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REVIEW PAPER

Geobotanical survey of wood-pasture habitats in Europe: diversity, threats and conservation

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Abstract Agro-silvopastoral land-use has a long tradition throughout Europe. Depending on the region, wood-pasture occurs as vanishing relic of historical land-use, or still more or less widespread as multiple-use rangeland. A new development is that former intensively managed land is being left to evolve towards wood-pasture as an economically and ecologically favourable alternative. In a review of European wood-pasture habitats we distinguish 24 types based on the geobotanical criteria of region, structure, land-use and tree species composition. The European wood-pasture types may be classified as hemiboreal and boreal (4 types), nemoral old-growth (7), nemoral scrub and coppice (5), meridional old-growth (2), meridional scrub and coppice (4), and grazed orchards (2). Wood-pasture forms part of the cultural heritage of Europe, and may add significantly to the preservation of regional biodiversity. The role of wood-pasture in ecological restoration planning and the possibilities of maintaining or enhancing features of wood-pasture deserve more recognition. Many wood-pastures suffer from regeneration failure and are over-mature. Other threats to wood-pasture include abandonment, intensification, oak disease, overgrazing and clearance. In the European Union Habitats Directive, wood-pasture habitats are represented but rather inconsistently. We suggest neglected wood-pasture habitat types to be considered for inclusion. Wood-pasture may form an important element for the economic integrity of rural areas aiming to improve ecological quality, provided they are managed sustainably.

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Introduction

Wood-pasture may be defined as tree-land on which farm animals or deer are systematically grazed (Rackham 2004). This type of land-use always involves grazing animals and trees or shrubs, and sometimes grass cutting, acorn collecting, litter raking and field crop cultivation. Such (agro-)silvopastoral land-use systems have been part of the cultural history throughout Europe from prehistoric to present times (Mosquera-Losada et al. 2009). Following the comprehensive definition of British wood-pastures by the Surrey Biodiversity Partnership (2008), wood-pasture and pasture-woodland are taken synonymously here. Their and our definition comprises pasture with scattered trees and shrubs, or groups of trees and shrubs, as well as grazed closed-canopy woodland. McAdam et al. (2009) provided a survey of multi-function agroforestry systems and its services in Europe. Wood-pasture habitats differ between regions in species composition, structure and ecology depending, as for other woodlands and grasslands, on climate, soil, topography, geology and the regional species-pool. Other key factors, in contrast to non-grazed woodlands, are land-use history, current management and grazing seasonality. The kinds of grazing animals and their numbers greatly affect the structure and species composition (Buttler et al. 2009; Gillet 2008; Mayer et al. 2003). The open structure of wood-pasture is similar to that of savanna ecosystems, and although some authors use 'savanna' for grasslands with trees and pastoral woodlands in Mediterranean and temperate Europe (Grove and Rackham 2003; Rackham 2007), we avoid the term in the present context, following, e.g., Schroeder (1998) in restricting 'savanna' to tropical grasslands with trees in regions of woodland climate. Although wood-pastures are managed in different and not always low-intensity ways, most habitats may be termed semi-natural in quite the same sense as nutrient-poor grasslands and heathlands.

This paper attempts to survey wood-pasture habitats in Europe using geobotanical criteria, to identify recent threats to wood-pasture habitats and to assess whether these habitats are recognized by, or should be a matter of concern for, European nature conservation legislation.

General characteristics and history of wood-pasture

Wood-pasture as land-use is now historical or neglected in most parts of Europe, but still recognizable and widespread as remnant scrub or woodland formation with other than traditional management. Relic wood-pasture sites may be identified using old records or maps or a combination of traits such as the presence of old (veteran) trees, trees with symptoms of former grazing pressure and/or leaf-hay collection, open or partially open grown trees, uneven stocking, irregular site boundaries, patchiness with frequent glades and areas with scattered trees (Surrey Biodiversity Partnership 2008). Where extant, wood-pasture is now often separated from types of forest used exclusively for firewood or timber. Exceptions are reindeer pastoral woodland with birch and pine in subarctic Europe, mountain summer pastures that extend into montane woodlands, and pastoral woodlands

and scrublands in parts of Eastern Europe, the Mediterranean and the Balkans, where wood-pastures to some extent retain their traditional usage.

In Central Europe, wood-pasture was common practice until, with the agrarian reforms in the nineteenth century, it was banned almost everywhere, and remained so except in times of destitution. Banning wood-pasture and litter-raking was a consequence of the shortage of wood and timber when the demands of the growing population and industries increased enormously (Behre 2008; Küster 1995; Luick 2009). Wood-pastures in common use formed part of the *allmende* (common land). Depending on local environment, traditions and needs, wood-pasture in the *allmende* was grazed by cattle, horses, sheep, pigs, geese and, prohibited first of all, goats. Trees were coppiced or pollarded for firewood, others cut for timber. Leaf-hay was also produced by lopping or shredding trees to feed the animals in late summer and autumn (Ellenberg 1996; Luick 2009; Machatschek 2002). While wood-pasture as part of the *allmende* did not normally involve regular cycles of pollarding or coppicing, other land-use systems that provided wood, charcoal, grass and even annual crops such as rye incorporated pasturing as part of the regular cycles. In the north-west German Siegerland, the *hauberg* cycle involved coppice, cereal cultivation, fallow and wood-pasture (Behre 2008; Pott 1990; Pott and Hüppe 1991). To prevent the animals from eating the regrowth of trees, coppices were excluded from grazing for a number of years subsequent to cutting. In recent years, semi-open pasture is being re-introduced in Germany as a conservation concept to preserve the biodiversity of pasture-woodland landscapes (Finck et al. 2002; Gerken et al. 2008). Such concepts use components of traditional farming (wood-pasture or other pastoral systems) and robust breeds, which are kept in a 'semi-wild' manner all year round in large grazing sites.

