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Chapter 12
The wood-pasture; for food, wood and biodiversity

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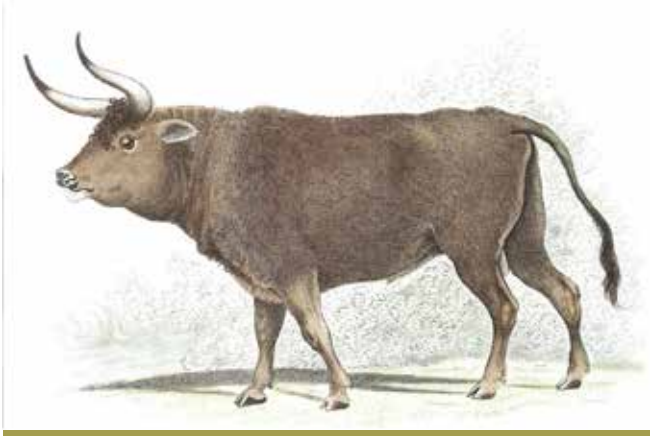
Introduction

This chapter is about the wood-pasture. It is based on research in Western and Central Europe (Vera, 2000; 2007; 2013). The wood-pasture is a park-like landscape, consisting of a mosaic of grasslands, bushes, thickets, solitary trees and groves (Flower, 1977; Pott and Hüppe, 1991; Rackham, 1980; 2003; Vera, 2000). It has an enormous variation in types of vegetation and an enormous variation in combination of these (Photograph 1). Because of that the wood pasture is very rich in wild plant and animal species (Alexander, 1998, 2001 and 2005; Alexander et al., 2006; Appelqvist et al., 2001; Bossuyt et al., 2005; Green, 2009; Harding and Rose, 1986; Manning et al., 2006; Ranius et al., 2005; 2008; Schuffenhauer, 2011; Schulze-Hagen, 2004; Ek and Johanesson, 2005; Vera, 2000; Vodka et al., 2009). Being an agricultural system of pasturing livestock, the wood-pasture in Western and Central Europe goes back to the beginning of history and back to the introduction of agriculture between 7,000 and 5,550 years BP (Bogucky, 1988). It once covered large parts of the European continent (Pott and Hüppe, 1991; Rackham, 1980; 2003; Vera, 2000). It is the result of the wilderness taken into use by mankind in order to provide what was needed to fulfil the needs of its household, which consisted of grazing livestock, collecting of hay and honey, extraction of firewood and timber, and hunting of wild animals. This section describes how the wood-pasture as system works, how it provided mankind his living and how it is related to the originally present wilderness.

Photograph 1: A wood-pasture still in practice in Transylvania, Romania (F. Vera).

The wood-pasture

The wood-pasture is a park-like landscape grazed by livestock such as cattle (*Bos taurus*), horse (*Equus caballus*), sheep (*Ovis aries*), goat (*Capra hircus*) and pig (*Sus domestica*) and if present, by wild indigenous herbivores such as red deer (*Cervus elaphus*), roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*). Up to historic times also vanishes or almost vanished indigenous wild ungulates such as aurochs (*Bos primigenius*), tarpan (*Equus przewalksi gmelini*), elk (*Alces alces*) and European bison (*Bison bonasus*) roamed in wood pastures up to historic times (Brincken, 1826; Szafer, 1960; Vera, 2000). In the course of centuries loss of habitat, hunting and poaching made all wild herbivores decrease in numbers and density and disappear from large parts of their natural range. Two species even became extinct; the aurochs, the wild ancestor of cattle in 1627 (Szafer, 1960) (Photograph 2) and the tarpan, the wild ancestor of domestic horse in 1887 (Wrześniowski, 1878; Pruski, 1963). The European bison became extinct in the wild in 1921. The last specimen was killed in the former wood-pasture the forest of Białowieża by a poacher. However, 12 specimens survived in zoos, which became the founders of the population of about 3,000 specimens living in zoos and in areas in Europe where they have been reintroduced. This includes the forest of Białowieża



Photograph 2: The aurochs (*Bos primigenius*), the wild ancestor of our domestic cattle. The aurochs became extinct in 1627 in Poland. Besides prehistoric cave paintings, this is the only one left. It is a lithograph from 1862 after a painting from the 16th century that got lost.

where it was released in 1952 (Krasińska and Krasiński, 2007). The wild boar (*Sus scrofa*), the wild ancestor of the pig, still lives throughout Europe. So, livestock such as cattle, horse and pig in wood-pastures are indigenous species in Western and Central Europe. The wild ancestor of cattle and horse, aurochs and tarpan lived in Western and Central Europe up to historical times side by side with their domestic counterparts, while wild boar still does. Sheep and goat are non-indigenous in Western and Central Europe. They originate from where the domestication of all livestock species occurred, namely in what nowadays are Turkey, Syria and Ukraine (Clutton-Brock, 1989; Larson et al., 2005; Hongo et al., 2009; Outram et al., 2009; Ludwig et al., 2009; Ottoni, 2013; Felius et al., 2014).

The social context of the wood-pasture

The wood-pasture was uncultivated common land that lay beyond the cultivated that bordered the farms that formed settlements. The cultivated land consisted of fields with crops and hay lands. Beyond it was the uncultivated wilderness. "Germanic" people in Western and Central adopted an ancient system of law passed down by word of mouth for the use of the surrounding wilderness (Vera, 2000). The wilderness outside the farm and the cultivated land, the fields and the hay lands, could be used by any member of the local community to meet their needs (Meyer, 1931; Mantel, 1990). This included grazing and collecting fodder (from wild grass, trees and shrubs) for livestock, collecting firewood and timber for building and collecting honey. The customary law was passed on by word of mouth every year at the so-called commoners' meeting (Grossmann, 1927; Trier, 1963; Buis, 1985). The measure of common use was what necessary was for the livelihood of the household, the so-called "own" needs ("eigenen notdurft", "zur notturfft", "des Hauses Notdurft") (Endres, 1888; Grossmann, 1927: Hilf, 1938; Kaspers, 1957; Rubner, 1960; Hesmer and Schroeder, 1963; Buis, 1985; Tack et al., 1993). The concept of need was inextricably linked to the way in which the medieval economy was organized; that is mainly based on local self-sufficiency (autarchy). This meant self-subsistence of meat, milk, skins, wood and manure for the fields where they cultivated cereals. Equality with regard to meeting the people's needs was the starting point of the common land (Endres, 1888). Therefore a local community had to have access to the natural resources that could deliver these. There were also neighbouring communities which also had to meet their needs from the uncultivated wilderness (Endres, 1888). As a result of the increasing pressure by a growing population the individual local communities eventually made boundaries in the wilderness to indicate which area was considered as the common being for their exclusive usage. This gave rise to so-called "marken", derived from the word "marca" that means border. The earliest mention in the Netherlands goes back to a charter of 792/793 (Buis, 1985). Other words which more reflect the common usage in Western and Central Europe are: "gemeynte", "meente", "Gemeinde" or "Allmend" (from German: "für Allen gemein") (Hilf, 1938; Hesmer and Schroeder, 1963; Schubart, 1966; Streitz, 1967; Buis, 1985; Mantel, 1990). In addition to rights, also duties of the individual commoners were laid down in regulations that were imposed on the use of the common (Hesmer and Schroeder, 1963; Buis, 1985). In charters written in Latin the uncultivated wilderness, among it the wood-pastures were named: "forestis", from which in German "Forst", in French "fôret", in Dutch "foreest" or "forest" and in English "Forest" was derived. In the common Germanic languages the uncultivated was named: "woud", "wald", "wold" and "weald" (Vera, 2000).

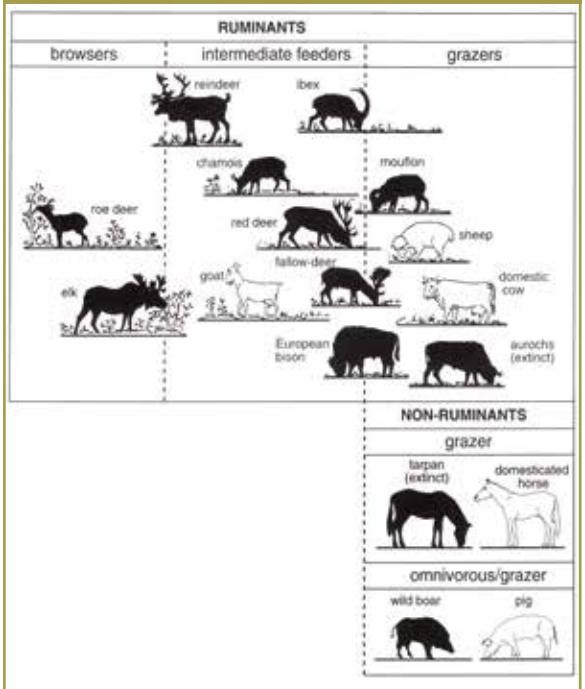
As mentioned above, equality with regard to meeting the people's needs was the starting point of the common land (Endres, 1888). This meant that a wood-pasture had to remain closed. Trading in livestock or food for livestock was forbidden, or subject to strict restrictions (Endres, 1888; Weimann, 1911; Hilf, 1938; Hesmer and Schroeder, 1963; Buis, 1985; Vera, 2000). Nothing could be traded from the common, such as wood, fodder or livestock. Any advantage to one member, e.g., if he sold products from the common, was seen as disadvantaging the other members of the community (Endres, 1888). If someone wanted to graze animals on the wood-pasture, he had to breed them himself and feed them in winter on fodder collected in the wood-pasture he as a commoner was privileged to use (Hausrath, 1898; Endres, 1888; Kaspers, 1957; Mantel, 1980; Vera, 2000). The animals of commoners from a particular common were branded, so that it was possible to establish whether there were any "foreign" animals in the common (Sloet, 1913; Ten Cate, 1972). As regards the grazing of livestock, it was therefore not possible to graze more animals than there was food produced by the common. This automatically led to a sort of ceiling on the number of livestock that

could be kept (Endres, 1888; Vera, 2000), namely the number of animals which common land could provide with fodder all year round. This number included the livestock consumed by the commoners. Therefore, this system based on autarchy was very sensitive to fluctuations in the availability of food for livestock by weather conditions, resulting in fluctuations in the number of livestock. Fluctuations in the numbers of ungulates will also have been the consequence of diseases like rinderpest and anthrax. These diseases were widespread and until vaccination against them became possible in the 20th century a plague that locally could kill more than 80% of domestic ungulates and up to 95% of the wild ungulates (Sinclair, 1979; Prins and van der Jeugd 1993; Huygelen, 1997; Sternbach, 2003).

The feeding strategies of the ungulates in the wood-pasture

In wood-pastures domestic and wild ungulates exert by grazing, pruning and debarking an effect on the vegetation. What the effect is depends on their food preference and in turn on their digestive physiology in combination with their densities. The animals can be divided in two groups, the ruminants and the non-ruminants. Ruminants have a rumen in front of the intestinal tract. They are characterized as foregut fermenters. In fact it is the bacteria inside the rumen of the animals that digest cellulose by fermentation. Cattle, sheep, goat, European bison, red deer, roe deer and moose are ruminants (Van Soest, 1982). Non-ruminants have the bacteria in their intestinal tract, especially in the large cecum. There are called hindgut fermenters. Horse is a hindgut fermenter, as well as pig (Van Soest, 1982) (Figure 12.1).

The aurochs (*Bos primigenius*), the wild ancestor of our domestic cattle **Figure 12.1**



The aurochs became extinct in 1627 in Poland. Besides prehistoric cave paintings, this is the only one left. It is a lithograph from 1862 after a painting from the 16th century that got lost.

Because of their diet and digestive physiology cattle and horse are specialized grass-eaters, so-called grazers. They mainly graze the grasslands in the wood-pastures. They can cope with a broad spectrum of quality of the grasses, ranging from young with relatively low levels of poorly digestible cellulose in the cell wall to the aged (and because of that yellow coloured) grass that has a relatively high proportion of the poor digestible cellulose in the cell wall. They are therefore characterized as roughage feeders (Van Soest, 1982). Sheep is like cattle a ruminant and a grass-eater, but less capable to digest cellulose of the cell wall. It is therefore selects more on the quality of grasses, in a sense that compared to cattle and horse it selects on for a higher digestibility due to a lower content of cellulose in the cell wall. Old grass, still grazed by cattle and horses is ignored by sheep. The diet of sheep contains more leaves, twigs and bark of trees and shrubs, than these. Therefore sheep has also been characterized as an intermediate feeder (Van Soest, 1982). This category of ruminants is with its diet and feeding strategy intermediate between grazers, such as cattle and browsers, such as roe deer and elk. Browsers feed almost exclusively on leaves, twigs and bark of trees and shrubs (Van Soest, 1982; Hofmann, 1989; 2007). Of livestock, goat is an intermediate feeder (Van Soest, 1982). It selects the whole year on average on the highest digestibility in its food. For grasses this means selection on a low level of the poorly digestible cell wall material cellulose, which means selection of the highest possible level of the highly digestible cell content. With the aging of grass, goat will switch from grasses to leaves, twigs and bark of shrubs and trees, which then have the relatively highest level of digestible cell content (Van Soest, 1980; Hofmann, 1989; 2007; Jago, 1999). Wild ungulates that are characterized as intermediate feeders are red deer and European bison. The majority of the food of these species consists of grasses. During the winter they switch to twigs and bark of shrubs and trees (Van de Veen, 1979; Van Soest, 1982; Van de Veen and Van Wieren, 1980).

