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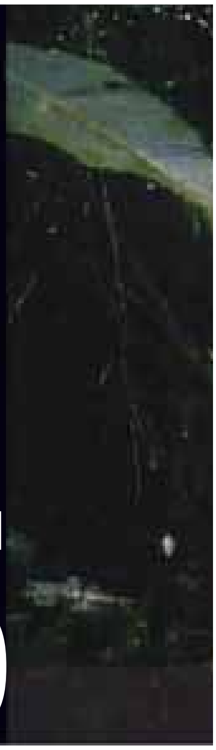

Livestock's impact on biodiversity

5.1 Issues and trends

An unprecedented crisis

Biodiversity refers to the variety of genes, species and ecosystems that can be found in the environment. Short for biological diversity, the term encompasses the entire expression for life on the planet and is generally categorized in three dimensions:

- genetic diversity or the total of genetic information contained in the genes of individual plants, animals and micro organisms;
- species diversity or the variety of living organisms on earth; and
- ecosystem diversity or the variety of habitats and ecological processes in the biosphere.

Biodiversity contributes to many constituents of human well-being, including security, basic materials for a good life, health, good social relations and freedom of choice and action (MEA, 2005b). It does so directly (through provisioning, regulating and cultural ecosystem services) and indirectly (through supporting ecosystem services). Biodiverse ecosystems tend to be more resilient and can therefore better cope with an increasingly unpredictable world (CBD, 2006). For centuries, human beings have benefited from the exploitation of biodiversity, at the same time as they were often reducing it by conversion of natural ecosystems for human uses. Agriculture, livestock, fisheries and forestry have placed significant pressures on biodiversity while providing the basic building blocks for development and economic growth.

The world's biodiversity is facing a crisis without precedence since the end of the last ice age, affecting all its three dimensions. Genetic diversity is at risk, as wild population sizes shrink drastically and with them the gene pool. Species diversity is confronted with rates of extinction that far exceed the "background rate" found in the typical fossil record. The full range of ecosystems diversity is being threatened by transformation through human activities.

The millennium ecosystem assessment (MEA) examined the state of 24 ecosystem services that make a direct contribution to human well-being. It concluded that 15 out of 24 are in decline. And as the Global Biodiversity Outlook of the Convention on Biological Diversity points out, there are important additional reasons to care about the loss of biodiversity, quite apart from nature's immediate usefulness to humankind. Future generations have a right to inherit a planet thriving with life, and which continues to afford opportunities to reap the economic, cultural and spiritual benefits of nature (CBD, 2006). Many would argue that every life form has an intrinsic right to exist. Species alive today are millions of years old and have each traveled unique evolutionary paths, never to be repeated, in order to reach their present form.

Concern over the loss of biodiversity, and the recognition of its crucial role in supporting human life, led to the creation, in 1992, of the Convention on Biological Diversity (CBD) a legally binding global treaty having the objective of the conservation of biodiversity and the sustainable use of its components. As important tools, the CBD includes the development of national biodiversity strategies and action plans. Although almost every country developed such strategies, progress remains very limited towards essential goals such as the improvement of capacity for implementation and national-level planning, as well as actual implementation (CBD, 2006). The greatest conservation efforts are pursued over endangered species and their habitats, while ecosystems services receive less consideration.

According to the MEA Report (2005b), the most important direct drivers of biodiversity loss and ecosystem service changes are:

- habitat change (such as land use changes, physical modification of rivers or water withdrawal from rivers, loss of coral reefs, and damage to sea floors resulting from trawling);
- climate change;
- invasive alien species;
- overexploitation; and
- pollution.

Livestock play an important role in the current biodiversity crisis, as they contribute directly or indirectly to all these drivers of biodiversity loss, at the local and global level. Typically, biodiversity loss is caused by a combination of various processes of environmental degradation. This makes it hard to single out the contribution of the livestock sector, and this is further complicated by the many steps in the animal food product chain at which environmental impact occurs.

Livestock-related land use and land-use change modify or destroy ecosystems that are the habitats for given species (see Chapter 2). Livestock contribute to climate change, which in turn has a modifying impact on ecosystems and species (see Chapter 3). Terrestrial and aquatic ecosystems are affected by emissions into the environment (nutrient and pathogen discharge in marine and freshwater ecosystems, ammonia emissions, acid rain). The sector also directly affects biodiversity through invasive alien species (the livestock themselves and diseases for which they may be vectors) and overexploitation, for example through overgrazing of pasture plants. This complex picture is further complicated by the fact that livestock first started to affect biodiversity millennia ago when they were domesticated and provided humans with a way to exploit new resources and territories that were previously unavailable. These historic changes continue to affect biodiversity, while the effect of current degradation processes (many of which are described in the preceding chapters) is superimposed.

This chapter first provides an overview of the status of global biodiversity. Then livestock's contribution to biodiversity loss is assessed, along the various steps of the animal product food chain. As a consequence of the complexity described above, this assessment is sometimes necessarily fragmentary and anecdotal, but it still provides an indication not only of the significance of the livestock sector's impact but also of the challenges of – and opportunities for – slowing, halting or reversing the degradation process. A number of technical options exist to reduce the negative impact of a number of some current practices and change processes. These options are presented in a last section.

5.2 Dimensions of biodiversity

Biodiversity is characterized by multiple dimensions. At the level of living organisms intra- and inter-species diversity mostly refers to the genetic and phenotypic side of biodiversity. At higher scales biodiversity through ecosystem richness refers to how species are assembled into diverse biotic communities within a wide range of biotopes.[1]

Inter-species diversity

Inter-species biodiversity refers to the total number of species (animals, plants and microbes) on earth. The total number of species is still unknown. Around 1.8 million species have been described to date, but many more are believed to exist – estimates range from 5 to nearly 100 million. 14 million has been proposed as a reasonable working estimate (see Table 5.1). Based on the latter figure, only 12 percent of the estimated total number of species have been classified so far.

Table 5.1

Estimated numbers of described species, and possible global total

Kingdoms	Described species	Estimated total species
Bacteria	4 000	1 000 000
Protoctists (algae, protozoa, etc.)	80 000	600 000
Animals	1 320 000	10 600 000
Fungi	70 000	1 500 000
Plants	270 000	300 000
Total	1 744 000	14 000 000

Source: UNEP-WCMC (2000).

Existing species are not evenly distributed on the globe. Some areas are much richer in species than others and many species are endemic to a specific region. In general diversity declines towards the poles. Humid tropical regions are particularly rich in species and contain numerous endemic ones. The environments richest in biodiversity are moist tropical forests that extend over some 8 percent of the world's land surface, yet they hold more than 50 percent of the world's species. Tropical regions support two-thirds of the estimated 250 000 plant species, and 30 percent of the bird species. Similarly, inland waters represent a vanishing small proportion of the earth's total water but they contain 40 percent of all aquatic species that are often endemic (Harvey, 2001).

Intra-species diversity

Intra-species diversity refers to richness of genes within a given species. It encompasses the genetic variation among individuals within the same population and among populations. Genetic diversity represents a mechanism for populations and species to adapt to changing

[1] A biotope is an area that is uniform in environmental conditions and in its distribution of animal and plant life.

environments. Intra-species diversity is crucial to the resilience of populations and ecosystems against unpredictable and random events. The greater the variation, the higher the chances that a species will have some individuals with genes adapted for a new environment that can be passed on to the next generation. Reduced intra-species diversity not only reduces resilience, but also increases the probability of inbreeding, often leading to an increase in genetic diseases that may in the long run threaten the species itself.

The best known example of intra-species diversity is in agricultural biodiversity. Agricultural biodiversity is a creation of humankind and includes domesticated plants and animals, as well as non-harvested species that support food provision within agro-ecosystems. In the case of livestock, the initial natural selection that gave birth to the wild progenitor was followed by thousands of years of domestication and selective breeding by humans. Farmers and breeders have selected animals for a variety of traits and production environments, resulting in the development of more than 7 600 breeds of livestock (FAO, 2006c). From just nine of the 14 most important species (cattle, horse, ass, pig, sheep, buffalo, goat, chicken and duck) as many as 4 000 breeds have been developed and used worldwide.

In the wild, intra-species genetic diversity is becoming a central preoccupation for wildlife management and conservation. When populations become too isolated, inbreeding phenomena may result if the size of the population is not large enough. Therefore, allowing isolated wildlife populations to interbreed can help exchange of genes and improve the genetic pool of wildlife populations.

Ecosystem diversity

An ecosystem is an assemblage of living species within a biotope that through the interaction with its physical environment functions as a unit. Most classification systems for ecosystems use biological, geological and climate characteristics, including topography, vegetation cover or structure, even cultural or anthropogenic factors. Ecosystems can be of any scale, from a small pond to the entire biosphere, and interact with each other.

Attempts have been made to characterize ecosystems and their diversity over wide areas. WWF (2005) defines an ecoregion as a large area of land or water that contains a geographically distinct assemblage of natural communities that (a) share a large majority of their species and ecological dynamics; (b) share similar environmental conditions, and; (c) interact ecologically in ways that are critical for their long-term persistence. Using this approach, WWF has identified 825 terrestrial ecoregions globally (a set of approximately 500 freshwater ecoregions is under development) and assessed the status of ecosystem diversity in each of these regions. On a still broader scale the World Resources Institute (2000) distinguishes five major and critical biomes shaped by the interaction of physical environment, biological conditions and human intervention: agro-ecosystems, coastal and marine ecosystems, forest ecosystems, freshwater systems and, grassland ecosystems. Forests, which harbour about two-thirds of the known terrestrial species, have the highest species diversity and local endemism of any biome.

Ecosystems are central to the functioning of the planet as they provide services that regulate the main natural cycles (water, carbon, nitrogen, etc.). These services include: maintenance of watershed functions (infiltration, flow and storm control, soil protection); pollution removal from air and water (including the recycling and sequestration of carbon, nutrients and chemical pollutants); and provision of habitat for wildlife. For humans, ecosystems provide a wide range of goods and services including food, energy, materials and water, but also aesthetic, cultural and recreational values. The level of goods and services provided vary greatly between the different ecosystems.

Biodiversity under threat[2]

The three dimensions of biodiversity (genes, species and ecosystems) are all interconnected, and all are eroding at a fast pace worldwide. Any phenomenon impacting one dimension will inevitably impact the others: reduction of genetic diversity can lead, at the extreme, to local or total extinction of a species. The disappearance of one species can break the balance between the different wildlife population species, which may in turn affect ecosystem functioning: predators have been shown to be critical to diversity and stability. For example, the hunting of carnivores has often resulted in increased herbivore populations leading to changes in vegetation affecting many species. Similarly, habitat destruction, change and fragmentation threaten intra- and inter-species genetic diversity. This occurs first because the total area and carrying capacity of the wildlife habitat is reduced by the conversion process, and second because fragmented habitats isolate populations from another, narrowing the genetic pool of each population and making them more vulnerable to disappearance.

The principal threats by ecosystem are presented in Table 5.2. Forested ecosystems, and in particular primary forest ecosystems, are under great threat at the global level. Global forest cover has been reduced by 20 and 50 percent since pre-agricultural times (Matthews *et al.*, 2000). As much as 30 percent of the potential area of temperate, subtropical and tropical forests has been converted to agriculture. Since 1980 forest area has increased slightly in industrial countries, but has declined by almost 10 percent in developing countries (WRI, 2000). The great majority of forests in industrial countries, except Canada and the Russian Federation, are reported to be secondary forest (having regrown after being logged over at least once) or converted to plantations. These areas are poor in biodiversity, compared to the original primary forest, and the loss of many species during the land-use transition is often final. Tropical deforestation affecting primary forest probably exceeds 130 000 km^2 a year (WRI, 2000).

The world's freshwater systems are so degraded that their ability to support human, plant and animal life is greatly imperiled. Half the world's wetlands are estimated to have been lost in the twentieth century, converted to agriculture and urban areas, or filled and drained to combat diseases such as malaria. As a result, many freshwater species are facing rapid population decline or extinction and freshwater resources for human use are increasingly scarce.

The conversion of coastal ecosystems to agriculture and aquaculture, along with other pressures such as erosion and pollution, are reducing mangroves, coastal wetlands, sea grass areas and coral reefs at an alarming rate. Coastal ecosystems have already lost much of their capacity to produce fish because of over-fishing, destructive fishing techniques and destruction of nursery habitats.

Temperate grasslands, savannahs, and shrublands have experienced heavy conversion to agriculture, more so than other grassland types including tropical and subtropical grasslands, savannahs and woodlands. In many places the introduction of non-native species has negatively affected grassland ecosystems leading to a decrease in biodiversity.

Agro-ecosystems are also under great threat. Over the last 50 years, about 85 percent of the world's agricultural land has been affected to some degree by degradation processes including erosion, salinization, compaction, nutrient depletion, biological degradation and pollution. About 34 percent of all agricultural land contains areas only lightly degraded, 43 percent contains moderately degraded areas and nine percent contains strongly or extremely degraded areas (WRI, 2000). Agricultural intensification often diminishes biodiversity in agricultural areas, for example through the excessive application of fertilizer and pesticides, by reducing the

[2] Drawn from UNDP, UNEP, WB and WRI (2000); and Baillie, Hilton-Taylor and Stuart, 2004.