In Britain, wood-pasture commons similar to *allmende* existed (McAdam 2005; Rackham 2007). They are to be distinguished from fenced parks and non-fenced Forests, both of which were private lands used for gamekeeping, especially of deer (Rackham 2004; Spencer 2002). Game parks have a long tradition in Europe at least since Roman times, whilst Forests were for centuries the hunting grounds of nobles. Thanks to Forests and to similar game reserves and grazed woodlands on the European continent, old-growth woodlands survived in some lowland areas where almost all other woodland was cleared.

In northern Europe, traditional management of forests has frequently been connected with hay-making, such as in the southeast Fennoscandian and Baltic *lövängar*. Such wooded pastures and meadows have a habitat tradition of 4,000 years or more (Dierßen 1996; Hytönen 1995). Their structure resembles that of *weidfeld* systems in the mountains of central Europe (Haas and Rasmussen 1993) and similar ones in southern European mountains (Eichhorn et al. 2006; Halstead and Tierney 1998; Loidi 2005). Restoring traditional forest management in nature reserves has been practised, albeit rarely, in western, central and northern Europe (e.g., Losvik 1989).

In Spain and Portugal, pastoral woodlands of the *dehesa* and *montado* type are kept as grazing grounds for pigs, cattle and sheep, and locally for deer hunting (Diaz et al. 1997). Iberian pastoral woodlands are estimated at approximately 55,000 km^2 (Tucker and Evans 1997), of which *dehesas* (23,000 km^2) and *montados* (7,000 km^2) form the major part (Moreno and Pulido 2009). Extensive areas of present-day wood-pasture also exist in Greece and the Balkans (Bergmeier et al. 2004; Grove and Rackham 2003; Horvat et al. 1974), in sites very different in size, vegetation structure and management. According to Papanastasis et al. (2009) the area used for various kinds of agroforestry systems in Greece amounts to more than 20,000 km^2. In Germany, for comparison, *hudewald* remnants cover a total area of only 55 km^2, split in 218 sites of which few are more than 20 ha (Glaser and Hauke 2004). Together with more open pastures with woody component the total area of

wood-pasture in Germany has been estimated at 500–1,000 km^2 (Luick 2009). For lack of national inventories and comparable land coverage definitions, information on the extent of wood-pastures is not available for most European countries.

While Vera (2000) and other authors claim that pre-Neolithic landscapes in west and central Europe comprised wood but also grassland to a large extent, pollen evidence suggests that the opening-up of lowland woodland was initiated by Neolithic man to provide and improve grasslands for livestock: in Britain, north-western Germany and Denmark approximately 6,000 years ago (Behre 2008; Ellenberg 1954; Lang 1994; Rackham 2004), and 7,500 years ago in south-eastern central Europe. In the western Mediterranean there is evidence for agro-silvopastoral systems from Middle Neolithic times (Delhon et al. 2009; Stevenson and Harrison 1992), and presumably earlier in the east (Grove and Rackham 2003). In high-mountain grasslands, pastoralism has been practised since prehistoric times, e.g. in the Alps for 6,000 years (Cernuska et al. 1999; Etienne 1996; Lichtenberger 1994), and longer in the Mediterranean mountains (Hempel 1995; Papanastasis 1998; Pignatti 1983). In antiquity, it attracted the attention of several classical authors (Chaniotis 1991; McNeill 2003). From medieval times until the sixteenth century, the economy of the southern Italian highlands rested on a system of silvopastoralism (McNeill 2003). It opened up montane woodland and led frequently to treeline depression (Stanisci et al. 1996). In the Spanish Central System, municipal *dehesas* came into being in the Middle Ages through transformation of local forests (Pardo and Gil 2005). For case studies and historical reviews of the human influence on Mediterranean forests in different regions see, e.g., Meiggs (1982), Pignatti (1983), Blanco Castro et al. (1997), Gerasimidis (2005), Loidi (2005), Pardo and Gil (2005), Casals et al. (2009) and Castro (2009). Long-distance pastoralism practices such as transhumance involved shuttling between lowland wood-pastures and high-mountain grasslands, travelling via traditional migration routes such as the *cañadas* in Spain (Rodríguez Pascual 2001). Transhumance or similar seasonal grazing systems occurred, with fluctuating intensities, throughout the human history of the Mediterranean, and still occur, albeit on a minor scale (McNeill 2003). Formerly, transhumance linked northern Spanish mountains with regions in southern Spain as far as 800 km away. The *dehesas* of Spain and *montados* of Portugal formed an important part of the transhumance systems, having been used as pastures in winter and spring. In northern Spain, seasonal grazing with cattle, sheep, goats and horses is still practised using communal pastures. Nowadays, long-distance transhumance works by using railway and road transport (Mayor Lopez 2002). Similarly, in the southern Balkans and in Italy the herds of sheep, goats and cattle roamed the lowland wood-pastures in winter and spring before moving to the mountain summer pastures (Pardini 2009). In the Balkans, up to the beginning of the twentieth century long-distance pastoralism connected mountains and lowlands now separated by national boundaries (Beuermann 1967). Seasonal movements of the magnitude of former times between Balkanic regions ceased over a century ago. 'Motorized transhumance', however, still exists in Spain, Italy, Greece and other Mediterranean regions.

A glossary of terms associated with wood-pasture landscapes

To describe wood-pasture types, we use terms well-established in geobotany, but not all of which are known outside their regions of origin. Most of these have local, temporal or regional connotations which may not be fully reflected by our definitions below.

Dehesa Pastoral woodland of the Iberian peninsula dominated by chiefly old-growth sclerophyllous oak-trees, notably *Quercus rotundifolia* and *Q. suber*. There are various

subtypes but most common are extensive grasslands with 30–100 lopped trees per hectare (Blanco Castro et al. 1997; Grove and Rackham 2003). While *dehesa* is the Spanish name, the Portuguese equivalent is *montado* (Castro 2009; Moreno and Pulido 2009).

