013). Whilst such communal governance systems have largely disappeared in the north and west of Europe, they remain widespread in Romania today as a means of grassland and forest regulation (Mantescu 2009; Sutcliffe *et al.* 2013). This chapter considers the communal governance of wood-pastures in the region of Târnava Mare in Southern Transylvania (central Romania), an area rich in wood-pastures that have been important productive elements of low-intensity farming for centuries, and continue to be actively farmed. These wood-pastures are important not only as a means of sustainable agroforestry, supporting both agricultural production and high levels of biodiversity, but as a community resource are also tightly linked to the cultural history of the region. Nevertheless, increasing incidences of felling, burning, changes in management practices and abandonment in recent years evidence the fact that the relevance of wood-pastures for local communities is waning and the communal management is failing.

This chapter addresses the question of how the governance of wood-pastures in Târnava Mare can adapt to the current and future needs of the local populations. Based on information from the literature, it describes their historical development and stable communal management in the Saxon communities, as well as the destructive impact of the communist era. The chapter also draws on information from qualitative interviews with 30 commons users and members of the local administration, carried out in the region of Târnava Mare in 2012, to examine the challenges faced by wood-pastures today as Romania enters a new era of agricultural development. It discusses the opportunities provided by commons governance to adapt the use of wood-pastures to meet the changing needs of the local communities, and suggests ways in which associations of farmers can be strengthened in order to provide sustainable management to maintain these wood-pastures into the future.

### Development and structure of wood-pastures in the Târnava Mare area in Southern Transylvania

Târnava Mare is a region of steep-sided valleys and fertile farmland in the south of the Transylvanian plateau, enclosed within the southern arc of the Carpathian Mountains (Figure 1). Ranging from around 500 to 700 m a.s.l., the potential natural vegetation of the area is temperate continental oak-hornbeam and beech-hornbeam forest (Bohn *et al.* 2000), which can still be found, albeit somewhat modified, in the forests in the area (Mountford & Akeroyd 2005). Nevertheless, the vegetation has long been shaped by human management, and centuries of continuous low-intensity management have created a mosaic of species rich habitats, among which the wood-pastures can be included. Although the wider Transylvanian region was settled sporadically by different cultures from the stone age onwards (Gündisch 1998), we know for certain that since around the 13th century the Târnava Mare area has been continuously inhabited by the Transylvanian Saxons (Teşculă & Goţa 2007). This German-speaking ethnic group migrated from present-day Germany and Luxembourg in the 12th and 13th century upon invitation of the Hungarian rulers of Transylvania, and for the next 800 years were the dominant ethnic group in the region.

The Saxons were granted autonomy from the Hungarian rule through the *Diploma Andreanum* of 1224, giving them the freedom to govern both themselves and the land that they inhabited. This independence allowed them to build up a number of institutions, those at the local scale revolving mainly around forestry, farming and the church. These various institutions provided not only a support network in everyday life, such as the 'Nachbarschaften' (neighbourhoods) within villages, who would collectively help if one household was in need of assistance, but also continuous monitoring of adherence to the rules. If, for example, a woman did not attend church on Sunday without giving a good reason, the absence would be noted by the 'Altschwester' (senior sister) of her 'Schwesterschaft' (sisterhood) and she would have to pay a fine. The same of course applied to the men within their 'Bruderschaft' (brotherhood). With time, the Saxons became renowned for their tightly knit communities and strict rules, as well as their exemplary farming, forestry and land management techniques (Dorner 1910). Grazing in closed canopy woodlands as well as more open pasture with scattered trees – both referred to here as wood-pasture – is likely to have been a farming practice used by the Saxons from the beginning of their settlement, as it was widespread in Europe at that time (Vera 2000). One of the first written records of this activity is a letter from 1583 from the then ruler, Stefan Báthory, King of Poland and Prince of Transylvania. In it, he responds to a request by the Saxons to grant them sole control over the grazing of sheep and pigs in the 'lands and the oak forests' of their territory (Oroszi 2004), demonstrating the importance of wood-pasturing to the Saxon community by allowing them to exclude the livestock of outsiders.