Horse and pig are not ruminants. They are hindgut fermenters. The fermentation of cellulose happens in the colon (Van Soest, 1982; Hofmann, 2007). Although the proportion of grass in the diet of the pig can be considerable, it is less capable to ferment cellulose than the horse. The grass has to be of good quality that is with a low content of cellulose, so growing green grass. In the autumn acorns from pedunculate and sessile oak (*Quercus robur* and *Q. petraea*), apples from crab apple (*Malus sylvestris*), pears from Wild pear (*Pyrus communis*) and fruits from Sorbus-species like Service tree (*Sorbus domestica*) are staple food for the pig in wood-pastures,

where they are herded. Acorns contain much starch. For making fat they need protein as a supplement on a diet of acorns. Without it they fell ill, because they start to mobilize protein form their muscle tissue in order to form fat (Hobe, 1805; Herrmann, 1915; Meyer, 1931; Hilf, 1938; Hesmer, 1958; Ten Cate, 1972; Mantel, 1990). Pigs get protein from animal food that is rich in protein and that they collect upon or by rooting in the soil, such as soil-dwelling insects and their larvae and slugs. Wild boars also eat grasses, acorns, and fruits from wild fruit trees as well as every animal's food they find, ranging from young mammals and birds and eggs in birds' nests to carrion (Groot-Bruinderink, 1994; Schley and Roper, 2003; Hofmann, 2007). Because the diet of pig and wild boar consists of both animal and vegetable food, they are not categorized as grazers, but as omnivorous (Hofmann, 2007).

To each category of feeding strategy that is discussed above applies that the bigger the species, the lower the quality of the food on which is can survive. This is the consequence of the relation between the content of the body of the animal that produces the body warmth by combustion and the surface of the body with which it loses its body warmth. The content of the body increases with the third power, while the surface of the skin rises with the second power. Therefore, large animals, loose less body warmth compared to smaller ones and need less quality food to keep their body on temperature (Van Soest, 1982). Therefore, as grazer, the small sheep is more selective on quality than the lager cattle; as browser, the small roe deer is more selective than the larger moose and as intermediate feeder, the smaller red deer is more selective for quality than the larger European bison. As hindgut fermenter is pig more selective than the larger horse (Hofmann, 1973; 1976; 1985; 2007; Van Soest, 1982; Van Wieren, 1996). Both feeding strategy and size make clear that neither of these animal species are interchangeable if it concerns their effect on the vegetation. They are complementary.

The effect of large ungulates on the vegetation in the wood-pasture

It is known from wood-pastures that grazing livestock has a great influence on its vegetation. (Watt, 1919; Hart, 1966; Flower, 1977; 1980; Rackham, 1980; Tubbs, 1988; Pott, 1992; Pot and Hüppe, 1991; Vera, 2000; 2013; Newton et al., 2013). The specialized grass-eaters, cattle and horse concentrate on the grass and herbs in open grassland. They facilitate there the establishment of light-demanding species such as spiny or thorny shrubs like blackthorn (*Prunus spinosa*), hawthorn (*Crataegus monogyna*) and poisonous herbaceous species that are defended by chemical substances, like great yellow gentian (*Gentaina luea*), Ragwort (*Jacobaea vulgaris*), Bracken (*Pteridium aquilinum*) and Heather (*Calluna vulgaris*) (Iason and Hester, 1993; Mountford and Peterken, 2003; Bakker et al., 2004; Smit et al., 2006; Smit and Ruifrok, 2011). These species are avoided by the large herbivores, and thereby can protect palatable seedlings and saplings of shrub and tree species against herbivores (Bakker et al., 2004; Bossuyt et al., 2005; Rousset and Lepart, 1999; Smit et al., 2006). This phenomenon is known as associational resistance (Callaway et al., 2000; Ollf et al., 1999; Milchunas and Noy-Meir, 2002; Smit et al., 2006). Seedlings of blackthorn and hawthorn however are palatable as long as they have not developed spines. Until then they need in grazed grassland the protection of so-called swards, where they establish. Swards are spots in the grasslands with tall herb species such as nettle (*Urtica dioica*) and tall grasses. They are the result of variability in the grazing intensity of the herbivores over years, for instance as the result of fluctuations in numbers from year to year, because - as mentioned above - of less availability of food or disease. The omnivorous pig and wild boar may also play an important role in the establishment of the nurse species by grubbing in the soil. In this way they create loose bare soil, which is a perfect establishment niche for sward species, as well as spiny nurse species blackthorn and hawthorn. Large-scale establishment of blackthorn and hawthorn in abandoned arable fields (Eglar, 1954; Klaudisová and Osbornová, 1990) is an indication of this. Carnivores such as foxes and badgers and birds seem the most important dispersers of the seed of blackthorn and hawthorn to swards in grazed grassland (Smit and Ruifrok, 2011). Swards in grazed grassland are less attractive to the large herbivores, and therefore offer the temporal protection to the spiny shrubs they need to develop as saplings with fully developed protective spines (Smit and Ruifrok, 2011). This takes at least two to three growing-seasons (Smit and Ruifrok, 2011). Once armed with spines blackthorn and hawthorn can offer protection against herbivores to palatable seedlings and saplings of shrub and tree species that germinate next or in the very close vicinity (Bakker et al., 2004; Bossuyt et al., 2005; Rousset and Lepart, 1999; Smit et al., 2006). However, those established spiny nurse species are not immune to herbivores for the rest of their lives. Their annual shoots lack spines. It takes at least one growing season to harden small branches as spines (Rackham, 1989). Therefore, during that period they are vulnerable to browsing by large herbivores (Bokdam, 1987; Buttenschøn and Buttenschøn, 1978; Bakker et al., 2004; Smit et al., 2010; Smit and Ruifrok, 2011). It takes up to three weeks for the spines to harden (Rackham, 1989). The browsing of unprotected twigs of blackthorn and hawthorn induces a divaricate branching, which in turn creates a thicket that is almost impenetrable for the snouts of the herbivores (Photograph 3). As a consequence, browsing large herbivores enhance the protection of the undefended palatable tree species within the thicket (Bakker et al., 2004).

Mature shrubs of blackthorn expand clonally into open grazed grassland by root-suckers at a rate of 0.3 or 0.5-1 m.year^{-1} (Photograph 4). A blackthorn seedling can in this way expand into a hurst of 0.1-0.5 ha in 10 years. Tree seedlings establish in the fringes of the advancing blackthorn (Photograph 5). They settle only in the fringe,

Photograph 3: Hawthorn (*Crataegus monogyna*), browsed by free living cattle and horse in the nature reserve De Blauwe Kamer, The Netherlands. Up till the browsing height the thorny shrub reacted with a divaricate branching, forming impenetrable natural barbed wire (F. Vera).

Photograph 4: Blackthorn (*Prunus spinosa*) spreading clonally by rootsuckers in the grazed grassland. The Borkener Paradise, Germany (F. Vera).

Photograph 5: Seedling of oak in the fringe of the thorny scrub of blackthorn (*Prunus spinosa*). The Borkener Paradise, Germany (F. Vera).

Photograph 6: Blackthorn (*Prunus spinosa*), spreading into the grassland by rootsuckers, forming a scrub that acts as barbed wire for seedlings and saplings of palatable trees, which can grow up in that way within that scrub. The Borkener Paradise Germany (F. Vera).

Photograph 7: Trees, mainly pedunculate oak (*Quercus robur*) that emerged from the thorny scrub, forming a bundle of trees, named a grove. Their crowns grew together forming a closed canopy. The Borkener Paradise, Germany (F. Vera).

because within the thicket itself the level of daylight - less than 2 per cent - is too low for the seedlings, whether they are light demanding or shade tolerant (Dierschke, 1974; Tubbs, 1988; Vera, 2000). In this way, trees advance into the grassland with the speed of the spreading fringes of the thorny scrub (Pott and Hüppe, 1991; Watt, 1924) (Photograph 6). Because blackthorn expands in every direction, forming scrub which is characteristic convex shaped group of trees, called a grove (Bakker et al., 2004; Vera, 2000; Vera et al., 2006) (Photograph 7). In this way, a grove of 0.1 up to 0,5 ha can develop in the grassland during 10 years (Hard, 1975; 1976; Wolf, 1984; Wilmanns, 1989; Schreiber, 1993). Eventually a grove can have a surface varying from some tenth up to many hundreds of hectares (Vera, 2000). Combined cattle and rabbit grazing can importantly suppress the expansion of blackthorn; rabbit more than cattle (Bakker et al., 2004; Smit et al., 2010).

Trees growing up in thickets forming a grove compete for daylight. This results in trees with long branchless trunks small narrow crowns with branches growing on the trunk at an angle of about forty-five degrees, as known from forest grown trees (Photograph 8). Contrary to blackthorn, hawthorn does not spread, because it lacks

Photograph 8: The trees that emerged from the thorny scrub, forming a grove have small, narrow crowns, with upwards directed branches, because they competed for light. The shape of their crowns is like those in forest grown trees in forestry. The Borkener Paradise, Germany (F. Vera).

Photograph 10: Under the closed canopy of the trees forming a grove, the light demanding thorny scrubs of blackthorn (*Prunus spinosa*) disappear. It survives only in front of the grove under full daylight. It is typical for a wood-pasture that in the grove a shrub layer is lacking or almost lacking. The Borkener Paradise, Germany (F. Vera).

Photograph 9: Trees that grew up in openness, protected (nursed) by a single or a few thorny shrubs that do not spread vegetatively such as hawthorn (*Crataegus monogyna*) develop to open grown trees with a large crown that starts low at the trunk. The light demanding nurse shrubs disappear, because of the shade that casts the wide canopy of the tree that grew above it. In this way a savannah-like landscape develops. The Borkener Paradise, Germany (F. Vera).

Photograph 11: Large herbivores like cattle and horses enter the grove on places where there is a hole in the scrub surrounding the grove. Inside they prevent the regeneration of trees. In this way they prevent shade tolerant tree species to grow up under the canopy of oaks and outcompete them, which they do in former wood-pastures in the absence of these large herbivores. They also prevent the regeneration of trees in gaps in the canopy. The New Forest, England (F. Vera).

rootsuckers. Therefore, they mostly nurse a single tree or a few ones. In open grassland this results in open grown trees. These trees are characterised by a huge crown that starts very low at the trunk with very thick branches, growing on the stem at an angle of almost ninety degrees. This results with a savannah-like landscape (Photograph 9). In reality and dependent of the soil combinations of both types of landscapes will develop with as main character grasslands from different sizes, groves with different sizes and trees with different postures (Vera, 2013).

So, in time trees that are protected by associational resistance will grow above the thorny nurse species. The shade of the closed canopy of the grove and the large crown of open grown trees eventually kill the light-demanding nurse shrubs under the crowns, because they are light demanding and do not tolerate the shade of the canopy above them (Puster, 1924; Watt, 1924; 1934; Ekstam and Sjörgen, 1973; Ellenberg, 1986; Tubbs, 1988; Coops, 1988) (Photograph 10). In the case of hawthorn the large crown of the open-grown tree will kill the shrub. Clonally expanding blackthorn can stay ahead of the shade casting canopy of the grove with again and again, seedlings settling in the advancing edge of the thicket. Within the grove the regeneration of trees initially is prevented by the shade of the canopy, but moreover by the trampling and browsing by the large herbivores (Bakker et al., 2004; Mountford et al., 1999; Mountford and Peterken, 2003) (Photograph 11). They enter the grove through small gaps in the spiny mantle vegetation that surrounds the grove as the mantle and fringe vegetation. They do so to look for shade and to escape from biting flies. Densities of ungulates of 110-130 kg.ha^{-1} (Flower, 1980;

Photograph 12: Because the large herbivores prevent the regeneration of trees by trampling and eating the seedlings and because they transport seeds of grasses and herbs with their dung, they create in gaps in the canopy grazed grassland which grow as more and more trees die by aging, fungi and or drought. The New Forest, England (F. Vera).

Photograph 13: The jay (*Garrulus glandarius*) collects and hoards acorns. The bird takes up to six acorns at a time, the largest or longest in its beak. It transports acorns up to several kilometers from the oak where they collect them (J. Korenromp).