Forest In its original sense in Britain, woodland or non-wooded unfenced areas where owners kept deer (Rackham 2004, 2007).

Garrigue (*garigue*, *garriga*) Mediterranean low scrub formation of browsed evergreen trees and shrubs, sub-shrubs and herbs resulting from long-term grazing, cutting and burning. Greek *phrygana*, Spanish *tomillares* and Israelian *batha* are similar but lack browsed or wind-shorn trees and are hence not dealt with in this paper.

Hudewald (*hutewald*) Pastoral woodland dominated by tall old-growth oaks (*Quercus petraea*, *Q. robur*), beech (*Fagus sylvatica*) hornbeam (*Carpinus betulus*) or other deciduous trees, often with pollarded or shredded, but not coppiced trees.

Kratt (*krattskogar*) Deciduous coppiced woodland dominated by oaks (*Quercus petraea*, *Q. robur*) in northern central Europe and in southern Fennoscandia.

Lövängar Fennoscandian deciduous or semi-deciduous low-intensity pastures and meadows with open scrub and groves dominated by *Betula* spp., *Corylus avellana*, *Fraxinus excelsior* and *Populus tremula*.

Macchia (*makija*, *maquis*) Dense sclerophyllous broadleaved or ericaceous Mediterranean scrub derived from coppicing and burning of evergreen *Quercion ilicis* woodland. A Spanish equivalent is *matorral*, which is sometimes used in a wider sense (e.g. in the Interpretation Manual of European Union Habitats, European Commission 2007) comprising all open or dense Mediterranean tall scrub.

Park (*game park*, *wildpark*) Enclosed woodland or grassland with scattered trees, scrub or groves, used to keep deer or other animals in quantities that require additional feeding. Popular in Europe and beyond since ancient times.

Pseudomacchia Semi-sclerophyllous scrub of the southern Balkans dominated by kermes oak (*Quercus coccifera* s.l.) resulting from long-term grazing and harvesting of submediterranean *Quercetalia pubescentis* woodlands (Adamović 1906).

Shibliak (*šibljak*, Шибљак) Thermophilous deciduous or semi-deciduous scrub of the Balkans and the Black Sea area resulting from long-term grazing and forest degradation. *Shibliak* may be composed or dominated by a variety of shrubs, notably *Carpinus orientalis*, *Paliurus spina-christi*, *Prunus tenella*, *Quercus trojana*, *Syringa vulgaris* and others (Adamović 1901).

Streuobst Low-intensity orchards with tall standard (*Hochstamm*) fruit-crop trees close to villages in temperate Europe. Most common are apple, pear, plum and cherry trees. Underneath is usually grassland which is cut or grazed.

Wacholderheide Nutrient-poor grasslands and heathlands interspersed with open scrub of tall, often columnar, *Juniperus communis* in central and western Europe. It occurs both on calcareous and siliceous soils.

Weidfeld Non-intensive pastures with scrub of *Cytisus scoparius* and browsed trees, with scattered single- or multi-stemmed *Fagus* trees, especially in the Schwarzwald (Germany) (Schwabe-Braun 1980).

Diversity of wood-pasture: a geobotanical classification of habitats in Europe

Wood-pasture occupies a spatial level between ecosystem and landscape, namely that of an ecosystem complex. Ecosystem complexes may be serial, describing a range of plant communities or ecosystems along a successional gradient, or they may be catenal, describing

a predictable range of spatially close plant communities (sigmeta). Wood-pastures have elements of both types of ecosystem complexes, and they can only be understood if the ecology and dynamics of the plants and plant communities involved are understood. There is still some way to go to reach this aim. In the framework of this paper our descriptions of the wood-pasture categories have to be brief and general. Specific local types may not always be covered, as our categories cannot describe the full range of intermediates that exist.

This survey is based on geobotanical criteria used for woodlands and grasslands alike, such as climatic zone, altitudinal belt, physiognomy, and dominant species. The major bioclimatic zones in Europe are boreal, meaning the northern conifer-dominated taiga zone, nemoral, comprising the temperate and submeridional broadleaved forest zone, and meridional for the sclerophytic Mediterranean forest zone (Schroeder 1998). Hemiboreal (or boreonemoral), with its deciduous and coniferous woodlands, is the transition zone between the first two, and submeridional, with its chiefly thermophytic deciduous woodlands, between the temperate and the meridional zone. The wooded altitudinal belts are lowland, colline, submontane, montane, altimontane. In the meridional zone the altitudinal belts thermo-, meso-, supra- and oro-mediterranean are arranged using criteria of temperature and distance from coast. For further characteristics see Table 1.

Hemiboreal and boreal wood-pastures

1. Deciduous wood-pastures associated with *kratt* in the temperate to hemiboreal zone of north-central and northern Europe
2. Deciduous wood-pastures associated with *lövängar* in the hemiboreal zone of south-eastern Fennoscandia and the Baltic area
3. Deciduous or semi-deciduous wood-pastures dominated by birch (*Betula pubescens* agg.) in the Fennoscandian lowlands and lower mountains
4. Deciduous or coniferous north-boreal to subarctic wood-pastures

Nemoral old-growth wood-pastures

5. Nemoral deciduous *hudewald* or *park* of lowland to submontane *Fagetalia* landscapes in western and central Europe
6. Montane to subalpine deciduous, coniferous or mixed pastoral woodland or *weidfeld* dominated by *Fagus*, *Picea* or *Acer* in the mountains of central, southern and south-eastern Europe
7. Nemoral lowland deciduous *hudewald*, *park* or *Forest* of *Quercetalia roboris* landscapes in western, north-western and north-central Europe
8. Thermophilous deciduous *hudewald* of colline to montane *Quercetalia pubescentis* landscapes in southern, south-east and south-central Europe
9. Deciduous riparian and lowland *hudewald* with flooding regime of the great river basins, chiefly in eastern and south-eastern Europe
10. Montane to subalpine coniferous pastoral woodland dominated by *Pinus* or *Larix* in the high mountains of temperate Europe
11. Montane to altimontane coniferous or mixed *Pinus* and *Abies* wood-pasture of the mountains of the wider Mediterranean region

