

# Chapter 1

## Introduction: Grazers and Browsers in a Changing World

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### 1.1 Introduction

*“During the second half of the 20<sup>th</sup> century, the global population explosion was the big demographic bogey ... Now that worry has evaporated, and this century is spooking itself with the opposite fear: the onset of demographic decline. The shrinkage of Russia and eastern Europe is familiar, though perhaps not the scale of it: Russia’s population is expected to fall by 22% between 2005 and 2050, Ukraine by a staggering 43%. Now the phenomenon is creeping into the rich world: Japan has started to shrink and others, such as Italy and Germany, will soon follow. Even China’s population will be declining by the early 2030s, according to the UN which projects that by 2050 populations will be lower than they are today in 50 countries.... People should not mind, though. What matters for economic welfare is GDP per person ..... The new demographics that are causing populations to age and to shrink are something to celebrate [not in Russia or Ukraine though HP & IG]. Humanity was once caught in the trap of high fertility and high mortality. Now it has escaped into the freedom of low fertility and low mortality. Women’s control over the number of children they have is an unqualified good – as is the average person’s enjoyment, in rich countries, of ten more years of life than they had in 1960. Politicians [and companies] may fear the decline of their nations’ economic prowess, but people should celebrate the new demographics as heralding a golden age”.*

(the Economist Editorial 7 January 2006 p 12).

If humanity is at the brink of a ‘Golden Age’, what then is the divination for nature? In this book we will try to foretell how wild herbivores will react to the changes that take place in the world in which they live. That world has been changing since it formed, and for millions of years its plants have been consumed by herbivores. This has led to adaptations in plants in reaction to herbivory, and our present-day species assemblages and landscapes are a manifestation of the forces of natural selection that have been in operation for a very long time. Over a much shorter time, these landscapes have been heavily impacted upon by humans; firstly, by accidentally burning patches of the landscape, but later as a tool to modify that landscape either for capturing or luring game or even for changing the species composition towards a modified vegetation that yields desired produce (e.g., cultivation of hazel in the Mesolithic; Simmons et al. 1981). It is now increasingly clear that the ‘primordial’ Amazonian, Middle American and other rainforests have been strongly modified by local people

(Noble and Dirzo 1997); indeed when the first European colonists came to what is now called New England on the eastern seaboard of the USA the forests were so open and 'Arcadian' that settlers thought it had been created especially for them (Cronon 1983; Prins 1994; cf. Motzkin and Foster 2002; Russell and Davis 2001). In a way that was true since the indigenous people were decimated through diseases involuntarily brought to them by the newcomers, but their hunter-gatherer imprint was still there (e.g., Douglas and Hoover 1988). The same is true for what was first named New Holland and later Australia: non-agricultural people that had settled there some 40,000 years ago had been using fire to modify that landscape for an uncounted number of generations (e.g., Hughes 1987 p 3; Lewis 2002). Wild grazers and browsers that have survived to the present day must have found a way to cope with many of these man-induced changes.

Indigenous plants that had been shaped by natural selection reacted to the new forces, and new types of vegetation emerged. Really big changes started with the emergence of agriculture; not only did plant communities get modified because the competitive interaction between the domesticated and native plant species changed, but land was cleared and often alien species were introduced for food consumption or involuntarily. Many of these species are now considered part of the native flora and only palynological and archaeological research can reveal their non-local provenance and their alien roots. This can be done where the soil archive is good enough to yield the necessary information, and especially where there are sufficient sources and academics to unravel the arcane history of local plant communities, as for example in Europe (e.g., Godwin 1975; Knörzer 1971, 1975; Opravil 1978; Pennington 1969; Van Zeist 1980). In other places, it is the scourge of introduced species that became an economic threat which has fostered a desire to find out their origin (e.g., McFadyen and Skarratt 1996).

Major changes started when early farmers domesticated sheep, goats, cattle, onagers, and donkeys in the Middle East, dromedaries in the Arabian Peninsula, horses in southern Russia, camels and yaks in Central Asia, llamas in South America, water buffalo and zebu in South Asia, gaur, gayal, and banteng in Southeast Asia, and perhaps the latest to be domesticated, reindeer in northern Scandinavia and northern Siberia (e.g., Legge 1996; Köhler-Rollefson 1996; Zeuner 1967). In many of the centres of origin, the use of domestic grazers and browsers in the already modified landscapes led to a landscape that would have been unrecognisable to earlier generations of Man. Superimposed on the changes brought about by climatic change, fire, and felling, the impact of domesticated indigenous browsers and grazers caused forests to disappear first from the Zagros Mountains (e.g., Hole 1996) or in the Lebanon, and then from across that whole range of landscapes of much of Europe (Prins 1998), the high altitude areas of South America, China, and Japan.