Table 5.2

Major ecosystems and threats

Categories	Major ecosystems	Major threats
Marine and coastal	Mangroves, coral reefs, sea grasses, algae, pelagic communities, deep sea communities	Chemical pollution and eutrophication, overfishing, global climate change, alterations of physical habitat, invasion of exotic species.
Inland water	Rivers, lakes, wetlands (bogs, fens, marshes, swamps)	Physical alteration and destruction of habitat through water extraction, drainage, canalization, flood control systems, dams and reservoirs, sedimentation, introduced species, pollution (eutrophication, acid deposition, salinization, heavy metals).
Forest	Boreal and temperate cornifers, temperate broadleaf and mixed, tropical moist, tropical dry, sparse trees and parkland	Physical alteration and destruction of habitat, fragmentation, changes of fire regimes, invasive alien species, unsustainable logging, extraction of non-timber forest products, fuelwood extraction, hunting, unsustainable shifting cultivation, climate change, pollutants including acid rain.
Drylands	Mediterranean, grasslands, savannahs	Physical alteration and destruction of habitat, changes of fire regimes, introduced herbivores (particularly livestock), non-native plants, depletion of water resources, harvest of fuelwood, over-harvest of wild species, chemical pollution, climate change.
Agricultural	Arable land (annual crops), permanent crops, permanent pasture	Soil degradation, excessive use of fertilizer, nutrient depletion, loss of genetic diversity, loss of natural pollinators.

Source: UNDP, UNEP, WB and WRI (2000).

space allotted to hedgerows, copses, or wildlife corridors, or by displacing traditional varieties of crops with modern high-yield but uniform crops.

Ecosystem change and destruction can reduce both intra- and inter-species biodiversity. Furthermore, the increasing pressure on species through over-harvesting and hunting (of predators, for bush meat or for leisure) and the side effects of pollution processes further erode intra- and inter-species biodiversity.

The IUCN Red List published in 2006 reports that more than 16 000 species are threatened with extinction, of which 1 528 are critically endangered. Some groups of organisms are more threatened than others: the highest proportions of species threatened were for amphibians and gymnosperms (31 percent), mammals (20 percent) and birds (12 percent), while for fish and reptiles the proportion was 4 percent (IUCN, 2006).

Africa south of the Sahara, tropical South and Southeast Asia and Latin America, i.e. the regions that are home to the majority of species in the world, have a greater number of threatened species. Though alarming, the Red List figures do not represent the real scale of the problem because it was only possible to evaluate 2.5 percent of all described species (which in turn are only a small proportion of the total number of species). The difficulty of quantifying diversity of species makes the evaluation of the impacts of human activities even more difficult.

Extinction of species is a natural process, and throughout the fossil record – except for periods of mass extinction there has been a natural "background rate" of extinction. Recent extinction rates far exceed the background rates found in the fossil record. The known rate of extinctions of birds, mammals and amphibians over the past 100 years indicate that current rates are 50 to 500 times higher than background rates found in the fossil record. If "possibly extinct" species are included this increases to 100 to 1 000 times the natural extinction rates (Baillie, Hilton-Taylor and Stuart, 2004). This may be a conservative estimate, as it does not account for undocumented extinctions. Although the estimates vary greatly, current extinction rates suggest that the earth may be on the threshold of a new mass extinction event generated by human activities.

Similarly, agricultural genetic diversity is declining globally as specialization in plant and animal breeding and the harmonizing effects of globalization advance. Although 5 000 different species of plants have been used as food by humans, the majority of the world's population is now fed by less than 20 staple plant species (FAO, 2004c). And only 14 domesticated mammalian and bird species now provide 90 percent of human food supply from animals (Hoffmann and Scherf, 2006).

Forests currently host the highest number of threatened species. Many forest-dwelling large mammals, half the large primates, and nearly 9 percent of all known tree species are at some risk of extinction (WRI, 2000). The biodiversity of freshwater ecosystems is even more threatened than that of terrestrial ecosystems. Twenty percent of the world's freshwater species have become extinct, threatened, or endangered in recent decades. In the United States, which has the most comprehensive data on freshwater species, 37 percent of freshwater fish species, 67 percent of mussels, 51 percent of crayfish and 40 percent of amphibians are threatened or have become extinct (WRI, 2000). Marine biodiversity is also under great threat. Commercial species such as Atlantic cod, five species of tuna, and haddock are threatened globally, along with several species of whales, seals, and sea turtles, while invasive species are frequently reported in enclosed seas (WRI, 2000).

5.3 Livestock's role in biodiversity loss

As we have seen, the most important drivers of biodiversity loss and ecosystem service changes are habitat change, climate change, invasive alien species, overexploitation and pollution. These drivers are not independent. The impact of climate change and much of the impact of pollution on biodiversity for example is indirect, through the modification of habitats, while the latter often goes hand in hand with the introduction of invasive species.

5.3.1 Habitat change

Habitat destruction, fragmentation and degradation are considered the major category of threat to global biodiversity. They are the major threat faced by birds, amphibians and mammals, affecting over 85 percent of threatened species in all three animal classes (Baillie, Hilton-Taylor and Stuart, 2004). It has been possible to examine some of the key drivers of habitat destruction using data on birds. Large-scale agricultural activities (including crop farming, livestock ranching and perennial crops such as coffee and oil palm) are reported to impact nearly half of the globally threatened birds affected by habitat destruction. A similar proportion would be affected by smallholder or subsistence farming. Selective logging or tree-cutting and general deforestation is said to affect some 30 percent of threatened bird species, firewood collection and the harvesting of non-woody vegetation would affect 15 percent and conversion to tree plantations some 10 percent. Overall, over 70 percent of globally threatened birds are said to be impacted by agricultural activities and 60 percent by forestry activities (Baillie, Hilton-Taylor and Stuart, 2004).

Livestock are one of the major drivers of habitat change (deforestation, destruction of riparian forests, drainage of wetlands), be it for livestock production itself or for feed production. Livestock also directly contribute to habitat change as overgrazing and overstocking accelerate desertification.

Deforestation and forest fragmentation

Habitat change by and for livestock started from the beginning of domestication of animals, between 10 000 and 8000 BC. Around the Mediterranean Basin, clearing by fire, pastoralism and primitive agriculture were the primary impacts (Pons *et al.*, 1989). Most of the natural vegetation in the basin has since been modified by human activities. In northern temperate regions such as Europe, native vegetation has also been largely destroyed or modified by deforestation, agriculture and grazing (Heywood, 1989). In more recent times, much of the temperate forest in Australia has been converted to grassland (Mack, 1989).

Livestock production plays an important role in **habitat destruction**. At present, the link between deforestation and livestock production is strongest in Latin America, where extensive cattle grazing is expanding mostly at the expense of forest cover. By the year 2010 cattle are projected to be grazing on some 24 million hectares of Neotropical land that was forest in 2000 (Wassenaar *et al.*, 2006; see also Chapter 2). This means that about two-thirds of the deforested land is expected to be converted to pasture, with a large negative effect on biodiversity.

In addition to pasture, a substantial and increasing share of this region's cropland, and more particularly of cropland expansion into forest, is dedicated to intensive large-scale production of soybeans and other feedcrops destined for livestock production. Between 1994 and 2004, the land area devoted to growing soybeans in Latin America more than doubled to 39 million ha, making it the largest area for a single crop, far above maize which ranks second at 28 million hectares (FAO, 2006b). The demand for feed, combined with other factors, has triggered increased production and exports of feed from countries such as Brazil where land is relatively abundant. Wassenaar *et al.* (2006) project large hotspots of deforestation in the Brazilian Amazon forest related to the expansion of cropland, mainly for soybean (see Box 5.1). Similar processes are reported to be taking place south of the Neotropics, particularly in Argentina (Viollat, Le Monde Diplomatique, April 2006).

Besides forests, this expansion of livestock-related land use has fragmented other valuable landscapes. In Brazil's ecologically very sensitive tropical savannah region, the Cerrado (recently described as the "forgotten" ecosystem – Marris, 2005), the rapid settlement and the accompanying pollution and erosion severely impact biodiversity (see Box 5.2).

It is not just the sheer area of conversion involved. The pattern that pasture expansion is taking poses a threat of **habitat degradation** through loss of neotropical biodiversity. Some 60 percent of pasture expansion into forest is projected to occur in a rather diffuse manner, in already fragmented forest landscapes (Wassenaar *et al.*, 2006). More concentrated "hotspots" of pasture expansion into forest are predominantly projected in lowland ecosystems. The tropical Andes mountain region though is the most biologically diverse of the hotspots identified by Myers *et al.* (2000), containing some

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The endangered Peruvian Plantcutter Phytotoma raimondii *is endemic to the dry forest of north Peru. Conversion of forests for farming and firewood threatened the last stronghold of for the species - 2006*

6 percent of total plant and vertebrate species world-wide. Biodiversity in the northwestern Andean moist forest and Magdaleña Valley dry and montane forest ecoregions is reported to be under severe pressure (UNEP-WCMC, 2002). These areas are projected to be affected by both pasture- and cropland-dominated diffuse deforestation.

Habitat degradation threatens many other ecoregions. Most are projected to be affected by diffuse deforestation: important examples are cropland expansion into Central American pine-oak forest and pasture expansion into the Brazilian Cerrado or the Atlantic forests of eastern Brazil which are among the most endangered habitats on earth (Myers *et al.*, 2000; UNEP, 2002). In fact almost all the diffuse deforestation areas are located in WWF's "Global 200" priority ecoregions (Olson and Dinerstein, 1998). In addition the North and Central Andes, as well as eastern coastal Brazil have extremely high densities of important bird areas (BirdLife International, 2004).

Habitat fragmentation occurs when patches of native habitat become isolated in a landscape increasingly dominated by human activities.

Under the species-area relationship it has long been recognized that large islands have more species of a given group than do small islands. For example Darlington evaluated that the reduction of an area by a factor of ten in the West Indies divides the number of species of Carabidae (beetle) by two (Darlington, 1943). Researchers are today increasingly applying this relationship to fragmented habitats and, in particular, to rain forest fragmentation stating that forest patches are hosting less biodiversity than continuous ones. In the context of forest fragmentation the decreased biodiversity would result from: a decrease in variety of habitats in the fragmented section, new opportunities for invasive alien species to intrude and compete with native ones, a decreased size of wild population easing inbreeding and eroding intra specific biodiversity, a disruption of natural equilibrium between species and in particular between prey and predators.

As a direct result, the real impacts of habitat change on biodiversity is greater when the habitat is fragmented as the actual biodiversity carrying capacity of fragmented habitats is much smaller than the overall area loss would suggest.

The effect of fragmentation on biodiversity in pasture-dominated landscapes is often aggravated by changes of fire regime. As described in Chapter 3 (Box 3.3), burning is a common practice for the establishment and management of pastures. It is practised in many grassland regions of Africa, Australia, Brazil and the United States.

Burning usually has a negative impact in large agricultural regions with fragmented natural habitat. One of the reasons is that the remaining forest fragments in these regions appear unusually vulnerable to fire, because their dryer, fire-prone edges lie adjacent to frequently burned pastures. Under the generally low prevailing level of control of burning this frequently leads to considerable penetration of fire into forest interiors (Cochrane and Laurance, 2002). Another reason is the indirect impact that fire has on biodiversity, by facilitating invasions of alien species. In a review, d'Antonio (2000) concluded that fire most often increases such invasions, even when used to control an invasive species. In addition some invasive species can also directly alter the fire regime. They can increase fire intensity in fire-prone systems or introduce fire into systems where it was previously uncommon.

Intensification of agricultural land use

In his historical perspective of biological invasions, Di Castri (1989) defines the Old World as the zone where the instruments for cultivation were the spade and particularly the plough. Deep turning of soil by ploughing has far-reaching effects on biological processes in soil, including germination. Such practices and their subsequent spread to other regions represent an

Box 5.1 The case of the protected areas

The destruction and modification of habitats in the world continues at a steady pace. According to FAO some 29.6 percent of the total land area of the world is currently under forest cover. This area is being deforested at a rate of 0.2 percent points per year (FAO, 2004).

Major efforts at the global and national levels have aimed to protect areas to safeguard key habitats and species. In 2005, 6.1 percent of the total land area of the world was under protection (WRI, 2005). This includes strict nature reserves, wilderness areas, national parks, national monuments, habitat/species management areas, and protected landscapes.

Despite the efforts to increase the number of protected areas in the world, the extinction of species and habitat losses continue. Many protected areas face significant threats including poaching, encroachment and fragmentation, logging, agriculture and grazing, alien invasive species and mining. Among those related to livestock, park managers have identified:

- incursion by nomadic groups and subsequent conflict with wild animal populations;
- establishment of ranches spreading into protected areas, and
- agricultural pollution, affecting protected areas through eutrophication and pollution by pesticides and heavy metals (Mulongoy and Chape, 2004).

Livestock pose a particular threat to protected areas.

An analysis for this report comparing global bovine density with protected areas in the top three IUCN[1] categories shows that 60 percent of the world's protected areas in these top categories have livestock (cattle and buffaloes) within a 20 km radius from the centre. Bovine density in protected areas is generally still low, but some 4 percent have an average density of four or more animals per square kilometer, representing a significant menace.

Projected land use changes in the neotropics for the year 2010 (see Maps 33A and 33B, Annex 1) show that protected areas are under further threat of livestock-linked deforestation. In Central America, for example, significant pasture expansion is expected into forest in the Maya Biosphere reserve in Guatemala's northern Petén region, mainly in the Laguna del Tigre national park. In South America, a few parks appear to be severely threatened; the Formaciones de Tepuyes natural monument in eastern Venezuelan Amazon, the Colombian national park Sierra de la Macarena and the Cuyabeno reserve in northeastern Ecuador.

Although deforestation in protected areas represents a limited portion of total deforestation, it may have a considerable ecological significance. The Macarena national park, for example, is the only remaining significant corridor between the Andes and the Amazon lowlands. Small spots of deforestation, which could be only the beginning, are also noted at the high end of the Carrasco Ichilo national park on the Andes slopes between the Bolivian highlands and the lowlands towards Santa Cruz. In all cases, the majority of the deforested area would be occupied by pasture.

[1] Category Ia or strict nature reserve: protected area managed mainly for science; Category Ib or wilderness area: protected area managed mainly for wilderness protection; and Category II or National park: protected area managed mainly for ecosystem protection and recreation.

Source: Wassenaar *et al.* (2006).

early form of intensification leading to habitat change. However, the effect on biodiversity loss has surely been far less than that resulting from intensification of agriculture through mechanization and agro-chemical use, following the industrial revolution.