As a primarily subsistence farming community, with each household carrying out a variety of agricultural activities for their own consumption, the Saxon community highly valued wood-pastures for livestock grazing. 'Acorn' forests were the most valuable category of forest in medieval Transylvania (Dorner 1910; Makkai 2003), as was also the case in most of Europe at that time (Vera 2000). Oaks were selectively maintained to produce acorns particularly for pig grazing, and the extraction of timber and other products played a lesser role. Oaks (*Quercus robur* and *Q. petraea*) still predominate in the wood pastures in the area, but wild fruit trees, beech, hornbeam and sometimes ash also provided fodder and shelter. The natural regeneration in particular of *Q. robur* and *Q. petraea* is facilitated by low-intensity grazing by cattle and pigs (the two main livestock species kept by Saxons), as the saplings of these species do not grow well under a closed canopy, or under close grazing by sheep or goats (Vera 2000).

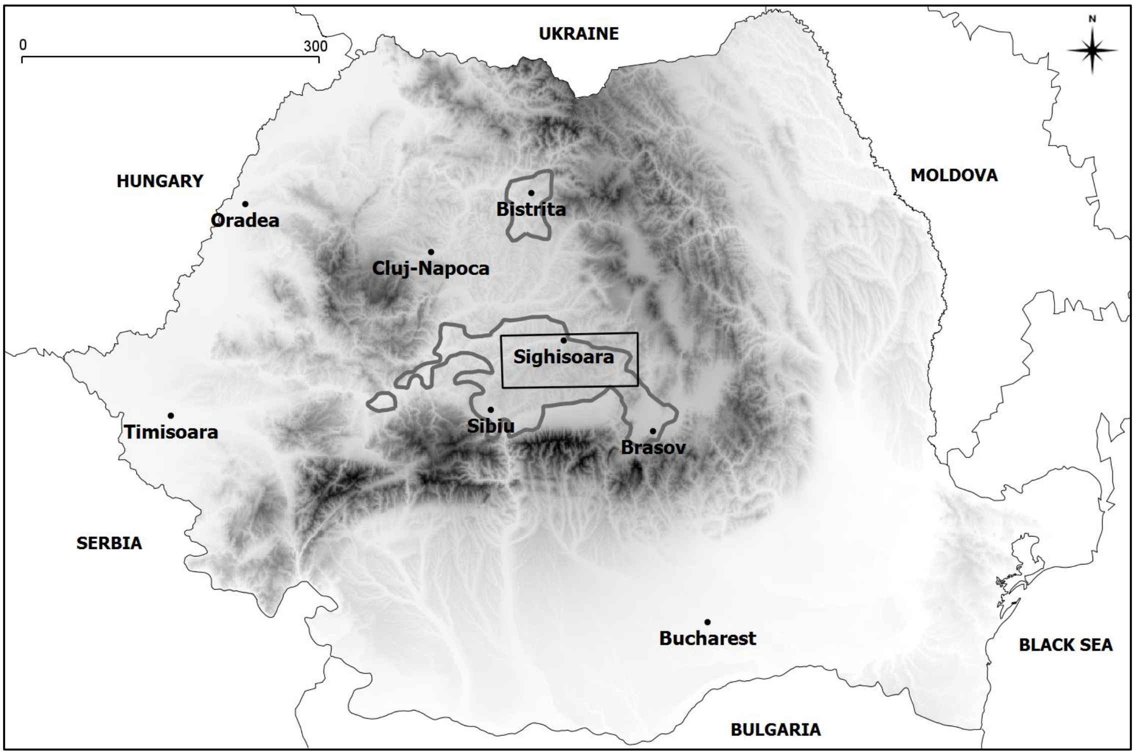


**Figure 1** Digital elevation map of Romania showing present-day borders and historical regions predominantly inhabited by Saxon communities (grey outline), based on Gündisch (1998). The location of the Târnava Mare region, an old administrative unit of approx. 850 $km^2$ within the arc of the Carpathian Mountains, is indicated by the black box.

