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COMMISSION ON GENETIC RESOURCES FOR FOOD AND AGRICULTURE

ECOSYSTEM SERVICES PROVIDED BY LIVESTOCK SPECIES AND BREEDS, WITH SPECIAL CONSIDERATION TO THE CONTRIBUTIONS OF SMALL-SCALE LIVESTOCK KEEPERS AND PASTORALISTS

by
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Executive summary

This study explores the nature of ecosystem services provided by livestock species and breeds, with special consideration to the important contributions to these by small-scale livestock keepers and pastoralists. It has been developed on the basis of multiple information sources: A global and a European survey on ecosystem services provided by livestock species and breeds in grazing systems, County Reports for *The second report on the State of the World's Animal Genetic Resources for Food and Agriculture*, an extensive literature review, and an assessment of breed types by livestock production systems. The Global Survey attracted 120 responses from 47 countries across all regions and covered all major grassland habitats, providing information on more than 150 breeds.

Humankind benefits in a multitude of ways from ecosystems, from providing for its most basic needs, such as food, clean water and shelter, to the realization of its higher personal and collective aspirations and future resilience. Together, these benefits are known as ecosystem services. The concept of ecosystem services serves as a vital link for understanding the relationship between environmental challenges and human development. Biodiversity is linked to the concept of ecosystem services in many direct and indirect ways. The multiple dimensions of biodiversity (e.g. habitats, communities, species, individuals and genes, including the diversity within species - both wild and domesticated - and the way in which they interact in communities and ecosystems) play different roles in the delivery of ecosystem services and are essential for the sustained production of food, fibres, fuels, energy, clean air and freshwater on which humans depend.

Livestock species and breeds are key components of agro-ecosystems and therefore play an essential role in the provision of ecosystem services. Like other genetic resources for food and agriculture, livestock breeds are both providers of ecosystem services and, in themselves, an ecosystem service arising from, and dependent on, other ecosystem functions. Their interaction with other ecosystem components and processes is more complex than that of plants, because of livestock's higher position in the food web, which results in conversion losses and associated environmental externalities. There are three characteristics of livestock that shape their specific roles in ecosystems: (1) livestock's unique ability to convert non-human edible feed and organic waste into useful products, through their digestive tracts; (2) the direct nature of their interaction with ecosystems (e.g. land, vegetation and soil) through trampling, grazing and browsing, as well as the production of urine and dung; and (3) their mobility and resulting ability to respond to temporal and spatial fluctuations of ecosystems in resource availability. Finally, the contribution of livestock species and breeds to ecosystem services is intimately tied to the production systems they are associated with and hence the diverse human management systems affecting these.

Ecosystems can be categorized in different ways. The Millennium Ecosystems Assessment distinguished four groups of ecosystem services: (1) provisioning services referring to products obtained from ecosystems; (2) regulating services referring to benefits obtained from the regulation of ecosystem processes; (3) supporting services which are necessary for the production of all other ecosystem services; and (4) cultural services referring to non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences. Other classifications separate habitat services from supporting services, to emphasize the role of landscapes, including agricultural landscapes, in the provision of habitats for biodiversity and wildlife. This study has grouped supporting, regulating and habitat services together, because of their interconnected nature, as well as their shared roles in underpinning the delivery of provisioning and cultural services.

Ecosystem services can also be divided into those that can be converted into and marketed as private goods (e.g. provisioning services and to some extent cultural services) and those that underpin the production of these, but are of a non-market public good nature (e.g. regulating, supporting and most cultural services). One of the main challenges in ensuring the continued flow of ecosystem services other than provisioning and marketable cultural services is that their value is relatively invisible.

Studies have been undertaken to assess the economic value of pastoralism and the value of temperate grasslands. Both find that few country case studies exist, and that global understanding of the total

economic value of the goods and services provided by these systems is virtually non-existent. This lack of understanding will continue to threaten the long-term ecological viability of these systems.

While there is a wealth of information on the ecosystem services provided by livestock in general, it is more difficult to find studies at species level and almost impossible to find studies at breed level. To assess the extent of the provision of ecosystem services at breed level, it was therefore necessary to take an indirect approach, in which a combination of data on production systems, land cover and climatic zones were taken as a proxy for the presence of species and breeds in ecosystems, and their roles in the delivery of related ecosystem services.

There are indications that hardiness, pasturing behaviour and dietary choice play a role in this, in addition to the size and weight of the animals, which are traits that differ between breeds. Such traits are particularly advantageous in the provision of services in environments that are harsh or challenging (e.g. those at high elevations or characterized by steep slopes, rugged terrain or extreme climates). Breeds well adapted to temperature extremes, harsh environments and coarse and scarce feed resources are mostly found in mountain regions or semi-arid rangelands. Environments with low productivity of vegetation require low stocking rates and breeds with low feed requirements. Particularly on dry pastures, only breeds that have low fertility and low performance can be sustained. On degradation-prone soils, the weight of the animals, their use of the terrain and their spatial mobility are important.

Provisioning services – such as the supply of food, fibres and skins – are easier to quantify and value than other ecosystem services, since most have a direct use value and a related market price. Livestock provide approximately 26 percent of human global protein consumption and 13 percent of total calories. Foods of animal origin, such as meat, eggs, milk and dairy products, supply a concentrated variety of essential, highly bioavailable nutrients to the diets of people, such as protein, iron, vitamin A, vitamin B12 and zinc, with special nutritional importance for vulnerable populations. They provide a critical supplement and diversity to staple plant-based diets, and are particularly appropriate for combating malnutrition and a range of nutritional deficiencies. The total value of livestock production in 2010 was US$836 787 million, equivalent to 37 percent of the value of all agricultural production. Significant other provisioning services include draught power, manure and urine for fertilizer, manure for methane and energy, as a genetic resource itself, including for biotechnical and/or medicinal purposes. The role of specific breeds relates mostly to the fact that they are able to deliver provisioning services in challenging environments to which they are adapted, which often coincide with poverty and poor nutritional conditions. Additionally, their multipurpose nature may respond well to many poor people’s livelihood needs, including the distinct needs of women.

