9 Grazing as a tool for wood-pasture restoration and management

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Introduction

Land-use change is a major threat to biodiversity and whole landscapes worldwide. The increasing demand for food and infrastructural, urban and industrial development represent an increasing and dual pressure on open landscapes. On the one hand, there is a trend towards land-use intensification, especially in flat, lowland regions. On the other hand, there is land abandonment, especially in remote regions (Benjamin *et al.*, 2005). Both pressures are detrimental to traditionally managed ecosystems such as wood-pastures (see also Bergmeier and Roellig, this volume). There is no doubt that the dramatic change of forest landscapes of Europe due to anthropogenic factors in the past caused a substantial loss in biodiversity. This is particularly the case for animals such as large predators, but also for large numbers of insects related to old-growth forests (Warren and Key, 1991, and see Falk, this volume). But there is also a huge biodiversity loss as a consequence of afforestation of traditionally open and semi-open landscapes, which are most typically represented in farming landscapes across Europe (Bignal and McCracken, 1996; Prévosto *et al.*, 2011). In Europe (all countries except Russian federation), large areas of former agricultural land are subjected to afforestation, both spontaneously (ca. two-thirds) and through planting (ca. one-third): between 1990 and 2000 at a rate of ca. 0.9 million ha per year; and between 2000 and 2010 ca. 0.7 million ha per year (FAO, 2010). There are no indications that this process will stop in the near future. Therefore, understanding the development of plant and animal communities on former agricultural land (abandoned as well as intensively used) will become increasingly important from biological conservation, habitat and landscape restoration, policy and scientific perspectives (Cramer *et al.*, 2008).

Wood-pastures are thought to be highly diverse in species and habitats, and have high cultural and aesthetical values (Bergmeier and Roellig, this volume, and Rozas, 2004; Smit *et al.*, 2005; Strandberg *et al.*, 2005). The rich European flora and fauna of extensively farmed open landscapes is largely restricted to – and dependent on the existence of – semi-natural pastures (Bokdam, 2003). Open landscapes can be maintained by large herbivores in interaction with various other natural phenomena and processes (see for example Vera, 2000). After human colonisation, the native large grazers have mostly been replaced by domestic livestock (for example cattle, goats, sheep, ponies or pigs). Therefore, from the perspective of vegetation, large areas continued to be grazed even after the replacement of the wild large grazers by domestic ones, but the spatiotemporal dynamics and intensity of grazing pressure are now largely under human control (Bakker *et al.*, 2004). In this way, a large amount of native plant species related to open grazed ecosystems may have persisted for many centuries in the European landscape, even after the extinction of the native large grazers (but see alternatively the niche shift theory in Eriksson, 2013).

To better understand the role of large herbivores in nature conservation, it is important to understand the impact they may have on vegetation at various spatial scales from local to landscape and beyond, under specific environmental conditions. The principal idea is that large herbivores, whether wild or livestock species, can play a key role in restoring the functioning of ecological processes. Concerning wood-pastures, the challenge will be to manage them in an ecologically and economically sustainable way.

Ecological and historical framework for management

In this chapter, we focus on grazing management as a tool for the restoration of structurally diverse wood-pastures on former intensively used agricultural land (i.e. abandoned pastures and abandoned arable fields). Central issues for grazing management of wood-pastures are the ability of large herbivores to restore or maintain half open landscapes and their role in natural regeneration of woody species (Kirby et al, 1994; Vera, 2000; Birks, 2005; Mitchell, 2005). In wood-pastures, the impact of large herbivores can be handled by man, although the final results will not always be predictable. The reason for this is that grazed ecosystems under natural settings fluctuate *between* different stages (for example between grassland, scrub and forest) rather than fluctuating *around* one particular stage (for example around grassland). Therefore, handling of processes is more appropriate for the preservation and the development of different stages in the grazed ecosystems rather than management of patterns (Buttler and Peringer, this volume). The most important processes for the management of wood-pastures are those that influence vegetation dynamics (Vulink and Van Eerden, 1998).

In wood-pastures, large herbivores are ‘part and parcel’ of the system. Wood-pastures in good condition should have a wide range of tree ages to ensure the persistence of tree populations (Vera, 2000; Quelch, 2001). The management of wood-pastures has always been characterised by low-intensity grazing by domesticated herbivores, but simultaneously, traditional land-use practices took place: hay making, litter collection and burning, often completed with the extraction of tree-related goods by logging, coppicing and pollarding (Bakker and Londo, 1998; Pott, 1998; see also Oppermann, this volume). Also, planting various tree species with economic interest was common practice in the past. For example, Flower (1980) mentions planting of European beech (*Fagus sylvatica*) in bundles of seven young trees, around which spiny species such as hawthorn (*Crataegus monogyna*), sloe (*Prunus spinosa*), holly (*Ilex aquifolium*) or roses (*Rosa* species) were sown. Rosén and Bakker (2005) point at high species diversity of the ängars and alvars in Öland (southern Sweden), where mowing, low-intensity grazing (also in the aftermath), logging, tree thinning, burning branches and leaves and the spreading of the ashes were applied. At present, grazing management is the dominant management measure in wood-pastures. This might overestimate the role of large herbivores in the present remnant wood-pastures compared to other management interventions for biodiversity.