Putman, 1986; Vera, 2000) up to 187 kg (Rackham, 1980) that were present in wood-pastures, and did facilitate the regeneration of trees in the grazed grassland, prevent at the same time the regeneration of trees in forests, also after a gap is formed in the canopy (Gill, 2006). As a result in due time the canopy of the grove opens up; a process that is facilitated by fungi and drought that kill more and more of the senile trees (Dobson and Crawley, 1994; Green, 1992). Grass seeds are brought in by the large ungulates in their dung and fur and as the grove becomes more open as more trees die, a grazed lawn develops (Bokdam, 2003; Mountford and Peterken, 2003). This process is well known as retrogressive succession of high forest towards open grassland or heath, and is considered in vegetation science and forest ecology as a degradation of high forest by retrogressive succession (Tansley, 1953; Ellenberg, 1988) (Photograph 12). In this way, groves change from the centre with the oldest trees onwards gradually into grassland again (Goriup et al., 1991; Mountford et al., 1999; Mountford and Peterken, 2003; Peterken, 1996). When the grassland has reached a certain surface, swards will locally develop because of variability in grazing intensity of the herbivores. Spiny and thorny nurse species will establish there again and in their wake palatable shrub and tree species, especially the light demanding ones. While the grove expands in the grassland, the centre of the groves disintegrates. Both processes are driven by large herbivores, resulting in a non-linear succession (Vera, 2000).

The dominance of oak and hazel in wood-pastures

A remarkable phenomenon in the wood-pasture in the lowlands of Europe is that compared to other tree species both oak species (*Quercus robur* and *Q. petraea*) regenerate very well (Buttenschøn and Buttenschøn, 1985; Smith, 1980; Tansley, 1922; 1953). They are very common in wood-pastures (Pott and Hüppe, 1991; Rackham, 1980; 2003; Watt, 1919). This phenomenon is caused by the activity of the jay (*Garrulus glandarius*) and the wood mouse (*Apodemus sylvaticus*). Both species hoard acorns in the ground, seed by seed, at different places (Bossema, 1979; Den Ouden et al., 2005). They are true scatter-hoarders, although wood mice will sometimes hoard several acorns in one catch (Den Ouden et al., 2005; Smit and Vermijmeren, 2011). The jay collects acorns in the oak and hoards them at a distance from the oak, from a few meters up to several kilometres, with a preference for open areas, such as large open spaces in forests, and open grasslands and fields (Bossema, 1979; Chettleburgh, 1952; Kollmann and Schill, 1996; Schuster, 1950) (Photograph 13). There they prefer a transitional area of short to long grass or brushwood, the outer edge of hedges and the fringes of thorny scrub that form mantle and fringe vegetation of the groves in wood-pastures (Bossema, 1979; Chettleburgh, 1952; Rousset and Lepard, 1999; Vullmer and Hanstein, 1995). Chettleburgh (1952) observed a jay flying down into a hawthorn bush and burying an acorn at the foot of the bush. This observation explains the phenomenon of oaks, which seem to grow entwined with hawthorn in wood-pasture (Photograph 14). In addition, jays like to bury acorns in places where the soil is loose and they can easily push the acorns into the ground (Bossema, 1979). This may be an indication of the facilitating role of pig and wild boar in wood-pastures. The distance between

Photograph 14: A jay can fly down into a hawthorn bush burying an acorn at the foot of the bush. This results in an oak which seem to grow entwined with hawthorn like on this photograph. The Borkener Paradise, Germany (F. Vera).

two hoarded acorns varies from 0.2-15 m, but is generally between 0.5 and 1 m (Bossema, 1979). Jays easily find the acorns they buried. The vertical structures for which jays appear to have a clear preference when they bury the acorns seem to serve as a beacon (Bossema, 1979). They dig up and eat the acorns they hide throughout the year, but do so far less in the period from April to August (Bossema, 1979). It is during this period that the seedlings appear. In June, together with their young, the jays start to look for seedlings that have grown from the acorns they buried the autumn before. When a parent bird finds a seedling, it takes hold of the stem with its beak and lifts the plant. This raises the acorn above the ground, or the soil that is brought up, and shows where it is hidden under the ground. The jay will then dig the acorn up. The jay removes the acorn from the seedling, peels it and feeds it to its young (Bossema, 1968; 1979). The development of the seedlings is not hampered in their growth by the removal of the cotyledons (Bossema, 1979), because the seedlings grow in full daylight, which is what seedlings of both oak species need to grow up (Krahl-Urban, 1959; Anderson and Frost, 1996; Sonessen, 1994). The chance that the young oak will be uprooted is small because in the full daylight immediately after germination they formed an extremely extensive root system with a long tap-root (Jarvis, 1964; Jones, 1959; Ziegenhagen and Kausch, 1995). This root system ensures that the seedling is securely anchored and not easily uprooted during the inspection of a jay. So, the disadvantage of the inspection is offset by the advantage of growing in extremely good light conditions. Only very young seedlings that have grown late in the season are occasionally totally pulled out of the ground with their roots by a jay. Wood mice transport acorns from the mother tree over a distance up to 50 m (Den Ouden et al., 2005). Like the jay, they predate on the acorns they hoarded.

Woodmice disperse acorns towards shrubs (Smit and Verwijmeren, 2011). At first sight, it looks like the wood mouse therefore contributes the most to the successful regeneration of oak in the spiny shrubs of wood-pastures. However, they hoard most acorns in the centre of the scrub where the chances of successful establishment of the light demanding oak species are less because of the very low level of daylight (Den Ouden et al., 2005; Vera, 2000). To a lesser extent they hoard acorns at the outer edge of the shrubs, where oak has the best opportunity to grow successfully in wood-pastures (Pott and Hüppe, 1991; Rackham, 1980; 2003; Tansley, 1922; 1953; Watt, 1919). This is where the jay prefers to hoard acorns (Bossema, 1979). This may mean that overall the jay contributes more to the successful regeneration of oak in wood pastures than wood mice (Den Ouden et al., 2005). Woodmice also hoard the seeds of beech (*Fagus sylvatica*) as does the nuthatch (*Sitta europaea*). However, nuthatch store mostly in bark crevices of trunks and thick branches and make few caches below ground (Källander, 1993; Moreno et al., 1981; Perea et al., 2011). This and the low density of avian seed removers in beech forests (Perea et al., 2011) may explain the observed infrequent appearance of beech seedlings and the frequent appearance of oak seedlings in the grassland and thorny scrub, even adjacent to beech woods (Tansley, 1922; Watt, 1925). Besides beechnuts, the nuthatch also hoards seeds of small-leaved and broad-leaved lime (*Tilia cordata* and *T. platyphyllos*), sycamore (*Acer pseudoplatanus*), ash (*Fraxinus excelsior*) and hornbeam (*Carpinus betulus*). Like beechnuts, these are usually hidden in bark furrows, and in the cracks of trunks and branches of trees; places that are not regeneration niches for these species (Källander, 1993; Löhrl, 1967; Matthyssen, 1998). Therefore, they are dependent on the wind in order to disperse them to nurse species sites, and this happens by accident. Besides beech, lime, sycamore, ash and hornbeam, also silver fir (*Abies alba*), Norway spruce and elm species (*Ulmus glabra* and *U. leavis*) regenerate successfully in wood-pastures in spiny shrubs and thickets by associational resistance (Rackham, 1980 and 2003; Smit et al., 2006; Tansley, 1953). However, they also lack vectors like the jay and the wood mouse for the distribution of their seeds, vectors that give both oak species in a natural way a huge advantage in wood-pastures above other tree species (Den Ouden et al., 2005; Smit and Verwijmeren, 2011; Vera, 2000). This explains the dominance of oaks in wood-pastures in the natural distribution area of oak and the subordinate appearance in wood-pastures of the other tree species. Beech, silver fir, Norway spruce, sycamore, lime, hornbeam and elm species dominate only wood-pastures at heights where oak cannot grow, like in the more mountainous parts of the natural distribution area of both oak species, that is above 600 meters (Vera, 2000; Smit et al., 2006; 2007; 2008).

Besides the palatable tree species, palatable light demanding shrub species such as hazel (*Coryllus avellana*), guelder rose (*Viburnum opulus*), bird cherry (*Prunus padus*), spindle tree (*Euonymus europeus*), elder (*Sambucus nigra*) and privet (*Ligustrum vulgare*) grow successfully by means of associational resistance. The nuthatch collects hazelnuts (Hagerup, 1942; Källander,

1993; Löhrl, 1967; Matthyssen, 1998). A pair of territorial nuthatches can deprive hazel shrubs totally from their nuts in a few days (Löhrl, 1967). Although studies show that nuthatch hides few seeds in the ground, some data suggest that from all the seeds they collect, those of hazel are the most frequently stored in the ground, 60-73% compared to 16-20% of beechnuts (Källander, 1993; Matthyssen, 1998). It hides the hazelnut close to hazel shrubs by pushing and hammering it into the ground and covering the spot, as jays do for acorns (F. Vera, pers. obs.). That they store seeds close to the food source (up to 40 m away) (Matthyssen, 1998) and seedlings of hazel are found in open grassland and in the fringes of spiny scrub (Sanderson, 1958), makes it very plausible that the nuthatch acts as a vector for hazel, as the jay does for oak. The shrub itself can cope with heavy grazing outside the spiny scrub by forming new shoots from the roots (Bär, 1914; Jahn, 1991; Sanderson, 1958). It also spreads by underground runners (Sanderson, 1958). The other mentioned shrub species have fleshy seeds that are eaten by bird species, especially singing birds (Passeriformes) that defecate the seeds in the thorny shrubs, where they roost (Namvar and Spethmann, 1985; Snow and Snow, 1988). This can explain how these light-demanding shrub species are part of mantle and fringe vegetation (Ellenberg, 1988; Hondong et al., 1993; Pietzarka and Roloff, 1993; Smith, 1980; Vera, 2000).

Within the groves the large herbivores prevent the regeneration of trees, especially the livestock that are there in high densities. This is essential for the persistence of oak trees in the grove. It is well-known from former wood-pastures, such as forest reserves and national parks where livestock was removed and wild ungulates were absent or culled to such low densities that they did not prevent the regeneration of trees in forest that shade-tolerant tree species regenerate under the canopy of oaks. If they overgrow the oaks they kill them (Vera, 2000). The crown of oaks permits sufficient daylight to penetrate through the canopy for shade tolerant species like beech, broad-leaved and small-leaved lime and hornbeam to grow up. This is known from the practice in forestry for the production of wood for veneer. Beech and lime are planted under oaks in order to prevent with their shade that the oaks develop dormant buds on their trunks. They also ensure that the trunk grows as straight as possible. These branchless straight trunks provide the valuable wood for veneer (Mantyk, 1957; Hesmer and Günther, 1966; Rühl, 1968; Fricke, 1982; Koss, 1982; Jahn, 1987). Unless beech and lime are regularly cut back, they will overgrow the oaks and kill them (Schwappach, 1916; Wiedeman, 1931; Bonneman, 1956a; 1956b; Vera, 2000; Erteld, 1963; Hesmer, 1966; Hesmer and Günther, 1966; Böckmann, 1990). The process of displacement of light demanding oak species by shade tolerant tree species in forests is a well-known phenomenon and good documented issue in forest ecology and forestry (Schwappach, 1916; Wiedeman, 1931; Bonneman, 1956a,b; Krahl-Urban, 1959; Erteld, 1963; Hesmer, 1958; 1966; Hesmer and Günther, 1966; Bezanski, 1971; Fricke et al., 1980; Böckman, 1990; Dengler, 1990; 1992; Pigott, 1991). This happens in former wood-pastures where livestock has been removed and wild ungulates reduced by culling to densities they do not prevent the regeneration of trees in the forest (Morosow, 1927; Malmer et al., 1978; Fritzbørger and Emborg, 1996; Emborg et al., 1996; Emborg et al., 2000; Vera, 2000; Wijdeveen, 2004; Wolf, 2005; 2011; Rapp and Schmidt, 2006; Bobiec, 2012). Besides pedunculate and sessile oak also other light demanding tree species disappear, such as wild apple (*Malus sylvestris*), wild pear (*Pyrus pyraster*) and wild cherry (*Prunus avium*), as do light demanding shrubs species, such as hazel, blackthorn and Guelder rose (Malmer et al., 1978). According to historic data these species were all very common in wood-pastures (Brincken, 1826; Bühler, 1922; Hart, 1966; Rackham, 1980; Vera, 2000). They are not only outcompeted by beech and broad-leaved and small-leaved lime, but also by elm (*Ulmus* spp.), (*Tilia playphyllos* and *T. cordata*) hornbeam (*Carpinus betulus*), ash (*Fraxinus excelsior*), Field maple (*Acer campestre*) and sycamore (*A. pseudoplatanus*) (Malmer et al., 1978; Fritzbørger and Emborg, 1996; Emborg et al,, 1996; Emborg et al., 2000; Vera, 2000; Wijdeveen, 2004; Wolf, 2005; 2011; Rapp and Schmidt, 2006; Bobiec, 2012).