In Europe today, traditional grazing is seen as having positively affected biodiversity in pastures, by creating and maintaining sward structural heterogeneity, particularly as a result of dietary choice (Rook *et al*., 2004). Other important heterogeneity-creating mechanisms are treading, which opens up regeneration niches for gap-colonizing species (although some of these may be invasive) and nutrient cycling – concentrating nutrients in patches thereby altering the competitive advantage between species. Grazing animals also have a role in propagule[3] dispersal.

However, when established traditional pastures become more intensively managed, much of the remaining diversity is lost. Today's sown pastures have lost almost all the sward canopy structure, and this effect on plant communities has led to secondary effects on invertebrate diversity, both by changing the abundance of food plants and by changing breeding sites (Rook *et al*., 2004). The direct effects of invertebrate diversity then feed through to vertebrate diversity (Vickery *et al*., 2001).

Similar effects may occur in other relatively intensive systems such as the "cut and carry" system, affecting grasslands of the more densely populated areas in developing regions, although cut and carry has considerable environmental and productivity advantages. Another aspect of more intensively managed pastures is that productivity is often hard to maintain: the export of nutrients through products and soil degradation leads to a decrease in soil fertility. This often results in increased competition among weeds and undesired grass species. The subsequent increased use of herbicides for control may constitute another threat to biodiversity (Myers and Robins, 1991).

Clearly, the recent trend towards intensive production of feedcrops, in line with the overall intensification of crop agriculture, leads to profound micro- and macro-habitat change, although the extent of the area concerned is less than for extensive pastures. Advanced technology now fosters high land-use intensity, and allows agriculture to expand into previously unused land, often in biologically valuable regions (see Box 5.2). Under such use virtually no above- or below-ground habitat remains unaffected: even within a generally very diverse soil microbial population few species may be able to adapt to the modified environment.

Desertification and woody encroachment

Another area where livestock have fuelled habitat degradation is in rangelands. Rangeland degradation results from a mismatch between livestock density and the capacity of the pasture to support grazing and trampling. Such mismanagement occurs more frequently in the less resilient arid and semi-arid regions, characterized by a relatively erratic biomass production. Section 2.5.2 describes the process in more detail. Excessive pressure on dryland ecosystems leads to fragmentation of herbaceous cover and an increase in bare soil (i.e. desertification). In semi-arid, subtropical rangelands often, though not always woody plant cover increases (Asner *et al*., 2004). Woody encroachment results when overgrazing of herbaceous cover, reduced fire frequency, helped along by atmospheric CO_2 and nitrogen enrichment, modify the equilibrium in favour of woody species.

The spread of rangeland degradation in the arid and semi-arid climates is a serious source of concern for biodiversity; although quantifying the extent is a complex exercise. Land quality indicators used to assess conditions are inadequate. There are also natural long-term

[3] Any of various, usually vegetative, portions of a plant, such as a bud or other offshoot, which also seeds, thus facilitating dispersal of the species and from which a new individual may develop.

Box 5.2 Changes in the Cerrado, Brazil's tropical savannah

The Cerrado region of woodland-savannah makes up 21 percent of Brazil's area. Large mammals such as the giant anteater, giant armadillo, jaguar and maned wolf still survive here. Biodiversity in this fragile and valuable ecosystem is endangered by a combination of fragmentation, intensification, invasions and pollution.

Like the Amazon basin, the Cerrado is a great source of biodiversity. It supports a unique array of drought- and fire- adapted plant species and surprising numbers of endemic bird species. Its 137 threatened species include the maned wolf (*Chrysocyon brachyurus*), a striking, long-legged beast that resembles a fox on stilts. The sparse, scrubby vegetation features more than 4 000 species that grow only here.

However, over the past 35 years, more than half of the Cerrado's original expanse of two million km^2 has been taken for agriculture. It is now among the world's top regions for the production of beef and soy. At the current rate of loss, the ecosystem could be gone by 2030, according to estimates by Conservation International.

Agriculture in the Cerrado started in the 1930s with extensive cattle ranching, which severely impacted the ecosystem's functioning and biodiversity. Besides altering the local vegetation by trampling and grazing, much of the impact was through damage to the neighbouring fragile natural ecosystems through fires set on pastures. The change in fire regime proved to be disastrous: the oily molasses grass (*Melinis minutiflora*), widely planted for pasture, has invaded the fringes of the wild Cerrado, causing fires to rage at such intensity that they burn through even the tough fire-adapted bark of native woody plants.

Still, the Cerrado's inaccessibility and poor soil spared large areas from large-scale exploitation. As Brazil embraced the Green Revolution in the 1970s, the availability of new soy varieties and fertilizers turned the region into a viable agricultural prospect. Soybean cultivation has since invaded the Cerrado where national production increased by 85 percent between 1993 and 2002. Soybean production in the Cerrado is characterized by high intensity land management, known as the "Patronal" model, based on advanced technology, full mechanization and extensive use of agrochemicals. Production units are generally well over 1 000 ha. This intensive system allows for high productivity: soy is harvested twice a year sometimes with an intermittent maize crop.

The replacement of originally rich habitats by an intensive monoculture landscape strongly affects biodiversity. Habitats have been lost on a large scale and pesticides and fertilizers, sprayed in large quantities to control pests and diseases and to maintain fertility, pollute the water and the soil. Though the use of herbicides against weeds is on the increase, weeds were previously dealt with using mechanical methods that have favoured erosion; WWF (2003) estimates that a soy field in the Cerrado loses approximately 8 tonnes of soil per hectare every year.

There is a growing realization among conservationists that their strategies must accommodate economic development (Odling-Smee, 2005). To this end, ecologists working in the Cerrado are now stressing the ecosystem services it provides — many of which have a tangible economic value. Some are investigating the role of the native landscape as a carbon sink, as a centre of genetic diversity for the crop cassava, or as a protector of Brazil's soil and water.

Source: Marris (2005).

Le Bheyr lake is of vital importance to the microclimate of the zone. Apart from providing grazing along its shores, it is a fishing and crossing point for migratory birds in December and January. The photo shows striking images of environmental degradation and drought – Mauritania 1996

oscillations in ecosystem changes that are difficult to disentangle from anthropogenic changes. However, many grazing systems are undergoing desertification. Africa, Australia and the southwestern United States have experienced a severe reduction in plant populations, with a corresponding loss of biodiversity. Often they are dominated by one or a few woody species, with little herbaceous canopy remaining (see review by Asner *et al.*, 2004). Biodiversity erosion creates a negative feedback: it reduces the system's resilience and thereby indirectly reinforces desertification. This acknowledged inter-linkage has led to the development of a joint work programme between the United Nations Convention to Combat Desertification (UNCCD) and the Convention on Biological Diversity (CBD).

Vegetation-grazing interactions associated with woody encroachment strongly depend on grazing intensity. Grazing probably facilitates bush encroachment, and thus system structure, by reducing risk of fire for woody seedlings. Grazing also encourages erosion on some landscapes, which affects the herbaceous cover more than the deeper-rooted vegetation. Reduction of herbaceous cover through grazing can also advantage woody vegetation in the competition for access to limited resources such as water. Changes are more pronounced in cases of long-term, heavy grazing (see the example of Texas in Box 5.3). Woody encroachment sometimes results from concentration of grazing pressure that has occurred because of declines in the mobility of pastoral people and their herds. Under heavy grazing, herbaceous cover is often replaced by woody vegetation while perennial grasses replace annual ones.

Effects of woody species on the herbaceous community vary according to the type of woody species and site. Effects can be positive, neutral or negative. The change from grassland to woodland through the process of woody encroachment affects several key ecosystem functions, including decomposition and nutrient cycling, biomass production and soil and water conservation. The dynamics of rainfall interception, overland flow and water penetration into the soil in overgrazed areas often is such that water from rainfall events is quickly lost to drainage systems with a concomitant increase in soil erosion. Pristine grassland may intercept water more efficiently and, therefore, prevent loss of the soil resources that form the basis of the entire ecological and agricultural production system. In arid environments, effects are eventually mostly negative both for animal production and biodiversity. Habitat diversity may also be affected. Savannah-like openings in wooded landscapes for example may gradually vanish as a result of woody encroachment.

Forest transition and the conservation of pastoral landscapes

Forest transition, i.e. the process of previous agricultural land being turned back into forest - was presented in Section 2.1.2. This increasingly widespread land use change process is characterized by the abandonment of agricultural land in remote areas with poor soil. These are predominantly pastures, which when abandoned, can regenerate back into forest.

Box 5.3 Woody encroachment in southern Texas

The woody plants that invade areas during woody encroachment are typically species that were present somewhere in the landscape before the introduction of grazing. For example, in a southern Texas rangeland containing a diverse array of trees, shrubs, and subshrubs, heavy grazing caused increases in the cover of the nitrogen-fixing tree *Prosopis glandulosa var. glandulosa* (mesquite). Long-term records and aerial photographs indicate that mesquite encroachment then facilitated the establishment of other woody plants in its understory, which subsequently out-competed mesquite for light and other resources. Mesquite remnants are commonly found among well-developed patches of woody vegetation known not to have existed a century ago.

Source: Extract from Asner *et al.* (2004).

Some abandoned pastures turn into fallow/shrubland with little biological diversity. In temperate regions such as Europe, natural and semi-natural grasslands have become an important biodiversity and landscape resource worth preserving in their own right. These plant communities, and the landscapes of which they form a part, are now highly valued and the subject of numerous agro-environmental and nature conservation schemes. These habitats are under threat from two contrasting directions: on the one hand, the ongoing intensification of land use, and on the other, an increasing number of former meadows and pastures lying fallow owing to changing economic conditions and "set-aside" subsidies.

As early as 1992, Annex 1 of the European Council Habitat Directive (EU, 1992, cited in Rook *et al.*, 2004) listed habitats that are considered of European importance for their biodiversity value. It has been estimated that this list includes 65 types of pasture habitat that are under threat from intensification of grazing and 26 that are under threat from abandonment (Ostermann, 1998). In some cases, there is not only a loss of biodiversity value but also other environmental problems. For example, in the hills and mountains of Mediterranean countries there are now large areas of former grazing covered by shrub vegetation of very low biodiversity. This accumulation of woody biomass may increase risks such as fire and erosion, resulting in extensive environmental and economic losses (Osoro *et al.*, 1999).

One of the main objectives of nature conservation in Europe is, therefore, to protect semi-open landscapes. In several countries the establishment of larger "pasture landscapes" with a mixed character of open grassland combined with shrubs and forests has been recognized as one solution (Redecker *et al.*, 2002).

Within grassland communities spatial heterogeneity is the key to maintaining critical biodiversity. The role of the grazing animal in fostering this has already briefly been mentioned under "Intensification of agricultural land use," above.

Woodland pastures (Pott, 1998; Vera, 2000) harbour higher biodiversity as they contain both grassland and forest species. A different mix of grazers and browsers may be needed to manage such landscapes (Rook *et al.*, 2004). In premodern times, woodland pastures were used for communal grazing: today the challenge is to develop analogous grazing systems that achieve similar biodiversity but are socio-economically viable. Vera (2000) argues that long-term preservation of biodiversity requires the development of wilderness areas with wild herbivores in addition to the existing semi-natural landscapes.

Examples of species extinction at least partly resulting from livestock induced habitat change

A few positive roles of livestock have been mentioned with respect to habitat change, concerning either its role in habitat regeneration or in maintaining a relatively slow pace or low level of change (see also Sections 5.3.4 and 5.5).

Still, it is clear that while not all indirect effects have been analysed, other aspects of livestock production have affected many habitats badly at enormous scales. The table on livestock's contribution to species extinction via habitat loss or habitat degradation (Table 16, Annex 2) gives specific examples of how these various mechanisms have led to the loss of particular species. It shows clearly that habitat degradation by and for the livestock sector has contributed to the extinction of many plants and animals. Nevertheless, it is unknown what the status of the affected habitats would have been in the absence of livestock.

5.3.2 Climate change

The impact of climate change on biodiversity is recent, and only now starting to be recognized, observed on the ground and understood. Climate change affects biodiversity in three main ways: by changes in the mean climate, changes in the incidence or severity of extreme climate events and changes in climate variability.

According to Thomas *et al*. (2004) between 15 and 37 percent of all species could be threatened with extinction as a result of climate change.

The projected impacts on biodiversity owing to climate change include the following (Secretariat of the Convention of Biological Diversity, Technical Series No. 10, 2003):

- As a result of global warming, the climate range of many species will move poleward or upward in elevation from their current locations. Species will be affected differently by climate change: some will migrate through fragmented landscapes whilst others, less mobile, may not be able to do so.
- Many, already vulnerable species are likely to become extinct, especially species with limited climate ranges and/or with limited geographical opportunities (e.g., mountain top species, species on islands, peninsulas). Species with restricted habitat requirements, very large ranges, slow breeding rates or small populations are typically the most vulnerable.
- Changes in the frequency, intensity, extent and locations of climatically- (and non-climatically-) induced disturbances will affect how existing ecosystems will be replaced by new plant and animal assemblages. Species are unlikely to migrate at the same rates; long-lived species will persist longer in their original habitats leading to new plant and animal assemblages. Many ecosystems will become dominated by opportunistic, 'weedy' species, well adapted to dispersal and rapid establishment, especially if the frequency and intensity of disturbance is high.
- Some ecosystems are particularly vulnerable to climate change, such as coral reefs, mangroves, high mountain ecosystems, remnant native grasslands and ecosystems overlying permafrost. Some ecosystems may be slow to show evidence of change, whilst others, e.g. coral reefs, are already showing a rapid response. The net primary productivity (NPP) of many plant species (including some but not all crop species) increase due to the "fertilizer effect" of rising concentrations of atmospheric carbon dioxide. However, when temperature, nutrient limitation and rainfall changes are also considered there may be losses in net ecosystem and biome productivity in some regions. The differential changes in NPP will result in changes in the composition and functioning of ecosystems. Losses in net ecosystem and biome productivity can occur, for example, in some forests, at least when significant ecosystem disruption occurs (e.g. loss of a dominant species or a high proportion of species owing to changes in incidence of disturbances such as wildfires, pest and disease outbreaks).