Grazing systems are often ecologically very complex. There are conflicting opinions concerning the role of large herbivores in succession from open habitats to closed forest,. Experiences in low-productive areas show that large herbivores in year-round grazing systems cannot prevent the succession of grasslands, heathlands and other unfertilised rangelands to woodland (Archer, 1996; Pott, 1998) but evidence from the New Forest (Tubbs, 2001), historical ecology concerning woodland use in northern Belgium (Tack et al, 1993) and the long-term grazing experience in some Flemish nature reserves (Van Uytvanck, 2009), reveal the high capacity of large herbivores to suppress tree regeneration and maintain open habitats.

The key processes to be understood in grazed treed landscapes involve the strategies used by various plant species to cope with herbivory, herbivore selectivity and the light requirements of the woody vegetation. Olff et al (1999) present a descriptive model of long-term cyclic vegetation succession in grazed ecosystems in which free-ranging herbivores and alternating associational resistance and competition play a crucial role. The core assumption in the model is that unpalatable, thorny or spiny shrub species create safe sites for the establishment of palatable tree species in a palatable grassland matrix (i.e. associational resistance) (see also Vera, 2000). In a next stage, light demanding shrubs gradually disappear due to competition with the growing trees. In a last stage, gaps created by falling of the old, large trees allow the development of grassland that will attract herbivores. Spatial asynchronisation of this cyclic mechanism causes shifting mosaics with patches of all structural vegetation types involved.

Plant–herbivore interactions in the restoration process of wood-pastures

As the younger life stages of trees are most susceptible to herbivory, the understanding of the impact of grazing on the earliest life stages reveals underlying mechanisms controlling tree community structure in wood-pastures (Meiners and Handel, 2000). Interaction mechanisms include both positive and negative effects of herbivores on woody species regeneration. In a palatable vegetation patch, the establishment of woody species may be favoured by grazing or trampling through the reduced competition with other grassland species if these species escape from grazing. Associated palatability negatively affects establishment, if tree seedlings or saplings are eaten together with the surrounding palatable vegetation. In an unpalatable/resistant vegetation patch (such as for example *Juncus* tussocks, *Rubus* scrub), establishing woody species may be favoured through associational resistance (i.e. the herbivore avoids the vegetation patch where the tree saplings develop). However, in avoided vegetation patches juvenile trees may suffer from increased competition from grasses and herbs or from neighbour contrast susceptibility (making saplings vulnerable for small herbivores) (Figure 9.1). It is clear that the ability and the pattern of tree regeneration are crucial in the restoration process of wood-pastures.

Regeneration patterns: comparing abandoned pastures and abandoned arable fields

The regeneration of woody species in grazed environments occurs in a non-random pattern and it is related to the spatial heterogeneity of abiotic and biotic factors. A mosaic pattern of tall stands (for example tussocks, tall herb mats, scrub patches) and short stands (lawns) is a common feature of grazed environments, including wood-pastures. The development of such a spatial heterogeneous vegetation structure may be a result of permanent grazing interacting with differences in plant palatability and spatial variation in light conditions, soil and litter features (Quilchano *et al.*, 2008). It may also be a result of changing human land use, for

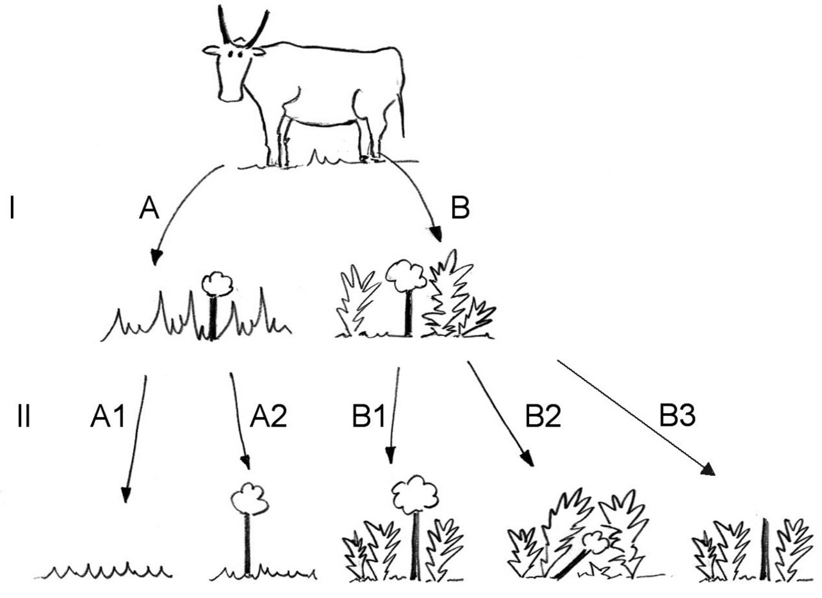

Figure 9.1 Grazing and vegetation structure interaction: positive and negative effects on woody species establishment