The practice of wood pasturing may therefore have played a role in the current distribution of oaks in the region, especially given the frequency of this land-use type. Although only making up around 7 % of total grassland in each municipality today, the majority of villages in the area have at least one wood-pasture, ranging from around 10 to over 450 ha and with an average size of around 100 ha (M. Roellig unpublished data; Figure 2a). Tree density is currently on average 7.6 per hectare in the wood-pastures in the region (Hartel *et al.*. 2013; see Figure 2b for an example), however, this open nature would not have been typical until about a century ago. In 1853 a law was passed requiring the separation of forest and pasture between landlords and local farmers in the process of decreasing the dependence of serfdom. As an outcome, local farmers lost their rights of free grazing in forests owned by landlords. This, together with the 1879 forestry law which restricted grazing in the forests due to its harmful effects on soil quality and tree regeneration, resulted in the transformation of the traditional forest grazing practices (Saláta, Horváth & Varga 2009). This led to the opening up of many grazed forest areas, still shown on the 1st Ordnance Survey of the Habsburg Empire (1769-1773) as closed canopy woodland, but recognizable on maps a century later as clearly open pastures but with scattered trees remaining (Öllerer 2013). Land cover depicted on the maps suggest that by the end of the 19th century almost every Saxon village had at least one clearly defined wood-pasture, which was communally used by the inhabitants and governed by the communal authorities (Dorner 1910). The location close to the village – typically only around 1 km from the centre of the village for the wood-pastures surveyed in a recent study (Hartel & Moga 2010) – highlights its presence in the daily lives of the local community.

Many of the wood-pastures created by the Saxons in Târnava Mare survive today, as illustrated by the relatively high density shown in Figure 2a. Half of the wood-pasture sites surveyed in a recent study in the area contained veteran trees (sensu Read 2000, i.e. over 2 m in diameter at breast height, corresponding to an age of >200 years): given the practice of removing oaks from forests before they reach 150 years old, the presence of trees estimated at 400 years or more suggests continuous use as wood-pastures for at least several centuries (Hartel & Moga 2010). Although there has been no comprehensive inventory of wood-pastures at larger scales in Romania, unpublished data suggests that wood-pastures remain a common landscape element throughout Transylvania.