Supporting and regulating ecosystem services are non-consumptive and in economic terms have only indirect use values or non-use values. They are partly interlinked and are inputs to other services, particularly provisioning and cultural services. Most regulating and supporting services arise from the direct interaction of animals with their environments, and are therefore related to land management practices, especially in grazing systems. The study found the following ecosystem services to be prominent: waste recycling and weed control; biological control and animal/human disease regulation; maintenance of soil structure and fertility (nutrient cycling and distribution, organic matter, etc.); prevention of land degradation and erosion; climate regulation; regulation of water flow and quality; moderation of extreme events (shrub control and maintenance of fuel breaks, prevention of landslides and avalanches); pollination and seed dispersal; and habitat services (facilitating the life cycles of animals and plants, prevention of succession to less valuable ecological states through encroachment of bush and/or invasive species, and the conservation of wild-life and protected areas found in co-evolved landscapes). A close spatial overlap of livestock grazing with nature conservation areas was found, indicating that the goals of breed conservation and nature conservation can be combined.

It is estimated that nutrient cycling provides the largest contribution (51 percent) of the total value of all ecosystem services provided each year. Breed roles in supporting and regulating services prominently relate to the ability of indigenous breeds to provide these ecosystem services in harsh, remote and/or fragile environments, which correlate strongly with the presence of poor small-scale livestock keepers and pastoralists, who are highly dependent on nature’s goods and services.

Supporting and regulating ecosystem services are, however, critically mediated by human management: Low intensity grazing in most grasslands has a positive influence compared to intense grazing or no grazing at all. Overstocking and mismanagement can easily tip the balance to the provision of disservices.

Cultural services refer to non-material benefits people obtain from ecosystems. This study and its related Global Survey found the following cultural services related to livestock species and breeds to be significant: contribution to cultural heritage and identity; existence and spiritual values; roles social events and relations; roles in social status; related knowledge systems and educational values; relation to natural heritage and roles in cultural landscapes; as well as roles in recreation and tourism, including through breed specific product. The study found strong correlations with and many examples of specific indigenous and rare breeds. This strong correlation was found both in the case of small-scale livestock keepers and pastoralists, in whose cultures non-provisioning services are an integral part of life, as well as in developed countries, where consumer preferences and policies are driving the recognition and conservation these services.

There is a strong link between the presence of small-scale livestock keepers and pastoralists, the prevalence of indigenous breeds and the provision of supporting, regulating and cultural services. These links are found in mixed farming systems, and especially in extensive livestock keeping in drylands and mountainous regions. The large areas covered by these production systems, the importance of grasslands to biological diversity and the link between livestock grazing and nature conservation affirms the role of small-scale livestock keepers and pastoralists as guardians of biodiversity beyond the management of their breeds.

Although numbers for small-scale livestock keepers in mixed farming systems are difficult to estimate, nomadic and transhumant pastoralists number between 100 million and 200 million people worldwide. The strong link between ecosystem services and these populations is rooted in their distinct cultural features and livelihood systems. Although communities can differ significantly in this regard, their cultures tend to embody a much higher appreciation of ecosystem services other than provisioning ones, compared to modern (urban) lifestyles. Simultaneously, their intergenerational knowledge systems allow them to understand and monitor ecological processes and changes in relation to their own management choices.

Many small-scale livestock keepers' and pastoralists' management practices are eroding quickly, due to several converging factors: absolute and relative poverty as well as resource competition, driving the adoption of unsustainable livelihood alternatives; insecure land and natural resources tenure, including transboundary tenure; policies and programmes driving sedentarization, land-use changes and cultural changes; political marginalization and low levels of participation in decision-making; armed conflicts; exclusion from protected areas; as well as negative stereotypes and low status.

The study and its related Global Survey identify the following constraints to the provision of ecosystem services by livestock species and breeds, to be the most serious: lack of sufficient income from livestock production; lack of supporting policies, rules and financial incentives; and lack of recognition of services other than provisioning services. Additionally, cultural changes, environmental factors (e.g. climate change), considerable knowledge and research gaps, especially at the level of breeds; institutional, political and operational aspects (e.g. participation in decision-making, infrastructure, tenure) are identified.

In terms of opportunities, the following priorities are identified: improved recognition of and accounting for non-provisioning ecosystem services, including through valuation methods; the development of favourable policies, as well as cross-sectorial collaboration (among e.g. livestock, land, environment, infrastructure, heritage, nature conservation and cultural sectors); and fair and inclusive stakeholder mechanisms. In order to address the most prominently observed constraint (lack of income/poverty), which leads to low maintenance of and investment in ecosystem services other than provisioning ones, incentive mechanism may be explored. The development of niche markets, value chains and labelling system is under way in many countries, but their significance in developing countries has been limited so far. It was also found that markets cannot compensate for the total economic value of the full range of ecosystems alone. Under such conditions, payment for environmental and ecosystem services schemes can be explored. Their functioning relies to a large extent on favourable institutional conditions, especially fair and clear tenure over land and natural resources. Therefore, more general investments in sustainable livestock development may remain more relevant to the conditions found in most developing countries.