As people moved across the landscape in prehistoric times they took with them their domesticated browsers and grazers. The rate of this spread was about 20 km per generation; the spread of farming (or farmers) from the Levant across Europe was 1 km.yr<sup>-1</sup> (Cavalli-Sforza 1996) while the rate for pastoralism across Africa was 0.9 km.yr<sup>-1</sup> (Prins 2000). The result was that by the beginning of our Common Era

across most of the Old World domesticated grazers and browsers (including so-called mixed feeders) were modifying indigenous vegetation communities, but two continents stayed free of domestic livestock, namely Australia and North America.

## 1.2 Dominance of Domesticated Grazers and Browsers

With the advent of European colonialism, Australia and the Americas became an open access area to the grazers and browsers from the Old World. In North America the successful newcomers were cattle, horses, and sheep; in South America cattle, zebu, water buffalo, and sheep took over much of the grasslands, while in Australia introduced sheep, cattle, water buffalo, banteng, camels, donkeys, and horses lived side-by-side, while kangaroos expanded their range as a reaction to surface water becoming available through dams and boreholes. In other places, other non-native grazers and browsers, such as deer and thar (New Zealand) or reindeer (South Georgia) were introduced for sport. The newcomers invaded niches of local mammals (e.g., Breebaart et al. 2002; Dawson et al. 1992; Edwards et al. 1996; Escobar and Gonzalez 1976; Fritz et al. 1996; Genin et al. 1994; Hubbard and Hansen 1976; Lightfoot and Posselt 1977; Prins 2000; Schwartz and Ellis 1981; Thill and Martin 1986).

By the end of the 19th century, the world as we know it took further shape: railway lines opened up the vast prairies of Canada and the United States, and steamships made it possible to start commercially transporting agricultural produce to metropolises where an industrial revolution spurred human population growth. In a series of Homestead Acts, pioneers staked out 110 million hectares of land (Anon. 2005c), which is about 30–50 times the size of countries like the Netherlands, Belgium, Denmark, or Switzerland. As part of the same industrial revolution, railway lines and steamships led to a massive exodus of people from the Ukraine, Poland, Germany, Scandinavia, Scotland, Italy, England, France, Ireland, the Low Countries, and Spain to the New World and Australia. Many of these people went to the cities, but many went also to become farmhands or farmers, cowboys or ranchers. In Argentina, Uruguay, and Paraguay native people were pushed off their land, just as they were in the United States and Canada, Australia, South Africa, and Zimbabwe. Along the Trans-Siberia railway, the Russian Far East was ‘opened up’. As a consequence the human population burgeoned, demanding more and more meat, milk, and fibre. Australia and New Zealand became world leaders for the production of mutton and wool, Chicago became the beef capital of the world, and horses and cattle were exported in enormous numbers from the southern part of South America for meat. Horses were likewise exported from Poland to Western Europe for meat and draught power. The end of the 19th and the beginning of the 20th century saw an enormous demand for horses, not only for transport but also for the war machinery of clashing empires; some 8 million horses were killed at only the Western Front during the Great War. The net result of all these transformations was an enormous growth of domestic browsers and graz-

ers, while indigenous wild ungulates declined or even went extinct, such as the Bluebuck (*Hippotragus leucophaeus*) and Quagga (*Equus quagga*) in southern Africa, the Aurochs (*Bos primigenius*) and the Wild (forest) horse (*E. caballus*) in Europe, the wild Dromedary (*Camelus dromedarius*) in Asia, and in Australia the Eastern hare wallaby (*Lagorchestes leporides*), Central hare wallaby (*L. asomatus*), Toolache (*Macropus greyi*), and Crescent nailtail wallaby (*Onychogalea lunata*). Ungulates that reached the brink of extinction during the last century were the European bison (*Bison bonasus*), American bison (*Bison bison*); Père David's deer (*Elaphurus davidianus*) in China; Swamp deer (*Cervus duvaucellii*) in India; Camel (*Camelus bactrianus*) and Przewalski horse (*Equus przewalskii*) in Central Asia; Wild Asian buffalo (*Bubalus bubalis*), Gayal (*Bos frontalis*), Kouprey (*Bos sauveli*) in South East Asia; Black wildebeest (*Connochaetus gnou*) and White rhinoceros (*Ceratotherium simum*) in South Africa. In 2005 the northern form of the white rhino was declared extinct. Many grazers and browsers became very rare and are presently listed as endangered on the IUCN's Red List. Heavy hunting is cited as the cause of these (near) extinctions, in other cases it has been clearing of indigenous vegetation, or the introduction of new predators such as Red fox (*Vulpes vulpes*) in Australia. A new cause is lawlessness associated with failing nation states or civil war, but competition with domestic stock is a seriously underrated cause. So, what about this heralded 'Golden Age'?