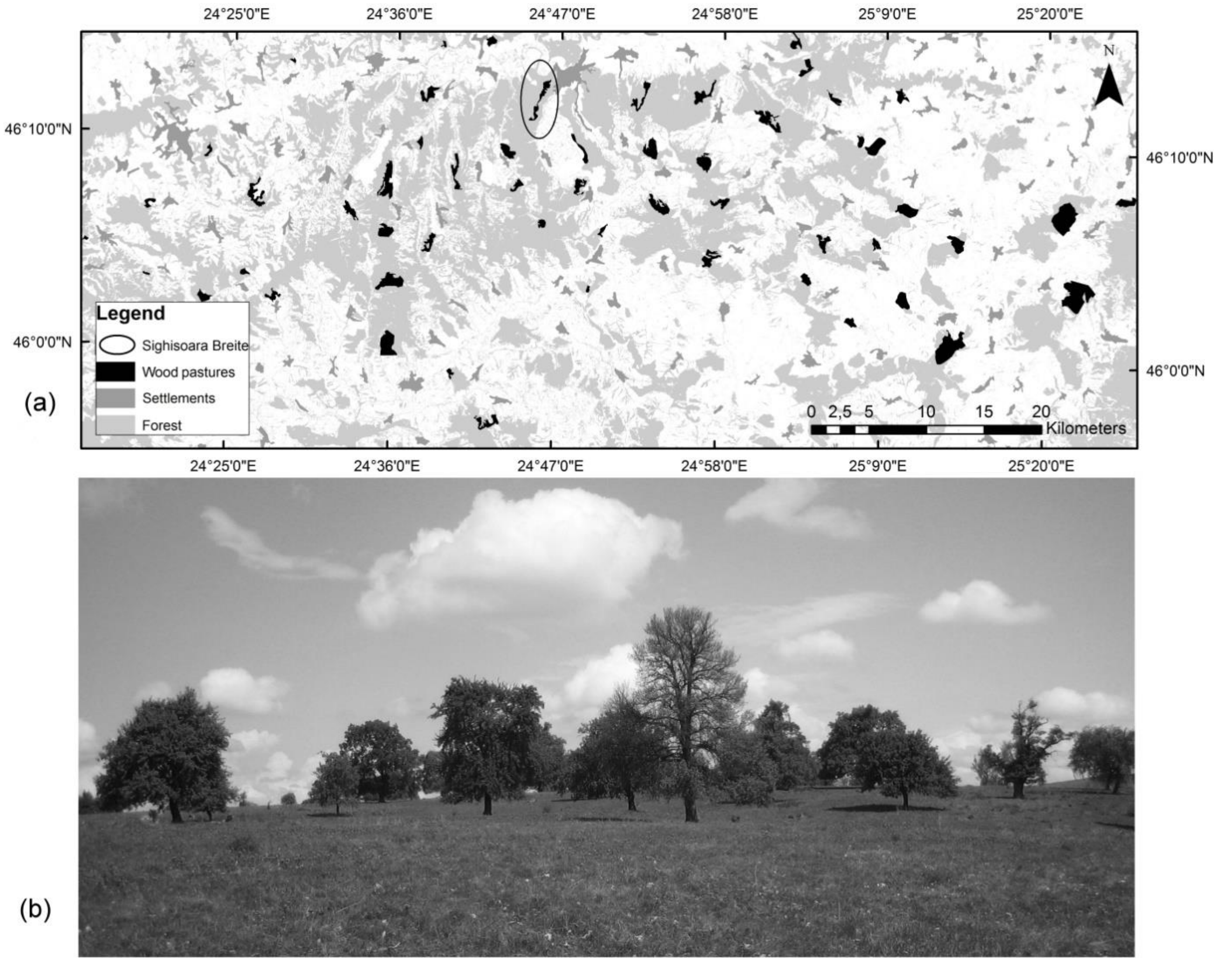


**Figure 2 (**a) Map of the distribution of 55 of the most representative wood-pastures in the Târnava Mare area, surveyed in a recent study. (b) Photo of a typical wood-pasture with scattered oaks and fruit trees in the village of Mercheaşa (Streitforth) in the Târnava Mare region (M. Roellig 2012).

The presence of scattered veteran trees in wood-pastures provides not only important habitats within the tree itself, but also a variety of vegetation structures that supports both typical forest species such as woodpeckers (Dorresteijn *et al.* 2013) and brown bears, as well as species of open grassland such as many butterflies (Hartel & Moga 2010). The best studied of the wood-pastures in the area, the Sighişoara Breite (Figure 2a), has been shown to support 476 species of vascular plants (Öllerer 2012), 40 species of xylophagous beetles 281 species of Lepidoptera 27 species of nesting birds and 38 species of mammals (summarised in Hartel & Moga 2010). The longer the continuity of use, generally the older and more valuable the trees, and the more species-rich grassland communities become (e.g. Dauber, Bengtsson & Lenoir 2006; Aavik *et al.* 2009): in the case of Târnava Mare, long-term sustainable use of wood-pastures was ensured through stable governance by the Saxon communities.

**Wood-pasture governance in the Saxon society**

From the beginning of the Saxon settlements, almost all land within the village boundaries was communal and administered by the village authorities (Nägler, Schobel & Drotleff 1984). This meant that although the land belonged to the rulers of the time, all members of the village's Saxon community had rights to use these resources. In later centuries, land was also bought by individuals or communities, however the use of the pastures almost always remained a formal legal right for all villagers. This right was linked to a set of rules and responsibilities, overseen by the village authorities, ensuring that all users had the same benefits and costs (see Table 1). Such common management provides a number of labour saving benefits through cooperation: animals were generally herded, so employing a herder to tend a collective herd was more efficient than each farmer taking his own livestock to graze. However, the many challenges for commons governance compared to private use have been extensively discussed, such as the temptation to freeload, i.e. to benefit at the cost of others, or overharvest (see e.g. Olson 1965). For many years, commons systems were thought of as an ineffective and even damaging for resources, however, as demonstrated by Elinor Ostrom in her seminal work on commons governance (Ostrom 1990), stable institutions that are monitored and enforced can provide long-term sustainable management of common resources. Analysing the problems and solutions found by commons governance institutions around the world, Ostrom (1990) developed a number of design principles or core factors shared by long sustained commons regimes. Although not a blueprint for success, these lessons have been reviewed in multiple studies (see e.g. Cox *et al.* 2010) and shown to hold for most robust resource systems. Table 1 highlights some of the basic characteristics of the Saxon common grazing regime in the context of the design principles in order to demonstrate why it may have been so successful and enduring.