International instruments and bodies that support and can further promote the actual and potential roles of livestock species and breeds, as well as their keepers in the provision of ecosystem services, include the *Global Plan of Action for Animal Genetic Resources* that was negotiated by the Commission on Genetic Resources for Food and Agriculture and endorsed by the FAO Conference. Strategic Priority 5 (Promote agro-ecosystems approaches to the management of animal genetic resources) and Strategic Priority 8 (Establish or strengthen *in situ* conservation programmes) of the *Global Plan of Action* emphasize the link between livestock breeds and agro-ecosystems, and Strategic Priority 6 (Support indigenous and local production systems and associated knowledge systems of importance to the maintenance and sustainable use of animal genetic resources) stresses the links between breeds and small-scale livestock keepers and pastoralists.

Other supporting international instruments and bodies are the World Heritage Convention, the CBD, the African Union's Policy Framework for Pastoralism and the AU's Interafrican Bureau for Animal Genetic Resources, the UN Permanent Form on Indigenous Issues, the RIO+20 process, The Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security, and the Committee on Food Security.

Acronyms and abbreviations

ADB	Asian Development Bank
ATNESA	Animal Traction Network for Eastern and Southern Africa
AU-IBAR	African Union Interafrican Bureau for Animal Resources
C	Carbon
CAP	Common Agricultural Policy
CBD	Convention on Biological Diversity
CFS	Committee for Food Security
COP	Conference of the Parties
County Report	County Report for *The second report on the State of the World's Animal Genetic Resources for Food and Agriculture*
DAD-IS	Domestic Animal Diversity Information System
DAP	Draught animal power
EC	European Commission
EEA	European Environment Agency
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FCR	Feed conversion ratio
FYM	Farmyard manure
GHG	Greenhouse gases
GLEAM	Global Livestock Environment Assessment Model
HNV	High nature value farmland
IEA	International Energy Agency
ILO	International Labour Organization
IUCN	International Union for Conservation of Nature
LCA	Life-cycle assessment
MA	Millennium Ecosystem Assessment
MSA	Mean species abundance
N	Nitrogen
PDO	Protected designations of origin
PES	payments for environmental/ecosystem services
PGI	Protected geographical indication
SDGs	Sustainable development goals
Second Report	*The second report on the State of the World's Animal Genetic Resources for Food and Agriculture*
SFSP	Sustainable Food Systems Programme
SGM	Sustainable grassland management
TEEB	The Economics of Ecosystems and Biodiversity
TEV	Total economic value
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WWF	World Wide Fund for Nature

1. Introduction

The *Global Plan of Action for Animal Genetic Resources* (FAO, 2007c) was negotiated by the Commission on Genetic Resources for Food and Agriculture, which also oversees its implementation, and endorsed by the FAO Conference. Strategic Priority 5 (Promote agro-ecosystems approaches to the management of animal genetic resources) and Strategic Priority 8 (Establish or strengthen *in situ* conservation programmes) of the Global Plan of Action (FAO, 2007c) highlight links between livestock breeds and agro-ecosystems, and Strategic Priority 6 (Support indigenous and local production systems and associated knowledge systems of importance to the maintenance and sustainable use of animal genetic resources) links breeds to small-scale livestock keepers and pastoralists.

This study aims at identifying the nature of ecosystem services provided by livestock species and breeds kept by all livestock keepers, with special consideration to the important contributions of small-scale livestock keepers and pastoralists. Given its relatively novel subject matter, this study represents FAO's first exploration and overview of the available science and experts' perspectives on the topic. It has been developed on the basis of multiple information sources: a global and a European survey on ecosystem services provided by livestock species and breeds in grazing systems, County Reports for the second State of the World's Animal Genetic Resources for Food and Agriculture (FAO, 2014a), an extensive literature review, and a spatial assessment of breed types by livestock production systems.

The current section introduces the concept of ecosystem services, its relationship with biodiversity in general and animal genetic resources for food and agriculture in particular. It also introduces the methodology for ecosystem services valuation. Chapter 2 provides a detailed account of the methodology followed in the current study. Chapters 3 to 5 present the findings of the study on the nature and importance of different categories of ecosystem services provided by different livestock production systems and, indirectly, by the species and breed types prevailing in these systems. Chapter 6 highlights the specific contributions by small-scale livestock keepers and pastoralists in the delivery of ecosystem services. Chapter 7 outlines the current challenges to and opportunities for the sustainable delivery of ecosystem services provided by livestock species and breeds, as well as ways and means to support livestock keepers therein. Chapter 8 concludes with a discussion of the findings in the context of international agreements.

1.1. Ecosystem services, biodiversity and the roles of livestock species and breeds

The concept of ecosystem services is rooted in the simple notion of humanity's dependence on its natural environment. Humankind benefits in a multitude of ways from ecosystems, from providing for its most basic needs, such as food, clean water and shelter, to the realization of its higher personal and collective aspirations. Together, these benefits are known as ecosystem services. The concept of ecosystem services, as we know it today, was largely developed by and gained widespread acceptance through the Millennium Ecosystem Assessment (MEA, 2005a). It serves as a vital link for understanding the relationship between environmental challenges and human development; between the international community's environmental conventions, particularly the Convention on Biological Diversity (CBD), the Convention to Combat Desertification (UNCCD), and the United Nations Framework Convention on Climate Change (UNFCCC), and its goals for economic development and the eradication of poverty and hunger, reflected in the Millennium Development Goals and the Sustainable Development Goals under the UN Commission on Sustainable Development.