Note: I. Herbivore effects on vegetation patches: A: Large herbivores forage in palatable vegetation patch; B: Large herbivores avoid unpalatable vegetation patch. II: Indirect effects on establishing trees: A1: Associational palatability; A2: Reduced competition; B1: Associational resistance; B2: Increased competition; B3: Neighbour contrast susceptibility example decreasing herbivore pressure on pastures. Conversely, vegetation structure is also found to be important with regard to the availability and quality of food resources for large herbivores (for example low quality of wood or tall herb stands versus high quality of low grass or herb stands), and therefore it affects the foraging strategy and/or the habitat use of large herbivores. Large herbivores do not uniformly graze the entire pasture; certain regions are consistently more grazed than others, for example because of their better nutritional content. This results in the permanent presence of tall vegetation patches in a pasture (Mouissie, 2004). These stands may potentially represent fertile and safe sites for the establishment of woody species (Olff et al, 1999; Van Uytvanck *et al.*, 2008a).

The role of vegetation structure in the establishment of woody species is emphasised by the contrasts between the two major starting points for wood-pasture restoration; these are abandoned pastures and the former arable fields. Intensively grazed and structurally uniform pastures gradually change in patchy vegetation with tall and short stands when grazing intensity is lowered or even ceased. In such pastures the pattern of woody species colonisation is a rather slow and influenced by associational resistance/palatability of the developing vegetation. The regeneration pattern is patchy or scattered in this case. In contrast, the establishment of woody vegetation on abandoned arable fields is fast and rather dependent on the adaptive traits (for example unpalatability) of the pioneer trees themselves (see below). At the initial stages, the establishment of woody vegetation is rather explosive, and grazers increase horizontal and vertical heterogeneity by browsing seedlings and saplings (Van Uytvanck *et al.*, 2010a). On former arable land, less palatable tree species (for example *Betula*) gradually take over the role of grazing tolerant species (for example *Salix caprea*) and are able to grow beyond the browse line. These species will dominate the tree layer in the early forest stages and can be present for decades (Falinski, 1998). In contrast, it is mainly palatable species (for example *Fraxinus* sp. and *Quercus* sp.) that will determine the tree layer on former pastures, although the unpalatable (for example *Alnus* sp.) may locally be important when regenerating in tall herb patches (Van Uytvanck *et al.*, 2008b).

Regeneration mechanisms

Facilitation mechanisms between different plant species are thought to play a key role in tree establishment in grazed ecosystems. Facilitating vegetation types in successional series on former agricultural land are, for instance, unpalatable or spiny ruderal vegetation (mainly on former arable land), unpalatable tall herbs (for example soft rush, tall sedge vegetation) and spiny scrub (bramble, sloe, hawthorn, roses; mainly on pastures) (Smit *et al.*, 2005). Except for large spiny scrub patches, these vegetation types will enhance survival through protection against browsing and drought, but they will not allow trees to grow out beyond the browsing line (ca ± 2 m). Although there is a high mortality of seedlings in spiny scrub due to competition for light, some tree saplings may grow up in it and grow out beyond the reach of herbivores. Large herbivores may even cancel some competitive interactions and improve light conditions in dark vegetation patches and enhance tree emergence (Vandenberghe et al, 2006; Van Uytvanck *et al.*, 2008b). The preference of large grazers such as cattle and horses for short vegetation types, such as grasslands, with sufficient nutrient rich leaves (Wallis-DeVries *et al.*, 1999) causes a very low survival rate of tree seedlings in grassland vegetation through the mechanism of associational palatability. It is likely that grazing pressure and/or selective capacities of grazers may tip the balance to either dominating associational palatability or release of competition. High grazing pressure and low selective capacities (mainly herbivores with large mouths) will promote associational palatability, while low grazing pressure and high selective capacities (mainly herbivores with small or pointed mouths) will promote release of competition.

Besides the mechanisms that function through positive or negative interaction with surrounding vegetation, intrinsic *adaptive plant traits* of establishing woody species against herbivory play an important role in tree regeneration. Resistance (a reduction of the amount of damage) and tolerance (the capacity of regrowth after grazing damage) represent two general strategies of plant defence against herbivores. Since resources available for allocation to defence are limited and resistance and tolerance are likely to serve the same functions for plants, there is a trade-off between these two strategies (Leimu and Koricheva, 2006). On grazed former arable land, adaptive traits – tolerance and unpalatability – are more important than the mechanism of associational resistance. In general, resistant and tolerant woody species are favoured due to the avoidance of grazing, while palatable species need facilitation. But all tree species are able to expand if grazing pressures are lowered during a number of successive growing seasons or when grazing abruptly ceases, i.e. when time gaps in grazing occur.