**Table 1** Applying the eight design principles developed by Ostrom (1990) to the Saxon pasture governance system. Information on the Saxon grazing system based on Schuller (1895), Dorner (1910) and Nägler, Schobel & Drotleff (1984).

| Design Principle | General characteristics of the historic Saxon common grazing regime from around the 16th to the 20th century |
|---|---|
| **1. Clearly Defined Boundaries** | Different pasture areas were delimited and one herder did not encroach on the other herder's pasture. Village boundaries were respected, although deals could be negotiated between villages to use each other's land. Common grazing was restricted to a certain period over the summer: often between the feast of St. George (24th April) and St. Martin (11th November), in order to allow the vegetation to regenerate or to be used for other purposes. Livestock also followed a certain order: first cattle would graze a pasture, then buffalo (after their introduction in the 18th century), then horses, followed by pigs, then sheep and goats. When resources became scarce, sheep and goats were restricted from using the pastures as they caused the most damage to the vegetation. |
| **2. Proportional Equivalence between Benefits and Costs** | Villagers had to contribute a number of days of pasture maintenance work (removing scrub, repairing water sources etc.) proportional to the number of animals they grazed (e.g. 2 days per cow or 10 sheep per year). |
| **3. Collective-Choice Arrangements** | A yearly meeting was held before the grazing season in which all users could discuss and vote on issues concerning the pasture, such as maintenance work to be done, which areas to graze and with how many animals. This was presided over by a grazing committee, whose members were elected from among the users. |
| **4. Monitoring** | Pasture maintenance and adherence to rules was monitored by peers, as users were aware of each other's activities, and formally recorded by the grazing committee. As such, infractions were rare. |
| **5. Graduated Sanctions** | Fines were imposed e.g. for not carrying out maintenance work, equivalent to the cost of paying someone else to do the work. Exclusion from the community was possible for very serious offences. |
| **6. Conflict-Resolution Mechanisms** | Depending on the type of problem, conflicts could be resolved with the help of the grazing committee. |
| **7. Minimal Recognition of Rights to Organize** | Sole rights to control grazing on pasture and oak forest were awarded to the Saxon community in 1583. The Saxon 'Nationsuniversität' (the 'intact unity' of the Transylvanian Saxons) had political, administrative and judicial autonomy over their community since 1224. |
| **For resources that are parts of larger systems: 8. Nested Enterprises** | Local grazing institutions, under the authority of the mayor, had control over grazing resources at the local level. However, to resolve more far-reaching problems such as the sovereignty over grazing resources, the Saxon 'Nationsuniversität' represented the Saxon community as a whole. |

Not only the congruence with the design principles, but also the fact that communal management of wood-pastures survived so long in the Saxon society, suggests that their commons institutions were robust. This long-term integration through personal involvement, as well as the involvement of predecessors in the management of the land, can lead to such landscape elements developing a cultural significance for the community (Whiteman & Cooper 2013). There is also evidence for the Saxon wood-pastures that they were not just locations of cooperation and collective action for work, but also for community cultural events. The first record for the 'Skopationsfest' on the wood-pasture next to the historic town of Sighişoara (Schäßburg, in German) is from 1866, although it probably began much earlier, and this festival took place regularly in the month of May up until 1939 (Figure 3a). The name, derived from the Latin 'scopa' meaning broom, probably referred to the practice of pupils bringing brooms to school to clean away the winter dust and was a celebration of the beginning of summer. It seems that scattered trees were clearly present in the Saxon concept of idyllic open landscapes (Figure 3b), but the Sighişoara Breite wood-pasture was a location for celebrations and also general recreational activities for all inhabitants, not just the Saxons (Teşculă & Goţa 2007).