Being the first global study of its kind, the MA examined how on-going changes in the world's ecosystems impact on human well-being. It started from the understanding that human actions have impacts on ecosystems, causing changes in ecosystem structure and function and that, in turn, such changes influence human well-being through changes in the flow of ecosystem services upon which humans depend (Costanza *et al*., 1997). It defined human well-being widely, comprising of multiple constituents, including the basic material for a good life, health, good social relations, security, and freedom of choice and action.

The MA distinguished four groups of ecosystem services: **(1) provisioning services** referring to products obtained from ecosystems; **(2) regulating services** referring to benefits obtained from the regulation of ecosystem processes; **(3) supporting services** which are necessary for the production of all other ecosystem services; and **(4) cultural services** referring to non-material benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences. Some services (in particular supporting and regulating services) are inputs for the production of others, particularly provisioning services. Supporting services differ from the other services in the sense that their impacts on human welfare are indirect and occur over long time scales, whereas changes in the other services have relatively direct and short-term impacts. Some services like soil formation and erosion control, or climate regulation, can be categorized as either supporting or regulating services, depending on the time horizon. Many regulating services depend on landscape heterogeneity and the existence of certain landscape elements, such as: grasslands and forests for water and soil retention, hedges against wind erosion and as ecosystem corridors, uncultivated land as a reservoir for biological control, and wetlands for water regulation and as a species refuge. Although the MA classification has become widely accepted, some concerns have been raised regarding the difficulties of its use, for example in capturing spatial and temporal dynamics, the difficulty in separating services produced by the same ecosystem or in reflecting the complexity of interactions between ecological structures, functions and services (Salles, 2011).

A second key initiative on ecosystem services, the Economics of Ecosystems and Biodiversity (TEEB, 2010), defined these as "the direct and indirect contributions of ecosystems to human well-being". TEEB separates services from benefits in order to explicitly identify services providing multiple and indirect benefits. It omits supporting services such as nutrient cycling and food chain dynamics which are seen as ecological processes. However, it elevates habitat services into a separate category to highlight the importance of ecosystems to provide habitat, e.g. breeding ground for migratory species and for the conservation of gene pools and the continuation of natural selection processes. The importance of the gene pool protection of habitats within ecosystems is increasingly recognized, both as "hot spots" for conservation and to maintain the original gene pool of species for food and agriculture.

Ecosystem services can also be divided into those that can be converted into and marketed as private goods (e.g. provisioning services and to some extent cultural services) and those that underpin the production of these, but are of a non-market public good nature (e.g. regulating, supporting and most cultural services). This distinction allows for the evaluation of different livestock production systems in terms of their contribution to the production of private goods, as well as underpinning public goods, and as such, of their overall and long-term contribution to human well-being.

For some ecosystem services, e.g. biological control of crop and livestock pests and diseases, feed or soil fertility, human-made alternatives and complements are available, such as biocides, compound feed or mineral fertilizers. These alternatives increase the provisioning services, but can lead to additional costs and negative impacts on human health and underpinning ecosystem services. Rural poor such as smallholder farmers and pastoralists have limited access to such inputs. They are therefore highly reliant on the provisioning of local ecosystems and are directly affected by ecosystem degradation and agricultural biodiversity loss (CBD, 2012).

Ecosystems may also provide disservices, for example when they facilitate reproduction and dispersal of pathogens for livestock or human health. For example, tropical forests in Africa provide a range of benefits from wild species habitat to climate regulation and water purification. However, they are also a source of trypanosomiasis, which could be classed as an ecosystem disservice. The same applies to malaria as a disservice of wetlands (Silvis and van der Heide, 2013). Vector-borne diseases and zoonoses are disservices of ecosystems to livestock production and human health.

Biodiversity is linked to the concept of ecosystem services in multiple direct and indirect ways. Mace *et al*. (2012) distinguish between biodiversity as a regulator of ecosystem processes, as an ecosystem service in its own right and as a good. While the first role aligns with a functional perspective of biodiversity as an ecosystem service, the latter two often go hand in hand with a wildlife conservation perspective. Itself a multi-facetted concept, biodiversity comprises the variability of all living organisms at various hierarchical levels (e.g. habitats, communities, species, individuals and genes), including the diversity within species - both wild and domesticated - and the way in which they interact in communities and ecosystems. An ecosystem is defined as the complex of interactions, at a specified location, of living organisms and their abiotic environment. These multiple dimensions of biodiversity play different roles in the delivery of ecosystem services and are essential for the sustained production of food, fibres, fuels, energy and freshwater on which humans depend.

Animal genetic resources are defined as those animal species that are used, or may be used, for the production of food and agriculture, and the populations within each of them. Distinct populations within species are usually referred to as breeds. Breeds are generally not completely isolated in genetic terms, and are a social rather than a technical unit. Breed are either a sub-specific group of domestic livestock with definable and identifiable external characteristics that enable it to be separated by visual appraisal from other similarly defined groups within the same species, or a group for which geographical and/or cultural separation from phenotypically similar groups has led to acceptance of its separate identity (FAO, 2007b).

Livestock species and breeds are key components of agro-ecosystems and interact closely with natural ecosystems and therefore play an essential role in the provision of ecosystem services. Like other genetic resources for food and agriculture, livestock breeds are both providers of ecosystem services and, in themselves, an ecosystem service arising from, and dependent on, other ecosystem functions.