The cause of the displacement is the change of the wood-pastures into closed canopy forests. Both oak species as well as the other light demanding species cannot regenerate successfully in forests in the presence of the shade tolerant tree species, neither in gaps in the canopy, nor in large wind-blown areas (Dengler, 1990; Vera, 2000). In forestry oak is only successfully regenerated in the presence of shade tolerant tree species with a lot of human assistance. This assistance consists of working the soil by for instance ploughing, and further destroying tall grasses and herbs, and shrubs and trees that will kill the seedlings of oak by their shade. Confusingly, this way of human assisted regeneration in forests is called in forestry "natural regeneration". It suggests that it is a process which takes place under natural conditions in untouched nature. However, it is not. Since the beginning of the 20th century, "natural" regeneration is defined as: regeneration with seedlings which grow from seed dispersed by the trees forming the canopy (Bühler, 1922; Dengler, 1990). Whether the origin of the trees is by planting or not, does not matter (Cotta, 1865). The practice of forestry is that without this human assistance, "natural regeneration" of oak is impossible in forests (Bühler, 1922; Krahl-Urban, 1959; Tendron, 1983; Dengler, 1990; 1992; Vera, 2000).

The wood-pasture; a dynamic system

The wood-pasture is a dynamic system. There is grazed grassland first. Then thorny or spiny scrub or other unattractive (that is inedible) species of plants establish, either forming a clonally spreading scrub like blackthorn or remaining solitary like hawthorn. Then seedlings of palatable trees and shrubs establish successfully if they

are protected by these inedible nurse species. Trees grow up solitary or forming groves (forests), depending on whether the nurse species' ability to spread clonally or not. Aged trees die in the groves and the groves change into grazed grassland again because large herbivores prevent the regeneration of trees within the groves (forests). Solitary trees die and give also space for grassland again. Then, in the grassland as a result of variability in the grazing intensity of the herbivores in temporarily not grazed parts swards develop, where spiny or thorny nurse species become established. Sward development can be facilitated by the rooting of pig or wild boar. Next, spiny, thorny or otherwise unpalatable plant species act as safe sites for seedlings and saplings of edible shrub and tree species, which grow up. Either open grown, solitary trees or clumps of trees, groves are formed. The solitary trees and trees in the groves eventually die of age. The single tree disappears and the grove disintegrates to grassland again. The process of the dying of the trees can be facilitated by drought and fungi. Then again in the grassland swards develop and in them thorny and spiny shrubs establish and finally single trees or clumps of trees, groves, develop. The cycle is then closed. In this way a nonlinear cyclical succession develops consisting of grassland → shrub and or scrub → single trees or grove (forest) → grassland again (Vera, 2000). The whole cycle is driven by large herbivores (Vera, 2000).

This system is based on chronosequences (space-to-time substitution) (Picket, 1987) in accordance with the autecology of the plant and animal species that inhabit the wood-pasture (Vera, 2013), which is a prerequisite for using chronosequences (Johnson and Miyanishi, 2008; Walker et al., 2010). Contrary to a closed canopy forest, the wood-pasture system enables light-demanding tree species to survive in the presence of shade-tolerant tree species (Vera, 2000; Vera et al., 2006). Hereafter I will show that especially light demanding plant species in the wood-pasture such as oak, hazel, wild fruit and grasses and herbs met the daily needs of the households of the commoners.

The wood-pasture as pasture

The wood-pasture provided food for livestock. We know this from written sources that date back to the 6th and 7th century. These regulations concern the use for grazing of pigs and other livestock, cutting foliage, collecting honey and protecting trees, including those which produced food (mast) for pigs, such as oak, wild apple, wild pear and wild cherry (Bühler, 1922; Meyer, 1931; Kaspers, 1957; Trier, 1963; Ten Cate, 1972; Mantel, 1990). The food for the livestock were not just grasses and herbs which are today in western and central Europe associated with food and with pasture for livestock. It consisted also of the twigs with leaves and the fruits of trees (Trier, 1963; Rackham, 1980; Mantel, 1980; Pott, 1983; Tack et al., 1993; Vera, 2000). According to texts dating from the Middle Ages and later, the wood-pasture indicated as "forestis", "Forst", "fôret", "Forest", "wald", "wold", "weld" or "weald", was the place with food for livestock, birds and bees (Vera, 2000). In the Frankish language, the place where animals found food or where food was collected was described as a "weide" (pasture) (De Vries, 1970; Van Veen and van der Sijs 1990 and 1991). Animals which were looking for food were engaged in "weiden" (pasturing). Cattle grazing grasses and herbs were engaging "weiden" (were pasturing) in the wood-pasture as did the pigs who ate the fruits fallen off the trees, the acorn, apples, pears and cherries, known as "waid" for pigs (Habets, 1891; Weimann, 1911; Kaspers, 1957; Ten Cate, 1972; Mantel, 1980). The bees that collected their nectar from flowering trees like the wild fruit trees as well as from broad-leaved and small-leaved lime trees were known as "Bienenweide" (bee-pasture). Bees also collected their nectar from flowering shrubs like Blackthorn, Hawthorn and from heath (*Calluna vulgaris*), and flowering herbs in the grasslands. References to this were mentioned the pasture of bees (seu apium pascuis) (Remling, 1852; Hesmer, 1958). Flowering trees like wild fruit and lime were important for bees. Bees were kept and honey was collected in wood-pastures (Krause, 1892; Hilf, 1938; Mantel, 1990; Vera, 2000).

Confusing for historical research is that in the modern meaning of "weiden" (pasturing or pasture), trees are not included, while in these historical texts they are. In texts dating from the Middle Ages, and for several centuries subsequently, words such as "forest", "Forst", "fôret" and "Wald", which nowadays according to modern dictionaries are translated as closed canopy forest, included pasture, that is the food ("weide") and the place (also "weide") where it was collected (Vera, 2000). Therefore these words include grassland. With research on historical texts for the meaning of the words "forest" and "wald" one will therefore look in vain for evidence of pasture in the modern meaning of grassland opposite or separate to grove or forest. The reason is that such a classification for the people at that time was meaningless, for grassland was the same as trees, namely providers of food for animals, therefore pasture ("weide"). So in contrast to our modern view, grasses, grasslands, trees and groves were all pastures. The people at that time looked from a utilitarian point of view to the landscape and not on the basis of vegetation science and forestry, as we do nowadays.

Regulations on grazing livestock were not concerned with the regeneration of trees at all (Bühler, 1922; Hesmer and Schroeder, 1963; Streitz, 1967; Mantel, 1968; Rackham, 1980; Buis, 1985; 1993). The absence of regulations about the regeneration of trees is because the regeneration took place without any action on the part of the users. After all, what happened spontaneously did not require regulations, and anything which did not require regulations was not laid down in practical rules (Bühler, 1922; Vanselow, 1926; Streitz, 1967; Rackham, 1980; Stamper, 1988; Mantel, 1990).

This is not surprising, knowing how the regeneration of trees in wood pastures is mediated by grazing and unpalatable plant species such as spiny shrubs. What was

regulated was the use of grasslands, shrubs and trees that were there without human intervention. Therefore it was not necessary to create grasslands in the wilderness by felling trees in a so-called closed canopy forest. Felling was regulated, but for getting firewood and timber or to create a field for growing crops (Vera, 2000).

Trees; the pasture for livestock

As we saw above, light demanding tree species such as pedunculate and sessile oak and wild fruit species such as wild pear, wild apple and wild cherry are very common in wood-pastures. These fruits were important for the pannage that is to fatten the pigs on those fruits in autumn. Those fruits were known as the mast. The most important mast consisted of acorns (Endres, 1888; Hilf, 1938; Nietsch, 1939; Hesmer en Schroeder, 1963; Schubart, 1966; Ten Cate, 1972; Duby, 1968; Slicher van Bath, 1987; Mantel, 1990; Tack et al., 1993). These were also collected to feed the pigs when they were kept indoors (Hesmer, 1958; Tendron, 1983; Buis, 1985). The Anglo-Saxon word for acorn is "aecer" (Rackham, 1993). In Dutch the pannage of pigs was known as "aecker", "eycker, "eckel", "akeren"; in German, "Acker", "Ecker(ich)", "Geäcker", "Äkeret", "Acherum") (Habets, 1891; Hilf, 1938; Buis, 1985; Elerie, 1993; Tack et al., 1993). In French it was "le panage" from which the English word "pannage" is derived (Rackham, 1980; Tendron, 1983). The mast, or collection of acorns, was in Germanic languages known as "acker" (Hilf, 1938; Ten Cate, 1972). The "acker" was also the "acker", that is the place where the food, the acorns, the "acker", in Germanic languages the "weide" (the pasture), the mast was. They were brought to the place where they could find the acorns by a herdsmen (you cannot drive pigs), that is the "acker". Therefore, in medieval texts, the "acker" was a place where the oak trees and wild fruit trees were, and where the pigs were taken to be fattened (Hilf, 1938; Schubart, 1966; Ten Cate, 1972; Buis, 1985). So, the "acker" was situated in the uncultivated wilderness, the "forestis" or "Wald". In the Middle-Ages, pork, and particularly bacon, was an essential source of energy for the winter, and therefore an important part of the daily winter diet (Reed, 1954; Bogucki and Grygiel, 1983; Jahn, 1991; Tack et al., 1993).

The pigs were from a few weeks to about four months outside in the uncultivated in order to fatten on acorns and the fruit of wild pear, wild apple and wild cherry, berries of the whitebeam, sloe berries, rosehips and hazelnuts. These trees were described as "fruitful trees" or "fruit trees" ("arbores fructiferae" or "silva fructicans") or bearing trees ("tragenden", "tragbaren", "beerenden" or bärenden Bäumen") (Bühler, 1922; Vera, 2000). Although every commoner had a right to as much wood for building as he needed (Endres, 1888; Hesmer and Schroeder, 1963; Buis, 1985), it was prohibited to fell or to damage these trees in any other way (for instance by illegally peeling the bark from the oak for tanning leather) without express permission (Endres, 1888; Bühler, 1922; Meyer, 1931; 1941; Hilf, 1938; Nietsch, 1939; Kaspers, 1957; Hesmer and Schroeder, 1963; Trier, 1963; Hart, 1966; Schubart, 1966; Streitz, 1967; Ten Cate, 1972; Dengler, 1990; Mantel, 1990). A commoner did have to show that he really needed the timber (Endres, 1888; Reed, 1954). When this proof had been presented to and permission granted to fell a tree (almost always an oak) by an official who was in charge to apply the regulations, a "holtrichter" (wood assessor) or "forestarius", he was shown the tree by such an official who marked the tree with a special axe (Endres, 1888; Vanselow, 1926; Hesmer and Schroeder, 1963; Mantel, 1990; Buis, 1993).

The oldest regulations about the protection of fruit bearing trees refer specifically to oak, beech, wild apple, wild pear, wild cherry and service trees. Later, protected trees also included whitebeam, chestnut (*Castanea* spp.), walnut (*Juglans* spp.), hazelnut (*Corylus avellana*), and alder buckthorn (*Rhamnus frangula*). In all these regulations, the oak has a central place because of the importance of the acorns for pannage. There were barbaric punishments for infringements of these regulations (Kasper, 1957; Ten Cate, 1972; Mantel, 1990). The importance of pannage is also shown by the fact that in the medieval documents from the Netherlands, England and Germany, the size of an area was expressed in terms of the number of pigs that could be kept there (Herrmann, 1915; Ten Cate, 1972; Rackham, 1980; Buis, 1993; Stamper, 1988).

In German-speaking parts of Europe the fruit bearing trees were known as "Herrenholz" or "hovetbome" [trees of the court, the "curtis", that is the property of the lord] (Sloet, 1913; Hilf, 1938; Musall, 1969; Rackham, 1980; Hausrath, 1982). In England, the trees were named "highwood". They belonged to the lord and could be felled only with his express permission (Hart, 1966; Flower, 1977; Tubbs, 1988). In the 16th century, the term "highwood" was completely replaced by the term "timber" (Tubbs, 1964; Hart, 1966; Flower, 1977; Rackham, 1980; 1993). The protection of the "Herrenholz" in German-speaking parts of Europe was in contrast to so-called "herrenlose" wood (the wood – that is the material – that did not belong to the lord), also known as bad wood ("malae"), infertile wood ("unfruchtbarn holtz"), unreal wood ("unecholt"; "Unholtz"), useless wood ("unnützes"; unnützliches" holz) and dead, dry or harmless wood ("douffholtz" or "duisholt"). These names also referred to the shrubs (named: "fürholz", "vorholt" and "vorholtz", "Unterholz", "underholt", "onderholt", "underbusch", "onderbuss"). These names mean what one sees if one stands in a wood-pasture in front of a grove. The spiny mantle and fringe vegetation that encloses the grove like a belt in a wood-pasture lies in front of the trees that are behind it and is down the trees. The firewood cutting was aiming for the wood that is the material in the belt, that was in front of and down the trees. The material is named in old Germanic languages "holt, or "holtz". "In front of" is in old Germanic languages: "voor", "vor" or "für". "Down" is in Germanic languages "under", "Unter", "onder". So the wood in the spiny belt that surrounded the grove

as named as": "underwood" "Unterholz", "underholt", "onderholt", "underbusch", "onderbuss", "brushwood" (Vera, 2000). In England "highwood" and "timber" was differentiated from "underwood" (Tubbs, 1964; Hart, 1966; Flower, 1977; Rackham, 1980; 1993). Another clear indication that these terms refered to the spiny mantle and fringe vegetation in wood-pastures is that regulations demanded that with the firewood cutting seedlings and young trees had to be spared. As shown before, the regeneration of trees in the wood-pasture takes place in the thorny and spiny shrubs. There are data to show that not all young trees called "heesters" had to be retained (Wartena, 1968; Buis, 1985). Besides the spiny shrubs trees which did not bear fruit and dead trees that could be used by the commoners freely to meet their own needs for firewood (Endres, 1888; Sloet, 1913; Kasper, 1957; Schubart, 1966; Mantel, 1990).