An important regeneration mechanism is related to such *time gaps in grazing*. In general, temporal absence of large herbivores can create a window of opportunity for woody species to establish. Prolonged exclusion of livestock allowed abundant regeneration of trees and shrubs in Denny Wood (New Forest, UK), whereas there was no recruitment at all in adjacent, permanently grazed woodland (but the result was the development of species rich grasslands) (Mountford and Peterken, 2003). Putman et al (1989) mention that continuous and high grazing pressure also prohibits the establishment of potentially protective shrubs in which trees can regenerate (see mechanism above). In the majority of wood-pastures of the New Forest (one of the largest known remnant wood-pasture landscapes in temperate Europe), the locally dominant trees, such as *Quercus robur* and *Fagus sylvatica*, have failed to recruit for several decades (Tubbs, 2001). Kuiters and Slim (2002) argue that browse-sensitive woody species such as *Quercus* will successfully regenerate, only if temporal and spatial variation in browsing pressure can occur. If not, woodland regeneration on abandoned land may take several decades (Smit and Olff, 1998; Harmer et al, 2001). Short-term exclusion of large herbivores may be an alternative to the mechanism of associational resistance in native woodland regeneration, in particular in small areas. Because the seedling's first year is important for definitive establishment, a time gap before grazing has a large positive impact on survival and growth of palatable tree saplings, but this result is highly dependent on vegetation structure. Time gaps of two years are too short to enhance sapling survival in grasslands. In tall herbs and ruderal vegetation, the sapling survival is enhanced but definite outgrowth is hampered, confirming the results of Clarke (2002) for sheep grazing. Experiments indicate that longer periods are needed for successful regeneration in grassland ecosystems, but that this is not the case on former arable land, where mainly tolerant and unpalatable trees establish (Van Uytvanck *et al.*, 2008a). The duration of time gaps also depends on regeneration capacities of tree species, in particular the time that is needed to grow above the browse line. For example, already established *Fraxinus excelsior* saplings are able to regenerate and grow fast after long periods of browsing, while *Quercus robur* is less able to survive a long period of repeated browsing and regrowth is much slower.

Herbivory by wild and domestic ungulates is a *chronic disturbance* that can have dramatic effects on vegetation dynamics. One of the central ideas in ecology is that disturbance plays an important role in natural communities, influencing population persistence, community composition and diversity (Pickett and White, 1985). The relevant disturbance parameters to describe drivers of mosaic cycles are spatial extent, frequency and magnitude (for example biomass loss). Individual disturbances may be seen as 'ecological reset' mechanisms, creating a link to the concept of succession. In this context, grazing can be seen as fine-scale disturbance, affecting the re-vegetation dynamics after disturbances at a larger scale (for example fire, floods, storms, insect plagues) (Vandvik *et al.*, 2005). In cultural landscapes such as wood-pastures, disturbances that 'reset' succession are often caused by human intervention, (for example fire, clearing) (Webb, 1998). Human-related disturbances (such are those related to land use) are usually regular and deterministic in space and time, in contrast to the year-round grazing by free-ranging large herbivores (Kleyer *et al.*, 2007). Sandom et al (2013) found that wild boar could be useful for woodland management in the Scottish Highlands because of their rooting behaviour, which acts as a disturbance and provides patches for seedling germination.

In the context of restoration, soil disturbance on former arable land (resulting in bare ground) is a dominant disturbance factor, strongly determining community structure of the establishing wind-dispersed pioneer species that will dominate early restoration stages. So, it may be necessary to control this process by additional management techniques such as intensive grazing, burning, cutting, hay-making and sod-cutting.

An important premise for restoration of species rich vegetation types in wood-pastures is the ability of large herbivores to cause *spatial redistribution of nutrients* among habitats in such a way that nutrient-poor conditions can be restored in preferred foraging habitats, and consequently induce the mechanism of shrub and tree establishment in avoided vegetation patches. It was shown that cattle grazing can compensate for high atmospheric nitrogen (N) inputs, maintaining grassland types that support N loads of 20–25 kg N $ha^{-1}y^{-1}$, but that the restoration potential for oligotrophic grasslands is limited. Moreover there is no indication that high phosphorus loads in the soil, which may prevent sustainable restoration, can be reduced by grazing or other traditional management techniques. It is mainly in excretion-free patches of highly preferred grassland habitat that N balances can be altered and N-poor conditions can be restored, given that the proportion of these habitats is relatively small (i.e. ± 20 per cent) (Van Uytvanck *et al.*, 2010b).

Conceptual model for wood establishment in contrasting environments

Based on the obtained insights in patterns and mechanisms of woody species regeneration under grazing, a conceptual model for tree establishment success in high competitive (for example grassland) and in low competitive environments (for example former arable land) is presented (Figure 9.2). Moderate grazing (<0.3–0.5 animal units (AU) ha^{-1}y^{-1}) results in a heterogeneous vegetation structure that develops in both former pastures and former arable land. Establishment success of woody species is related to episodic disturbance processes (for example one-time flooding, burning, soil trampling events), grazing or not and facilitating mechanisms (Figure 9.2). Time gaps may have similar effects on establishment success as one-time disturbance events. In grassland systems, slow tree establishment is accelerated by disturbance events (successional reset mechanisms) and extensive grazing (development of a heterogeneous vegetation structure). Facilitation (associational resistance in protective vegetation patches) enhances establishment success. On former arable land, bare ground enables fast establishment of woody pioneers with adaptive traits against herbivory (tolerance, unpalatability). Grazing reduces regeneration success by decreasing the number of seedlings (being vulnerable for grazing). Facilitation by invading spiny forbs and scrub becomes more important over time and enables establishment of palatable woody species.