The use of multi-species and multi-breed herds and flocks is one strategy that many traditional livestock farmers use to maintain high diversity in on-farm niches and to buffer against climatic and economic adversities. Different breeds and species make different contributions to livelihoods through provision of food, fibre, fertilizer, cash income, draught power and transportation. Generally, the more complex, diverse and risk-prone peasant livelihood systems are, the more they will need animal genetic resources that are flexible, resistant and diverse in order to perform the required functions. Further development of tolerance to abiotic stress can be achieved by using a range of adaptive strategies, both behavioural and physiological (Hall, 2004).

The capacity of ecosystems to provide goods and services depends on the outcomes of the processes of interactions between its specific components, the so-called "ecosystem functions". Whether more biodiversity results in more ecosystem services depends mostly on the type of ecosystem service. The value of biodiversity is most evident in permanent grassland and pasture ecosystems (CBD, 2010; EEA 2012; Alkemade *et al*., 2013), where increased species richness often enhances biomass productivity and ecosystem functioning (Tilman *et al*., 1996, 1997a,b). Understanding and enhancing the role of biodiversity and the genetic resources and ecosystem functions it conveys is essential. Biodiversity is critically important for the provision of regulating, supporting and habitat services, and highly relevant for many cultural services. It underpins to food security, sustainable livelihoods, ecosystem resilience, coping strategies for climate change, adequate nutritional requirements, insurance for the future and the management of biological processes needed for sustainable agricultural production (Galluzzi *et al*., 2011).

Livestock's interaction with other ecosystem components and processes is more complex than that of plants, because of livestock's higher position in the food web, which results in conversion losses and associated environmental externalities. There are three characteristics of livestock that shape their specific roles in ecosystems: (1) livestock's unique ability to convert non-human edible feed and organic waste into useful products, through their digestive tracts; (2) the direct nature of their interaction with ecosystems (e.g. land, vegetation and soil) through trampling, grazing and browsing, as well as the production of urine and dung; and (3) their mobility and resulting ability to respond to temporal and spatial fluctuations of ecosystems in resource availability. Finally, the contribution of livestock species and breeds to ecosystem services is intimately tied to the production systems they are associated with and hence the diverse human management systems affecting these. This study will examine the roles of the keepers of livestock species and breeds, paying particular attention to the roles and management practices of small-scale livestock keepers and pastoralists, associated with the significant provision of ecosystem services, especially in grassland ecosystems.

In recent years the livestock sector has received increasing global attention for its negative environmental impacts. Livestock-related threats to biodiversity and ecosystem services arising from different production systems have been the topic of a number of publications (e.g. FAO, 2006a; Zhang *et al*., 2007; Herrero *et al*., 2009; Steinfeld *et al*., 2010; Pelletier and Tyedmers, 2010; Wirsenius *et al*., 2010; Bouwman *et al*., 2013; Herrero *et al*., 2013a). This debate is highly relevant, but has, unfortunately, been hampered by a number of conceptual and methodological obstacles, especially in the realm of biodiversity conservation. All too often, ecosystems and agricultural systems are evaluated exclusively as opposites, despite their substantial synergies, ignoring the ecosystem services provided by livestock and other agricultural systems, as well as the value of agricultural biodiversity as a part of global biodiversity itself. Generally, these problems stem from a failure to sufficiently recognize that most ecosystems are to a greater or lesser extent the result of long histories of co-evolution of the natural environment with agricultural practices, and from the attribution of a relatively high value to certain types of biodiversity (e.g. large wild mammals and birds) over other types. This has particularly hampered the understanding of free-ranging livestock systems in grasslands, where co-evolutionary linkages and ecological synergies are significant, and which also represent significant diversity of livestock breeds. This study will not further elaborate the negative environmental impacts of livestock systems, but aims to contribute to a better understanding of the interactions between livestock species and breeds with ecosystems by clarifying their positive contributions to ecosystem services.

1.2. Ecosystem services valuation

One of the main challenges in ensuring the continued flow of ecosystem services other than provisioning and marketable cultural services is that their value is relatively invisible, and often taken for granted. Vital as supporting and regulating services may be, human beings benefit mostly in indirect ways from these, through their enjoyment of provisioning services. Quite often, it is only when ecosystems start failing to deliver these services - when ecosystems are pushed beyond certain thresholds, that humans become aware of their existence and their own reliance on these. The invisibility of these services is reflected in market mechanisms, economic and agricultural policies, land-use planning and other regulatory, policy and planning instruments. Regrettably, this leads to insufficient incentives for livestock keepers and other land managers to look after and invest in ecosystems' ability to provide regulatory and supporting services. It is the shared aim of various emerging methods for the valuation of ecosystem services to increase the understanding, visibility and appreciation of all ecosystem services, in order to allow societies and their leaders to account for these, as well as to devise measures that support and incentivise their continued provision.

The MA (2005a) and especially TEEB (2010) have contributed significantly to raising awareness about the multiple values of nature. In TEEB's Total Economic Value (TEV) framework, ecosystems are understood to generate services for actual and potential uses, with services that have consumptive direct use values and services that have non-consumptive, indirect use values. Following the MA approach, the TEEB framework makes a distinction between ecological, socio-cultural and economic benefits and values, while potential future uses include insurance values. Since economic valuation influences the notion of ownership and property applied to biodiversity, it is expected that in the long term, it may lead to an internalization of environmental and biodiversity externalities.