Nemoral scrub and coppice wood-pastures

12. '*Wacholderheide*' pastures wooded with *Juniperus communis* of *Fagetalia* and *Quercetalia roboris* landscapes in lowland to montane north-western and central Europe

Table 1 Survey and characteristics of European wood-pasture habitats

Wood-pasture habitat type	Predominant trees	Traditional land-use		Landscape type, potential natural vegetation
		Animals	Trees and ground	
1	*Quercus petraea, Q. robur*	Cattle, sheep	Coppicing, lopping, barking	Quercetalia roboris
2	*Corylus avellana, Populus tremula, Fraxinus excelsior, Quercus robur, Tilia cordata*	Cattle	Pollarding, coppicing, grass cutting, shredding, cultiv. fields	Fagetalia, Vaccinio-Piceetalia
3	*Betula pubescens* s.l., *Fraxinus excelsior, Picea abies, Quercus robur*	Cattle, sheep	Coppicing, lopping	Cladonio-Vaccinietalia
4	*Betula pubescens* s.l., *Pinus sylvestris*	Reindeer		Cladonio-Vaccinietalia
5	*Fagus sylvatica, Quercus petraea, Q. robur, Carpinus betulus*	Cattle, pigs, sheep, deer, horses	Pollarding, lopping, shredding	Fagetalia
6	*Fagus sylvatica, Picea abies, Acer pseudoplatanus*	Cattle, sheep	Lopping, grass cutting	Fagetalia, Vaccinio-Piceetalia
7	*Quercus robur, Q. petraea, Q. pyrenaica, Carpinus betulus, Pinus sylvestris*	Sheep, cattle, horses	Pollarding, shredding, bee-keeping	Quercetalia roboris
8	*Quercus pubescens, Q. petraea* agg., *Q. frainetto, Q. cerris, Castanea sativa*	Sheep, cattle, pigs	Pollarding, shredding, acorn collecting	Quercetalia pubescentis
9	*Q. robur* s.l., *Ulmus* spp., *Fraxinus excelsior, F. angustifolia* s.l.	Cattle, pigs, horses	Pollarding, shredding, grass cutting	Fagetalia
10	*Larix decidua, Pinus cembra, P. uncinata*	Cattle, sheep	Grass cutting	Vaccinio-Piceetalia
11	*Pinus heldreichii, P. sylvestris, Abies alba, A. borisii-regis, A. cephalonica, A. pinsapo*	Sheep, cattle, goats, horses	Bee-keeping	Fagetalia sylvaticae, Quercetea pubescentis, Pino-Juniperetalia, Vaccinio-Piceetalia
12	*Juniperus communis*	Sheep, goats	Bee-keeping	Fagetalia sylvaticae, Quercetalia roboris
13	*Quercus pubescens, Q. frainetto, Q. cerris, Carpinus orientalis, C. betulus, Juniperus oxycedrus*	Cattle, goats, sheep	Coppicing, pollarding, lopping, barking	Quercetalia pubescentis
14	*Paliurus spina-christi, Quercus petraea* agg., *Carpinus orientalis, Juniperus excelsa, J. foetidissima*	Sheep, goats, cattle	Grass cutting, cultiv. fields, lopping, bee-keeping	Quercetalia pubescentis

Table 1 continued

Wood-pasture habitat type	Predominant trees	Traditional land-use		Landscape type, potential natural vegetation
		Animals	Trees and ground	
15	*Paliurus spina-christi, Quercus trojana, Q. pubescens, Q. petraea* agg., *Carpinus orientalis*	Sheep, goats	Grass cutting, cultiv. fields, lopping, coppicing, bee-keeping	Quercetalia pubescentis
16	*Juniperus excelsa, J. foetidissima, J. thurifera*	Goats, sheep	Bee-keeping	Quercetalia pubescentis, Pino-Juniperetalia
17	West: *Quercus rotundifolia, Q. suber;* East: *Quercus coccifera* s.l., *Q. ilex*	Pigs, cattle, sheep, deer	Cultiv. fields, lopping, barking, charcoal, bee-keeping, acorn collecting, resining	Quercetalia ilicis
18	*Quercus ithaburensis* subsp. *macrolepis, Q. pubescens, Q. frainetto, Castanea sativa*	Cattle, pigs, sheep	Cultiv. fields, lopping, pollarding, acorn collecting	Quercetalia ilicis
19	*Arbutus unedo, A. andrachne, Erica arborea, Pinus* spp.	Goats, sheep	Coppicing, burning, resining, bee-keeping	Quercetalia ilicis
20	*Quercus coccifera* s.l., *Juniperus oxycedrus*	Goats, sheep, cattle	Lopping, burning, charcoal, bee-keeping	Quercetalia pubescentis
21	Thermo-mediterranean: *Pistacia lentiscus, Ceratonia siliqua, Olea europaea*; meso-mediterranean: *Quercus coccifera* s.l., *Phillyrea latifolia, Q. pubescens, Pyrus spinosa*	Sheep, goats	Cultiv. fields, tree cropping, burning, bee-keeping	Quercetea ilicis
22	*Quercus coccifera* agg., *Cupressus sempervirens, Acer sempervirens*	Sheep, goats	Lopping, pollarding, charcoal, bee-keeping	Quercetea ilicis
23	*Malus domestica, Pyrus communis*	Sheep	Grass cutting, lopping, bee-keeping	Fagetalia sylvaticae, Quercetalia pubescentis
24	*Olea europaea, Ceratonia siliqua, Phoenix dactylifera*	Sheep	Cultiv. fields, bee-keeping, lopping	Quercetea ilicis