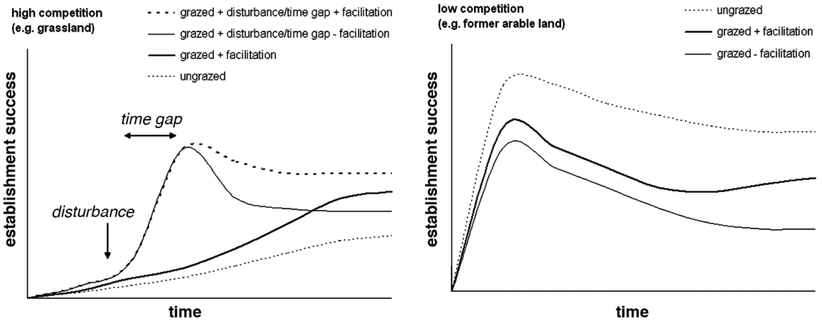

Figure 9.2 Conceptual model for woody species establishment success in grazed high and low competitive environments

Wood-pasture management

An insight into the process of woodland development by scrub encroachment is useful to counteract negative effects on grassland biodiversity. When individual shrubs aggregate (forming scrub patches), a decrease in number of vascular plants may be expected when a given threshold in scrub cover is passed. For example, for the species rich *Veronica spicata–Avenula pratensis* community in a wood-pasture system in Öland (Sweden) a dramatic decrease in species richness coincides with scrub cover exceeding the threshold of 70–80 per cent (Rejmanék and Rosén, 1992). Probably, comparable thresholds count for a large variety of species-rich grassland communities throughout Europe. In most cases, conservation managers are able to interfere and steer grazing management and woodland development by controlling grazing pressure, choosing the grazing regime (for example seasonal or year-round) and allowing time gaps in grazing.

Grazing pressure

From a nature conservation perspective, both undergrazing and overgrazing affect semi-natural landscapes and their elements such as wood-pastures, grasslands and forests (Green, 1990; Gibson, 1997; Rackham, 2003). Grazing pressure can be expressed as the number of grazing animals per hectare per year (AU ha^{-1} y^{-1}) or as the yearly number of grazing days per hectare of all animals pooled together. Figure 9.3 gives a general insight into the role of grazing pressure on woodland regeneration in mosaic vegetation that develops on abandoned pastures and abandoned arable fields, based on 19 study sites from Belgium (Van Uytvanck, 2009). A threshold for woodland regeneration on former pastures was found around 130 grazing days ha^{-1} y^{-1} (= ±0.35 AU ha^{-1} y^{-1}); on former arable land around 180 grazing days ha^{-1} y^{-1} (= ±0.50 AU ha^{-1} y^{-1}). For the main regeneration phases in the New Forest, Mountford and Peterken (2003) give comparable maximum thresholds for cattle (0.3 AU ha^{-1} y^{-1}), while for ponies and deer the values are 0.15 and 0.45 AU ha^{-1} y^{-1}, respectively. For wood-pasture grazing in the UK, Chatters and Sanderson (1994) recommend 0.1–0.2 AU ha^{-1} y^{-1}. Kuiters and Slim (2002) found that Iceland ponies (0.08–0.1 AU ha^{-1} y^{-1}), grazing on former arable land in the Netherlands, restricted successful regeneration to patches with bramble shrub, but without giving thresholds for regeneration outside protective vegetation structures. In former pastures and arable fields, a grazing pressure that is below the thresholds of 0.35 and 0.50 AU ha^{-1} y^{-1} respectively, allows tree regeneration in the developing mosaic vegetation during the first five to ten years after the cessation of agricultural use.

In large areas where nature conservation is the principal objective, a year round ‘natural grazing’ by mixed, free-ranging feral herbivores, with populations limited by late winter conditions, is preferred to seasonal grazing limited by summer fodder (Mountford and Peterken, 2003). The former requires lower stocking rates and should produce greater habitat diversity and allow trees to regenerate in open areas (Helmer, 2002). However, European literature on the effects of different grazing regimes and woodland regeneration is very scarce. For example, Hester *et al.*,