For economic evaluation to work, studies on ecosystem services should be transparent about which specific services are considered, and how these are measured and valued (De Groot *et al*., 2002). With regard to food and agriculture, assessments and valuations of ecosystem services should encompass all agricultural systems, including large-scale conventional agricultural and livestock production. The assessment of services needs to include both the capacity of an ecosystem to provide a service (e.g., how much livestock can a grassland provide for on a sustainable basis), and the actual use of that service (e.g., the off-take rate of livestock for meat consumption). The valuation component assesses the importance of the products (e.g. meat) in terms of nutrition value, a source of income and/or a way of life (TEEB, 2010). Different values can be attached to a particular benefit, depending on peoples' perspective. For example, slaughtering livestock from pastures by pastoralists provides food (nutrition, health), but also cultural identity and income. Valuation of these benefits is subjective: some people will value the income higher than their cultural identity. The observation of "shifting baselines" (Pauly, 1995) takes into account that the properties of ecological systems people regard as "useful" may change over time even if the ecosystem itself remains in a relatively constant state.

The valuation of ecosystem services has spatial and temporal dimensions. With regard to time, even if an ecosystem currently generates no output value, its option value for future use may be high. For example, the conservation of the diversity of livestock breeds is of long-term interest for maintaining a viable and resilient livestock population. With regard to space, trade-off analysis of land use change for livestock production, for example, should base the costs and benefits of the transitions on the economic value of the total bundle of services and disservices provided by each transition state (TEEB, 2010; Teillard *et al*., 2014). Ultimately, benefits and dis-benefits should be addressed within a consistent accounting framework (e.g. EC, 2009; Boyd and Banzhaf, 2010). Although monetary assessments only partially capture the total value of ecosystem services, they are important for the internalization of externalities in economic accounting procedures and thus influence policies that affect ecosystems (Boyd and Banzhaf, 2010).

The economic invisibility of many links between ecosystems and livestock systems makes economic assessment difficult. Some provisioning services for which markets exist constitute private goods, whereas others are common pool resources or club goods (Cooper *et al*., 2009). The non-provisioning ecosystem services mostly constitute public goods or common goods. Different economic valuation methods exist to grasp the heterogeneous values derived from ecosystem services (Table 1). These approaches estimate the monetary value of ecosystem services on the basis of stakeholders' preferences, expressed either in real markets (market and revealed-preference methods) or in hypothetical markets (stated-preference methods) (Oteros-Rozas *et al*., 2013). Although stated preferences remain the most elaborated methods to address the social value of ecosystems, it is acknowledged that stated preference methods results are design-dependent, especially when related to non-use values (Salles, 2011).

Table 1. Type of ecosystem service and economic values and valuation methods

	Approaches to value ecosystem services		
Economic good type	**Private goods: excludable, rivalrous**	**Common or club goods**	**Public goods: non-excludable, non-rivalrous**
Ecosystem service type	Provisioning services with markets (e.g. food, fibre), some cultural services (e.g. ecotourism, art and fashion)	Regulating and habitat services	Regulating and habitat services
	Some Provisioning services (e.g. genetic resources, manure for fertilizer and energy) have elements of private and common or club goods		
Economic value type / valuation subject	Direct use values Consumptive	Indirect use values Non consumptive	Non-use values: option, bequest, altruistic and existence values
Economic valuation methods	Market prices or other revealed preference, replacement, prevention or avoidance costs, travel cost	Revealed preference: Hedonic pricing Stated preference: Contingent valuation, willingness to pay	Economic methods: Contingent valuation, willingness to pay, replacement, prevention or avoidance costs; Political and social sciences methods: Livelihoods assessments, capabilities approaches and vulnerability assessments

After: MA, 2005a; TEEB, 2010; Salles 2011; Oteros-Rozas *et al*., 2013; Rodríguez-Ortega *et al*., 2014

The ecosystem services approach goes beyond what people both perceive and are willing to pay for (Costanza, 1998; 2008). The ecosystem services' dimensions of human well-being such as cultural and spiritual values, freedom of choice, human rights and intrinsic values can be analysed through livelihoods assessments, capabilities approaches and vulnerability assessments (e.g., Sen, 1993; Nussbaum, 2003, 2011). A review of socio-cultural and biophysical valuation methods was undertaken by Rodriguez-Ortega *et al*. (2014). They conclude that there are trade-offs between biophysical, socio-cultural and economic evaluation frameworks. Due to the dominance of economic approaches, the information can be biased towards markets, ignoring social and cultural values.

Therefore, a combination of valuation methods is recommended. Recently, social preference methods were used to assess ecosystem services bundles (Martín-López *et al*., 2012; Bernués *et al*., 2014). Although ecosystem bundles can be used for trade-off analysis, Salles (2011) cautions that the valuation of ecosystem services will not necessarily lead to the internalization of the non-market benefits of biodiversity conservation, due to the lack of an operable framework that conceptually links empirical observations with normative social objectives.

Although the topic of this study is not the economic valuation of ecosystem services provided by livestock and breeds, an attempt is made throughout the study to estimate the extent to which the valuation of specific services has been documented.

2. Methods and concepts

2.1. Sources of information

The findings of two surveys and an extensive literature review provided the basis for the current Background Study Paper. In 2013, FAO, in collaboration with the European Regional Focal Point for Animal Genetic Resources, the European Federation of Animal Science's Working Group on Animal Genetic Resources and the Universities of Wageningen and Milan, organized a survey, targeting the Europe region, on environmental benefits of the grazing activities of livestock breeds (European Survey). Twenty-nine responses were received covering 57 breeds. The European Survey provided an opportunity to test the methodology for a global survey on the ecosystem services provided by grazing livestock in grazing systems, which was undertaken in 2014 (Global Survey). The questionnaire and the detailed results of the Global Survey are presented in Annexes 1 and 2.