13. Thermophilous deciduous coppice wood-pasture of *Quercetalia pubescentis* landscapes in southern and south-eastern Europe
14. Subcontinental *shibliak* distributed in pastures of woodsteppe and *Quercetalia pubescentis* regions in south-eastern and south-east central Europe
15. Submediterranean *shibliak* distributed in *Quercetalia pubescentis* regions of south-eastern Europe
16. Rangelands with tall juniper in southern and southern central European mountains, more widely distributed in Anatolia, the Black Sea area and the Middle East

Meridional old-growth wood-pastures

17. Sclerophyllous pastoral woodland, including the *dehesa* type, of *Quercetea ilicis* landscapes in Mediterranean Europe
18. Deciduous pastoral woodland of *Quercetea ilicis* landscapes in the Mediterranean

Meridional scrub and coppice wood-pastures

19. Grazed macchia/matorral of *Quercetea ilicis* landscapes in the Mediterranean
20. Rangeland mosaic with sclerophyllous or mixed scrub of the *pseudomacchia* type in southern and south-eastern Europe
21. Low evergreen open scrub-pastures of the *garrigue* type in *Quercetea ilicis* landscapes, interspersed with scattered sclerophyllous, coniferous and deciduous shade-giving trees and small groves, in the Mediterranean lowlands and lower mountains
22. Rangeland mosaic of montane grassland with sclerophyllous broadleaved trees and/or conifers, frequently lopped or pollarded, in the Mediterranean mountains

Grazed orchards

23. Grazed deciduous orchards with fruit-crop trees of the '*streuobst*' type
24. Grazed evergreen orchards and groves with olive-trees, carob trees or date palms

Biodiversity and conservation relevance

Where grassland and woodland are kept apart their margins are well-defined and the ecotone is narrow, in contrast to the margins of wood-pasture which are wide, indistinct and not always identifiable. In patchy wood-pastures the wood-grassland ecotone forms a major part of the entire area of wood-pasture. High ecotone proportion is the key factor for high species and niche densities of pastoral woodlands (Bergmeier 2004). Wood-pasture provides a wide range of light and shade conditions, nutrient-poor and small-scale nutrient-rich sites and a certain low level of disturbance.

Old trees, rare in commercial forests and plantations, are a common, though often relictual, element in pastoral woodlands. They provide structural qualities common to both primeval and pastoral woodland. Certain beetles associated with primeval woodland and indicating considerable habitat age have been found on senescent trees and deadwood in old-growth, formerly pastoral, woodland in central Europe (Müller et al. 2005). The general diversity of beetles has been shown to be related to the structural diversity of wood-pasture, with positive effects of traditional forest management on the fauna of Carabidae and other groups (Desender et al. 1999; Taboada et al. 2006). Heterogeneity in vertical and horizontal vegetation structure seems to favour snail diversity both at the local and landscape scales (Labaune and Magnin 2002).

Pasture-woodland is of 'habitat importance' for at least 37 European bird species, and for 18 species a high proportion of their European populations uses this habitat (Tucker and Evans 1997). The following countries are particularly rich in bird species dwelling in pastoral woodland (in decreasing order, according to Tucker and Evans 1997): Spain, France, Portugal, Turkey, Ukraine, Greece, Romania, Bulgaria, Albania, Croatia, Italy, Poland, Slovakia. Spanish imperial eagles (*Aquila adalberti*) and woodchat shrikes (*Lanius senator*) are breeding birds almost exclusive to wood-pasture habitats, with the former restricted to Iberian *dehesa*. Scops owl (*Otus scops*), hoopoe (*Upupa epops*), roller (*Coracias garrulus*) and wryneck (*Jynx torquilla*) are also characteristic birds of pastoral woodland with old trees. *Dehesas* and *montados* are also important habitats for carnivorous mammals such as lynx (*Lynx pardinus*, a priority species of Annex II of the Habitats Directive), genet (*Genetta genetta*) and mongoose (*Herpestes ichneumon*).

Among vascular plants, there is a trend that species more or less common in thermophilous woodland habitats in southern Europe occur in central and northern Europe chiefly in wood-pasture habitats. In the Sava floodplains in Croatia, about 300 plant species (as well as 238 bird species, of which 134 breeding) were found on species-rich pastures and in pasture-woodland. Many of these are threatened and red-listed in central Europe (Poschlod et al. 2002). At a European scale, species that are more or less exclusive to pastoral woodland are poisonous or distasteful herbs, such as peonies (*Paeonia broteri*, *P. clusii*, *P. coriacea*, *P. mascula* s.l., *P. officinalis* s.l., *P. parnassica*, *P. peregrina*, *P. tenuifolia*, some of which narrow endemics and taxa listed in Annex II of the Habitats Directive), hellebores (*Helleborus bocconei*, *H. foetidus*, *H. odorus*, *H. viridis* agg.), *Asphodelus albus*, *Dictamnus albus*, *Melittis melissophyllum* and *Veratrum nigrum*. These are species of chiefly southern European distribution which are moderately thermophilous and shade-tolerant and sufficiently protected from grazing animals by poisonous chemicals. They may be gregarious in grazed woodland as well as in pastures with few trees left.

Threats to the biodiversity of wood-pasture habitats

Threats to wood-pasture habitats result primarily from changes in traditional land-use practices caused by overall social and economic change in rural landscapes. Such changes may go two different ways: intensification of livestock rearing and thus higher stocking levels, or land abandonment followed by loss of small-scale habitat diversity. As for other non-intensively used habitats, agricultural expansion and intensification, urbanization and road construction have led to increased fragmentation of wood-pasture habitats. More specific problems are:

Reduction in old-growth tree density

Much of the diversity 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 or others. If the natural loss of senescent trees is not compensated by rejuvenation, the result will be either open pastures or stony slopes (if stocking levels remain high), or, if wood-pasture is neglected, dynamic processes will lead to more or less dense forest.