Many studies suggest that climate change (including its effects on habitats) will surpass other, more direct, forms of human-induced habitat change as the main threat to biodiversity loss. In any case, the combined impact of continued habitat loss and climate change will pose a major and potentially catastrophic threat to biodiversity in the future. The changes to current pristine areas resulting from climate change will force species to move to and through already degraded and fragmented habitats, worsening their opportunities of dispersal and their chances of survival.

The IPCC (2002) has reviewed the extent to which biodiversity has already begun to be affected by climate change. Higher regional temperatures have affected the timing of reproduction in animals and plants and/or migration of animals, the length of the growing season, species distributions and population sizes, and the frequency of pest and disease outbreaks.

The IPCC modelled the impact of four different climate change scenarios on biodiversity, producing impact scenarios for different world regions. Climate change is projected to affect individual organisms, populations, species distribution and ecosystem function and composition both directly through heat, drought, and indirectly through changes in the intensity and frequency of disturbances such as wildfires. The IPCC observes that a realistic projection of the future state of the earth's ecosystems would need to take into account human land- and water-use patterns, which will greatly affect the ability of organisms to respond to climate change. Many other information needs and assessment gaps persist, partly because of the extreme complexity of the issue.

What is livestock's contribution to the loss of biodiversity induced by climate change? Since climate change is a global process, livestock's contribution to the resulting erosion of biodiversity is in line with its contribution to climate change (see Chapter 3 for a detailed assessment). As a major driver behind landscape and habitat changes, the livestock sector may also aggravate the impact of climate change on biodiversity, by making it more difficult for climatically-challenged organisms and species to migrate across fragmented and disturbed habitats and human agricultural and urban environments. However, a shift to well-managed industrial intensive livestock production systems, by reducing the area taken up by livestock production, may work to reduce this effect.

5.3.3 Invasive alien species

Before modern times, natural ecosystems evolved in isolation on the various continents and large islands, constrained by biogeographic barriers such as oceans. Today, almost all these ecosystems have become functionally connected by the human capacity to transport biological material long distances in a short amount of time. Humans have transported animals and plants from one part of the world to another for thousands of years, sometimes deliberately (for example livestock released by sailors onto islands as a source of food) and sometimes accidentally (e.g. rats escaping from boats). Many of the world's major crops were deliberately transplanted from one continent to another – for example, maize, potatoes, tomatoes, cocoa and rubber from the Americas to the rest of the world. Following human-assisted introduction, many alien species became invasive, i.e. their establishment and propagation led to ecological and/or economic harm.

Invasive species can affect native species directly by eating them competing with them, and introducing pathogens or parasites that sicken or kill them or, indirectly, by destroying or degrading their habitat. Invasive alien species have altered evolutionary trajectories and disrupted many community and ecosystem processes. In addition, they can cause substantial economic losses and threaten human health and welfare. Today invasive species constitute a major threat affecting 30 percent of globally threatened birds, 11 percent of threatened amphibians and 8 percent of the 760 threatened mammals for which data are available (Baillie, Hilton-Taylor and Stuart, 2004).

The contribution of the livestock sector to detrimental invasions in ecosystems goes well beyond the impact of escaped feral animals.

Because of the many forms this contribution takes, the overall impact in this category of threat is perhaps even too complex for accurate assessment. One such other dimension is livestock's role as an important driver behind habitat change leading to invasions. Animal production has also sometimes driven intentional plant invasions (for example, to improve pastures). On a different scale grazing animals themselves directly produce habitat change facilitating invasions. Movement of animals and animal products also makes them important vectors of invasive species. Livestock have also been a victim of alien plant species invasions in degrading pasture land, which may in turn have driven pasture expansion into new territories. We will examine these different dimensions in the rest of this section.

Livestock as an invasive species

According to IUCN (2000) an invasive alien species is one that becomes established in natural or semi-natural ecosystems or habitats and threatens native biological diversity. Under this definition livestock can be considered as alien species that are invasive, particularly when little attempt is made to minimize the impact on their new environment, leading to competition with wildlife for water and grazing, the introduction of animal diseases and feeding on seedlings of local vegetation (feral animals are among the main threats to biodiversity on islands). The IUCN/SSC Invasive Species Specialist Group (ISSG) classifies feral cattle, goats, sheep, pig, rabbits and donkeys as invasive alien species (among a total of 22 invasive mammalian species)[4]. Indeed, feral pigs, goats and rabbits are classified among the top 100 world's worst invasive alien species.

One of the best documented effects of invasive-species is the dramatic impact of mammalian herbivores, especially feral goats and pigs, on the vegetation of small islands, causing extinction of native species and pronounced changes in dominance and physiognomy and directly affecting many other organisms (Brown, 1989). As invasive alien species, feral animals also contribute to biodiversity loss at the continental level. Nearly all livestock species of economic importance are not native to the Americas, but were introduced by European colonists to the Americas in the sixteenth century. Many harmful feral populations resulted from these introductions and the often very extensive patterns of management.

Despite the negative impact of some introduced species, exotic vertebrates continue to be imported. Government agencies are gradually becoming more cautious, but they continue deliberately to introduce species for fishing, hunting and biological control. The pet trade is perhaps the single largest source of current introductions (Brown, 1989). The contribution of the livestock sector to current vertebrate introductions is currently minimal.

Other direct livestock contributions remain important. Seed dispersal by vertebrates is responsible for the success of many invaders in disturbed as well as undisturbed habitats. In Australia, more than 50 percent of naturalized plant species are dispersed by vertebrates (Rejmánek *et al.*, 2005). Grazing livestock have undoubtedly contributed substantially to seed dispersal and continue to do so. However, seed dispersal by vertebrates is a complicated process; when and where vertebrates promote plant invasions requires substantially more research (Rejmánek *et al.*, 2005).

Dispersal by trade in animal products is also poorly documented. An interesting exception is the detailed analysis of the impact of the increased demand for wool in the early twentieth century. The monograph of Thellung (1912) on the adventive flora of Montpellier was largely inspired by the expansion of alien species resulting from the import, hanging out and drying of wool at Port-Juvénal (near Montpellier). It is not

4 http://issg.appfa.auckland.ac.nz/database/welcome/

Box 5.4 Wild birds and highly pathogenic avian influenza

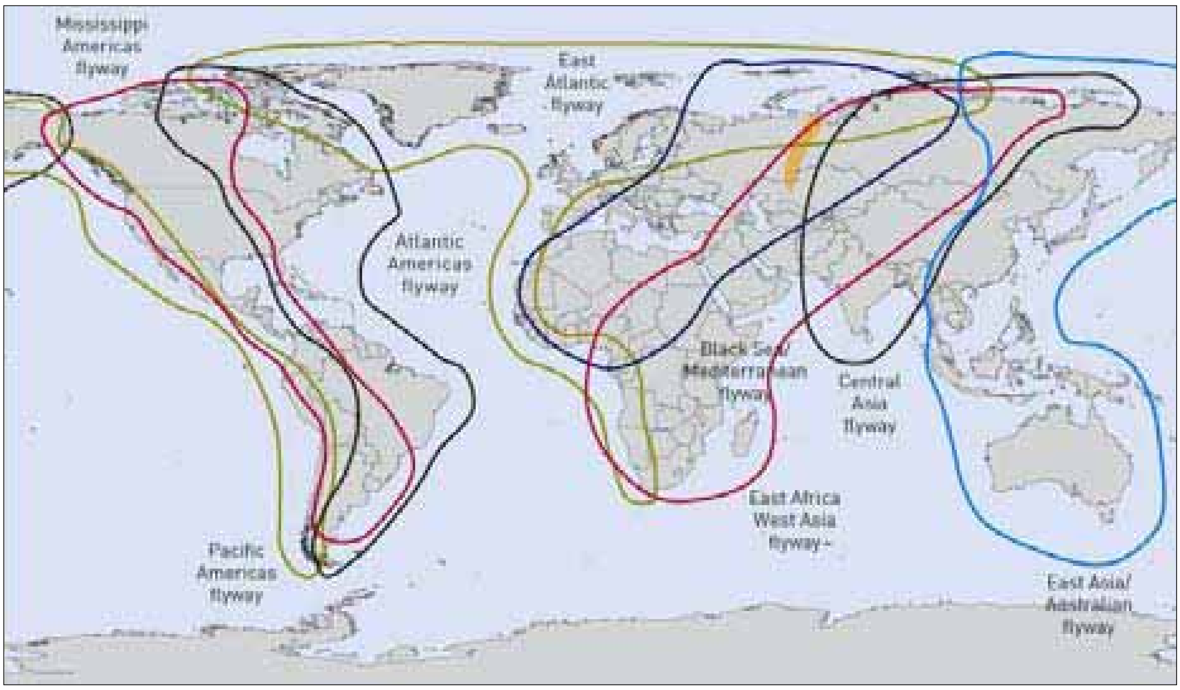
There is a possible and plausible link between wild birds and poultry in the transmission of highly pathogenic avian influenza (HPAI) that has recently affected the poultry sector worldwide and raised concern over human health. Since 2003, there has been a series of outbreaks of this new disease. By July 2006, the disease had affected the poultry industries in 55 countries; 209 million birds were killed by the disease or had to be culled. HPAI is a zoonotic disease, which is potentially fatal to human beings. By July 2006, disease had been caused in 231 cases, killing 133 people. The disease has now become endemic in several countries in Asia and Africa.

The widespread simultaneous occurrence of the disease poses a substantial risk of a potential disruption to the global poultry sector (McLeod *et al.*, 2005). The emergence of the specific strain of HPAI involved in these recent outbreaks, called H5N1, raises concerns regarding the potential role of wild birds as one possible transmission mechanism (Hagemeijer and Mundkur, 2006).

Before the Asian H5N1 epidemic in 2003, HPAI was considered a disease of domestic birds. Wild aquatic birds of the world were only known as natural reservoirs of low pathogenic influenza A. The series of initial outbreaks, particularly in Asia has pointed to possible interactions between domesticated and wild bird populations in HPAI virus transmission (Cattoli and Capua, 2006; Webster *et al.*, 2006).

Bird migratory patterns annually connecting land masses from the northern and southern hemispheres (including the African-Eurasian, Central Asian, East Asian- Australasian and American flyways) may contribute to the introduction and to

Map 5.1 Major flyways of migratory birds (Shore birds)



Source: Flyways – Wetlands International.

Box 5.4 cont.

the spread of the infection to AI-free areas. Recent outbreaks of HPAI in Africa, Central Asia, Europe and the Russian Federation suggest that A/H5N1 may have been carried by wild birds during their autumn and spring migrations (Cattoli and Capua, 2006; Hagemeijer and Mundkur, 2006). In particular, migratory wild birds were found positive in many European countries with no associated outbreaks in poultry (Brown *et al.*, 2006).

On the other hand wild bird populations could possibly be contaminated and impacted by infected poultry units. According to Brown *et al.* (2006) further infection of wild birds through exposure to infected 'backyard' poultry in Eastern Europe appears probable.

known whether today's much stricter sanitary regulations impede the sharply increasing global trade in animal products from having similar impacts.

Historically, livestock played an important role in the transmission of disease organisms to populations that had no immunity. The introduction of rinderpest into Africa at the end of the nineteenth century devastated not only cattle but also native ungulates. This transmission remains an issue in today's world. The introduction of avian pox and malaria into Hawaii from Asia has contributed to the demise of lowland native bird species (Simberloff, 1996).

Even if there is no sound evidence as yet of cross-contamination between wild and domesticated bird populations, this mechanism possibly plays a role in today's spread of highly pathogenic avian influenza (see Box 5.4).

Livestock-related plant invasions

The natural temperate grasslands of Australia, South America and western North America offer some of the most extreme examples of what has been called "the great historical convulsions" of the earth's biota – massive changes in the species composition of once vast communities through the transoceanic transport of alien organisms and their subsequent incursion into new ranges (Mack, 1989). In less than 300 years (and mostly only some 100 years) much of the temperate grassland outside Eurasia has been irrevocably transformed by human settlement and the concomitant introduction of alien plants.

Clearly, livestock production was only one among many other activities driving the largely unintentional trans-Atlantic movement of alien species. However, large ruminants are considered to have largely enhanced the invasive potential of these species. According to Mack (1989), the two quintessential characteristics that make temperate grasslands in the New World vulnerable to plant invasions are the lack of large, hooved, congregating mammals[5] in the Holocene or earlier, and the dominance by caespitose grasses (which grow in tussocks). The morphology and phenology of such grasses make them vulnerable to livestock-facilitated plant invasions: the apical meristem becomes elevated when growth is resumed and is placed in jeopardy throughout its growing season to removal by grazers, while these grasses persist on site exclusively through sexual reproduction. In caespitose grasslands trampling can alter plant community composition by destroying the

[5] The only exception are enormous herds of bison that were supported on the Great Plains of North America, yet these large congregating animals occurred only in small, isolated areas in the intermountain west. The phenology of caespitose grasses may account for this paucity of bison (Mack, 1989). In both vulnerable grasslands in western North America the native grasses on zonal soils are all vegetatively dormant by early summer when lactating bison need maximum green forage.

matrix of small plants between the tussocks.

Once European settlers arrived, alien plants began to colonize these new and renewable sites of disturbance. Whether through grazing or trampling, or both, the common consequence of the introduction of livestock in the three vulnerable grasslands were the destruction of the native caespitose grasses, dispersal of alien plants in fur or faeces, and continual preparation of a seed bed for alien plants. Even today, New World temperate grasslands are probably not yet in a steady state, but are certain to experience further consequences from existing and new plant invasions (Mack, 1989).