The Global Survey attracted 120 responses from 47 countries across all regions and covering all major grassland habitats, providing information on more than 150 breeds. Out of the 120 responses, 53 percent originated from the Asian, African and American continents and 47 percent were from European countries. The distribution of responses across different grassland types indicated significant diversity in the grasslands used for livestock grazing. Temperate grasslands (35 %), found on most continents, formed the majority of responses. Less frequently mentioned were montane grassland (21%), tropical and subtropical (19%) and Mediterranean grasslands (17%). Only a few responses received described flooded savannas and grasslands, as well as steppes and deserts.

Grazing systems were chosen as the focus of both surveys, because 1) these systems involve the most direct interactions between livestock and the environment, 2) they cover the largest share of terrestrial land areas, 3) large numbers of poor livestock keepers and pastoralists derive their livelihoods from such systems, and 4) indigenous and diverse breeds of livestock feature prominently in grazing systems. Both surveys were accompanied by an extensive review of scientific literature. Research on ecosystem services, for example in grazing systems, has increased significantly since the MA (Rodriguez-Ortega *et al*., 2014). The study therefore aims at including the most recent findings.

Additionally, textual responses relating to ecosystem services contained in County Reports for *The second report on the State of the World's Animal Genetic Resources for Food and Agriculture* (Second Report) (FAO, 2014a), specifically answers to the questions in Part III of the country questionnaire[1] were included. The FAO livestock production system classification and spatial

[1] III Data contributing to the preparation of the State of the World's Biodiversity for Food and Agriculture Question 6: Do your country's policies, plans or strategies for animal genetic resources management include measures specifically addressing the roles of livestock in the provision of regulating ecosystem services and/or supporting ecosystem services?
6.1. If yes, please describe these measures and indicate which supporting and/or regulating ecosystem services are targeted, and in which production systems.
6.2. Please describe what the outcome of these measures has been in terms of: • the supply of the respective ecosystem services (including an indication of the scale on which these outcomes have been obtained). • the state

distribution of livestock in these systems were used to indirectly assess the contribution of livestock production systems and breeds to the provision of ecosystem services at the global level. Literature and other existing FAO sources were used to assess ecosystem services provided by livestock in production systems other than grazing systems.

2.2. Livestock's special functions

From the livestock sector supply perspective on ecosystem services taken in this study, their provision depends on the production system and the species and breeds kept, and the biological functions that underpin them.

Livestock make their most important contribution to provisioning services, especially food supply, when they use feed sources that cannot directly be eaten by humans, which is usually in places where crops cannot be grown easily, such as marginal areas, or when they graze on public land. In these situations, they add to the balance of energy and protein available for human consumption (FAO, 2011a).

The species of livestock and the production system both affect the food balance. Monogastrics such as pigs and poultry naturally eat a diet that is closer to a human one than that of ruminants. Worldwide, grain is mostly fed to pigs and poultry in industrial, intensive systems. A smaller amount is used for dairy production in mixed systems and for feedlot operations. At 28 percent, grains were estimated to be the second largest share of global feed biomass in 2000, with 59 percent of total grain used in developing regions, where monogastric production substantially increased over the past decades (Herrero *et al*., 2013a, see also MacLeod *et al*., 2013).

Livestock in grazing systems consume mostly grass, and browse to a lesser extent, whereas those in mixed systems consume a diversity of feeds. Extensive systems require animals to find a large proportion of their feed from sources not edible by humans, while animals in intensive systems are fed concentrate feed that includes cereals, soya and fishmeal. As locally adapted breeds tend to occur in grassland or mixed systems, they consume more roughage than international transboundary breeds that dominate more intensive systems. Equally, the waste recycling function that pigs and poultry have in small-scale farming systems diminishes or disappears altogether with intensification.

Feed efficiency is usually expressed as feed conversion ratio (FCR) that takes into account all feeds consumed by animals to produce a unit of output. A more realistic estimate of feed efficiency can be arrived at by accounting for the proportions of human-edible feeds used in livestock production systems. CAST (1999) and Gill and Smith (2008) proposed using 'human edible return' as an indicator to assess livestock efficiency, taking account not only of the gross efficiency of converting feed inputs to human food, but of species' different abilities to use forages that cannot otherwise be used by humans. The target edible FCR is that a livestock system produces more edible energy or edible protein than it consumes as feed (FCR less than 1). Monogastrics, especially commercial breeds

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of animal genetic resources and their management (including an indication of the scale on which these outcomes have been obtained).
8. Please describe any constraints or problems encountered or foreseen in the implementation of measures in your country aimed at promoting the provision of regulating and supporting ecosystem services or reducing environmental problems
9. Please provide examples of cases in which the role of livestock or specific animal genetic resources is particularly important in the provision of regulating and/or supporting ecosystem services in your country. Please also describe any examples in which diverse animal genetic resources are important in terms of reducing the adverse environmental effects of livestock production.
10. Please describe the potential steps that could be taken in your country to further expand or strengthen positive links between animal genetic resources management and the provision of regulating and/or supporting ecosystem services or the reduction of environmental problems. If your country has specific plans to take further action in this field, please describe them.
11. Please provide any further information on the links between animal genetic resources management in your country and the provision of supporting and/or regulating ecosystem services and/or the reduction of environmental problems.

and hybrid lines selected for lean tissue growth, are most efficient on the basis of total food produced from total feed dry matter intake, but their edible protein FCR range from 2 to 3 and their edible energy FCR from 3 to 6 (CAST, 1999; Wilkinson, 2011). By contrast, ruminants return more human food per unit of human-edible feed consumed, because most of their feed is obtained from materials that cannot be consumed directly by humans. Dairy is the most efficient livestock system in terms of converting potentially human-edible feed into animal product in the United Kingdom and the United States of America, with edible energy FCR of 0.5 to 0.93 and edible protein FCR of 0.71 to 0.48, respectively (CAST, 1999; Wilkinson, 2011). This is the result of the high share of forage (75%) in the total feed dry matter input and the low share of edible components in dairy concentrate formula in the United Kingdom (Wilkinson, 2011). The low FCR is further explained by genetic selection for increased milk yield, which leads to a "dilution" of maintenance requirements. In beef cattle and small ruminant production systems, the share of the female's maintenance requirements is higher. Grass fed beef achieved an edible protein FCR in the United States of America and the United Kingdom of 0.84 to 0.92, with edible energy FCR of 1.4 to 1.9 (CAST, 1999; Pelletier *et al*., 2010; Wilkinson, 2011).