High stocking levels

A principal problem among many current wood-pastures in Greece and Spain is regeneration failure and woodland-ageing (Diaz et al. 1997; Dimopoulos and Bergmeier 2004; Plieninger et al. 2003). It is not well understood whether this is a problem immanent to permanent, century-old wood-pasture, or one that arose only during the last decades of overgrazing. Lack of seedlings and juvenile trees can be observed chiefly in pastoral woodlands with sheep and goat grazing. In high numbers, the former affect the ground layer through trampling, the latter are known to selectively browse young trees and shrubs. Overgrazing also reduces the extent of underscrub. Shrubby nurse plants would otherwise serve as shelter for shade-demanding tree seedlings. In some areas, numbers of sheep and other livestock have increased in the last 2 decades through EU per capita subsidies (Lyrintzis 1996).

Land abandonment

While lowland pastoral woodlands of the *hudewald* type in western and central Europe were abandoned chiefly in the nineteenth century, rural depopulation and agricultural abandonment in the European Mediterranean took place in particular in the second half of the twentieth century. The abandonment of wood-pasture and low-intensity farming systems leads to scrub encroachment and denser woodlands with increasing fire hazards, and the loss of the patchiness that is so characteristic of many types of wood-pasture.

Oak disease

High mortality rates among large mature cork and holm oaks (*Quercus suber*, *Q. rotundifolia*) in southern Portugal, Spain and Italy have been reported since the 1970s and especially in the last 12–15 years. The oak decline is attributable to aggressive root-fungus, viz. *Phytophthora cinnamomi*, interacting with drought, insect attacks and land-use change (Brasier 1992, 1996; Brasier et al. 1993; Kaltenbach 2007; Moreira and Martins 2005). *Phytophthora* species have also been identified as pathogens causing dieback in oak-trees in central Europe (Jung et al. 2000). The chestnut bark fungus *Endothia parasitica* has led to a sharp decline of *Castanea* groves, especially in Italy and southern France, including former and present pastoral woodlands.

Removal of olive groves and streuobst meadows

Groves with old olive-trees have been a characteristic feature of the Mediterranean cultural landscape, often used in multiple ways including wood-pasture. The pasturelands underneath the ancient olive-trees can be very rich in species, especially orchids and other bulbous plants. In the last 2 decades, major parts of old stands were cut and substituted by olive-plantations of high-yield varieties. Plantations have also been established in former fields and wood-pastures, especially in southern mainland and insular Greece, Italy and Spain. These plantations are generally ploughed, irrigated and pesticides are applied.

Streuobst meadows with standard apple and pear trees have been and are still a common sight in Germany and elsewhere in temperate Europe on the outskirts of villages. In the course of reallocation of farming lands and rural development, there has been a substantial loss of trees and conversion to silage grasslands, fields and development areas. If still

extant, the grassland underneath is commonly fertilized and no longer part of low-input grazing or hay-making systems.

Wood-pasture in the EU Habitats Directive

Pros and cons

Due to its multifunctionality and broad range of ecosystem services, wood-pasture systems have received increasing attention by scientists and policy-makers concerned with agriculture and forestry, but also in the fields of rural development, tourism and nature conservation (Mattison and Norris 2005; Rigueiro-Rodríguez et al. 2009; Terzi and Marvulli 2006). The Habitats Directive (Council of the European Communities 1992) is a legislative instrument of the European Community in the field of nature conservation. 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. A "coherent ecological network of special areas of conservation"—Natura 2000—has been established "hosting the natural habitat types listed in Annex I and of the species listed in Annex II…" (art. 3). Among the 231 European natural habitat types listed in Annex I (European Commission 2007), very few are related to wood-pasture.

Do we need wood-pasture as habitats of Community interest? The biodiversity of these habitats provides convincing arguments, as wood-pasture habitats, if not overgrazed, are ecosystems with intermediate disturbance and high species richness and density, although the soil may be impoverished and the ecosystem as a whole may have a deficient nutrient balance. It is misleading, though, to compare wood-pasture habitats with natural woodlands, as the former are more a semi-natural formation treated in a similar manner to man-made agricultural and grassland habitats of low-intensity management. As with such habitats, traditional management practices have been abandoned or modified in much of the European pastoral woodland, or they have been substituted by more intensive management. Some would call wood-pasture an economic anachronism and its conservation a museum approach. However, the same could be said of almost all low-intensive agricultural habitats. Most conservationists agree that while conservation of climax woodlands and ecosystems deserves to be given high priority, the diversity of European cultural landscapes should also be maintained. As wood-pasture is still of economic relevance in parts of Europe, especially in the south and south-east, future development should be subject to nature conservation concern just like those of semi-natural grasslands and heathlands.

Following an Interpretation Guide on Natura 2000 and forests (European Commission 2003), habitats of community importance listed in Annex I of the Habitats Directive can be separated into three functional groups (Barbier 2000):

- "habitats which occur in environments that have always been marginal in economic terms and were never colonised by man, such as riverine formations, dune areas, wet pockets in forests and active bogs;
- […] climax habitats, such as certain oak forests, beech forests and natural spruce forests, which have been exploited for timber and kept in a stable condition by management of the indigenous species;
- habitats which are mainly man-made landscapes or their transition to the climax vegetation, such as heaths, wooded bogs, open (grazed) woodlands, natural grasslands or pastures.

This leads to the conclusion that there is too little conclusive evidence to determine, with a reasonable degree of confidence, what would have been the exact composition of potential natural vegetation cover on any given spot in Europe and that, in many cases, the continuation of human intervention is absolutely essential to habitat conservation."