Besides the natural grasslands, the world's managed pastures owe their origin and history to human action. Livestock-related land-use changes continue, as do their impacts on biodiversity through habitat destruction and fragmentation. These areas are often rich in alien invaders, some of them deliberately introduced. Planned invasions have taken place in vast areas of tropical savannah, often assisted by fire. Such invasions have a long history in Australia as reviewed by Mott (1986). With the exception of some savannahs of edaphic origin, the grassland ecosystems in Africa usually result from the destruction of forest or woodland. They are often maintained through the use of fire regimes and are frequently invaded by alien species (Heywood, 1989). Likewise, in South America, the region of the great savannahs, including the cerrados and campos of Brazil, and the llanos of Colombia and Brazil have become increasingly exploited leading to invasion by weedy and pioneer species. Many of the ranch lands of South America were established on previous forest land after the European-led colonization. Similarly, in Madagascar vast areas of the natural vegetation have been burned since Palaeo-Indonesians invaded the island, to provide pasture land for zebu cattle, and are burned annually. These pastures are now largely devoid of trees and shrubs and low in biodiversity and characterized by weedy species (Heywood, 1989).

Invasive species threats to pasture

Some invasive alien species alter grazing lands in a detrimental way. These include many thistle species found on most continents (see the case of Argentina in Box 5.5). In California, Star Thistle was introduced during the gold rush as a contaminant of alfalfa. By 1960 it had spread to half a million hectares, to 3 million hectares by 1985, and nearly 6 million by 1999 (Mooney, 2005). It alters the ecological balance, particularly through depletion of water, and degrades pasture value. According to Gerlach (2004) it causes soil moisture losses that represent 15 to 25 percent of mean annual precipitation, representing a value of lost water ranging between US$16 and 75 million per year in the Sacramento River watershed alone. Together with other invasive weeds such as Black Mustard it causes more than US$2 billion of damage annually (Di Tomaso, 2000). A grass that is widespread and used for permanent pastures in various parts of the tropics is *Axonopus affinis*. It invades degenerated pastures of *Paspalum dilatatum, Trifolium repens* and *Pennisetum clandestinum*, leading to a decline in animal production (UNESCO, 1979). Major problems are caused by other introductions such as *Lantana camara*, one of the world's ten worst weeds (GISD, 2006), which has invaded many natural and agricultural ecosystems of the Palaeotropics. The replacement of native pastures by Lantana is threatening the habitat of the sable antelope in Kenya and Lantana can greatly alter fire regimes in natural systems. It is toxic to livestock (in some countries, it is therefore planted as a hedge to contain or keep out livestock). At the same time it benefits from the destructive foraging activities of introduced vertebrates such as pigs, cattle, goats, horses and sheep creating micro habitats for germination. It has been the focus of biological control attempts for a century, yet still poses major problems in many regions.

Box 5.5 **From pampas to cardoon, to alfalfa, to soy**

The Pampas, the humid grasslands of northern Argentina dominated by caespitose species, were the site of one of the earliest documented and dramatic transformations of a landscape by alien plants. In the Origin of Species (1872) Darwin remarked that the European cardoon (*Cynara cardunculus*) and a tall thistle (*Silybum marianum*) "are now the commonest [plants] over the whole plains of La Plata, clothing square leagues of surface almost to the exclusion of every other plant." Even in Southern Uruguay he found "very many square miles covered by one mass of these prickly plants, impenetrable by man or beast. Over the undulating plains, where these great beds occur, nothing else can now live." These scenes had probably arisen in less than 75 years.

Von Tschudi (1868) assumed that the cardoon arrived in Argentina in the hide of a donkey. Many early plant immigrants probably arrived with livestock, and for 250 years these flat plains were grazed but not extensively ploughed (Mack, 1989). Cardoon and thistle were eventually controlled only with the extensive ploughing of the pampas at the end of the nineteenth century.

However, this was far from the end of livestock-related plant invasions. The transformation of the pampas from pasture to farmland was driven by immigrant farmers, who were encouraged to raise alfalfa as a means of raising even more livestock. This transformation greatly expanded the opportunity for alien plant entry and establishment. Towards the end of the nineteenth century over 100 vascular plants were listed as adventive near Buenos Aires and in Patagonia, many of which are common contaminants of seed lots. More recent "immigrant" species pose further threats in the pampas and Patagonia. Marzocca (1984) lists several dozen aliens officially considered as "plagues of agriculture" in Argentina.

Cardoon (Cynara cardunculus) in Shoreline Park, Mountain View, California – United States 2003

While the massive transformation of Argentinean vegetation continues, the globalizing livestock sector recently drove yet another revolution of the pampas. In just a few years, soybean has become the country's major crop. In 1996 a genetically modified soybean variety entered the Argentinean market with a gene that allowed it to resist herbicides. Other important factors contributed to the success of what is now called "green gold". The extensive erosion of the Pampa soils (the GM soybean is cultivated without tillage, which reduces erosion), the sharp increase in demand since the European mad cow crisis and the devaluation of the Argentinean peso. Upon arrival of the GM variety in 1996, soybean covered six million hectares, while today it covers 15.2 million hectares, i.e. more than half Argentina's arable land. Rates of deforestation now exceed the effect of previous waves of agricultural expansion (the so-called cotton and sugarcane "fevers") (Viollat, 2006). At the same time the intensive cropping of soybean results in a severe mining of soil fertility. Altieri and Pengue (2006) estimated that in 2003 soybean cropping extracted a million tonnes of nitrogen and some 227 000 tonnes of phosphorus, losses that would cost some US$910 million if replaced by mineral fertilizers.

Sources: Mack (1989) and Viollat (2006).

Feed-crop related threats to biodiversity

Even the biodiversity of the world's cultivated crops is under threat because the narrowing genetic base of many of the world's crops put them at risk. This concern is reflected in the International Treaty on Plant Genetic Resources for Food and Agriculture, adopted by the member states of FAO in 2001. Important feedcrops like sorghum and maize are among the priority crops. Much of the genetic erosion of such staple crops occurred as a consequence of the Green Revolution, while currently there is substantial controversy around the effects to be expected from modern genetic engineering. Evidence is insufficient, but there exists strong societal concern about the possible contamination of conventional varieties by genetically modified ones, a mechanism that could be considered as "invasion". A much cited case is the contamination of local maize varieties in Mexico, the world's original centre of maize diversity, by commercial trans-genetic varieties cultivated for feed in the United States (Quist and Chapela, 2001), although this has been challenged (Marris, 2005). Similar concern exists for soybean, mainly cultivated for feed, because in countries such as the United States and Argentina (Box 5.5) genetically modified varieties tend to largely substitute conventional varieties.

5.3.4 Overexploitation and competition

Overexploitation refers to the unsustainable use of species for food, medicine, fuel, material use (especially timber), and for cultural, scientific and leisure activities. Over-exploitation has been identified as a major threat affecting 30 percent of globally threatened birds, 6 percent of amphibians, and 33 percent of evaluated mammals. It is believed that when mammals are fully evaluated for threats, overexploitation will prove to affect an even higher percentage of species (Baillie, Hilton-Taylor and Stuart, 2004). Among mammals threatened by over-exploitation, larger mammals, especially ungulates and carnivores, are particularly at risk. Mammals are used extensively in the wild meat trade, notably in tropical Africa and in Southeast Asia. Some mammal species are also harvested for medicinal use, especially in eastern Asia. Overexploitation is seen as the leading threat to the world's marine fishes.

The livestock sector affects overexploitation of biodiversity mainly through three distinct processes. Competition with wildlife is the oldest and renown problem, which often leads to reduction of wildlife populations. More recent processes include overexploitation of living resources (mainly fish) for use in animal feed; and erosion of livestock diversity itself through intensification and focus on fewer, more profitable breeds.

Competition with wildlife

Herder-wildlife conflicts

Conflicts between herders and wildlife have existed since the origins of livestock domestication. The competition arises from two aspects: direct interactions between wild and domesticated animal populations and competition over feed and water resources.

During the origins of the domestication process the main threat perceived by herders was predation by large carnivores. This led to large carnivore eradication campaigns in several regions of the world. In Europe, this led to the local extinction of several species including

Wild elephants and cattle competing for natural resources – Sri Lanka 1994 wolves and bears. In Africa, these tensions have led to a constant pressure on lion, cheetah, leopard and African wild dog populations.

Conflicts between herders and predators still persist in regions where extensive production systems are predominant and where carnivore populations still exist or have been reintroduced. This is the case even in developed countries, even though the predation pressure is lower and herders are usually compensated for their losses. In France, for example, the reintroduction of the wolf and the bear in the Alps and Pyrenees has led to intense conflicts between pastoral communities, environmental lobbies and the government.

In developing countries the conflicts can be acute. In sub-Saharan Africa, especially in East and Southern Africa, production losses from predation can be an economic burden to local communities. In Kenya these losses can represent up to 3 percent of the annual economic value of the herd: it is estimated that a single lion costs the herder community between US$290 and US$360 per year in production losses. Annual losses amount to US$15 for an African wild dog, US$211 for a leopard, US$110 for a cheetah, and US$35 for a hyena (Frank, Woodroffe and Ogada, in press; Patterson *et al.*, 2004; Woodroffe *et al.*, 2005). These losses compare to gross domestic product per capita of US$320 per year in Kenya. Even if the national economic impact remains negligible, the local and individual impact can be dramatic, particularly for poor people (Binot, Castel and Canon, 2006).

Predation pressure, and negative attitudes to predators among local populations, is worsening in the surroundings of the National Parks in developing countries, especially in East Africa. On the one hand, many of the protected areas are too small to host viable populations of large carnivores, as these populations often need vast hunting territories and so are forced to range outside of the parks. For example, the African wild dog in Africa has a hunting territory that extends over 3 500 km^2 (Woodroffe *et al.*, 2005). On the other hand, as land pressure mounts and traditional rangelands are progressively encroached by cropping, herders are often forced to graze their animals in the direct vicinity of the national parks. During dry seasons the surroundings of the national parks which are rich in water and palatable fodder, are often very attractive to the herders. There are, therefore, close contacts between wild predators and livestock.

Another source of intensifying conflict is that, as populations of wild ungulates are shrinking, wild predators are forced to look for other prey. Livestock do not represent a food of preference for the large carnivores, but they are easily accessible and large carnivores can get used to them. Conflicts between wild predators and livestock are, therefore, becoming frequent and acute (Frank, Woodroffe and Ogada, 2006; Patterson *et al.*, 2004; Binot, Castel and Caron, 2006).

The perception that wildlife is a threat to livestock has evolved considerably during the twentieth century. With a better understanding of the dynamics of infectious disease, herbivores, omnivores and bird populations came to be seen as disease reservoirs (buffaloes for cattle, boar for pig), as disease vectors, or as intermediary hosts (arthropod vectors such as tsetse fly for trypanosomiasis, molluscs such as *Lymnaea spp.* for the liver fluke *Fasciola hepatica*). Measures to limit the transmission of pathogens and parasites included the massive eradication of the vectors, and the limitation of contacts between the wild and domesticated animal population. In some cases, the eradication of wild mammalian species has been considered where they are disease reservoirs (the badger in Great Britain is considered a potential reservoir of tuberculosis for cattle) (Black, 2006). This threat has been exacerbated by the fact that it applies to both extensive and intensive production systems, where the introduction of new pathogens can have a dramatic impact (as suspected for avian influenza).

This wildlife-livestock interface is of acute importance to the livestock sector. It used to be

Herd of cattle entering reserve where forage is guaranteed for the animals – Mauritania 1996

an issue of local or regional dimensions (rinderpest in Africa). It has now become a global threat as demonstrated by the current avian influenza pandemic where wild bird populations may have a role in disease transmission.

Protected areas at risk of encroachment

Besides the direct interactions between wildlife and livestock resulting from predation and disease transmission, extensive livestock systems are increasingly competing with wildlife for access to land and natural resources in the African rangelands. Extensive production systems and wildlife have intermingled together for millennia in the dry lands of Africa, making simultaneous use of common resources. The actors' two forms of land use were compatible as pastoralism used natural resources with minimal impact in connection to land management and transformation. Furthermore, because of the high mobility of extensive production systems in Africa, their impact on resources was negligible and competition over access to common resources was low (Bourgeot and Guillaume, 1986; Binot, Castel and Canon, 2006).

Another form of competition for land between livestock and wildlife is the spread of protected areas. In the twentieth century most of the protected areas were created at a time when land was abundant and opportunity cost for the local communities was low. Nevertheless, with the extension of National Parks, and the spread of crop farming, extensive production systems were progressively deprived of an important part of their potential resources increasing the risk of potential conflicts. Today, protected and hunting areas represent almost 13 percent of the land in sub-Saharan Africa (Roulet, 2004). Under current population and land-use trends, the opportunity costs associated with protected areas are increasing, and are especially high in times of drought or conflict. The surroundings of these areas are under great pressure as they are often rich in water and fodder resources compared to the other, often degraded lands available. The interactions between wild fauna and livestock production systems is often localized on the peripheries of these conservation areas (Ballan, 2003; Rodary and Castellanet, 2003; Benoît, 1998; Convers, 2002).

Mobile herders often have great difficulties understanding the logic behind conservationist activities, especially when their cattle are threatened by thirst and famine while resources remain plentiful for the wild animals. To save their herds, or to minimize the conflicts with the croppers, herders are often tempted to graze their animals in the national parks. These actions have usually led to dramatic repression in the past, and herds grazing within protected areas have sometimes been slaughtered. Intense repression around parks has worsened the conflicts between conservation objectives and local communities (Toutain, 2001; Barraud, Salen and Mamis, 2001).