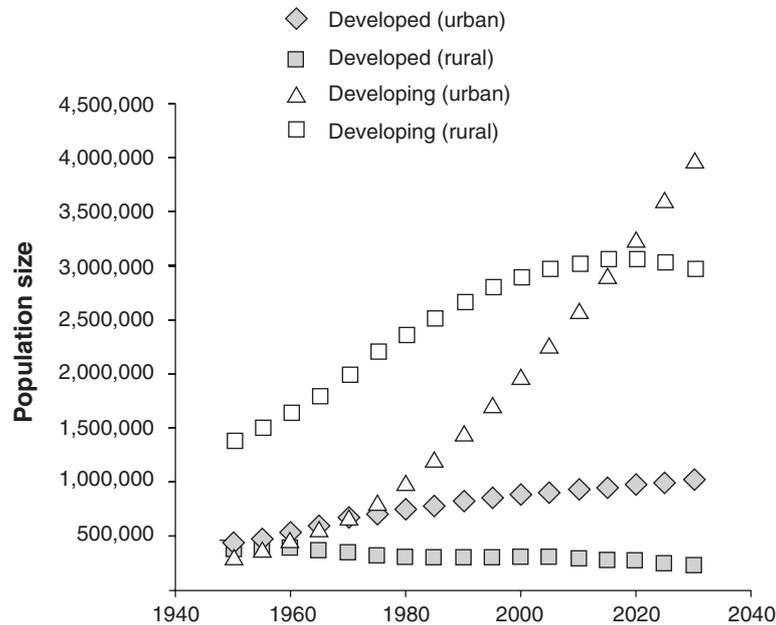
Natural grasslands have nearly been wiped off the face of the earth. For example, in the Ukraine only about 4% of the steppes were found to remain in the original state (Goriup 1998), the South African low veld is natural in about 11% of its extent only (Low and Rebello 1996), the North American tall-grass prairie is all but gone (Packard and Mutel 1997), while in SE Australia a stunning 99.5% of its native grasslands have been converted for agricultural use (Taylor 1998). Worldwide, forests have decreased too, from about 6.5 billion hectares to 3.5 billion since the rise of agriculture-based civilizations (Noble and Dirzo 1997). At present, about 15% of the Earth's land surface is occupied by row-crop agriculture or by urban-industrial areas, and another 6–8% has been converted to pastureland (Vitousek et al. 1997). Estimates of the fraction of land transformed or degraded by humanity, and the fraction of the land's biological production that is used by Man is about 40–50% (Vitousek et al. 1997). Managed grazings cover more than 25% of the global land surface and has a larger geographical extent than any other form of land use (Asner et al. 2004). In the beginning of the 21st century CE, nearly half the nitrogen atoms in the protein of an average human being's body came at some time or another through an ammonia factory, often using the Haber-Bosch process, invented in 1909, combining nitrogen from the air with hydrogen from coal (Anon. 2005a).

So even though landscapes were getting transformed from an often rather forested state to a landscape dominated by agriculture, the potential for increased opportunities were garnered by a small subset of browsers and especially grazers, namely by those few species that were useful to man. When artificial fertilisers were introduced on a massive scale in a number of countries, grassland productivity increased so much that now agricultural economies in the rich countries are reliant on only three domestic species, all three grazers, namely cattle, sheep, and horses.

In the United States, the European Union and also the former Eastern bloc, southern Africa, Australia and New Zealand agricultural policies then started to distort markets at a massive scale in the 1960s. World markets would have dictated a shift away from agriculture in these countries because unsubsidised agriculture became, to a large extent, not profitable if farmers in these areas had to provide their products at world market prices but had to pay labour costs as dictated by the local society's norms. Governments then started subsidising agriculture for two major reasons, namely, to maintain adequate national self-sufficiency and to guarantee farmers (and their dependent communities) a sufficiently high income so that they could continue to participate in society at large. These countries maintained a landscape geared towards maximum agricultural production and very high numbers of domestic grazers. However, there has been a substantial reduction in the numbers of horses in the world over the 20th century as horse power became transplanted by engine power. The first tractors had few advantages over the best horses, but they did not eat hay or oats. The replacement of draft animals by machines released about 25% more land for growing food for human consumption in the middle of the 20th century (Anon. 2005a). Cattle and sheep remained the dominant ungulates in temperate, semi-arid, or arid regions of the globe. In most of Africa and the Middle East goats continued to play an important role in addition to sheep, but for dromedaries there was less of a place as they too were replaced by engine power. South Asia remained dominated by zebu cattle and to a lesser extent water buffalo, while in Southeast Asia it is the other way around; but water buffalo are decreasing in numbers in Indonesia at a high rate. Worldwide, fewer and fewer ungulate species dominate the herbivore communities that modify the vegetation.