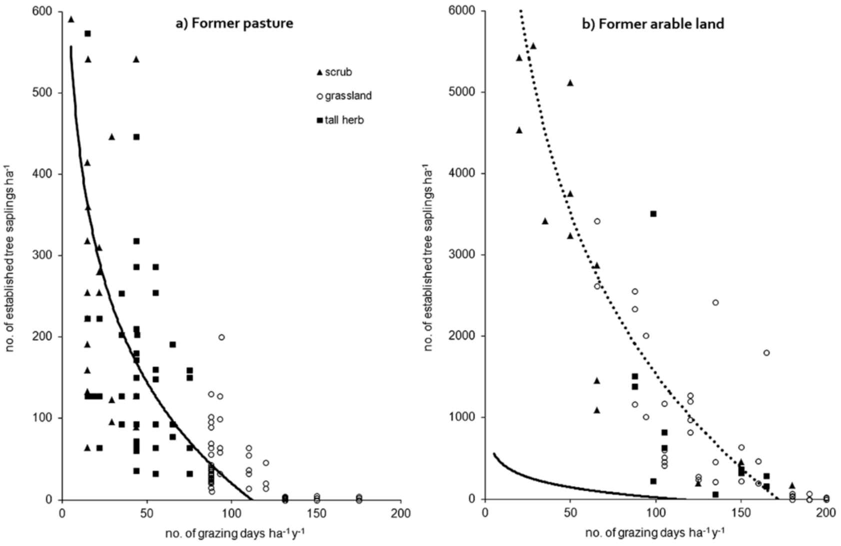

Figure 9.3 Number of established trees related to grazing pressure on former pasture grassland (a) and former arable land (b)

Note: Y-axis scales differ with a factor 10: the solid line in III.4.3.b is the trendline of Figure 9.3a (i.e. former pasture) to make the comparison easier. Data from 19 sites with grassland and former arable land in Flanders, Belgium.

Source: Van Uytvanck (2009)

(1996) compared summer and winter grazing regimes and three different grazing intensities (low: 0.6–1.2, medium: 1.2–2 and high: 2.1–3.8 sheep ha^{-1}). In this study, seedling recruitment for *Betula pubescens*, *Fraxinus excelsior* and *Sorbus aucuparia* was highest in the high-intensity grazed plots. Growth and survival to the sapling stage (>0.3 m) was negatively correlated with grazing intensity, but was much greater in winter-grazed than summer-grazed plots. Although, browsing was highest in winter – probably as a result of increased visibility of saplings and scarcity of alternative food – sapling density was highest in winter-grazed plots, suggesting that browsing in wintertime is less detrimental for tree survival and growth. Van Uytvanck (2009) found that browsing intensity on saplings was much greater in spring and summer, when saplings had nutritious buds and green leaves, than in spring or winter. These findings are useful for managers that are confronted with high scrub and tree encroachment. This evidence shows that woodland regeneration is not prevented by winter grazing or year-round grazing by domestic herbivores (cattle, sheep). However, there may be differences in browsing response according to tree or shrub species, plant size at the moment of browsing, local site conditions, frequency of browsing, amount and type of tissue eaten and competition with ground vegetation (Hester et al, 2006).

Time gaps in grazing and disturbances

Time gaps in grazing and one-time disturbances such as flooding and burning are discontinuous events that should be incorporated or accepted in management plans. Short time gaps (a few years) before grazing often occur after cessation of agricultural use and before the start of conservation management. This may be the result of practical regulations or a purposeful measure to trigger succession and tree regeneration. On former pastures, time gaps before grazing should be longer than two years to enable woody species establishment. Intermittent time gaps may be shorter, because regeneration can be accelerated due to already established woody vegetation, including saplings or juvenile trees. Prolonging time gaps may be an option, but this may threaten especially the species-rich grasslands (Bakker et al, 2002). Time gaps before grazing on former arable land should only be taken in consideration when there is a risk of insufficient seed dispersion. This is the case for example, in isolated sites where the establishment of woody vegetation depends on seed dispersal by wind (for pioneer species such as *Salix* and *Betula* species) over long distances. When pioneer species establish massively on former arable land, the immediate presence of grazers will increase spatial heterogeneity in woody pioneer assemblages, which is an important management objective for wood-pastures (Mitlacher et al, 2002). The problem with natural and episodic disturbance dynamics (such as fire, timber harvest, floods, drought and insect defoliation) and their interaction with large herbivore grazing is that the resulting effects are not easily predicted. This lack of predictability poses a substantial obstacle to effective management with large herbivores (Wisdom et al, 2006). However, for wood-pasture management, an insight into the development of vegetation structure and landscape openness is important.

Expected canopy covers on grazed former agricultural land

Determining the extent of landscape openness is a main goal in wood-pasture conservation. It may also be important to estimate economical returns (for example for wood, hay) in the future. The use of information on seedling emergence success, survival and growth of seedlings, existing models on establishment and recruitment in grazed conditions (García, 2001; Van Uytvanck, 2009), recruitment probability at the stage of outgrowth (above the browse line) and some basic demographic models can be used to estimate the degree of canopy cover in developing wood-pastures.