This situation was also worsened by policies that ignored the importance of mobility in extensive production systems in dry lands with their highly variable and shifting local rainfall, and the potential complementarities between conservation and pastoralist needs in terms of mobility. In Africa, policies encouraging settlement or sedentarization of pastoral nomads often included fencing to demarcate newly-created ranches. Nevertheless, as has been observed around Nairobi National Park, as soon as the first drought depleted ranch resources, herders decided to leave the ranches in search of water and green pasture. Often the land was sold to newcomers for cropping activities and fragmented into smaller plots. As more land is fenced, migratory routes for wildlife and nomads are blocked and both systems are impacted, increasing the risk of further conflicts (Binot, Castel and Caron, 2006).

One approach to reducing the conflicts between wildlife and livestock in the rangelands consists of working on the land-use complementarities between the two actors. This approach is, nevertheless, often opposed by conservation and livestock development programmes, as it may favour the transmission of diseases and may increase poaching pressure if regulatory mechanisms fail (Binot, Castel and Caron, 2006).

Overfishing

The role of fishmeal as a livestock feed

An important contribution of livestock to overexploitation consists in the production of fishmeal for livestock feed.

The world's ocean fish face serious threats to their biodiversity. The principle source of pressure is overexploitation by fisheries, which have affected the size and viability of fish populations, the genetics of target species, and the food chains and ecosystems of which they are part. FAO (2005b) estimates that 52 percent of the world stocks are fully exploited, and are therefore producing catches that are already at or very close to their maximum sustainable production limit, with no room for further expansion, and even some risk of decline if not properly managed. Approximately 17 percent are overexploited and 7 percent depleted.

The stocks of seven of the top ten species, accounting for 30 percent of the world total marine capture fisheries production, are either fully exploited or overexploited and, therefore, no sustainable increases in catches can be expected from these species. These include two stocks of Peruvian anchoveta (*Engraulis ringens*, an industrial "feed-grade" fish, which according to the International Fishmeal and Fish Oil Organization) are overexploited in the southeast Pacific after recovering from a recent decline; Alaska Pollock (*Theragra chalcogramma*), fully exploited in the North Pacific; Japanese anchovy (*Engraulis japonicus*), fully exploited in the northwest Pacific; blue whiting (*Micromesistius poutassou*), overexploited in the northeast Atlantic; capelin (*Mallotus villosus*) fully exploited in the North Atlantic; and Atlantic herring (*Clupea harengus*) with several stocks in the North Atlantic, most of them fully exploited. The latter three are largely used to produce fishmeal (Shepherd *et al*., 2005). The Chilean jack mackerel, another important fishmeal species, is assessed as fully or overexploited and yielded 1.7 million tonnes in 2002, having declined continuously from a peak production of 5 million tonnes in 1994.

Christensen *et al*. (2003) show that the biomass of top predator fishes in the North Atlantic has decreased by two-thirds in approximately 50 years. Similar declines were noted for other important species such as perch, anchovies, and flatfish as a result of overfishing between 1900 to 1999. However, the impact of overfishing goes beyond the impact on the populations of targeted species. One effect of overfishing is the progressive decrease of the trophic level of the catch. Overexploitation of the top of the food chain, leading to the targeting of more abundant species lower in the food chain, is called "fishing down the food chain" (Pauly and Watson, 2003). Overfishing has shortened the food chain and sometimes removed one or more of the links. This has increased the system's vulnerability to natural and human-induced stresses, as well as reducing the supply of fish for human consumption. In many cases restrictions on taking of smaller fish of each species has resulted in rapid evolution so that fish mature and reproduce at smaller sizes.

Livestock play an important role in the overall pressure of demand for fish. It is estimated than in 2004, 24.2 percent of world fishery production was used for fishmeal and fish oil for feed (Vannuccini, 2004). Approximately 17 percent of the fishmeal produced in the world is manufactured from trimmings from food fish processing and so has little independent impact on fish stocks. However, the remaining 83 percent comes from direct marine capture fisheries (Fishmeal Information Network, 2004). Fishmeal's importance as a feed component started in the 1950s in the United States industrial poultry production. It is now used as a feed ingredient in modern poultry and pig production, in developed and developing countries alike.

Fishmeal production increased until the mid-1980s and has been relatively constant at 67 million tonnes since then. As it takes 45 kilograms of wet fish to produce 1 kilogram of fish oil and dry fishmeal, this requires an annual ocean catch of 20–25 million tonnes of feed-grade fish, plus 4 million tonnes of trimmings from food fish (IFFO, 2006). To date, more than 80 percent of world fishmeal production originates in ten countries, of which the two largest producers are Peru (31 percent of the total) and Chile (15 percent). China, Thailand and the United States rank respectively third, fourth and fifth for production. At the same time, three Scandinavian countries (Denmark, Iceland and Norway), Japan and Spain rank respectively sixth to tenth. With more than 1 million tonnes per year, China is the largest world importer of fishmeal, followed by Germany, Japan and Taiwan (FAO, 2006b).

Currently, around 53 percent of global fishmeal production is used by the livestock sector (Fishmeal Information Network, 2004), 29 percent for pig production and 24 percent for poultry. Aquaculture is also a heavy user, and has expanded rapidly; it is now the fastest growing food producing industry in the world. Markets have reallocated the use of a fishmeal whose supply is limited. Between 1988 and 2000 the share of fishmeal consumed by the aquaculture sector more than trebled (from 10 percent to 35

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About 400 tonnes of jack mackerel (Trachurus murphyi) are caught by a Chilean purse seiner – Peru 1997 percent), while the poultry sector's share more than halved (from 60 percent to 24 percent) (Tveteras and Tveteras, 2004). The reduced reliance on fishmeal in the poultry sector came as a result of nutrition research.

The shift towards aquaculture is presented by the fishmeal industry as "environmentally friendly" since fish are more efficient feed converters than terrestrial livestock (Shepherd *et al.*, 2005; Tidwell and Allan, 2001). But while the demand from the aquaculture sector will surely continue to rise (despite the fact that research effort is placed on reducing the share of this protein source in fish feed), there is little prospect for a further decrease in demand by the poultry sector. The strongly industrialized sector remains the fastest expanding livestock production segment, and already uses up-to-date nutrition know-how. In the meantime, demand for fishmeal from the pig production sector continues to increase (from 20 percent of global fishmeal supply in 1988 to 29 percent in 2000) (Tveteras and Tveteras, 2004). Fishmeal constitutes only a few percent of concentrate feed for monogastrics and this is unlikely to decrease further as it constitutes a highly valued protein input in the feed of these animals, particularly during the early stages (e.g. early weaned pigs).

The fishmeal industry claims that the recent stability of official fishmeal production figures is a result of fishery controls governing production, especially quotas, and that therefore there will be no increase in the future (Shepherd *et al.*, 2005). In view of the expected rise in demand, the enforcement of such regulations will need to be very strong. It may not be a coincidence that illegal, unregulated and unreported fishing has increased in many areas (UNEP, 2003). Fishing fleets are venturing farther from their home ports, off the continental shelves and into deeper waters to meet the global demand for fish (Pauly and Watson, 2003).

In the period 1990–1997, fish consumption increased by 31 percent while the supply from marine capture fisheries increased by only 9 percent (FAO, 1999). Some people suggest that this has intensified pressure on fishermen, which has translated into increased pressure on, and overfishing of, many commercial fisheries. Others say that pressure has been too high for a much longer period and that despite an increase in the reach and intensity of commercial fishing operations, the total quantity of fish catches is estimated (contrary to some official data – see GEO Indicators section, UNEP, 2003) to have been declining by about 700 000 tonnes a year since the late 1980s (Watson and Pauly, 2001). The initiatives to manage catches for specific fisheries have been ineffective in halting this downward trend. Alder and Lugten (2002) demonstrate for the North Atlantic that there has been a decline in landings, despite a plethora of agreements that focus on the management of stocks.

Whether global catches and global livestock fishmeal consumption increase or decrease, the latter clearly represents a substantial part of the former and hence the livestock sectors also bears considerable responsibility for the overexploitation of marine resources and the effect on marine biodiversity.

Erosion of livestock genetic diversity

The genetic resources embodied in domesticated animals have been strengthened by the breeding and selection efforts of farmers over thousands of years, in environments ranging from frozen tundra to hot semi-desert. Several thousand domestic animal breed[6] populations have been developed in the 12 000 years or so since the first livestock were domesticated, each adapted

[6] Breed is often accepted as a cultural rather than a biological or technical term. Genetic diversity measured at the molecular level does not always correspond to phenotypic breed diversity, because a long history of exchange, upgrading and crossbreeding has sometimes created similar genotypes with different phenotypes, or different genotypes within similar phenotypes. About half of genetic variability may be found between breeds but the share of within- and between-breed diversity varies among species and traits.

to specific environmental and farming conditions and each representing unique combinations of genes (Hoffmann and Scherf, 2006). Altogether more than 6 300 breeds of domesticated livestock have been identified.

This livestock genetic diversity is threatened. In 2000, over 1 300 of the breeds are now extinct or considered to be in danger of extinction. Many others have not been formally identified and may disappear before they are described. Europe records the highest percentage of breeds that are extinct or at risk (55 percent for mammalian and 69 percent for avian livestock breeds). Asia and Africa record only 14 percent and 18 percent respectively - however the data for developing countries in the World Watch List for Domestic Animal Diversity (Scherf, 2000) are much less complete than those for developed countries. Out of the 7 616 breeds recorded in the Global Databank for Farm Animal Genetic Resources, 20 percent is classified at risk (FAO, 2006b). When breeds without recorded population data are included, the number at risk may be as high as 2 255. These figures represent a 13 percent increase since 1993 (FAO, 2000).

This erosion of biodiversity is the result of what can be seen as competition among breeds, as the large number of specialized traditional breeds adapted to specific environments and cultures lose out to a greatly reduced number of modern commercial breeds. During the twentieth century, research and development in the commercial livestock sector has concentrated on a very small number of exotic breeds, with which rapid increases in meat, milk or egg production were achieved. This has been possible, because the environment in which these breeds perform has been drastically transformed and globally homogenized, removing or controlling the adverse climate, nutritional and disease effects that vary so much from one area to another. Only 14 of the approximately 30 domesticated mammalian and bird species now provide 90 percent of human food supply from animals (Hoffmann and Scherf, 2006).

This reduction in dominant breeds has gone to extraordinary lengths. Examples of specialized stocks are Leghorn chickens, which are superior for egg production, and Holstein-Friesian cattle, which dominate other dairy cattle breeds because of higher milk production (National Research Council, 1993). Over 90 percent of America's milk supply comes from Holstein-Friesian cows, while nine out of ten eggs come from White Leghorn hens. This focus is dictated by economies of scale, allowing for increased productivity gains by increasing the homogeneity of production and products through mass production.

Meanwhile, the genetic base of specialized traditional and regional stocks is narrowing because of a reduction in the effective population sizes as increasing numbers of producers shift to commercial breeds and the size of operations increases.

The arguments in favour of management and conservation of livestock genetic resources are the same as for other types of biodiversity: to maintain use and non-use values to humans,[7] to preserve important components of cultural heritage or typical landscapes, or to preserve traits that may be of value in the future. From the production point of view, the genetic pool is a source of material to confer disease resistance, productivity, or other properties sought after by consumer preferences (length and quality of wool, for example). The gene pool is also the basis for intensification; using conventional breeding techniques (other than genetic modification) it is quicker and more economic, to develop livestock by importing genes from outside a breed than by selecting within a breed. So breed diversity

[7] Use values indicate the direct value derived from food or fibre or other products or services, as well as the indirect value of contributing to landscapes or ecosystems. Another use value is the option value, which is the flexibility to cope with unexpected future events (e.g. climate or ecosystem change) or demands (e.g. disease resistance or product quality). Non-use value (existence value) is the satisfaction of individuals or societies stemming from the existence of the diversity.

allows more rapid genetic progress. Given that unpredictable challenges may emerge in future, from climate change to emerging diseases, a diverse gene pool will be essential for adapting to any change that may occur.

From the environmental viewpoint, however, conservation and further development of diversity may not always be exclusively beneficial. The pool of genetic resources potentially allows livestock to adapt to more demanding, currently too marginal, production environments, enabling them to adapt to a greater variety of habitats and increasing their environmental damage. It remains to be seen if livestock genetic, in balance, contributes to environmental resilience or degradation. Much depends on the management of the genetic resources.

5.3.5 Pollution

Over the past four decades, pollution has emerged as one of the most important drivers of ecosystem change in terrestrial, freshwater and coastal ecosystems. Like climate change, its impact is increasing very rapidly, leading to declining biodiversity across biomes (MEA, 2005b). Overall, pollution affects some 12 percent of globally threatened bird species (187 species), 29 percent of threatened amphibian species (529 species) and 4 percent (28 species) of the 760 threatened mammals for which data are available. The much higher percentage of threatened amphibians impacted by pollution than birds or mammals is probably a reflection of the larger number of species that are dependent on aquatic ecosystems where pollution is more pervasive. Pollution directly affects species through mortality, as well as through sublethal effects such as reduced fertility. Pollution can also have strong indirect effects by degrading habitats or reducing food supplies for animals.

The flow of nutrients (particularly nitrogen and phosphorous) from land-based activities into waterways and oceans is increasing globally. The predominant anthropogenic sources of nutrients are agricultural and industrial activities (fertilizer residues, wastes from animal husbandry, sewage, industrial effluents and atmospheric emissions).

The excess nutrient loads have led to eutrophication of lakes, rivers and coastal waters. Eutrophication involves the increased growth of phytoplankton and can favour the growth of toxic, or otherwise harmful, species. The decay of excessive plankton biomass increases the consumption of dissolved oxygen and occasionally causes periodic or permanent oxygen depletion, leading to mass mortality of fish and other organisms.