Leaf-fodder cutting from trees as food for livestock was also done in wood-pastures. References to cutting leaf-fodder for livestock are very old. They can be found in written sources as early as those dating from Roman times. The elm (*Ulmus*) was considered the best fodder, followed by rowan (*Sorbus aucuparia*), and ash (*Fraxinus excelsior*). In addition to these species, hazel, hawthorn and even conifers, such as juniper (*Juniperus communis*), and Scots pine (*Pinus sylvestris*), were cut as fodder throughout Central and Western Europe (Trier, 1952; Hart, 1966; Flower, 1977; Rackham, 1980; Pott, 1983; Meiggs, 1982; 1989; Austad, 1990; Andersen, 1990; Mantel, 1990; Tack et al., 1993). All the deciduous trees and shrubs that were used for cutting foliage for fodder have an enormous potential for regeneration (Trier, 1952; Bühler, 1922; Rackham, 1980; Koop, 1987; Mantel, 1990; Mayer, 1992). In the sense of evolution, this may have been an adaptation to browsing by animals. Fodder was collected by cutting branches or twigs with foliage from the crown of the tree or shrub. Depending on the shape acquired by the tree by cutting the foliage, this was known as coppicing, pollarding or shredding the tree. Apart from cutting the foliage from trees, it was also possible to cut or strip the shoots sprouting from a tree stump or shrub (Rackham, 1980; Pott, 1983; Tack et al., 1993). In the course of the Middle Ages, cutting or breaking the foliage was increasingly restricted and eventually even entirely prohibited because of the damage which was caused, particularly to the flowering and thereby the production of fruits by the trees which were the mast for the pigs (Endres, 1888; Mantel, 1980; Pott, 1983).

There are also reports and regulations about a certain thinning of young oak trees in the spiny scrub to prevent there being too many. The extra light the young oaks received ceases them to form a larger crown and therefore blossom more profusely (Woolsey and Greeley, 1920; Bühler, 1922; Meyer, 1931; Hesmer, 1958; Hesmer and Schroeder, 1963; Schubart, 1966; Rackham, 1980). As a result, the oaks produced more acorns and therefore more mast for the pigs (Woolsey and Greeley, 1920; Bühler, 1922; Meyer, 1931; Hesmer, 1958; Hesmer and Schroeder, 1963; Schubart, 1966; Rackham, 1980; Muller and Renkema, 1995). Such young oaks and young single oaks were also coppiced at a height of a few metres. These oak trees then formed low down on the trunk an open grown broad crown, and produced a relatively large number of acorns at a young age (Flörcke, 1967; Pott, 1983; Pott and Hüppe, 1991). The low crown made it possible for a herdsman to knock acorns from the tree with a stick, and provide the pigs that accompanied him with acorns. All the inhabitants in a settlement kept pigs to meet their meat requirements, especially bacon; not only those who cultivated the fields, but also craftsmen, like the smith, and all the people who lived in towns (Endres, 1888, Meyer, 1931; Hesmer, 1958; Schubart, 1966; Ten Cate, 1972; Weimann, 1911, quoted by Hesmer, 1958).

Cutting firewood in the wood pasture

The earliest regulations on cutting firewood in commons refer mostly to thorn bushes, hazel and holly (Hausrath, 1898; Meyer, 1941; Tubbs, 1964; 1988; Hart, 1966; Schubart, 1966; Streitz, 1967; Flower, 1977). Thorny bushes such as blackthorn and hawthorn were particularly popular for firewood (Rackham, 1980; Tack et al., 1993). These regulations refer clearly to the mantle and fringe vegetation in the wood-pasture that formed a belt around the groves (Vera, 2000). The regulation speak of cutting fire wood in "underwood", "brushwood", "fürholz", "vorholt" and "vorholtz", "Unterholz", "underholt", "onderholt", "underbusch", "onderbuss". In the Middle Ages, these terms were used to refer respectively to shrubs, shrubbery, groups of shrubs, the sprouting stumps of shrubs, coppices and trees where wood was taken for firewood and timber (Hausrath, 1928; Trier, 1952; Hart, 1966; Rackham, 1975; 1980; Flower, 1977; Buis, 1985; Mantel, 1980; 1990; Dengler, 1990; Elerie, 1993; Best, 1998).

As mentioned above, there was thinning to provide light for young oaks. Another reason that is mentioned in documents is that when too many trees grew in the scrub, the shrubs may disappear and with this the scrub as potential firewood (Hart, 1966; Rackham, 1980; Simpson, 1998). As we have seen in the wood-pasture, the thorny scrub from which the trees emerge disappears when the crowns of the trees form a closed canopy as the result of the shade, casted by the canopy. According to Rackham (1980), the competition for light between timber (used for building) and underwood for firewood was generally recognized in England (Rackham, 1980). The commoners who had the right to cut underwood in the Forest of Dean tried to prevent the growth of "timber", because this was at the expense of underwood (Hart, 1966). Reports from German-speaking countries also indicate that the number of standing trees was limited in favor of the underwood (Hausrath, 1982; Mantel, 1980). Therefore, the strictly protected "fruitful wood", such as oak trees, which produced the mast for pigs, were also described as "harmful wood" ("schedlich Holz"), while the underwood was considered harmless ("unschedlich") (Endres, 1888; Gradmann, 1901; Hilf, 1938). Experience

has shown that the canopy of the standing trees could not account for more than approximately 25%, as the "underwood" would otherwise be damaged too much by the shade of the trees (Cotta, 1865; Warren and Thomas, 1992). The stools of the thorny shrubs sprouted again, forming new firewood that could be cut again after some years. This regularly cutting is known as coppice (Vera, 2000).

It is clear that the spared seedlings became deprived from their protecting thorny and spiny nurse shrubs when these were cut as firewood. The primary was to protect them, but also the vegetative regeneration, the young shoots or spring from the stump of the spiny shrubs against livestock and wildlife, because new sprouts lack their protective spines in the first growing season. From the 13th century, there were regulated coppices, in the sense that the stools were cut down on plots according to an established rotation of the felling cycle (Schubart, 1966). The earliest references to this date from the 12th century (Rubner, 1960; Buis, 1985). It was the wish or the need to protect the shoots from the stools of trees and shrubs from being eaten by livestock, as well as increasing the production of wood, which was the most important reason for concentrating stools in plots (Bühler, 1922; Vanselow, 1926; Hart, 1966; Hesmer and Schroeder, 1963; Mantel, 1990). It was the cutting of firewood that regulations for grazing livestock in relation to the regeneration of trees were issued in the oaks of Western and Central Europe (Vera, 2000). So, one was obliged to protect seedlings, saplings as well as the sprouting stools. Protecting measurements were temporary fencing off the newly cut shrubs. Such measurements were digging ditches around them and creating earthen walls planted with dead or living shrubs, such as hawthorn and blackthorn (Grossmann, 1927; Meyer, 1941; Hesmer and Schroeder, 1963; Tubbs, 1964; Hart, 1966; Flower, 1977; Rackham, 1980; Buis, 1985; Tack et al., 1993; Best, 1998; Jones, 1998). Hardly any additional or supplementary measures were taken (Buis, 1985; Vera, 2000). The trees which were spared grew up above the scrub, which was used for coppicing. This is how the coppices with standards developed. The shrubs remained known as "underholt", "unterholz" or "underwood", while the trees were referred to as the "grote holt", "Oberholz", or high wood (Vera, 2000). Trees in the groves may have been thinned by felling, giving way to the scrub under an opened canopy. In this way the scrub may have reconquered space under the thinned canopy. As mentioned above, a canopy of standing trees that accounts for less than approximately 25% will make the growth of "underwood" possible. With a denser the canopies of the standing trees cast too much shade (Cotta, 1865; Warren and Thomas, 1992). This would mean a maximum cover of approximately 50 trees of 120-150 years old, per hectare (Cotta, 1865). In this way coppice with standards developed from the scrub with seedlings and saplings that formed the mantle and fringe vegetation around the grove (Vera, 2000).

There were at first no real regulations about the number of seedlings and saplings that had to be spared in the spiny scrub that was cut as firewood. They were each individually marked when the shrubs were to be cut down (Kaspers, 1967; Hart, 1966; Wartena, 1968; Buis, 1985). Because not all young trees were spared, young trees were also cut down with the shrubs. As mentioned above virtually all the species of shrubs and deciduous trees found in the lowlands of Western and Central Europe have been cut a great capacity for resprouting from the stool (Bühler, 1922; Rackham, 1980; Koop, 1987; Mayer, 1992). Initially the felling cycles of the coppices were short, that is 3 to 9 years (Tubbs, 1964; Rackham, 1980; Buis, 1985; Mantel, 1990; Best, 1998; Gulliver, 1998). With this rotation all the species of deciduous trees and shrubs, retained the capacity for forming sprouts from the stool, including beech, who has the least capacity to sprout from its stool. With cycles over 40 years long, beech does little or not at all (Cotta, 1865; Landolt, 1866; Hausrath, 1982; Ellenberg, 1988; Mantel, 1990; Pott, 1992). With the exception of yew, conifers do not have this sprouting property. The stools of the seedlings and saplings that have not been spared produced shoots, and the next time, these were coppiced, together with the other shoots. In this way, all the species of trees which regenerate in spiny shrubs and scrub such as oak, beech, birch, ash, and lime, as well as hazel that was part of the mantle and fringe vegetation eventually also became part of the coppice (Cotta, 1865; Trier, 1952; Schubart, 1966; Evans, 1992; Mantel, 1990; Watkins, 1990). With the short rotations they could be cut down regularly without much danger of the stools dying. Moreover, a tree species can reach a significantly higher age as a stool than as a tree (Rackham, 1980), and therefore produce wood without the necessity of generative reproduction by vulnerable seedlings and saplings. For example, an ash dies after 180-200 years if it is a tree, but as a stool, it can reach an age of about 300 years, and even ages of 500 to 1,000 years are possible (Rackham, 1980). If they are not regularly cut down, hazel trees reach an age of 70-80 years (Savill, 1991). However, as coppiced stools, they easily grow to an age of 300 years (Rackham, 1980). When a large small-leaved lime, 200 to 300 years old, is cut down, new shoots still sprout from the stool (Rackham, 1980: Pigott, 1991). There was no need to give any thought to the regeneration after each harvest of wood; it was merely a matter of preventing the livestock for a few years from eating the young shoots on the stools. This explains why in the regulations hardly any additional or supplementary measures are mentioned (Buis, 1985; Vera, 2000). Those that are mentioned are the replacement of stools which have died. The dead stumps were replaced by planting young trees. There are reports of this practice in Flanders and England, dating from the 17th century (Flower, 1977; 1980; Tack et al., 1993). As all species of trees regenerated from the stools, later on the regeneration of the standing trees could take place not only by sparing seedlings and saplings in the scrub, but also by leaving one shoot on the stool of an oak or other species (Hausrath, 1982). This shoot was known in Dutch as a "spaartelg", in German as a "Labreiser", and in English as a "staddle" (Bühler, 1922; Rubner, 1960;

Tubbs, 1964; Flower, 1977; Rackham, 1980; Haustrath, 1982; Buis, 1985; Mantel, 1990). In this way during centuries in at least parts of the wood-pastures the mantle and fringe vegetation of the groves and probably the groves themselves changed into coppices with standing trees that is coppice with standards. With the development of coppice with standards characterized by vegetative regeneration, people became less dependent of the generative regeneration of shrubs and trees. The fact that coppices with standards could provide the mast for pigs, as well as producing timber in different ages (Rackham, 1980) and firewood, it may have contributed to the fact that this form of exploitation increased significantly in the course of the 15th, 16th and 17th centuries and reached a peak in the 18th century (Bühler, 1922; Vanselow, 1926; Rubner, 1960; Mantel, 1990; Vera, 2000).