Stage-specific recruitment probabilities assess the proportion of seeds or seedlings passing through a given recruitment limitation (desiccation, competition, herbivory). Because the strong effect of vegetation structure type, the probabilities for recruitment need to be refined. In all vegetation types, the germination-emergence stage and growth stage are crucial. For *Q. robur* and *F. excelsior* the average probability of an established seedling to grow beyond the browsing line was 0.08 and 0.148 respectively, with the highest probability in scrub, intermediate probabilities in tall herb vegetation and zero probability in grassland. Given these probabilities, and the establishment pattern in abandoned pastures and former arable land, the expected canopy cover in developing wood-pastures could be calculated, using the model of de Turckheim and Bruciamacchie (2005). We used a growth rate of an average deciduous tree (6 mm yearly diameter growth) to feed the model. It showed that on former pastures, a grazing pressure between 50 and 100 grazing days $ha^{-1}y^{-1}$ will result in an open woodland type in the next 75 years. Lower grazing pressure leads to a closed forest type. Higher grazing pressure almost completely prohibits woodland regeneration. On former arable land, even a moderate grazing pressure of 125 grazing days will result in a closed canopy in 50–75 years' time span (Figure 9.4). Different scenarios with higher growth rate (8 mm), increasing competition over time and decreasing outgrowth for higher grazing pressures didn't affect the model's output significantly (Van Uytvanck, 2009). Managers should carefully monitor the developing structure of ground and low shrub vegetation to predict possible changes in tree recruitment.

The above-mentioned model for former agricultural land (nutrient-rich systems) predicts an increase of canopy cover in a period of 100 years. In nutrient poor woodland ecosystems, Jorritsma et al (1997) predicted a strong and fast degeneration of *Pinus sylvestris* and *Fagus sylvatica* in forest habitat as an effect of ungulate activities (roe deer, deer, konik horse and highland cattle), even with a very low grazing pressure (0.01–0.08 cattle ha^{-1} y^{-1}). On the contrary, the open landscape components of grazed heathland-woodland complexes will gradually change in more closed woodlands through the establishment of *Pinus sylvestris* (van Wieren and Kuiters, 1997). Therefore, the direction in which wood-pastures may develop in a time span of 100 years may strongly depend on soil nutrient conditions.

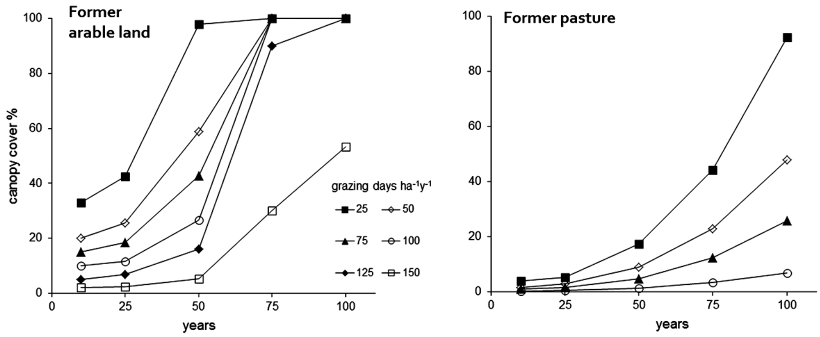

Figure 9.4 Predicted canopy cover in developing woodlands on former pasture and former arable land for different grazing pressures (animal unit grazing days ha^{-1} y^{-1})

Note: Assumed yearly diameter increment = 6 mm.

Source: Van Uytvanck (2009)

Conclusion

Conservation managers have some instruments to handle for the restoration of wood-pastures on abandoned pastures and former arable lands. These instruments are related to managing patterns and processes of woody species regeneration. Grazing intensity thresholds are crucial determinants of woody species establishment. Also, increasing evidence suggests that grazing regime should be adjusted to the nutrient conditions of the soil, because the rate of regeneration of woody species is related to the nutrient conditions of the soil. Also, time gaps between the abandonment of the land (pasture or arable land) and the introduction of large herbivores are of crucial importance in the restoration of wood-pastures. Short time gaps in grazing are generally useful to mimic natural population fluctuations of herbivores and to allow recovery and maintenance of grassland vegetation types with high biodiversity value. Moreover, short time gaps in grazing are important for the development of vegetation structure gradients and outgrowth of woody species. Natural disturbances often interact with grazing, and should also be understood and considered in wood-pasture management. Some uncertainty (for example unpredictable behaviour of large herbivores, appearance of facilitating scrub, seed dispersal potential) should be considered in certain degrees. Depending on the initial conditions, low grazing pressures (<100–150 grazing days ha^{-1} y^{-1}) allow the development of open to closed wood-pasture types within few decades (up to 50 years), some of them having high conservation value. It is clear that, given the appropriate stocking rates, the economical values for the private owner of wood-pastures will be rather low. The challenge will be to create larger areas with different owners and public–private cooperation to restore and maintain wood-pastures with a certain economical return and a high biodiversity. Most likely, areas that tend to be abandoned (for example areas with dry, nutrient poor soils in southeast Europe and medium to large sized river valleys in western Europe) should be considered for this purpose.

Conceptual models as presented in this chapter primarily aim to give broad guidelines for conservation managers. Also, these conceptual models may be used to stimulate new research and management thinking about the interaction effects of large herbivore grazing, episodic disturbances, time gaps and other operating mechanisms in space-limited conditions (for example management measures). An improved management of wood-pastures lies in an improved understanding of: (1) the effects of varying grazing densities of different large herbivore species and (2) the interaction between grazing and various episodic disturbances and other management measures on wood-pasture condition. Further, the spatial and temporal scale of herbivore effects must be explicitly considered to explain their impact on the species richness of wood-pastures. From this perspective, the impact of grazing can be either positive or negative. Studying the structural properties of grazed mosaics (for example configuration, landscape composition, relative covers of landscape elements, development time, land-use history) may give better insights in the related biodiversity.