Pollution is potentially among the most damaging of all human influences on the oceans, in terms of both scale and consequences. Excessive nutrient inputs can turn marine areas into "dead zones" almost devoid of higher animal life. Nutrients discharged in large quantities into coastal waters promote blooms of planktonic and benthic algae. Phytoplankton blooms contribute to increased water turbidity, reducing light penetration and adversely affecting pelagic and benthic biological communities (GESAMP, 2001). Algal blooms involving toxin-producing species can cause the accumulation of algal toxins in shellfish to levels that can be lethal to other marine species and humans. The organisms affected by algal toxins are shellfish and finfish as well as other wildlife such as seabirds, sea otters, sea turtles, sea lions, manatees, dolphins and whales (Anderson *et al.*, 1993). Other adverse affects on ecosystem functioning were presented in Section 4.3.1.

Coral reefs and seagrass beds are particularly vulnerable to damage from eutrophication and nutrient loading. Eutrophication can also change the dynamics of these marine ecosystems and cause loss of biodiversity, including changes in the ecological structure of both planktonic and benthic communities, some of which may be harmful to fisheries (National Research Council, 2000).

Acid rain has been shown to decrease species diversity in lakes and streams. It has not yet been shown to be a significant issue in tropical freshwaters, where a large proportion of global freshwater diversity is found (World Conservation Monitoring Centre, 1998) - perhaps because industry is currently less developed in the tropics. However, depending on where the precipitation occurs, acidification of freshwaters can affect biodiversity at the species and subspecies level. The effects on freshwater fauna can be catastrophic. In Sweden alone, more than 6 000 lakes have been limed to preserve fish populations (Harvey, 2001).

As with the impact of climate change, the contribution of the livestock sector to global biodiversity loss from pollution is estimated to be proportional to its contribution to water pollution as presented in Chapter 4, which demonstrated that livestock have a major role in the pollution process through erosion and loading with pesticides, antibiotics, heavy metals and biological contaminants. The effect of soil pollution on soil biodiversity is not included in the following discussion because there is insufficient knowledge concerning the extent of soil pollution, soil biodiversity and the loss of soil biodiversity. It is safe to assume, however, that livestock-induced soil pollution is substantial in many locations, and soil is one of the most diverse habitats on earth. It contains some of the most diverse assemblages of living organisms. Nowhere in nature are species so densely packed as in soil communities: a single gram of soil may contain millions of individuals and several thousand species of bacteria.[8]

Direct toxicity from livestock–related residues and wastes

Pollution can act directly on organisms - basically by poisoning them - or indirectly by damaging their habitats. Pollution from livestock-related activities is no exception.

According to IUCN, perhaps the most dramatic recent example of the potentially devastating effects of direct toxicity of livestock-related pollution on wild species relates to vultures. In South Asia, vultures in the genus Gyps have declined by more than 95 percent in recent years owing to the toxic effects of the veterinary drug, Diclofenac, which is consumed when the birds feed on carcasses of livestock treated with the drug. Diclofenac is widely used in human medicine globally, but was introduced to the veterinary market on the Indian subcontinent during the early 1990s (Baillie, Hilton-Taylor and Stuart, 2004).

Residues of drugs used in livestock production, including antibiotics and hormones, have also been identified in various aquatic environments (Section 4.3.1). Low concentrations of antimicrobials exert a selective pressure in freshwater, allowing bacteria to develop resistance to antibiotics. Because this confers an evolutionary advantage, the related genes spread readily in bacterial ecosystems.

In the case of hormones, the environmental concern relates to their potential effects on crops and possible endocrine disruption in humans and wildlife (Miller, 2002). Use of hormones, for example, the steroid trenbolone acetate can remain in manure piles for more than 270 days, suggesting that water can be contaminated by hormonally active agents through runoff. The links between the use of hormones on livestock and their associated environmental impact is not easily demonstrated. Nevertheless, it would explain wildlife showing developmental, neurologic, and endocrine alterations, even after the ban of known estrogenic pesticides. This supposition is supported by the increasing number of reported cases of gender shifts in fish and the increased incidences of mammalian breast and testicular cancers and alterations of male genital tracts (Soto *et al.*, 2004).

Other livestock-related pollutants presented in Section 4.3 directly affect biodiversity as well. Water-borne bacterial and viral pathogens that

[8] See the FAO Soil Biodiversity Portal at http://www.fao.org/ag/AGL/agll/soilbiod/fao.stm for references.

affect wildlife species, and even livestock parasitic diseases, are transmitted, via water, to wildlife species. Chemicals such as chromium and sulphides from tanneries affect aquatic life locally, while pesticides have ecotoxicological effects for aquatic flora and fauna on a much larger scale. Although many pesticides dissipate rapidly through mineralization, some are very resistant and impact the health of wild animals and plants, causing cancers, tumours and lesions, disrupting immune and endocrine systems, modifying reproductive behaviours and producing teratogenic effects (i.e. causing malformations of an embryo or fetus).[9] With regard to pesticide use, Relyea (2004) tested the impact of four globally common pesticides on the biodiversity of aquatic communities: numerous species were eliminated and the ecological balance severely disrupted.

Pollution of habitats by livestock-related activities

Manure and mineral fertilizers used in feed production cause nutrient overloads in soils, as well as point and non-point source pollution of freshwater. Indirect eutrophication through volatilized ammonia is also important. Beyond consequences on local freshwater and soil habitats, the effects may reach as far as coral reefs. Emissions of sulphur and nitrogen oxides (SO_2, NO_x) from industrial livestock operations may also contribute to acid rain.

It is difficult to assess the effects of these forms of pollution on biodiversity. First, point-source pollution will be affected by the location of industrial livestock operations. Most industrial livestock operations (pigs, poultry and milk) are currently situated in peri-urban areas or locations with good feed supply, where biodiversity is generally low compared with wild areas. Second, as regards non-point sources, discharges and runoffs from pastures and livestock production units into main streams are mixed with other non-point sources. Therefore, their effects on biodiversity cannot often be dissociated from other forms of pollution and sediments.

Eutrophication of surface water damages wetlands and fragile coastal ecosystems, and fuels algae "blooms" that use up oxygen in the water, killing fish and other aquatic life (see Section 4.3.1 for other adverse effects). The contribution of the livestock sector to the rapidly increasing impact of eutrophication on biodiversity (MEA, 2005b) varies greatly around the world, but the importance of fertilizer use for feed production (Section 3.2.1) and the local importance of industrial livestock production units (Section 2.4) may well constitute good indicators for the regional importance of the sector's contribution. Based on the case of the United States analysed in Section 4.3.3, it may for example well be that the livestock sector as a driver of feed production has prime responsibility for the worsening of hypoxia (very low oxygen levels) in the northern Gulf of Mexico (see Box 5.6).

Threatened coastal habitats of East and Southeast Asia

Nowhere have the rapid growth of livestock production, and its impact on the environment, been more evident than in East and Southeast Asia. Over the decade of the 1990s alone, production of pigs and poultry almost doubled in China, Thailand and Viet Nam. By the year 2001, these three countries alone accounted for more than half the pigs and one-third of the chickens in the entire world. Not surprisingly, these same countries have also experienced rapid increases in pollution associated with concentrations of intensive livestock production. Pig and poultry operations concentrated in coastal areas of China, Viet Nam and Thailand are emerging as a major source of nutrient pollution of the South China Sea (FAO, 2004e). Along much of the densely populated coast, the pig density exceeds 100 animals per km^2 and agricultural lands are overloaded with huge nutrient surpluses.

[9] See also Chapter 4.

Box 5.6 **Gulf of Mexico hypoxia**[1]

The Mississippi River and northern Gulf of Mexico system is a prime example of the worldwide trend of increasing river-borne nutrients and the resulting diminution in the quality of coastal water.

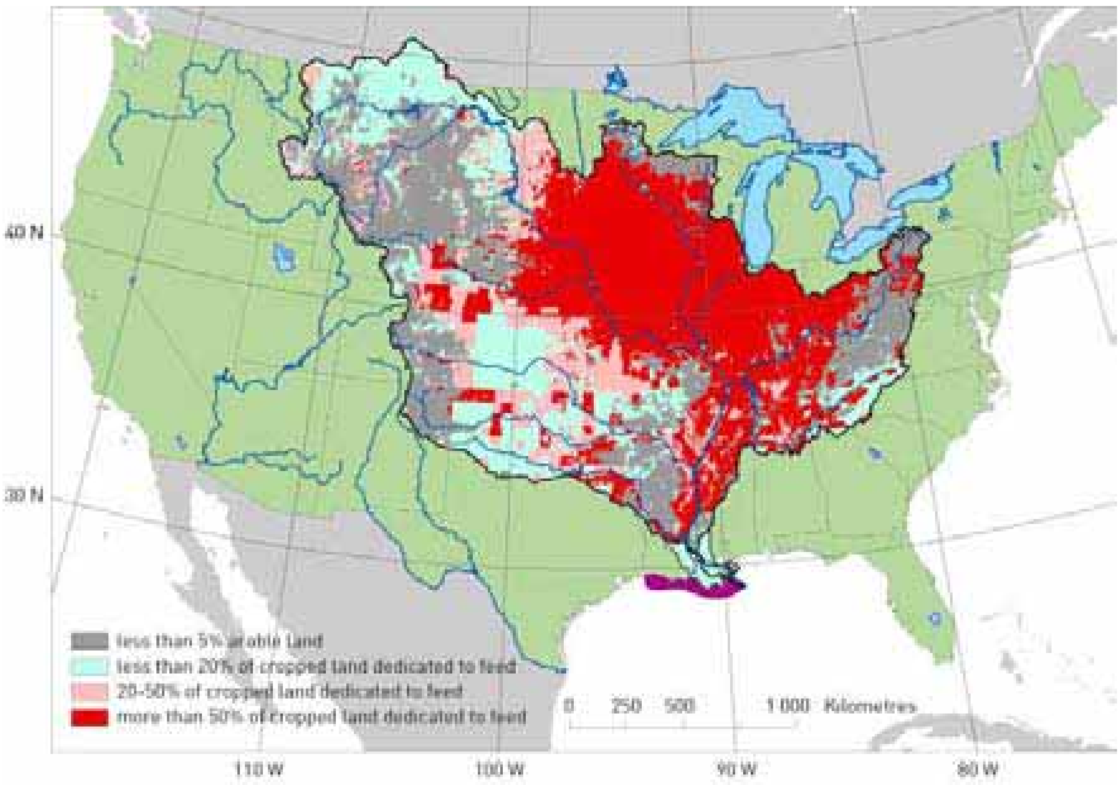
The Mississippi River system drains 41 percent of the contiguous United States into the Gulf of Mexico. It ranks among the world's top ten in length, freshwater discharge and sediment delivery (see Map 5.2).

The summer bottom-water hypoxic zone in the Gulf of Mexico has gradually grown to its present size, second in area only to the hypoxic zone of the Baltic basins (approximately 70 000 km^2). In midsummer 2001, the bottom-water area of the Gulf covered by hypoxia reached 20 700 km^2 (Rabalais, Turner and Scavia, 2002). Over this area, the level of oxygen fell to less than 2 mg/litre a level at which shrimp and demersal fish are not found. Hypoxia occurs usually only at the bottom near the sediments but can reach well up into the water column. Depending on the depth of the water and the location of the pycnocline (zone of rapid vertical density change), hypoxia typically affects 20 to 50 percent of the water column.

According to Rabalais *et al.* (2002) hypoxia might have existed at some level before the 1940–1950

[1] Hypoxia: a reduced concentration of dissolved oxygen in a water body leading to stress and death in aquatic organisms.

Map 5.2 **Feed production in the Mississippi River drainage basin and general location of the 1999 midsummer hypoxic zone**



Note: see Annex 3.4.
Source: adapted from Rabalais, Turner and Scavia, (2002).

Box 5.6 cont.

period; clearly it has intensified since then. For example *Quinqueloculina sp.* (a hypoxia-intolerant foraminiferan) was a conspicuous member of the fauna from 1700 to 1900, indicating that oxygen stress was not a problem at that time. Sediment core analyses also document increased eutrophication and organic matter sedimentation in bottom waters since the 1950s.

When polluted waters reach the ocean, much of the nitrogen will have denitrified by this point in the nitrogen "cascade." However, Rabalais and colleagues present compelling evidence for the close coupling of the levels of river-borne nutrients (nitrogen) and those of ocean primary production, net production, vertical carbon flux and hypoxia.

The analysis in Section 4.3.3 suggested that the livestock sector is the leading contributor to water pollution by nitrogen in the United States. In addition the Mississippi drainage basin contains almost all the United States feed production and industrial livestock production.

In light of these facts, the livestock sector may well bear the prime responsibility for worsening hypoxia in the northern Gulf of Mexico. This is confirmed by Donner (2006) who shows that a dietary shift away from grain-fed beef to vegetarianism in the United States could reduce total land and fertilizer demands of Mississippi Basin crops by over 50 percent, with no change in total production of human food protein. The change would return nitrate-nitrogen export by the Mississippi River to levels at which the Gulf of Mexico ''dead zone'' was small or non-existent.

Source: Rabalais *et al.* (2002).

Land-based nutrient pollution has caused algae blooms in the South China Sea, including one in 1998 that killed more than 80 percent of the fish in 100 km^2 along the coast of Hong Kong and southern China. These changes affect the habitats of many life forms, since the South China Sea supports substantial populations of fish, invertebrates, marine mammals and seabirds. The consequences for regional biodiversity may be far-reaching. As an example, since 2002 increasing masses of giant jellyfish reach the Japanese coast year round and severely hamper fishing campaigns. These species originate in the East China Sea, where they are proliferating because of an increasing availability of zooplankton resulting from land-based pollution induced eutrophication and decreasing fish stocks.