**Figure 3** (a) Picture of Skopationsfest on the Sighişoara Breite from the early 20th century (author unknown: from the personal archive of Walter Lingner). (b) Photograph of a painted wooden panel dating from 1776 in the fortified church in the village of Brădeni (Henndorf, Southern Transylvania), showing a pasture with scattered oaks (inscription: "Wer des Herrn gelüstet soll Brods die Fülle haben" - He who hungers for the Lord shall never want for bread. Photo: L. Sutcliffe 2013).

## Communism, post-communism and accession to the European Union

In the period after 1945, communist rule revolutionised the farming system and obliterated the traditional Saxon governance of the area. Most forest and agricultural land was taken into state ownership, agricultural productivity was significantly intensified in some areas and abandoned in others, and local communities were fragmented and dispersed. For wood-pastures, this meant a period of significant change: in some cases clearance and transformation into other forms of land use ("site amelioration"), or development into forest, and for those left as pastures most were taken out of common use and appropriated by state or collective farms.

This period of agricultural intensification was then followed by almost two decades of large-scale abandonment following the fall of the communist regime in 1989, as the communist agricultural institutions crumbled (e.g. Kuemmerle *et al.* 2008). Local institutions for both private and common land management were hindered from reforming, partly by the slow and piecemeal process of returning land to its former owners (restitution), but also by the changes in the local population. Many Saxons had fled persecution by the communist government under Nicolae Ceauşescu, or had been forcibly deported. Those who had been unable or unwilling to leave during the communist era flooded out of the country after 1990, mostly to Germany where they had been offered citizenship by the German government. Within several years of the end of the communist regime, only around 25,000 German-speaking citizens remained in Romania – less than 10% of the number at the start of the communist period (Gündisch 1998). Their empty houses were occupied by settling Rroma or bought by Romanians, many of whom had moved to the area within their lifetime or only one generation ago.

Although the wood-pastures were largely returned to communal administration, and the grazing committees continued to oversee their use by the community, the link between the people and the land, and the historical significance of the wood-pastures for the local population had been lost. Commons users in the Târnava Mare region interviewed in 2012 recalled a period of chaos, where rules were difficult to enforce in the general disruption following the political changes, and maintenance of pastures was neglected as local authorities struggled to adapt to the loss of central government control. Large solitary trees were, for example, sold for felling to raise money, and many pastures became overgrown with scrub and young trees during the 1990s and early 2000s (M. Roellig, unpublished interview data).

Romania's accession to the European Union in 2007 was the next key turning point in the fate of its wood-pastures. The introduction of basic requirements for subsidy payments for pastures spurred an upsurge in scrub clearance, and all interviewed commons users reported an increase in pasture maintenance activities to correct the neglect of the previous years. Due to the requirement for a minimum of 5 years entitlement to the land by a legal person (either an individual or a registered association) in order to claim agri-environment scheme payments, the use of the land quickly changed from that of a common to that of a rental system. Today, wood-pastures in the Târnava Mare region may be communally owned, but they will probably be divided into single user parcels rented by individuals. Thus, although the direct sale of state owned common land is technically illegal, a de facto privatization of common land is occurring.

The type of farmer using the communal pasture is also changing. Although Romania still has the highest number of agricultural holdings per capita in the EU (Eurostat 2011), in the last decade the number of subsistence and semi-subsistence farmers, i.e. who produce exclusively or mainly for their own consumption, has been dropping (Eurostat 2009). Such farmers made up the majority of commons users in Saxon times, but with better job opportunities in the cities or abroad, and the poor financial returns from farming, these are being replaced by fewer but larger scale farmers. For the dwindling number of small-scale farmers who do not own enough animals to rent their own parcel, space for a common herd is still provided by the Town Hall or they come to an arrangement with another renter. Nevertheless, many small-scale farmers complained of losing out under the current system to the interests of more powerful actors. Related to this, one interesting development in recent years has been the promotion by the Romanian government of the formation of graziers' associations for small-scale farmers, to collectively rent land for their animals and for which they can claim subsidy money to be used for the benefit of the members (Sutcliffe *et al.* 2013). These new associations hold the potential to be the commons institutions of the future, superseding the Town Hall governance and forming new rules and norms adapted to the current socio-economic and political conditions.