Representation

Forests are defined as "(sub)natural woodland vegetation comprising native species forming forests of tall trees, with typical undergrowth, and meeting the following criteria: rare or residual, and/or hosting species of Community interest" (European Commission 2007). The Interpretation Manual gives the following additional criteria that were accepted by the Scientific Working Group (21–22 June 1993):

- forests of native species;
- forests with a high degree of naturalness;
- forests of tall trees and high forest;
- presence of old and dead trees;
- forests with a substantial area;
- forests having benefited from continuous sustainable management over a significant period.

Wood-pastures do not meet the definition of forest habitats in the Interpretation Manual (Bergmeier 2008). Wood-pasture habitats do consist of native species, and they may comprise substantial areas. No less than 'true' woodlands, they may be rare or residual as such, and host species of Community interest. Some types of wood-pasture are famous for their old trees, even more so than in other types of used woodlands. The proportion of deadwood may also be high. Some are 'ancient' in that wood-pasture has been practised through centuries and, although no records of any significant age exist, some may not have been much changed over time, hence we may even call it a 'sustainable' kind of management. Nevertheless, woodlands eligible for the Natura 2000 network are supposed to show typical woodland undergrowth, i.e., mesophytic and shade-tolerant, and a "high degree of naturalness". However, the structure of wood-pastures is man-made, and if criteria and definitions of forest habitats were applied, even high-quality wood-pasture sites, with natural regeneration in the presence of grazing, could only be assessed with an unfavourable conservation status.

Nevertheless, the habitat type 9070 (Fennoscandian wooded pastures), clearly a type of wood-pasture, inconsistently has become a forest habitat type. Only few other wood-pasture habitat types have been recognized at all in Annex I of the Habitats Directive, under the headings of 'Submediterranean and temperate scrub' (5130: *Juniperus communis* formations on heaths or calcareous grasslands) 'Mediterranean arborescent matorral' (5210: Arborescent matorral with juniper), 'Sclerophyllous grazed woodlands' (6310: Dehesas with evergreen oaks), 'Mesophile grasslands' (6530: Fennoscandian wooded meadows). A few types of 'Temperate heath and scrub', notably 40A0 (Subcontinental peri-Pannonic scrub) and 40C0 (Ponto-Sarmatic deciduous thickets) also belong here.

What is missing?

Tables 2 and 3 shows the relation between Annex I habitat types and European wood-pasture types. Only few wood-pasture types fully match Annex I habitat types. Most wood-pasture types are somehow represented under certain forest habitat types. In fact, some of

Table 2 Relation between European wood-pasture types and Natura 2000 habitat types of Annex I

Wood-pasture type	Represention as Natura 2000 habitat type	Management	Matching Annex I code
1	+	f	2180; 9020; 9120
2	++	w	6530; 9070
3	++	w	9070
4	++	f	9010; 9040; 91C0
5	+	f	2180; 9020; 9110; 9120; 9130; 9150; 9160; 9170; 91L0
6	+	f	9110; 9130; 9140; 91K0; 91S0; 91V0; 91W0; 91BA; 9210; 9220
7	+	f	2180; 9120; 9190; 91A0; 9230
8	+	f	91G0; 91H0; 91I0; 91M0; 91Y0; 91AA; 9250; 9260; 9280
9	+	f	91E0; 91F0; 91L0; 92A0; 92C0
10	+	f	9410, 9420, 9430
11	+	f	91CA; 9220; 9270; 9510; 9520; 9530; 9590; 95A0
12	++	w	5130
13	+	f	91G0; 91H0; 91I0; 91M0; 91Y0; 91AA; 9250
14	+	w	40A0, 40C0
15	+	f	9250
16	+	f, w	5210; 9560
17	+	f, w	5230; 6310; 9330; 9340;
18	+	f	9240; 9260; 9310; 9350; 93A0
19	+	f	9330; 9340; 9390; 93A0
20	−		
21	+	f	9320; 93A0; 9540
22	+	f	9290; 9390; 9590
23	−		
24	−		

The wood-pasture types may be fully (++) or partly (+) matching a Natura 2000 habitat type, or it may not be represented at all (−). As Natura 2000 habitat type it is to be managed as wood-pasture (w) or forest (f)

The explanation for matching Annex I code is given in Table 3

the forest habitat types exist to date only as pasture woodlands. Clearly, this arrangement is unsatisfying and conflicting.

Adequate forest management should aim to maintain or restore high ecological quality and focus on natural processes. Restoration should lead to natural old-growth forest. Management of pastoral woodlands can only be targeted at one or the other. If a pastoral woodland is old-growth, in favourable semi-natural condition, sizeable and representing a rare woodland habitat type, it seems reasonable to treat it as forest habitat and improve its conservation status by performing management towards increased naturalness and lower human impact. If, on the other hand, wood-pasture consists of a mosaic of groves, scrub and open ground of economic relevance to the locals and forming part of a wider area of cultural landscape, it should not be treated as forest habitat nor developed as such. Instead, it should be maintained or developed as wood-pasture habitat (Bergmeier 2008).