In addition to coppicing, regulations were issued from the 13th century about planting young trees, usually oaks in wood pastures. Commoners were often obliged to plant a single oak or a few oaks when they were allocated an oak to fell (Bühler, 1922; Grossmann, 1927; Meyer, 1941; Hesmer, 1958; Hesmer and Schroeder, 1963; Schubart, 1966; Streitz, 1967; Buis, 1985; Mantel, 1990). The young trees which were planted had to be protected from the livestock by planting them in thorny scrub, placing them in the same planting hole with thorny shrubs, or surrounding them with thorn bushes (Puster, 1924; Grossmann, 1927; Rodenwaldt, 1951; Hesmer and Schroeder, 1963; Flower, 1977; 1980; Koop, 1981). In fact, this imitated the process of regeneration in thorny scrub. These measures were adopted until the 18th century (Grossmann, 1927; Meyer, 1941; Rodenwaldt, 1951; Hesmer, 1958; Hesmer and Schroeder, 1963; Schubart, 1966; Flörcke, 1967; Streitz, 1967; Koop, 1981; Buis, 1985).

If the coppice concerns only the spiny scrub, the sprouts emerge from the stools of the spiny shrubs are armed again with spines after one growing season. So after they have been deprived from livestock for at least three seasons as in the case of the shortest rotation, the sprouts form a spiny thicket that protects the seedlings and saplings again against livestock. Even the sprouts of the palatable shrubs like hazel and trees like oak needed times that fall within the rotation times mentioned in the regulations to grow to a thickness they could withstand livestock (Mayer, 1992; Vera, 2000). Therefore, these regulations did not apply to seedlings and saplings in groves or forests. People knew about the difference in growth of sprouts on a stool in a coppice and the growth of a seedlings is witnessed for instance by an English manual about cultivating oaks, dating from 1609. It says that coppices of oak needed to be fenced off for only seven to nine years, while a plot of land sown with acorns should be closed to grazing livestock for at least twenty years so that the seedlings could grow without any risk from the livestock (Flower, 1977). As mentioned above, shoots on stools grow faster, much taller and thicker for the first few years than a shoot from seed (Mayer, 1992), which explains that for regeneration from seed in the forest the traditional rule that shoots had to grow tall enough to be out of reach of the livestock was no longer appropriate (Cotta, 1865). Therefore, the difference in growth from sprouts from vegetative regeneration from stools in coppices and generative regeneration from seed explains why coppices needed only to be closed to livestock for such a relative short period of only three to five years under this traditional rule (Streitz, 1967; Mantel, 1980; Hausrath, 1982; Buis, 1985; 1993). Therefore the damage to seedlings by grazing livestock only really applied in Central and Western Europe after the tree forest had developed from coppices as a way of producing wood. According to written sources, the damage to seedlings by livestock in a regenerating tree forest only became a problem in the lowlands in the 18th century for the generative regeneration of the forest after this method of production had been generally introduced. Virtually all the preceding regulations about grazing livestock in relation to the regeneration of the forest relate only to vegetative regeneration in coppices.

The regulations on cutting firewood are believed to have been a result of the increasing demand for firewood for households because of the increasing population and population density and a growing demand for charcoal and firewood for industrial purposes that are the glass and metal furnaces (Bühler, 1922; Vanselow, 1926; Endres, 1929; Streitz, 1967; Schubart, 1966; Mantel, 1990; Perlin, 1991; Buis, 1993). Another indication of the increasing demand or even the scarcity of firewood as a result of the increasing population is that from the 14th to the 16th century, wood which was not "fruitful", the "non-fructiferae" or "malae" were banned from being cut freely. This included birch, aspen, alder, ash, sycamore, field maple, hornbeam, holly, thorns and juniper. They also became subject to regulated cutting (Rubner, 1960; Hesmer and Schroeder, 1963; Mantel, 1990).

It should be emphasized that none of the regulations on grazing livestock which were issued in the lowlands of Western and Central Europe from the 13th to the 18th century were aimed at regulating the grazing of livestock in general. They even clearly state that the coppicing should be organized in such a way that it obstructed the rights to graze livestock as little as possible (Endres, 1888; Hausrath, 1898; Bühler, 1922; Vanselow, 1926; Rodenwaldt, 1951; Hesmer and Schroeder, 1963; Hart, 1966; Flower, 1977; Mantel, 1980). In order to prevent damage to coppices by grazing livestock, it became eventually also compulsory for the livestock to be herded (Endres, 1888; Grossmann, 1927; Sloet, 1911, Reed, 1954; Hesmer, 1958; Mantel, 1990). The plots where the livestock were herded were indicated with signs (Grossmann, 1927; Mantel, 1990). In the 15th and 16th centuries, also regulations were issued for the protection of nurseries of young trees, which were established from that time (Hesmer, 1958; Hesmer and Schroeder, 1963; Buis, 1985; 1993; Mantel, 1990). In the 18th century, hawthorn and blackthorn were cultivated in "nurseries" so that they could be used to protect young trees planted in wood-pastures (Schubart, 1966; Pott and Hüppe, 1991). Characterizing for the view of the role of the spiny

species for the regeneration of trees in wood-pastures was for instance an old saying in the New Forest: "The thorn is mother to the oak" (Penistan, 1974). Therefore in England, these thorny shrubs were sometimes described as the "nursery crop" for trees (Addison, 1981). Thorns and holly were actually considered so important for the regeneration of trees that a statute dating from 1768 laid down a punishment of 3 months of forced labor for damaging thorns and holly in the New Forest, starting every month with a number of lashes of the whip (Rackham, 1980). In a number of areas in Germany, the young oak trees were planted at relatively large intervals so that they would grow into good mast oaks that are oaks with large crowns, which therefore produced many acorns (Hesmer, 1958; Pott, 1983; Rapp, 2002). In this way "ackers" were created. Because of the modern meaning of the word "acker" in Germanic languages being an open field for growing crops, this has been misunderstood as felling trees for creating such open fields (Vera, 2000). The greatest pitfall in research of history based on written sources is language, because words remain the same, while their meaning may change over centuries (Vera, 2000; 2010).

There is one animal species that virtually subject to regulations or even total grazing prohibitions over the years throughout Western and Central Europe in order to protect the coppice. This was the goat. The reason was that goats browsed particularly on buds, leaves and young shoots in the coppice (Endres, 1888; Vanselow, 1926; Grossmann, 1927; Meyer, 1931; Hausrath, 1982; Reed, 1954; Hesmer, 1958; Hesmer and Schroeder, 1963; Hart, 1966; Streitz, 1967; Addison, 1981; Mantel, 1990). After the goat, most restrictions were imposed on sheep (Endres, 1888; Mantel, 1980; Buis, 1985). In many cases, sheep were treated in the same way as goats (Mantel, 1990). The reason for this is that they destroyed the grass because they cropped it very short (Grossmann, 1927). In many cases, the number of sheep that could be kept was determined in the regulations (Mantel, 1990). As a result of the emergence of a trading economy and the flourishing cloth industry in the 16th century, there was a great demand for sheep's wool, so that there was a great increase in the number of sheep despite the restrictions, and consequently in their effect on the vegetation (Mantel, 1990; Bieleman, 1992). Grazing livestock was completely prohibited only in odd cases, as, for example, in the coppiced woodlands of the Swiss city of Zurich, which were completely closed to grazing in 1376 and 1477 (Grossmann, 1927; Meyer, 1931). In the Netherlands, grazing livestock, as well as felling trees and taking humus, were prohibited for 40 and 60 years respectively in the Rheder Forest and the Worthreder Forest. This indicates that there cannot have been much of the coppice left (Buis, 1993). Therefore it was almost certainly a last attempt to allow the coppice, which had been destroyed by over exploitation, to recover.

In modern forestry literature the measures taken from the 13th century onwards to regulate the grazing of livestock are interpreted on the basis of the prevailing theory in the 20th century that Europe originally covered with a closed canopy forest in which trees regenerated naturally in the forest in gaps in the canopy or in large windblown areas (Watt, 1947; Leibundgut, 1959; 1978; Vera, 2000). This theory is based on the spontaneous development of the vegetation on abandoned agricultural land in the absence of indigenous large herbivores (Vera, 2000; 2009; 2013; Vera et al., 2006). For this reason they submit that all the measures taken from the 13th century onwards to regulate the grazing of livestock are in line with those issued in the 19th century to protect seedlings in a tree forest (Bühler, 1922; Vanselow, 1926; 1949; Grossmann, 1927; Meyer, 1931; Hausrath, 1982; Streitz, 1967; Mantel, 1980; Buis, 1985). They extrapolate the generative regeneration of closed forests by seedlings, back to the Middle Ages and earlier. For instance Bühler (1922) stated: "*The destruction of the forests was prohibited in many places in the Middle Ages. As livestock grazing destroyed the forest, grazing in forests was regulated*". This is not correct, as we established in this chapter. The provisions dating from before 18th century all relate to protecting recently coppiced areas, as well as the protection of nurseries for young trees in the so-called "kampen". It is only the provisions on the grazing of livestock dating from after the 18th century can relate to the regeneration of trees by means of seedlings in a forest in modern forestry by producing wood in high forests (Cotta, 1865; Vera, 2000).

The demise of the wood pasture

Many reports from the Netherlands, Germany and Switzerland show that, despite all the regulations, trees and shrubs were illegally cut down and felled in large numbers, and there was widespread illegal grazing, so that the trees and shrubs eventually disappeared. Illegal cutting of firewood resulted in the greatest devastation of both wood-pastures and coppices (Bühler, 1922; Vanselow, 1926; Meyer, 1931; Hesmeren Schroeder, 1963; Hart, 1966; Streitz, 1967; Buis, 1985; 1993; Mantel, 1990; Vera 2000). The fact that decrees against the devastation of "Holz" (wood as material) were issued on average every ten years in the 17th and 18th centuries, it shows the extent to which these decrees were not obeyed. Reports from the lowlands of Central and Western Europe on damage by livestock are virtually always related to the biting off of the shoots sprouting from the stools in coppices. However the historical sources from these regions rarely mention the destruction of seedlings by livestock as such (Cotta, 1865; Landolt, 1866; Gayer, 1886; Vanselow, 1926; Grossmann, 1927; Hesmer and Schroeder, 1963). Unlike the general statement that cattle prevented the regeneration of trees in the forest and that therefore the regulations mentioned were issued to prevent that (Buhler, 1922), there is no proof from historical data that livestock prevented in general the regeneration of trees. In wood-pastures, they did so inside the groves, but at the same time facilitated it in grazed grassland. The problem is in the classic forestry

literature that wood-pastures are considered as degraded closed canopy forests (Tansley, 1953; Ellenberg, 1988), instead of well-functioning ecosystem driven by large ungulates. If there are problems with the regeneration of trees, it is in the first place of human actions that cause the problems and only in second instance the animals. In addition to the ignoring of the rules for protecting the coppice against livestock, an indirect form of damage for which the animals were blamed was caused by cowherds who started fires and ringed trees to increase the area of grassland for the grazing livestock (Hesmer and Schroeder, 1963; Mantel, 1980; 1990; Buis, 1993; Tack et al., 1993).

The increase in the population and an increase in the demand for firewood and pasture resulted in an enormous pressure on coppices and wood pasture. It caused a shift in the attitude towards thorny and spiny scrub. Gorse, juniper and thorny scrub became together with brushwood, heath and shifting sands considered as having replaced the original forests throughout the lowlands of Western and Central Europe (Hobe, 1805; Landolt, 1886; Gayer, 1886; Bühler, 1922; Vanselow, 1926; Grossmann, 1927; Hausrath, 1982; Rodenwaldt, 1951; Reed, 1954; Hesmer, 1958; Hesmer and Schroeder, 1963; Streitz, 1967; Holmes, 1975; Tendron, 1983; Buis, 1985; Van der Woud, 1987; Mantel, 1990). Thorny shrubs and juniper spread in grazed grassland, but unlike being consideerd as nurse species in the 18th century thorns are seen as irritating weeds which have to be destroyed. In many parts of Europe, blackthorn and juniper are still considered to be weeds (Grossmann, 1927; Ellenberg, 1986). They were removed because they impeded grazing and also took the place of more valuable sorts of wood, was the opinion then (Hobe, 1805; Landolt, 1886; Gradmann, 1901; Bernìtsky, 1905; Sloet, 1913; Vanselow, 1926; Grossmann 1927; Meyer, 1931; 1941; Nietsch, 1939; Hausrath, 1928; Hilf, 1938; Hesmer, 1958; Hesmer and Schroeder, 1963; Schubart, 1966; Musall, 1969).