However, the success of these new associations at self-organizing has been limited. Again, it is useful to consider the problems for the graziers' associations in the context of the commons literature, this time comparing the situation with some of the key threats for sustainable governance systems identified by Ostrom (1994, highlighted in bold in the following). **Blueprint thinking** tries to apply universal solutions to often locally specific conditions, in much the same way as current requirements for European agricultural subsidy payments dictate management parameters that associations must fulfil. For example, the maximum and minimum number of animals allowed per hectare under subsidy schemes applies to the whole country (APIA 2012; MADR 2012), whilst it is generally known that the carrying capacity of pastures can differ substantially from area to area and from year to year. **Rapid changes** in technology and human populations occurred with the mechanization of agriculture and the changes in farm structures, as well as the dramatic population changes that took place in Romania in the second half of the 20th century. Today the instability continues, with recent and rapid changes in agricultural policy and continuing rural depopulation as challenging factors for institutions to adjust to. The population changes have also led to **transmission failures**, in which the principles of an effective community-governed institution were not passed down from one generation to another, due to the interruption of the period of collectivization. The changes in technology and farming systems in general have increased the **heterogeneity of participants**. In Saxon times the commons users were almost exclusively subsistence or semi-subsistence farmers, but now villagers with rights to a communal pasture may own 1, 10 or 100 cows, increasing the heterogeneity of interests represented. Finally, **corruption** and other forms of opportunistic behaviour were rife in the communist era and are encouraged today by the subsidy money available, leading to a decrease in trust in commons institutions and in willingness to cooperate (Sutcliffe *et al.* 2013).

In addition to the issues related to access to the common pastures today, the current governance seems to be negatively affecting the ecological value of the wood-pastures. Although generally in a good state, over half those surveyed in Târnava Mare by Hartel & Moga (2010) were affected by under or occasionally over-grazing. Potentially more serious, however, is the burning (intentional or unintentional) or felling of trees in wood-pastures. Despite the fact that both burning of grassland and the cutting of solitary trees on agricultural land is now prohibited under the cross-compliance requirements for receiving subsidies (unless the tree is certified as being damaged or diseased: MADR 2012), these incidences are increasing (e.g. Rostás 2012a; Rostás 2012b). The disregard for the solitary trees could be partly a result of the changes in livestock patterns: the last known pig grazing in wood-pastures – for which the trees were highly important – took place in the region around the 1960s. Although the shade and erosion protection provided by the trees is still mentioned by farmers for their sheep and cattle (T. Hartel, unpublished data), they are no longer perceived as of major value to production. These changes in the farming systems have thus lead to loss of saliency of wood-pastures to local communities, however, it is arguably the demographic changes that have had the greatest impact on wood-pasture management in the region. In contrast to the strong links between the Saxon communities and the wood-pastures, these areas are now largely perceived as simply the property of the state, and of little relevance for the local population apart from to the now limited number of farmers that graze them.

## Conclusions - from communal to where?

The wood-pastures in Southern Transylvania were formed and maintained over centuries under communal governance, and their status as a community resource is an important part of their historical identity. The previous sections have described some of the characteristics of the Saxon institutions – such as autonomous control over their resources and effective monitoring systems leading to appropriate sanctions – that may have contributed to their long-term sustainable and productive management of the wood-pastures. As a result, from a conservation perspective, the region in general is currently in the enviable position that it retains a high density of actively used wood-pastures in a species-rich agricultural landscape. The Saxon communities which created them, however, have been irrevocably lost, and their institutions damaged by decades of political and social upheaval. Recent developments suggest that the future of the wood-pastures is not assured, and unstable governance increases susceptibility to threats such as abandonment and illegal felling. Given the considerable recent changes in the socio-economic, agricultural, political and demographic conditions in the region, the question thus arises as to whether the practice of common management is still fit for purpose today?