Table 3 Matching Annex I code of the EU Habitats Directive

Code	Name
2180	Wooded dunes of the Atlantic, Continental and Boreal region
40A0	*Subcontinental peri-Pannonic scrub
40C0	*Ponto-Sarmatic deciduous thickets
5130	*Juniperus communis* formations on heaths or calcareous grasslands
5210	Arborescent matorral with *Juniperus* spp.
5230	*Arborescent matorral with *Laurus nobilis*
6310	Dehesas with evergreen *Quercus* spp.
6530	*Fennoscandian wooded meadows
9010	*Western Taïga
9020	*Fennoscandian hemiboreal natural old broadleaved deciduous forests (*Quercus*, *Tilia*, *Acer*, *Fraxinus* or *Ulmus*) rich in epiphytes
9040	Nordic subalpine/subarctic forests with Betula pubescens ssp. czerepanovii
9070	Fennoscandian wooded pastures
9110	Luzulo–Fagetum beech forests
9120	Atlantic acidophilous beech forests with *Ilex* and sometimes also *Taxus* in the shrublayer (Quercinion robori-petraeae or Ilici-Fagenion)
9130	Asperulo-Fagetum beech forests
9140	Medio-European subalpine beech woods with *Acer* and *Rumex arifolius*
9150	Medio-European limestone beech forests of the Cephalanthero-Fagion
9160	Sub-Atlantic and medio-European oak or oak-hornbeam forests of the Carpinion betuli
9170	Galio-Carpinetum oak-hornbeam forests
9190	Old acidophilous oak woods with *Quercus robur* on sandy plains
91A0	Old sessile oak woods with *Ilex* and *Blechnum* in the British Isles
91C0	*Caledonian forest
91E0	*Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (Alno-Padion, Alnion incanae, Salicion albae)
91F0	Riparian mixed forests of *Quercus robur*, *Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (Ulmenion minoris)
91G0	*Pannonic woods with *Quercus petraea* and *Carpinus betulus*
91H0	*Pannonian woods with *Quercus pubescens*
91I0	*Euro-Siberian steppic woods with *Quercus* spp.
91K0	Illyrian *Fagus sylvatica* forests (Aremonio-Fagion)
91L0	Illyrian oak-hornbeam forests (Erythronio-Carpinion)
91M0	Pannonian-Balkanic turkey oak-sessile oak forests
91S0	*Western Pontic beech forests
91V0	Dacian Beech forests (Symphyto-Fagion)
91W0	Moesian beech forests
91Y0	Dacian oak & hornbeam forests
91AA	*Eastern white oak woods
91BA	Moesian silver fir forests
91CA	Rhodopide and Balkan Range Scots pine forests
9210	*Apennine beech forests with *Taxus* and *Ilex*
9220	*Apennine beech forests with *Abies alba* and beech forests with *Abies nebrodensis*
9230	Galicio-Portuguese oak woods with *Quercus robur* and *Quercus pyrenaica*

Table 3 continued

Code	Name
9240	*Quercus faginea* and *Quercus canariensis* Iberian woods
9250	*Quercus trojana* woods
9260	*Castanea sativa* woods
9270	Hellenic beech forests with *Abies borisii-regis*
9280	*Quercus frainetto* woods
9290	*Cupressus* forests (Acero-Cupression)
92A0	*Salix alba* and *Populus alba* galleries
92C0	*Platanus orientalis* and *Liquidambar orientalis* woods (Plantanion orientalis)
9310	Aegean *Quercus brachyphylla* forests
9320	*Olea* and *Ceratonia* forests
9330	*Quercus suber* forests
9340	*Quercus ilex* and *Quercus rotundifolia* forests
9350	*Quercus macrolepis* forests
9390	*Scrub & low forest vegetation with *Quercus alnifolia*
93A0	Woodlands with *Quercus infectoria* (Anagyro foetidae-Quercetum infectoriae)
9410	Acidophilous *Picea* forests of the montane to alpine levels (Vaccinio-Piceetea)
9420	Alpine *Larix decidua* and/or *Pinus cembra* forests
9430	Subalpine and montane *Pinus uncinata* forests
9510	*Southern Apennine *Abies alb*a
9520	*Abies pinsapo* forests
9530	*(Sub-)Mediterranean pine forests with endemic black pines
9540	Mediterranean pine forests with endemic Mesogean pines
9560	*Endemic forests with *Juniperus* spp.
9590	**Cedrus brevifolia* forests (Cedrosetum brevifoliae)
95A0	High oro-Mediterranean pine forests

See Table 2 for the relation of the habitat types to wood-pasture

A precondition for this would be to include several currently neglected wood-pasture habitat types in an updated version of Annex I. The following list of habitats suggested here is meant to serve as basis for discussion [in brackets the wood-pasture types that would be considered by the given habitat type]:

- Nemoral (agro-)pastoral woodland dominated by deciduous broadleaved trees [5, 6, 7, 8; 9]
- East Mediterranean *Quercus coccifera* s.l. woodlands [17]
- East Mediterranean macchia or arborescent matorral with *Arbutus andrachne* [19]
- East Mediterranean sclerophyllous kermes oak matorral or pseudomacchia (*Quercus coccifera* s.l.) [19, 20, 21, 22]
- Non-intensive fruit-crop tree orchards with grassland [23, 24]

Conclusion

Silvopastoral systems comprise habitats transitory in ecology between woodland and grassland, but with peculiar structures and species composition not commonly found in

either woodlands or grasslands. Many wood-pastures have a long habitat history and features such as old trees, deadwood, extent, disturbance by large herbivores and light sub-canopy conditions bridge historical pastoral use and Holocene primeval woodland. The peculiarities of wood-pasture cannot be maintained by either woodland or grassland management alone. Conservation of wood-pasture habitats requires long-term management similar to traditional land-use, and in sufficiently large areas, as well as careful monitoring to avoid both overgrazing and neglect. The EU Habitats Directive treats wood-pasture habitats rather half-heartedly and inconsistently. Most of the wood-pasture habitats distinguished in this paper are, however, in Annex I either not represented as wood-pasture but as forest habitat type, or not represented at all. To establish clarity in the future management and conservation targets of pastoral woodlands and wooded pastures in Europe, it is essential to define wood-pasture categories hitherto missing in Annex I and to estimate the size and conservation status of wood-pasture in the European countries. It will then be necessary to select stands to be restored towards natural woodland and others to be managed as wood-pasture. We hope that this paper provides useful suggestions and argumentation aid.

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