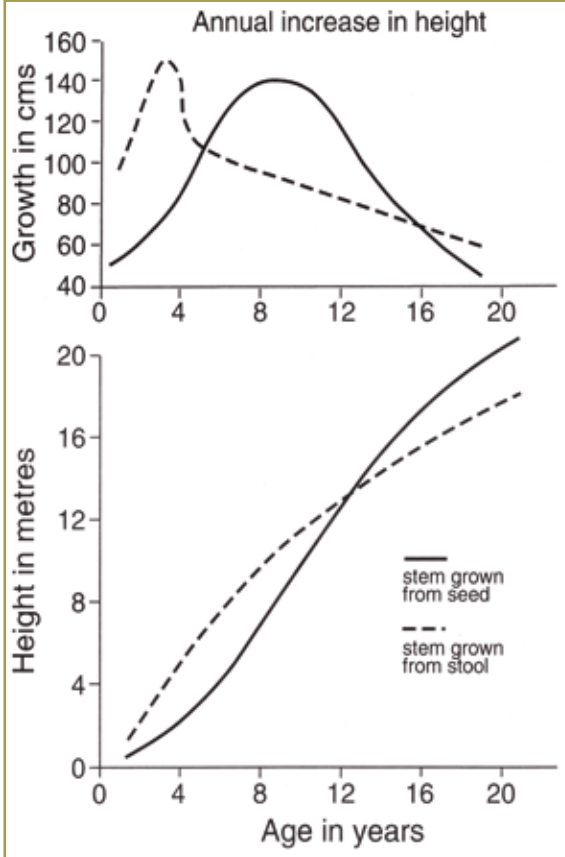
That grazing livestock was blamed is not surprising when one examines the density of livestock and the biomass recorded in the literature. For example, in 1784 in Prussia, there were 19 horses, 53 head of cattle and 215 sheep on 100 hectares of forest (319 kg per hectare) (The numbers of animals are converted into kilograms of biomass/hectare on the basis of the following weights: 1 sheep 40 kg; 1 cow 350 kg; 1 horse 250 kg; 1 pig 70 kg , verbal communication, S.E. van Wieren, 1997). The pigs have been left out of consideration in the comparison, as they were put out to pannage in the woods for only a few weeks to 4 months. Initially the other livestock grazed there throughout the year (Mantel, 1990). In addition, the commoners also had the right to collect acorns, beech nuts and other fruits, and to take litter. When these rights came to an end for instance the Bramwald in Germany, in 1870, there were 1,700 head of cattle, 3,880 pigs and 17,500 sheep on an area of 1,800 hectares (719 kg per hectare) (Krahl-Urban, 1959). In one particular part of Hessen in Germany, with an area of 2,409 hectares, there were 15,100 sheep in the 19th century (250 kg per hectare) (Gothe, 1949), while in one area in the west of Switzerland, 135 cows and 155 horses grazed on 250 hectares (344 kg per hectare) (Meyer, 1941). Moreover, grazing occurred even when there was no right to graze. Therefore there was illegal grazing, which means that the actual densities were higher than those suggested by the official figures (Hesmer, 1958; Peters, 1992). Therefore almost all the records about the damage of grazing for the regeneration of trees always date from the 18th century and later (Cotta, 1865; Landolt, 1866; Gayer, 1886; Vanselow, 1926; Grossmann, 1927; Hesmer and Schroeder, 1963). However, the real and final blow for the wood-pasture system was the invention of modern forestry in the 19th and 20th century with techniques such as shelterwood cutting, the selection system and group selection system. All these techniques aimed to regenerate the trees within the forest without the protection of thorny and spiny shrub species (Cotta, 1865; Landolt 1866; Vera, 2000).

At the beginning of the 18th century, there was a change in the demand of household and metal furnaces for firewood in the German states. The demand increased and people no longer wished to have the wood delivered in bundles of twigs or sticks, but in blocks (Vera, 2000). To obtain the necessary thickness, the usual coppice cycle was doubled, or even tripled, to 30 to 50 years and later extended even further to 60 to 80 years (Vanselow, 1926; Schubart, 1966; Mantel, 1990). As a result the coppices changed from a shrub layer under the standing trees, in a so-called pole-forest, known in German as “Stangenholz” or “Heisterwald” (Vanselow, 1926; Schubart 1966; Mantel, 1990). These forests of deciduous trees first appeared between 1700 and 1730 in Hessen in Germany (Hausrath, 1982, Mantel, 1990). The longer coppice cycle caused problems for the regeneration of beech, as the stool of this species sprouts little or not at all, with cycles over 40 years long (Cotta, 1865; Landolt, 1866; Hausrath, 1982; Ellenberg, 1986; Mantel, 1990; Pott, 1992). Therefore new young beech trees had to be planted after every felling. For this purpose, increasing numbers of beech were grown from seed in nurseries (in Germanic: “kampen” or “Kämpe”) in the 18th century for planting (Hesmer and Schroeder, 1963). When the coppice cycle was increased to 60 or 80 years, there was some spontaneous growth from seed on the forest floor (Hobe, 1805). Shoots of beech coppices actually develop flowers and seed after 20 to 30 years (Ellenberg, 1986). This resulted in a pole-forest with beech seedlings (Vanselow, 1926; Hesmer and Schroeder, 1963). Beech seedlings can survive for years under a virtually closed canopy in certain soils (Kraft, 1894; Bühler, 1918; Vanselow, 1949; Dengler, 1990; Korpel, 1995). Both recently germinated and dormant seedlings will grow without any problem when they receive more light when old beech trees above them are removed (Bühler, 1918; Woolsey and Greeley, 1920; Vanselow, 1949; Mayer, 1992). This happened when trunks were removed from the pole-forest in about 1740, as it was systematically introduced in Hessen in Germany (Bühler, 1922; Schubart, 1966; Mantel, 1990). The canopy was thinned out by felling part of the poles in

the wood in a regular pattern, so that the beech seedlings had an opportunity to grow. As the young beech trees continued to grow, more and more old beech trees were successively felled until all the poles were finally cleared and the whole area was covered by a new generation of beech (Vanselow, 1926; Mantel, 1990). This resulted in a forest now known as a productive standing forest, in which the regeneration of the trees took place in the forest, instead of in spiny scrub as is the case in a wood-pasture.

According to the regulations at that time livestock were still grazed in the pole-forest in accordance with the traditional rule which applied to coppices that a regenerated plot had to be opened up to grazing when the "growth" (that is in this case from seed) had grown up above the reach of the animals. However then it was ordered that when the regeneration from seed was the main aim, no livestock could graze in the forest at all. This was a break with the past, as well with the order in the second half of the 18th century that the cycle of the forest should be extended from 80 to 140 years (Schubart, 1966; Vera, 2000). The reason was that when the regeneration of trees is from seed within the forest the traditional livestock grazing according to regulations became a severe problem for the regeneration. The traditional rule of thumb that a regenerating plot could be opened to grazing when the shoots had grown above the reach of the livestock, that is after closing times of 3 up to 6 years, was not adequate anymore. Shoots growing from seed are not safe, even when they are higher up than where the livestock can reach them. They are still so thin that the animals can easily knock them over to get to the tips of the shoots and bite them off. A shoot on a stool grows to a much greater height and thickness in the first years of growth than the stem of a seedling. Seedlings of pedunculate and sessile oak reach a height in the first year of respectively 20 cm and 16 cm, while a shoot on the stool of an oak grows at least two meters that is ten times more. It reaches after one year a thickness of 2.5 cm, which makes it after more than 3 to 6 years impossible for livestock to knock it down. The height a sprout of a coppice reaches in one year is reached by the sprout of a seedling only after six or seven years (Turbang, 1954; Trier, 1963; Watkins, 1990; Rackham, 1993) (Figure 12.2). So, it takes much longer for seedlings to grow tall enough to be out of reach of the livestock and thick enough not to bowed by the animals and eaten. Empirically it was known that in high woods of beech, silver fir, hornbeam and oak, in areas where trees have been seeded they should not be opened to livestock in less than an average of 20 years. In woods of elm, ash and sycamore this should not happen in less than 15 years (Cotta, 1865; Hart, 1966; Darby, 1970; Flower, 1977; Rackham, 1980; Tubbs, 1988; Perlin, 1991). The strong rejection by foresters of allowing livestock to graze in the forest can be explained by this difference in growth of the stems of seedlings compared with the shoots on a stool of a particular tree species (Cotta, 1865; Mayer, 1992). It was this change in the regeneration of trees that grazing livestock as well as wild ungulates became entitled as the greatest enemy of forests (Landolt, 1866). Thus from the middle of the 19th century, there was an increasing insistence in forestry circles that grazing livestock in forests made regeneration impossible and should therefore be stopped altogether (Landolt, 1866; Gayer, 1886; Bühler, 1922; Vanselow, 1926; Grossmann, 1927; Meyer, 1941; Schubart, 1966; Mantel, 1990).

Growth curves of Grey alder (*Alnus glutinosa*) — **Figure 12.2**



It makes clear that the spring from a stool (coppice), i.e. vegetative regeneration grows much more rapidly in the first few years than growth form seeds, i.e. generative regeneration. This makes clear that stools in coppice are better able to withstand browsing animals which will try to bow down the spring (from Vera, 2000, redrawn from Mayer, 1992, p. 198).

In the 19th century, cutting of poles in long rotation times giving way to seedlings of beech to grow was developed as a regular wood harvest and forest regeneration technique. It is known as the shelterwood system. This technique meant that increasingly large gaps were made in the (grove) forest canopy by means of thinning out trees at intervals from several years to a decade. As the canopy become thinner, the seedlings of the standing trees grow taller. The term "shelterwood" system is based on the fact that after every felling, the remaining trees are so spread out their crown and form a screen that shelters the young trees against dryness and frost. Finally, after the last felling or clearing,

there is only an open area left with a new generation of growing trees. Fort beech this last felling was after 40 years (Vera, 2000). This technique was eminently suitable for the regeneration of beech in a beech forest, because of the shade tolerance of beech. However, it was not successful for regenerating the light demanding oak in a forest. The reason that "natural" regeneration of the oak using the technique of the shelterwood system initially failed, is the greater amount of light required by the oak, compared, for example, with beech (Vanselow, 1926; Krahl-Urban, 1959). Only after the modification that the canopy of the oak forest was thinned out much more and faster than was usual for the regeneration of beech, and the last trees of the shelter removed within 10 years, that oak was also successfully regenerated with this technique (Bühler, 1922; Vanselow, 1926; Hausrath, 1982; Krahl-Urban, 1959; Vera, 2000). Even then oak requires a great deal of human intervention, such as removing other sorts of trees, such as lime, hornbeam, elm and beech, which would outcompete oak (Cotta, 1865; Landolt, 1866; Gayer, 1866; Bühler, 1922; Vanselow, 1949; Dengler, 1990). Confusingly, this technique is described in forestry literature as "natural" regeneration, although unnatural measures such as working the soil or destroying unwanted plants, shrubs and trees are part of this "natural" regeneration. The development of "natural" regeneration showed that the oak needs a great deal of human intervention to be able to regenerate in forests. Without this help, it is impossible for oak to regenerate "naturally".

The abolishment of livestock grazing because of the destruction of the forest

On the basis of the prevailing theory that the original vegetation in the lowlands of Europe was a closed canopy forest, 20th century authors believe that the original vegetation of the lowlands of Central and Western Europe was a closed forest (Vera, 2000). For this reason they submit that all the measures taken from the 13th century onwards to regulate the grazing of livestock are in line with those issued in the 19th century to protect seedlings in a tree forest. They were all aimed at protecting seedlings in the forest (Bühler, 1922; Vanselow, 1926; 1949; Grossmann, 1927; Meyer, 1931; Hausrath, 1982; Hesmer, 1958; Streitz, 1967; Hesmer and Schroeder, 1963; Mantel, 1980; Buis, 1985). They extrapolated the generative regeneration of closed forests by seedlings, back to the Middle Ages. This also applies to the tree forest itself, with the conclusion that the remaining virgin forests of Europe, which were proclaimed as "forestes", and where regulations on the grazing of livestock were passed over the years, were originally closed forests. For example, Bühler (1922) stated: "The destruction of the forests was prohibited in many places in the Middle Ages. As livestock grazing destroyed the forest, grazing in forests was regulated" (Bühler, 1922). An additional argument which supports this hypothesis is the measures taken for the protection of fruitful trees, which go back to the early Middle Ages. They are interpreted as a measure for regeneration in the form of the shelterwood system. According to this view, the measures relating to the grazing of livestock were additional measures, and served to protect seedlings in the closed forest (Bühler, 1922; Vanselow, 1926; Meyer, 1931; Hess, 1937; Hausrath, 1982; Hesmer, 1958; Rubner, 1960; Hesmer and Schroeder, 1963; Schubart, 1966; Streitz, 1967; Buis, 1985; Dengler, 1990). They do not refer in any way to firewood cutting.