The impact of the decline in the quality of coastal seawater and sediment, in one of the world's most biologically diverse shallow water marine areas, the East Asian Seas, goes well beyond algal blooms and the related effects upon the food chain. Fragile coastal marine habitats are threatened, including coral reefs and sea grasses, which are irreplaceable reservoirs of biodiversity; the last refuge of many endangered species. Threatened coastal areas of the South China Sea, for example, have provided the habitat for 45 of the world's 51 mangrove species, almost all of the known coral species and 20 of 50 known sea grasses. In addition, the area is the world's centre for diversity of hermatypic corals, with more than 80 recorded genera, of which four appear to be endemic to the region; there are record high numbers of molluscs and shrimp species. It also contains a high diversity of lobsters, with the second highest endemism count (World Conservation Monitoring Centre, 1998). Southeast Asia contains one-quarter of the world's mapped reefs of which over 80 percent are at risk, and over half (56 percent) are at high risk. The most significant threats are overfishing, destructive fishing practices, sedimentation, and pollution associated with coastal development (Bryant *et al.*, 1998). Land-based pollution (industrialization, urbanization, sewage and agriculture) constitutes an increasing pressure on the coral reef ecosystems.

Pollution also drives habitat change in freshwater systems. Though eutrophication dramatically impacts locally, sediments from soil erosion, a non-point source pollutant caused by the livestock sector as well as by agriculture at large, are considered a larger threat. Section 4.3.3 discussed the numerous ways through which soil erosion impacts offsite habitats. Increased rates of sediment input into estuarine and coastal habitats have been observed (East Bay Municipal Utility District, 2001). Field studies have looked at the consequences of terrestrial sediment deposition, water-borne sediment and long-term changes in habitats. They indicate that (similar to the impact in freshwater ecosystems) increasing rates of sediment loading adversely affect the biodiversity and ecological value of estuarine and coastal ecosystems.

5.4 Summary of livestock impacts on biodiversity

We have attempted to present the full range of the more important and widespread impacts of livestock on biodiversity. Clearly livestock's shadow is very long: not only does it erode biodiversity through a wide range of distinct processes, but also its contribution to each of these processes takes multiple forms (e.g. Section 5.3.3). The shadow appears even larger if we consider that important ecosystem losses date back several centuries, with impacts still occurring today.

It is currently difficult to be precise when quantifying livestock-induced biodiversity loss. Losses are the result of a complex web of changes, occurring at different levels, each of which is affected by multiple agents. This complexity is further compounded by the consideration of the time dimension. In Europe, for example, practices such as extensive grazing that were responsible for much of the continent's historic habitat fragmentation are now seen as a means for conservation of today's much valued landscape (and sward) heterogeneity. Similarly in Africa, although pastoralists are responsible for past loss of wildlife through persecution of predators, pastoralism is often seen as a means to conserve the much needed mobility of remaining wildlife.

Nevertheless, we have attempted in this chapter to give an idea of the share of responsibility that livestock may carry for various types of loss and threat. Usually, this is based on our calculations in earlier chapters, for example on shares of greenhouse gas emissions, soil erosion or water pollution loads.

The processes can also be ranked in a more qualitative manner, according to their relative extent and severity. Table 5.3 presents such a ranking based on LEAD expert knowledge and the broad review of research results presented in this report. The large differences in impact between the losses related to extensive grazing and those to intensive livestock are reflected. The overall cumulative loss from extensive systems to date is much higher than that induced by the more intensive systems. This legacy is partly explained by the incomparably higher land requirements of extensive systems, and partly by the fact that intensive systems appeared only a few decades ago. The differences between the future trends (arrows in Table 5.3) show that for a number of processes, losses induced by intensive systems are increasing rapidly and may well surpass those that are more extensive. Some processes are related only to extensive systems (e.g. desertification), others to intensive systems (e.g. overfishing). In the past, the most dramatic losses were caused by extensive grazing, in the forms of forest fragmentation/deforestation and alien plant invasions, and by intensive systems in the form of habitat pollution.

Conversion of forest to pasture continuous to be an important process of biodiversity loss in Latin America, but this situation is rather atypical. At the global level, as described in Section

2.1.3, the land requirements of the livestock sector may soon reach a maximum and then decrease. More marginal land will revert back into (semi) natural habitat, and from there, under some circumstances, it may lead to the recovery of biodiversity.

Indications of the global impact of animal production and its distribution

International conservation organizations have collected vast amounts of data on the global status of biodiversity over the past decades. Data from organizations such as the WWF, the IUCN contain information on the nature of current threats to biodiversity (eg. Baillie, Hilton-Taylor and Stuart, 2004). These data collections, even though they do not cover the entire range of livestock related processes, provide clear evidence that the livestock sector's role in biodiversity erosion is very substantial.

An analysis for this report of the 825 terrestrial ecoregions identified by WWF shows that 306 of them reported livestock as one of the current threats – even though pollution from livestock is not considered, and important segments of the animal product food chain are ignored. The ecoregions threatened by livestock are found across all biomes and all eight biogeographical realms (see Map 29 in Annex 1).

The effect of livestock on biodiversity hotspots may indicate where livestock production is having the greatest impact on biodiversity. Conservation International has identified 35 global hotspots, which are characterized both by exceptional levels of plant endemism and by serious levels of habitat loss.[10] 23 of the 35 biodiversity hotspots are reported to be affected by livestock production (see Map 30 in Annex 1). The reported causes are related to habitat change and associated with the mechanisms of climate change, overexploitation and invasive alien species. Major reported threats are: conversion of natural land to pastures (including deforestation), planting of soybean for animal feed, introduction of exotic fodder plants, use of fire for pasture management, overgrazing, persecution of livestock predators and feral livestock. The role of the livestock sector in aquatic impacts (pollution and over-fishing) is not singled out.

An analysis for this report of the IUCN Red List of Threatened Species, the world's most authoritative source of information on extinction risk, indicates that the 10 percent of the world's species which face some degree of threat are suffering habitat loss from livestock production. Livestock production appears to have more impacts on terrestrial than on freshwater and marine species, as the important effects of habitat loss and habitat degradation are most significant on land.

5.5 Mitigation options for conservation of biodiversity

Classical approaches to conservation – such as attempting to preserve pristine habitats within national parks and other protected areas and to develop corridors between them – will always be necessary and will help to reduce the pressures on biodiversity. But in view of the severity and variety of current threats to biodiversity, efforts are also needed to reduce the many other pressures on wildlife. The livestock sector is a very significant source of many of these pressures, with a wide variety of impacts, many if not most of which occur in already disturbed environments.

Earlier chapters have described technical options for some of the specific threats which have an impact on biodiversity. In relation to wildlife, the focus should be on reducing those threats that currently have the largest impact or that are expected to become more important in the near future. Table 5.3 in the preceding

[10] The hotspot approach aims to identify the places where the most threatened biodiversity needs to receive the most urgent action. To qualify as a hotspot, a region must meet two strict criteria: it must contain at least 1 500 species of vascular plants (more than 0.5 percent of the world's total) as endemics and it must have lost at least 70 percent of its original habitat.

Table 5.3

Expert ranking of livestock- related threats to biodiversity resulting from the different mechanisms and types of production system

Mechanism of livestock sector induced biodiversity loss	Type of livestock production system: Extensive production	Type of livestock production system: Intensive production	Affected level of biodiversity: Intra-species	Affected level of biodiversity: Inter-species	Affected level of biodiversity: Eco-system
Forest fragmentation	↗ (very strong)	↑ (moderate)	●	●	●
Land use intensification	↗ (moderate)	↑ (moderate)		●	
Desertification	→ (strong)	(white)		●	
Forest transition (reversion of former pastures)	↗ (weak)	(white)		●	●
Climate change	↗ (weak)	↑ (white)	●	●	●
Invasive livestock	↘ (weak)	(white)		●	
Plant invasions	↘ (very strong)	→ (weak)		●	●
Competition with wildlife	↘ (moderate)	↑ (weak)		●	
Overfishing	(white)	↗ (moderate)	●		
Livestock diversity erosion	(white)	↑ (weak)	●		
Toxicity	(white)	↑ (moderate)	●		
Habitat pollution	→ (moderate)	↑ (strong)		●	●

Legend: Relative level and type of threat to biodiversity resulting from the different mechanisms. "Extensive" and "Intensive" refer to the importance of the contributions from both sides of the continuum of livestock production systems.

Red shading indicates the level of past impact

■ very strong
■ strong
■ moderate
■ weak
white: no effect

Arrows indicate the direction of current trends

↘ decreasing
→ stable
↗ increasing
↑ rapidly increasing

section provides an idea of which processes and production systems may require most attention. Examples that stand out as important are the impact of land use intensification and habitat pollution induced by the intensive production environments; desertification in extensive grazing areas; and forest fragmentation related to both the extensive and intensive sectors.

In essence, mitigating the impact will consist partly in reducing the pressures, partly in better management of the interaction with natural resources, be it fisheries, wildlife, vegetation, land or water. The improvement of that management is more an issue of policy and regulation than of technical capacity building and research. Consolidating a network of well protected areas is an obvious start. This policy component of biodiversity conservation is dealt with in Chapter 6. Still for a number of threats technical options are available, which are presented here without discussion of the policy conditions required for their successful adoption.

To a large extent, biodiversity loss occurs as a consequence of environmental degradation processes analysed in the preceding chapters. Numerous options, highlighted in earlier chapter sections on mitigation, therefore also apply here for example on deforestation (also an issue of mitigating CO_2 emissions, Section 3.5.1), climate change (Section 3.5), desertification (rehabilitation of cultivated soils and pastures, Section 3.5.1; management of water, herds and grazing systems in 4.6), pollution (waste management and air pollution, Sections 3.5.3; 3.5.4 and 4.6.2).

A number of technical options could lessen the impact of intensive livestock production. Concerning feed cropping and intensive pasture management, integrated agriculture[11] provides a technology response by reducing pesticide and fertilizer losses. Conservation agriculture (see also Section 3.5.1) could restore important soil habitats and reduce degradation. Combining such local improvements with restoration or conservation of an ecological infrastructure at the landscape level (Sanderson *et al*., 2003; Tabarelli and Gascon, 2005) and the adoption of good agricultural practices (sanitary measures, proper handling of seed lots avoiding contaminants, etc.) may offer a good way of reconciling the conservation of the functioning of ecosystems and the expansion of agricultural production.

Improvements in extensive livestock production systems can make a contribution to biodiversity conservation. Successfully tested options exist (see Sections 3.5.1 and 4.6.3) to restore some of the habitat lost by expansion of badly managed grazing land. In some contexts (e.g. Europe) extensive grazing may provide a tool to maintain a threatened but ecologically valuable level of landscape heterogeneity. Such options are commonly grouped under the denominator "silvopastoral systems" (including pasture management). Mosquera-Losada and colleagues (2004) present a wide range of such options and assess their effect on biodiversity.

These categories of options are all of great importance as they apply to wide-spread threats. Many others exist, often addressing threats of a more regional nature. Box 5.7 presents an example of a situation where the development of intensive farming of game species might contribute to the conservation of remaining wildlife.

It is important also to consider a more general principle. Land use intensification has been presented so far in this section as a threat to biodiversity because it is often synonymous with an uncontrolled profit-driven process with insufficient consideration for externalities (leading to loss of agro-ecosystem diversity). However, given the growth of the global livestock sector, intensification is also an important technological pathway, because it allows a reduction of the pressure on natural land and habitat, also reducing the risk of plant invasions.

[11] Integrated agriculture is a system of agricultural techniques developed in France in 1993 by Forum de l'Agriculture Raisonnée Respecteuse l'Environnement (FARRE). It is an attempt to reconcile agricultural methods with the principles of sustainable development, by balancing, in the words of FARRE, "food production, profitability, safety, animal welfare, social responsibility and environmental care."

Box 5.7 Livestock production to safeguard wildlife

Bushmeat was and remains an important inexpensive source of protein in African society. Hunting pressure on wild fauna has considerably increased over recent decades because of:

- population growth around forest and national parks has increased local demand for cheap and readily available meat;
- the development of the timber industry has opened many forested areas to settlers in areas where other sources of food supply may be less accessible. Settlers and timber industry workers may locally exert a significant level of hunting pressure on wildlife populations;
- hunting techniques improved massively during the twentieth century, with widespread diffusion of firearms and use of poisons; and
- the growth of urban centres creates an ever-increasing demand for meat supply as living standards improve.

The latter considerably modified the driving forces behind wildlife hunting and poaching. Urban demand evolves quickly, beginning with a demand for cheap protein to sustain food security, then adding on a demand for rare meats by the wealthy classes, who pay high prices. The bushmeat sector, though originally driven by subsistence needs from local actors, is increasingly driven by this economic rationale (Fargeot, 2004; Castel, 2004; Binot, Castel and Canon, 2006).

With the recent zoonosis crisis (Ebola, SARS), local consumers have changed their perception of bushmeat. Recent studies show that bush meat is no longer the food of preference for several local communities and temporary communities on the forest fringe (work forces hired by logging companies). Nevertheless, owing to the generally poor development of transport and marketing in the livestock sector in tropical Africa, availability of conventional meats is often too low – especially in areas where wildlife is at risk.

In this context, the livestock sector could help to lower the hunting pressure on wildlife by developing sufficient meat production and marketing capacity to guarantee food security and safety locally in areas where bushmeat consumption threatens wildlife. The development of an industrial livestock sector could supply the populations with meat at a cheaper price, but this is constrained by the lack of infrastructure. Carefully planned infrastructure development (transportation network, cold chain, etc.), to transport the products to the consumer or to transport production inputs (vaccines) required by livestock production units, might enable the livestock sector to contribute to wildlife conservation.

Non-traditional livestock production systems of selected wildlife species also offer alternatives to reduce hunting pressure on wildlife. The on-farm production of, the Greater Cane Rat (*Thryonomys swinderianus*) can be intensified, and can supply the urban centres with bushmeat. In rural areas "Game ranching" can provide regular bushmeat supply to the communities, regulating the market price of bushmeat and de facto reducing the poaching pressure on wildlife.

Sources: Houben, Edderai and Nzego (2004); Le Bel *et al.* (2004).

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Adult greater cane rat (Thryonomys swinderianu) – Gabon 2003