### **1.3 The Last 30 Years and the Immediate Future**

Since about 1980 major changes in the non-urban landscapes of Europe and North America have taken place because arable- and livestock-based agriculture is no longer cost-effective; the countryside is becoming devoid of people who use the local resources while an ever increasing number of people move to urban metropolises or peri-urban neighbourhoods (Fig. 1.1). The same trend is visible in other developed countries, such as South Africa, Japan, Thailand, and Australia. Nowadays proportionally more and more people live in cities and towns: in Australia about 85% of the people are living in urban areas (Anon. 2006a), in France it is over 80% (Anon. 2005b), in the most developed part of the world it is on average 76%, and worldwide it is now 40% (United Nations 2006). Fewer people realise, however, that the absolute numbers of people living in rural landscapes is decreasing and, as a result, the number of abandoned villages in France, Italy, Spain, and Portugal is increasing. Even when British or Dutch pensioners take over property in these villages, the surrounding country side remains unused. According to preliminary results of the first national Census since 1989, more than half of Russia's 155,290 villages are abandoned or



**Fig. 1.1** Estimated number of people since 1940 in different parts of the world, and the predicted number up to 2040. (Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2004 Revision and World Urbanization Prospects: The 2003 Revision, <http://esa.un.org/unpp>)

populated by 50 or fewer stragglers (Anon. 2006b). In Wyoming, Nebraska, or Colorado one can drive through ghost towns: “*Virtually all of the 20 poorest counties in America, in term of wages, are on the eastern flank of the Rockies or on the western Great Plains... The area does include several pockets of wretched Native American poverty, but in most of [these] areas the poor are as white as a prairie snowstorm. ...We are seeing a re-acceleration of the population decline. After the kids left in the 1980s and 1990s, things sort of leveled off. Now it's just plain attrition. People are dying. It is fairly common nowadays for rural counties across America to lose people: roughly one in four did in the 1990s*” (Anon. 2005c). In upstate New York and Maine people have voted with their feet: if one walks through the dense forests one stumbles over stone fences that, only a century ago, separated the potato fields of local crofters (Flinn et al. 2005; Litvaitis 1993; Motzkin and Foster 2002; Ramankutty and Foley 1999). In the drier parts of South Africa sheep farms are transformed into wildlife sanctuaries because of the high risks of stock theft or because of other factors that make it uneconomic to continue farming (e.g., Davies 2000). In Australia, one can drive through villages and towns that have been abandoned (cf. Newman 2005). In “Old Europe” (the European Union of 10 countries), the utilized agricultural

area diminished by more than 3 million hectares between 1975 and 1987; between 1980 and 1990 this was 1,251,000 ha in Germany, 1,000,000 ha in France, and 307,000 ha in Italy (EC Commission data). The surface area of permanent meadows and grassland have also strongly declined in “Old Europe” (between 1980 and 1990 1 million hectares; EC Commission data). Also the number of domestic stock declines. Between 1991 and 2001, the number of cattle in Western Europe stabilised at about 90 million head, in Eastern and Central Europe it declined from 50 to 30 million head, and in the EECCA countries (the 12 countries from the Caucasus up to Russia) it showed a massive decline from about 115 to 60 million head. Similar trends are reported for sheep and goats (Anon. 2003; see also FAO 2006).

The reasons for this abandonment are not the same in every situation, but nearly always the ultimate cause is that more jobs and an easier life is available in the cities. Additional factors include lack of children, stock theft, and lack of schools, hospitals, or other services. Demography, market and neo-liberalism all lead to the same result: shops close, services disappear, jobs disappear in the villages but are offered in towns. With the ever-increasing costs of labour as compared to assets, farmers lay-off farm-hands and use machinery to do the work, which further decreases the local job markets. Farmers then get more and more dependent on banks, fodder producers, or equipment sellers for loans, which makes them more vulnerable in times of adversity. Ultimately this frequently results in bankruptcy. Politicians have tried to stop this tide by doling out hundreds of billions of dollars, pounds, liras, guilders, pesetas, yen, kronor, euros, francs, and marks in subsidies to maintain the countryside in a productive posture. For example, “*the [American Great Plains] region has plainly failed to adapt to a world in which grain and cattle are cheap. ... The crops go out by the truckload to provide jobs elsewhere. How does the region survive? For all the brouhaha about independence, it leans heavily on federal government. In 2003, the government spent an average of US\$ 10,200 per person in Judith Basin county. North Dakota counties averaged \$ 9,000. Most of it comes in the form of farm subsidies: federal price supports and disaster payments*” (Anon. 2005c).