According to written sources, the damage to seedlings by livestock in a regenerating tree forest became a problem in the lowlands in the 18th century for the regeneration of trees after this method of wood production had been generally introduced. Foresters insisted on the end of the eternal grazing rights of commoners and a division between pasture and the cultivation of wood (Landolt, 1866; Grossmann, 1927; Vanselow, 1926; Meyer, 1941; Hesmer, 1958; Schubart, 1966; Buis, 1985; Mantel, 1990). For the realization of this division the abolition of the commons was necessary and after that the distribution of the common land. With the exception of a few places this took place in Western and Central Europe during the course of the 18th and 19th centuries (Hobe, 1805; Grossmann, 1927; Buis, 1985; Mantel, 1990). This division between pasture and the cultivation of wood still applies today. In this way, the landscape changed from a combination of fields with crops, coppices and wood-pastures into one of fields and open grasslands as pasture ("weide") on the one hand, and closed forests for wood production on the other hand. The words "forest", "forêt", "Forst", "Wald" or "woud" still applied on the uncultivated, but became synonymous with the uncultivated only intended for wood production, the high forest (Vera, 2000). The consequence of this division is that when it comes to trees, it seems that people and scientists can only see them in the context of the forest, and not as individual species with different requirements in relation to daylight (Vera, 2013).

The division between pasture and wood production meant also a division between forest and ungulates. From now on ungulates were only seen and characterised in terms of damage to the forest (Vera, 2000; 2013). As a consequence of the theory that the original natural vegetation was a high forest, as mentioned above, the wood-pasture as a whole was considered to be a degraded high forest (Ellenberg, 1988; Tansley, 1953). The grazing of livestock in wood-pastures was considered as unnatural because livestock were considered to be exotic species, introduced by man (Forbes, 1902; Moss, 1913; Tansley, 1911). Grasslands and heaths in wood-pastures were therefore characterized as 'stolen' from the forest (Warming, 1909). The evidence for the theft that when grazing ends, trees 'spring up' and the forest returns, as well as tree return in pieces of pasture that are fenced off from the grazing animals (Forbes, 1902; Krause,

1892; Tansley, 1911). Grazing livestock was seen as the greatest enemy of forests, which made any improvement of forestry impossible (Landolt, 1866; Vera, 2000). This separation between ungulates and forests caused eventually a great loss of biodiversity.

The wood-pasture and biodiversity

Unlike to the closed-canopy, high-forest, the wood-pasture system enables light-demanding and shade tolerant tree species to survive in the context of one system. As mentioned above these are sessile and pedunculate oak and wild fruit species such as wild apple, wild pear and wild cherry and European sorbus species such as whitebeam (*S. aria*), service tree (*S. domestica*), the chequers tree (*S. torminalis*) also includes all indigenous shrub species (Vera, 2000). On a European scale, some of these are threatened species (Kätzel et al., 2011). The wood-pasture is also a very diverse landscape, varying from savannah-like to park-like (see Photograph 1, 6 and 9). This results in a high diversity of tree shape, namely grove-grown and open-grown trees. The grove-grown trees are in shape like the closed-canopy grown trees, while the open-grown trees have short trunks and low at the trunk are massive spreading branches forming a majestic huge broad crown. They are very impressive and often recognisable individually by the shape of their crown. These open grown trees themselves are important for many plant and animals species, in combination with the open surroundings (Antonsson and Jansson, 2001; Butler et al., 2001; Green 2009; Manning et al., 2006). This applies especially to both oak species to which more species are connected that any other indigenous European tree (Morris, 1974; Schuffenhauer, 2011; Ek and Johanesson, 2005; Vodka et al., 2009). Many species, like for instance the rare hermit beetle (*Osmoderma eremita*), need trees of a very old age, called the veteran tree stage. In a closed-canopy high forest, oak will never reach this stage because of the low stature that is its characteristic. This low stature is caused by the downward growth of oak starting at the age of around 300 years. The upper canopy dies off while new branches and canopy forms lower down the trunk (Green, 2009) (Photograph 15). This results ultimately in the characteristic short conic formed oak of an age of about a thousand years. Such oaks can be seen in Windsor Great Park in England and other wood-pasture systems (Pater, 2010). An oak cannot develop such a shape because it will be killed before that by the shade of the trees that regenerate in the gap in the canopy that is formed by the downwards growth of the oak, or it will be killed by higher neighbouring trees (Alexander et al., 2011; Vera, 2000). The killing of veteran oaks is known from all former wood-pastures (Pater, 2010; Rapp and Schmidt, 2006; Sperber and Thierfelder, 2008). Both individual genetic characteristics as well as the genetic characteristics of the individual species of trees are revealed by the wood-pasture-system.

The epiphytic demanding lichen flora in the New Forest

Photograph 15: A conic formed oak. This shape develops after the crown dies back and new branches are formed low at the trunk forming a second crown. The trunk grows then thicker, which eventually result in this typical conic shape. Such trees harbor a typical beetle assemblage with nowadays rare species. Because of it characteristic low stature it cannot survive in a closed canopy forest, because it would be killed by adjacent higher trees. Calk Abbey Park, England (F. Vera).

in England forms one example of the floristic richness of a wood-pasture. The large majority of lichens requires light, and is found mainly on the fringes of groves (Rose, 1974; 1992). With 278 species is this flora the richest of the lowlands of Western Europe (Rose, 1974; 1992; Tubbs, 1988). The groves richest in this flora contain 130 to 178 species per km^2. By way of comparison, there is no forest area known in the lowlands of the continental part of Western Europe which contains more than 150 species (Rose and James, 1974, cited by Tubbs, 1988). The blackthorn scrub also contains flora of characteristic beard moss (*Usnea* sp.). The two species of oak are particularly rich in epiphytes, and up to 150 species of epiphytes can be found on them (Rose, 1974). Because this flora contain species which do no spread easily, and which are found, in so far as it is possible to check this, only in places where there has been a continuous cover of trees, Rose and James (1974) believe that their presence goes back to the Atlantic primeval forest (Rose and James, 1974, cited by Tubbs, 1988). However, in view of the importance of the two species of oak for this flora, and the fact that these epiphytes are mainly found on the periphery of forests, it could also be maintained that this character indicates the historical continuity of a park-like landscape, and the factors responsible for this, such as the large herbivores (Rose, 1974).

The mosaic of grasslands, shrubs, thickets, trees and groves – the last of these surrounded by mantle and fringe vegetation – vary in relation to each other in surface. The grasslands in the wood-pasture also contain a lot of grass and herb species. The grasslands of the wood-pastures are very rich in species (Salisbury (1918; Adamson, 1921; 1932; Tansley, 1953; Müller, 1962; Tüxen, 1952; Sjörgen, 1988; Dierschke, 1974; Rosén, 1988; Tubbs, 1988; Pott and Hüppe, 1991; Rodwell, 1991; Kollman, 1992;

Photograph 16: A dead oak (*Quercus* spp.) in a former wood-pasture, killed by shade tolerant tree species like beech (*Fagus sylvatica*) and hornbeam (*Carpinus betulus*) that came up after grazing by livestock ceased. The thick branches low at the trunk of the dead tree shows that it grew up in open landscape. It is nowadays presented as a new primeval forest. Sababurg, Germany (F. Vera).

Hondong et al., 1993; Pietzarka and Roloff, 1993; Bossuyt et al., 2005). It can be stated that it can contain all the species of grasses and plants which are now found only in various types of agricultural grasslands (Hillegers, 1986; Wolkinger and Plank, 1981; Ellenberg, 1988).

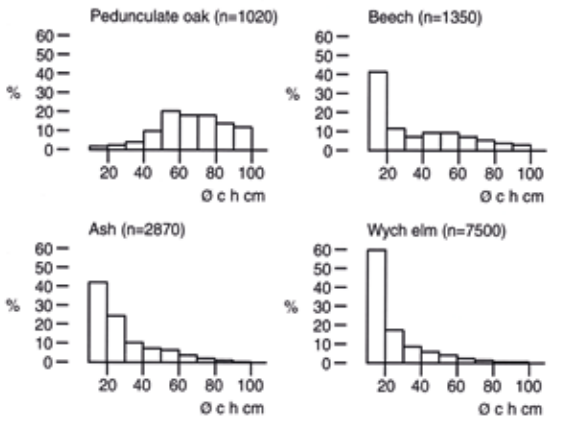
The variability in vegetation types, vegetation structures and combinations of these makes a high diversity of animal species possible. This is because of the high diversity (Alexander, 2011; Appelqvist et al., 2001; Bossuyt et al., 2005; Green, 2009; Harding and Rose, 1986; Manning et al., 2006; Schuffenhauer, 2011; Schulze-Hagen, 2004; Ek and Johanesson, 2005; Vera, 2000; Vodka et al., 2009). Wood-pastures are characterised by a large diversity of species of invertebrates, including insects (Darlington, 1974; Morris, 1974; Tubbs, 1988; Hondong et al., 1993; Alexander, 1998, 2001; 2005; Alexander et al., 2006; Appelqvist et al., 2001; Ranius et al., 2005; 2008; Vodka et al., 2009; Schuffenhauer, 2011). More than 50% of all the species of insects found in the whole of Great Britain live in the New Forest alone (20.000 hectares) (Tubbs, 1988). The New Forest and Windsor Forest are the richest areas in England. The cause of this is the presence of the very old trees in particular (Alexander, 1998). Of all the European species of butterflies, 80% live in a habitat combining grasslands, scrub and groves with mantle vegetation (Bink, 1992). The oak has a special place as a host for insects. There is no other species of tree in Europe associated with so many species of insects (Darlington 1974; Morris, 1974; Vodka et al., 2009; Schuffenhauer, 2011). As we read above, the oak plays a prominent role in wood-pasture. Furthermore, there is an enormous variety of species of birds in grazed, park-like landscapes (Smith, 1980; Tubbs, 1988; Hondong et al., 1993; Schepers, 1993; Cramp and Simmons, 1980; 1988; 1992). These include the nightingale (*Luscinia megarhynchos*), whitethroat (*Sylvia communis*), lesser whitethroat (*Sylvia cuorruca*), garden warbler (*Sylvia borin*), red-backed shrike (*Lanius collurio*), song thrush (*Turdus philomelos*), all the species of woodpeckers, and many birds of prey, including the common buzzard (*Buteo buteo*), goshawk (*Accipiter gentilis*), hobby (*Falco subbuteo*) and Imperial eagle (*Aquila heliaca*). Many species of birds, particularly songbirds, are dependent on the combination of grassland, scrub and groves. Grazed, park-like landscapes are even the last places in Europe where the imperial eagle breeds (Cramp and Simmons, 1980; Voous, 1986). In their turn, the birds contribute to the diversity in grazed landscapes, as noted above. Apart from the jay, whose role in the establishment of oak was discussed earlier in detail, songbirds are particularly important for the establishment of species of plants with fleshy fruits, such as wild fruit trees, hawthorn and blackthorn.

The wood pasture as the closest modern analogue of the natural vegetation

The wood-pasture system driven by indigenous large herbivores enables light-demanding tree species to survive in the presence of the shade-tolerant in the context of one system. Besides all light-demanding tree species mentioned before, it provides habitat to various shrub species such as hazel, common spindle (*Euonymus europeus*), Guelder rose (*Viburnum opulus*) common

Figure 12.3

The percentage diameter distribution of four species of trees in diameter categories in the National Park Dalby Söderskog in South Sweden



Only trees with a trunk diameter of >10cm at chest height are included. Pedunculate oak (*Quercus robur*) is a light demanding tree species with a bell-shaped distribution, which means that it is a population that is dying out. Beech (*Fagus sylvativca*), Ash (*Fraxinus excelsior*) en Wych elm (*Ulmus glabra*) are shade tolerant tree species. Their population shows an inverse J-curve, which means they have healthy population (from Vera, 2000, redrawn from Malmer et al., 1978, p.20).

privet (*Ligustrum vulgare*), blackthorn, hawthorn, common dogwood (*Cornus sanguinea*), elder (*Sambucus nigra*), common gorse (*Ulex europaeus*), broom (*Cysticus scoparius*), barberry (*Berberis vulgaris*), red currant (*Ribes silvestre*) and black current (*R. nigrum*). As far as it concerns wind pollinated species this is proven by pollen diagrams from the primeval vegetation. This is contrary to the closed-canopy, high-forest system where all light demanding tree and shrub species become extinct as proven in former wood-pastures that changed into closed canopy forests after large ungulates were removed or made functionally non-existent by culling (Malmer et al., 1978; Vera, 2000; 2009; 2013) (Photograph 16 and Figure 12.3). The wood-pasture system therefore can be regarded as the closest modern analogy of the natural vegetation (Smit and Putman, 2011; Vera, 2000; 2009; 2013). As mentioned above, the wood-pasture system is a very diverse landscape varying from savannah-like to park-like. This mosaic is shaped by a reciprocal interaction between plant and animal species. Beside a high diversity of shrub and tree species, the system is also characterized by a high diversity of animal species. This is because of the high diversity in vegetation types, vegetation structures and combinations of these (Alexander, 1998, 2001; 2005; Alexander et al., 2006; Appelqvist et al., 2001; Bossuyt et al., 2005; Green, 2009; Harding and Rose, 1986; Manning et al., 2006; Ranius et al., 2005; 2008; Schuffenhauer, 2011; Schulze-Hagen., 2004; Ek and Johanesson, 2005; Vera, 2000; Vodka et al., 2009).

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