9.1 Wood-pasture profile: **East Vättern Scarp Landscape, Sweden**

Simon Jakobsson and Regina Lindborg

Name of the wood-pasture: East Vättern Scarp Landscape (Figure 9.5)

Figure 9.5 Typical wood-pasture of the East Vättern Scarp Landscape with oak, hazel, birch and juniper shrubs and a unique and species-rich field layer flora

Source: S. Jakobsson

Altitude, location: The UNESCO Biosphere reserve East Vättern Scarp Landscape (Östra Vätterbranterna) is situated in the boreonemoral zone of southern Sweden, stretching about 60 km from north (64°52’80” N) to south (63°92’20” N), covering approximately 70,000 ha. In the west, the border follows the shore of Lake Vättern, the second largest lake in Sweden and reaches from about 10 to 20 km to the east. The landscape is varied and hilly with altitudes of 88 (Lake Vättern) to 345 m a.s.l.

Geomorphology and climate: The area is situated on primary bedrock of igneous origin, partly broken apart by rift valleys with a magnificent fault facing towards Lake Vättern. Soils are dominated by unwashed till transported here during the latest glaciation, some 10,000 years ago. Thus, shallow till soils and bedrock outcrops characterise most pastures in the area, whereas glaciofluvial deposits are concentrated to the valleys and the southern lowlands. The region belongs to the cold temperate continental climate zone with warm summers. The monthly average temperature is about -3 to -4°C for the coldest month (February) and approximately 15 to 16°C for the warmest month (July). Mean annual precipitation is about 600 mm. Due to the topographical variation and the proximity to Lake Vättern, both temperature and precipitation are varied and short-term disparities between nearby sites are a common weather phenomenon.

History of land use: The topographical complexity with rift valleys cutting through woody highlands combined with lowlands and steep slopes towards Lake Vättern has resulted in distinct subregions regarding land use. Valleys with deeper soils are subject to continuous management as arable fields, whereas the thinner soils of the woodland hills have been mainly used for forestry and grazing. In the 17th century, coal mining increased the demand for paper and timber resulting in large-scale forestry expansion. Even though the intensified forestry practices from the mid-19th century clearly affected the landscape, old traditional outland grazing still shows traces in current woodland management. Compared to the rest of Sweden, this region has a large amount of wood-pastures left that are still managed and form important landscape elements.

Physiognomy: The wood-pastures of the East Vättern Scarp Landscape vary a lot, ranging from very sparse tree cover to dense wood-pastures with up to 200 trees per hectare. Most pastures are heterogeneous with many different tree and shrub species, of which birch (*Betula pendula*), oak (*Quercus robur*), hazel (*Corylus avellana*) and rowan (*Sorbus aucuparia*) often dominate. Pure oak pastures exist, mainly restricted to certain areas formerly belonging to the nobility or the church. Where environmental conditions are suitable, pastures are dominated by birch or Scots pine (*Pinus sylvestris*). In addition, many of the current wood-pastures consist of mosaic lands where small woody patches are surrounded by open grassland strips that have been used for rotation agriculture, including both crop production and grazing.

Biodiversity: The East Vättern Scarp Landscape harbours many threatened species belonging to a wide range of habitats. Among these habitats, the widespread wood-pastures offer an environment essential for many nationally threatened species and species-rich environments in general. Each pasture has its unique properties, thus the between-site variation should be regarded as a biodiversity trigger itself. Birds such as the Eurasian golden oriole (*Oriolus oriolus*), ortolan bunting (*Emberiza hortolana*) and common rosefinch (*Carpodacus erythrinus*) all breed in these habitats. These wood-pastures also sustain very species-rich flora, with species originating from nature forest, meadow and open pasture. Species otherwise rare in Sweden, such as field gentian (*Gentianella campestris*) and eye worth (*Euphrasia rostkoviana ssp. fennica*), are found in these unique environments. Among the most important features of the wood-pastures are the old trees on and in which lichens (for example *Sclerophora farinacea* and *Chaenotheca cinerea*) and insects (for example beetles such as *Anaglyptus mysticus* and *Dinothenarus pubescens*) thrive.

Main threats and status: During the last century, intensification of agriculture has resulted in large-scale abandonment and overgrowth of these highly valuable pastures. This is, in combination with fertilisation, the main threat to the wood-pastures' ecological status. In addition, EU subsidy regulations inhibit the preservation of continuously grazed species-rich pastures with dense tree cover, resulting in clearance of trees and shrubs of many valuable pastures.

Socio-political conflicts between farmers, authorities and NGOs are other major threats to wood-pastures in general. Fortunately, such conflict was turned into a cooperative project including a range of stakeholders, resulting in the foundation of the biosphere reserve East Vättern Scarp Landscape in 2012. Since then, major efforts have been put into restoration and preservation projects throughout the whole area.

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