This has led to an ever-increasing cost for food for the urban people, and an ever-increasing call for reducing toll barriers around ‘Fortress Europe’. Agricultural subsidies have decreased already, and will decrease further. To save the last of the uneconomic farmers, governments dole out subsidies for maintaining the countryside for the sake of biodiversity, which often is a *gotzpe* because the type of biodiversity-rich agricultural landscapes of the early 1900s have been eradicated by these very same farmers when they were subsidised to meet production goals at the cost of the environment. Land abandonment leads to changes in the landscape to which wild grazers and browsers react, however, the decreasing numbers of domestic stock inhabiting the former extensive farms in developed countries offers opportunities for wild herbivores to exploit the unconsumed vegetation resource. White-tailed deer (*Odocoileus virginianus*) numbers, for example, have increased dramatically between 1980 and 2000 in many areas of North America (Riley et al. 2002).

Apart from economic drivers, sociological and demographic changes, and market distortions, there is a fourth insidious cause of change, namely climate change, especially the increasing concentrations of carbon dioxide in the atmosphere. This change may lead to changed competitive interactions between different plant groups; carbon dioxide is used in horticulture as an artificial “fertiliser” and it allows plants to grow for more hours in the day so that more carbohydrates are produced. It appears as if a number of woody species surpassed a threshold of starch deposition in their roots, making them much more fire-resistant, because with sufficiently high carbohydrate reserves these woody species can resprout and grow quickly out of the fire-trapping zone. This in turn leads to an altered balance between grasses and woody species, favouring the latter (Bond et al. 2003). This leads to changes in species composition creating decreasing opportunities for grazers and increased ones for browsers.

Under a mode of production that encourages high efficiency, land abandonment and land use intensification are two sides of one coin. “*With the [human] population growth rates falling sharply while [agricultural] yields continue to rise, even the acreage devoted to wheat may now begin to decline for the first time since the stone age.*” (Anon. 2005a). Wheat leads the field in world crops. In 2004, the worldwide area (in millions of hectares) under wheat was about 220, rice about 150, maize some 140, other cereals about 160, soybeans 90, pulses 70, roots and tubers 50 (FAO 2006). This intensification is much easier to achieve in flat areas than in montane or steeply hilly areas (Anon. 2005d). The number of farms decreases fast in OECD-countries. In Europe, most changes take place in mountainous areas (Batzing et al. 1997; MacDonald et al. 2000). For example in France the number of farms declined from about 880,000 in 1950 to 220,000 in 2005 (Anon 2005d). Poor, hilly areas in France, Italy, Spain, and Portugal lost more than half their active population since the 1970s (EC Commission data; Torrano and Valderrabano 2004). In the north of former East Germany, between 1991 and 1997 the number of people working in agriculture declined from 296,000 to 164,000 (Shaphiro and Stankevich 2000). Also in Australia the rural population is declining (Bennett et al. 2004), as it is in Patagonia where sheep stock halved between 1980 and 2000 and hundreds of farms were abandoned here (Borrelli and Cibils 2005) and in northwestern Argentina (Montero and Villalba 2005). In New Zealand’s hill country woody encroachment takes place because of economic marginalisation (Popay et al. 2002), and Japan’s countryside also is experiencing depopulation (Liu et al. 2003, Shimoda 2005). In a number of countries, even the absolute population numbers are falling. Russia’s population is expected to fall by 22% between 2005 and 2050, the Ukraine by a staggering 43%. Japan has started to shrink in 2005 and by 2050 a 12% fall is expected, the same fall as is expected for Italy. Germany is expected to have declined in 2050 by 5%. Even China’s population will be declining by the early 2030s, according to the UN, which projects that by 2050 populations will be lower than they are today in 50 countries (the Economist, Editorial, 7 January 2006). Russia’s Far East is quickly depopulating (Kontorovich 2000) but so is Nova Scotia and parts of Canada’s hinterland (Millward 2005).

The net results of these changes in land use, are to a large extent the focus of this book. In Portugal, for example, rural depopulation and land abandonment has led to a significant decline in agricultural land and low shrub and an increase in tall shrublands and forest, with an increase of 20–40% in fuel accumulation at a landscape level (Moreira et al. 2001; see also Debussche et al. 1999; Tinner et al. 1998; Preiss et al. 1997; Valderrabano and Torrano 2000). In Table 1.1 we have summarised different scenarios as we see them, focussing on the balance between woody species and grasses or herbs. Grazers and browsers react to these changes (Table 1.2), but they can also be used to prevent changes in vegetation composition, or to facilitate them. Herbivores, in contrast to many other organisms, can act as landscape modifiers, but they can only do this to a limited extent. Since browsers concentrate on woody species and herbs, while grazers focus on grass, the questions we are asking are:

1. What adaptations do large herbivores have to consuming browse- or grass-dominated diets?
2. What are the consequences of consuming these diets for large herbivore population ecology?
3. Are there difference between grazers and browsers in their impact on ecosystem structure and functioning?
4. How can we use this information to manage large herbivores in landscapes that are changing due to anthropogenic and climatic effects?