The drastic decline in the number of common grazing systems in northern and western Europe since the 18th century has led to the perception that commons are now an anachronistic concept, and European agricultural policy is designed with single-user management in mind, further disadvantaging the remaining commons systems (Brown 2006). The trend towards individual management of the commons in Târnava Mare could be seen as a way to provide more streamlined management as subsistence farming is replaced by fewer, larger farmers. However, whilst privatization can doubtless in some cases provide appropriate and careful management for wood-pastures, the relative ease of decision making by single users could rapidly lead to stark and irrevocable changes in land use, such as the removal of veteran trees. The legal status of commons (i.e. that decisions require the consent of multiple stakeholders), on the other hand, provides them with inertia against changes in management practices (Wilson & Wilson 1997).

Communal governance does not of course ensure good management per se: indeed, in the Târnava Mare area it has recently been responsible for poor conditions (over and undergrazing, damage to trees, erosion etc.) in many wood-pastures. However, as has been repeatedly demonstrated, modern management of common pool resources can be sustainable and successful under a variety of conditions if strong institutions exist (Ostrom 1990). By considering the current commons institutions in the context of knowledge about successful commons governance systems, including the Saxon governance, it is possible to identify areas for improvement. For example, providing the graziers' associations with greater central support in organization and administration, and measures to reduce corruption, would improve their robustness and capacity. Farmer associations are already seen as a priority in Romanian agricultural policy and the main tool for their support is funding to improve their competitiveness through several measures of the national Rural Development Plan (Luca & Toderiţă 2012). However, this has not helped many associations to form, and uptake of these funds is still very low in Romania, due partly to the relatively large bureaucratic demands of these measures (Luca & Toderiţă 2012). In the study area, it seems particularly a lack of knowledge and trust in associations at the local level is hindering them from forming in the first place. Better use of the provisions for training and information measures in the CAP could help alleviate this.

If successful, such local associations could also in turn play a role in developing such trust and community involvement in formal organizations, which is currently relatively low in Romania and eastern Europe as a whole (Pichler & Wallace 2007). Furthermore, they hold the potential to support the remaining small-scale farmers to adapt their production to the current agricultural conditions. Collective action through associations allows better exploitation of agricultural subsidies and marketing opportunities, as has been seen in the few positive examples of associations in the Târnava Mare region (Sutcliffe *et al.* 2013). Networks of associations would also help to overcome the poor dissemination of information related to agricultural practices and regulations in Romania (Fox 2010; Wegener *et al.* 2011; Mikulcak *et al.* 2013) by providing advice and expertise to smallholders. This kind of activity could help to increase the profitability of, and access to, the wood-pastures for the local communities again. Improving future prospects in the area is an important step towards providing the much needed economic stability for people to think long term and use their resources sustainably.

To ensure the future of wood-pastures in Târnava Mare, a number of approaches are needed, including single-user management, or dedicated conservation management such as the Sighişoara Breite. Nevertheless, commons governance still holds the potential to provide good management for the majority wood-pastures, which is adaptable to local needs and interests, and can reintegrate them with local communities. In contrast to single-user systems, it can also contribute to community cohesion through cooperation, providing a sense of place in communities that have experienced significant social upheaval and have lost to a large extent their link with the landscape. As an area currently undergoing a relatively rapid shift in socio-economic conditions, this case study illustrates the need for such 'traditional' landscape elements to adapt to the current context, as they have also done in the past (Fischer, Hartel & Kuemmerle 2012). This means not attempting to preserve the past, nor abandoning wood-pastures or common management, but transforming the use of wood-pastures though adaptive management. Strengthening of graziers' associations to provide a voice for small farmers, and support for the diversification of marketing strategies and use of subsidies can provide direct incentives for sustainable use into the future.

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# Declaration

I hereby certify that the submitted dissertation entitled ‘Biodiversity conservation in traditional farming landscapes: The future of birds and large carnivores in Transylvania’ has been written by me without using unauthorized aids. I did not use any aids and writings other than those indicated. All passages taken from other writings either verbatim or in substance have been marked by me accordingly.

I hereby confirm that in carrying out my dissertation project I have not employed the services of a professional broker of dissertation projects, nor will I do so in the future.

This dissertation, in its present or any other version, has not yet been submitted to any other university for review. I have not taken or registered to take another doctoral examination.

Lüneburg, 04.08.2017

Marlene Roellig