Land abandonment and woody encroachment are prevailing trends in the rich countries or in countries of the temperate zones. In the developing countries more typical for the tropics and sub-tropics, land abandonment is not prevalent yet although the level of urbanization is still increasing. However, after the expected peak in human numbers before the middle of the 21st century (Fig. 1.1), it is also likely that in these areas there will be an expansion of bush and forest.

## 1.4 Societal Relevance

Are changes in the landscape relevant? Should the public or the natural resource managers worry about a shift in the balance between woody species and grasses, or about the rapid increase of wildlife species, or about land abandonment? Is it important to know whether these shifts in the landscape mosaic can be controlled, either facilitated or suppressed? There are a number of reasons why we think this is important:

*Water.* A shift towards more woody cover often leads to a reduced amount of water infiltration into the soil, because trees evaporate more water than grasses, and pine trees or firs continue this evapo-transpiration even in winter (e.g., Persson 1997). This means less water is available for agricultural production and less aquifer replenishment, so less drinking water and/or process water for industry.

**Table 1.1** Different combinations of change lead to different effects on herbivores and the landscape

Increased CO <sub>2</sub> - levels lead to shift in balance between woody species and herbaceous layer	No depopulation of rural areas	No land abandonment	Market distortions and farm subsidies continue	Very strong intensification but no bigger farms; intensification also far from markets	No place for wild herbivores. Domestic herbivore species richness decreases and will only be kept indoors	Very intense use of fertilisers, irrigation, grass cutting; woody species only if necessary (e.g., fodder)
			Market distortions and farm subsidies stop	Very strong intensification and also bigger farms; intensification only where it pays	Place for wild herbivores on game farms. Domestic herbivore species richness can even increase if there is a market for novelty products	More interregional variation; some areas very intensively used, others much less so. Woody encroachment in less intensively used areas
		Land abandonment	Market distortions and farm subsidies continue	Intensification on bigger farms; intensification also far from markets	Increasing place for wild herbivores. 'Wild game' tolerated if incentives are paid to maintain them. Domestic herbivore species richness decreases	Governments can demand environmental schemes for biodiversity. Discouraging woody encroachment costly
			Market distortions and farm subsidies stop	Bigger farms at the cost of others; intensification only where it pays	Increasing place for wild herbivores. 'Wild game' tolerated if they provide economic return. Place for wild herbivores on game farms.	Interregional variation in farm profitability will increase, and so will on-farm variation. Woody encroachment will be tolerated in many places within the (farm) landscape even if they have no function.

Increased CO <sub>2</sub> levels lead to shift in balance between woody species and herbaceous layer	Depopulation of rural areas	No land abandonment	Market distortions and farm subsidies continue	Increased land holdings, leading to bigger farms; further intensification	Domestic herbivore species richness may increase if there is a market for novelty products
	Land abandonment	Market distortions and farm subsidies stop	Increased and intensified holdings only where it pays (increased abandonment elsewhere)	No place for wild herbivores on farms. Domestic herbivore species richness decreases	Intermediate use of fertilisers, irrigation, grass cutting; woody species maintained on farm only if necessary (e.g., fodder).
	Land abandonment	Market distortions and farm subsidies stop	Much bigger farms are possible but hardly any intensification taking place; land holding size will also increase far from markets and hence land abandonment will be countered	No place for wild herbivores on farms. Domestic herbivore species richness decreases	More interregional variation; some areas intensively used, others much less so. Woody encroachment in less intensively used areas
		Market distortions and farm subsidies continue		Little place for wild herbivores. Domestic herbivore species richness decreases, ample scope for mega dairy projects and feedlots	Importance of fertilisers decreases, but local irrigation, grass cutting; woody species maintained on farm only if necessary (e.g., as windbreak)

(continued)

Table 1.1 (continued)

Market distortions and farm subsidies stop	Much bigger farms are possible but hardly any intensification will take place, and only then where it pays (increased abandonment elsewhere)	Increasing place for wild herbivores. 'Wild game' tolerated if cost-effective. Place for wild herbivores in game parks. Domestic herbivore species richness may increase if there is a market for novelty products	Interregional variation in farm profitability will increase, and so will on-farm variation. Woody encroachment will be tolerated in many places within the (farm) landscape even if they have no function
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**Table 1.2** The effect of the scenarios from Table 1.1 on domestic herbivores and on wild herbivores

Scenario elements from Table 1.1 (CO <sub>2</sub> -levels are assumed to increase in all possible scenarios)	Effect on <i>domestic herbivores</i> in the context of the ecology of grazers and browsers	Effect on <i>wild herbivores</i> in the context of the ecology of grazers and browsers
Rural areas without land abandonment or depopulation, while market distortions and farm subsidies do not allow much scope for increased land holding size due to mergers, and farmers rely heavily on further farm intensification	Very few browsers, if any, will find a place in this system. Animals will be kept indoors, and be fed with imported food and silage from intensively used (parts of) farms.	Small wild grazers, like migratory geese, can benefit but otherwise the landscape will become devoid of wild grazers and browsers.
Rural areas without land abandonment or depopulation, but cessation of market distortions and farm subsidies lead to a moderate increase in size of land holdings in places where it is economically profitable to merge. Cessation of agriculture in regions where it is no longer viable, but in regions where it is profitable most farms will further intensify	Market for novelty products can become important, such as lammas in Europe, and farmers may switch to game farming as in South Africa or New Zealand.	There will be an effect outside the region towards other regions: there abandonment will be promoted leading to woody encroachment and build-up of browser populations.
Land abandonment but no depopulation of rural areas, while market distortions and farm subsidies continue leading to much increased land holding size due to mergers even in areas where it does not make sense economically. Intensification is driven by subsidies even in places far removed from markets. There will be little land abandonment because this trend will be counteracted by subsidies	Very few browsers, if any, will find a place in this system. The industry would like to keep animals indoors, and fed on imported food and silage from intensively used farms, but the public will demand 'romantic' landscapes with domestic stock kept outdoors	Little opportunity for wild species in the landscape because abandonment is counteracted upon by government and farmers. Nature management will ask for woody species suppression by browsing, mowing, and cutting. Increased options for small wild browsers; if wild grazers are available, they will be kept fenced

(continued)

**Table 1.2** (continued)

Scenario elements from Table 1.1 (CO <sub>2</sub> -levels are assumed to increase in all possible scenarios)	Effect on <i>domestic herbivores</i> in the context of the ecology of grazers and browsers	Effect on <i>wild herbivores</i> in the context of the ecology of grazers and browsers
Land abandonment but no depopulation of rural areas, but cessation of market distortions and farm subsidies lead to an increase in size of land holdings in places where it is economically profitable but cessation of agriculture where it is not. Intensification is not necessary on farms that stay in operation	‘Traditional’ grazers (cattle, sheep) will be used on big farms, but market for novelty products could become important, and farmers may switch to game farming.	Reasonable opportunities for wild species in the landscape because pockets of land will be abandoned by agriculture. The opportunities are there for small and not so small browsers. Little scope for 20th century nature management. Increased options for large herds of wild grazers if they can be made economically; they will be kept fenced.
Depopulation of rural areas but without land abandonment, while market distortions and farm subsidies continue leading to increased land holding size due to mergers and further farm intensification	Very few browsers, if any, will find a place in this system. Animals will be kept both indoors and outdoors, and be fed on imported food and silage from intensively used (parts of) farms	Small wild grazers, like migratory geese, can benefit but otherwise the landscape will become devoid of wild grazers and browsers
Depopulation of rural areas but without land abandonment, but cessation of market distortions and farm subsidies lead to a moderate increase in size of land holdings in places where it is economically profitable to merge. Cessation of agriculture where it is no longer viable, but on most farms intensification necessary	Very few browsers, if any, will find a place in this system. The industry would like to see animals kept indoors but to be outdoors as much as feasible, and partly fed on silage from intensively used parts of the farms. Feedlot farming	There will be a strong effect outside the region towards other regions: there abandonment will be promoted leading to woody encroachment and build-up of browser populations
Land abandonment and depopulation of rural areas, while market distortions and farm subsidies continue to lead to increased land holding size due to mergers. Intensification is not necessary on farms that stay in operation. There will be little land abandonment because this trend will be counteracted by subsidies	Very few browsers, if any, will find a place in this system. The industry would like to see animals kept indoors but to be outdoors as much as feasible, and partly fed on silage from intensively used parts of the farms. Good options for mega-dairy projects, feedlot farming and extensive ranching	Small wild grazers, such as migratory geese, can benefit to a limited extent because of decreased fertiliser input. The landscape will become devoid of grazers and browsers, because farmers will suppress woody encroachment and will see game as a competitor for forage

(continued)

**Table 1.2** (continued)

Scenario elements from Table 1.1 (CO <sub>2</sub> -levels are assumed to increase in all possible scenarios)	Effect on <i>domestic herbivores</i> in the context of the ecology of grazers and browsers	Effect on <i>wild herbivores</i> in the context of the ecology of grazers and browsers
Land abandonment and depopulation of rural areas, but with cessation of market distortions and farm subsidies will lead to an increase in size of land holdings in places where it is economically profitable but cessation of agriculture where it is not. Intensification is not necessary on farms that stay in operation	Domestic herbivore species richness may increase if there is a market for novelty products. Low fertilizer input, coupled with large farm sizes will require the suppression of woody encroachment. Burning and stumping necessary to maintain grazing lands	Increasing place for wild herbivores. 'Wild game' tolerated if cost-effective. Place for wild herbivores on game ranches and private game parks. Burning necessary to encourage grazers. There will be a strong effect outside the region towards other regions: there abandonment will be promoted leading to woody encroachment and build-up of browser populations

*Fire.* More trees and less herbaceous vegetation can result in large build ups of combustible material, changing landscapes that were fire resistant in their agricultural state into fire-prone landscapes (cf. Bonazountas et al. 2005; Finney 2005; Haight et al. 2004; O'Laughlin 2005; Sturtevant et al. 2004). This leads to loss of life and property (e.g., Chen and McAneney 2004), and increased transaction costs for society because of increasing insurance premiums. Uncontrolled forest succession as consequence of the accelerated socioenvironmental change in the Mediterranean forested landscapes has shown to lead to critically enhanced risk for fires (Tabara et al. 2004).

*Accidents.* Land abandonment together with higher wildlife densities increase chances for traffic accidents (e.g., Doerr et al. 2001). A person driving an ordinary car at 80km/hr who collides with a wild boar has a very high chance of being killed; tall-legged moose smash through wind screens in collisions. Apart from sorrow and suffering, increased insurance premiums lead to increased costs of transport.

*Diseases.* Increased wildlife densities, especially of deer, can lead to the closure of the life cycle of tick-borne diseases. For example, Lyme's disease needs small intermediary hosts such as mice or blackbirds but also large ones, such as roe deer or red deer. An increased number of deer leads to an increased incidence of life-endangering parasitic diseases (Jensen and Jespersen 2005; Randolph 2004; Zavaleta and Rossignol 2004).

*Cultural heritage.* Particularly in Japan and Europe, societies and governments have gone to great effort to stop the countryside from getting clogged-up with ungainly industry by applying zoning laws and heritage protection. In these regions, national parks have even been equated with mediaeval or pre-industrial landscapes, and not, like in Africa or North America, with pristine nature (where, admittedly, 'native peoples' had had an often unrecognised impact). Land abandonment and depopulation threaten this medium-intensity agricultural countryside that is still highly valued by the public.

By asking ourselves how grazers and browsers function in the landscape, we believe that we are able to help developing awareness of these often unwanted changes, but also that we are finding tools for the management of these landscapes. The negative aspects of landscape change that we spelled out are, however, offset by a very positive trend:

*Nature.* Changes in the balance between grasses and trees can have profound impact on the many other wild species that make use of the landscape. That local plant communities change is self-evident, but linked to that are the changes at lower and higher trophic levels (e.g., Litvaitis 1993; Preiss et al. 1997). Depopulation and land abandonment is leading to enormous opportunities for wildlife to re-establish itself in the countryside, and for a new natural system to develop. In many of the areas that have been intensively used for decades or even centuries, wildlife was on the brink of extinction, but now it is bouncing back. The number of roe deer in Europe or white-tailed deer in North America have not been so high for centuries, and that is true for many others species as well.

Many of the indigenous wild species have been wiped out, especially wild grazing species. Now browsers and intermediate feeders are doing well in the increasingly forested landscapes of Europe and North America. Also feral browsers do exceedingly well in some areas, for example goats and dromedaries in Australia. In the absence of wild grazers, horses and donkeys have the ability to thrive, but not sheep. Perhaps in coming years in Europe there will as much opportunity for wisent (European bison) as there is for bison in America.

Landscapes all over the world have been changing, and herbivores whether they are wild, feral or domestic, live and die at the hand of man. The different chapters in this book give clues about why some species live and others die, why some species or classes of species have selective advantages over others, and how an understanding of their ecology in the past or under 'pristine conditions' may give educated guesses about how they will fare in future. In the Third World or in the rapidly developing new economies the coming decades will be bleak, but in countries in the temperate zone we forecast a 'Golden Age' for wild browsers and to a lesser extent for wild grazers.

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