Despite the significant roles of grassland and crop by-products in the feeds of meat-producing livestock in developed countries such as United Kingdom and the United States of America, the overall edible energy and protein FCR across systems exceeds 1, highlighting the need to improve feed use efficiency in the livestock sector, through genetic selection or the substitution of cereals by by-products. For cross-country comparisons FAO (2011a) used FAOSTAT production and trade statistics, as well as feed and primary crop data, to estimate the volume of edible livestock produced in each country. Although the numbers need to be treated with some caution, as feed data are somewhat limited and likely to underestimate the use of feed that is produced on small farms, the trend fits the findings of CAST (1999) and Wilkinson (2011). In countries with the most concentrated and intensive systems, and high shares of monogastric production (e.g. China, Germany, Saudi Arabia), the livestock sector consumes more human-edible protein than it provides, while in those countries with a predominance of ruminants and extensive grazing systems (e.g. Mongolia, Ethiopia, Kenya), it adds to the overall supply of protein. Shifts in production systems can lead to fast changes in human edible FCR.

The sector specific ecosystem supply perspective allows for a better understanding of the physical and biological processes underpinning the ecosystem services under consideration. From the species' and breeds' feed requirements, and the land-dependency of the production system, they can be grouped as:

- services arising from livestock's ability to convert non-human edible feeds into useful products, through their digestive tracts, which are the basis of provisioning services and some supporting and regulating services, and
- services arising from livestock's direct interaction with land, vegetation and soil, which are most relevant to most supporting, regulating and cultural services.

2.3. Types of ecosystem services

Assessing the provision of ecosystem services from livestock, which constitute a diverse group of service providers with different physiological needs and ecological functions in a range of production systems, and at global level, is a methodological challenge. Unlike wild biodiversity, livestock is part of managed agro-biodiversity and directly depends on the role of humans as managers of livestock as well as the surrounding ecosystems. Like other genetic resources for food and agriculture, livestock breeds are both providers of ecosystem services and, in themselves, an ecosystem service arising from and dependent on other ecosystem functions.

Little information is available in the literature on ecosystem services provided by specific breeds; most information is at the level of species. Therefore, this chapter presents ecosystem services provided by livestock in general terms. Table 2 gives an overview of the many ecosystem services provided by livestock. It follows the MA classification but splits habitat services according to TEEB.

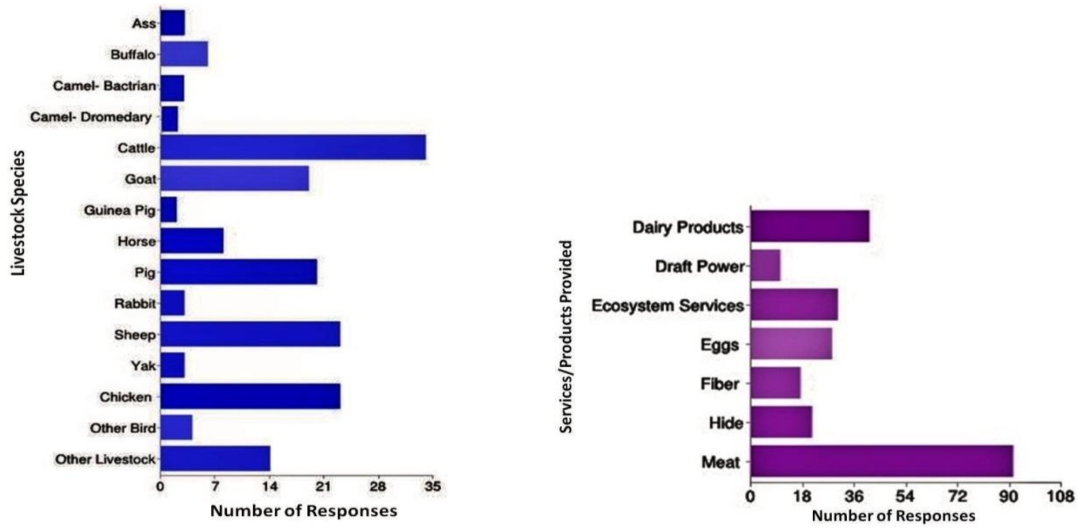
Table 2. Type of Ecosystem services provided by livestock

Provisioning services: products obtained from ecosystems	
Food	Meat, milk, eggs, honey
Fibre, skins and related products	Wool, fibre, leather, hides, skins, wax
Fertilizer	Manure and urine for fertilizer
Fuel	Manure and methane for energy, biogas from manure, slaughterhouses etc.
Power	Draught power
Genetic resources	Basis for breed improvement and medicinal purposes
Biotechnical/Medicinal resources	Laboratory animals, test-organisms, biochemical products
Regulating services: benefits obtained from the regulation of ecosystem processes	
Waste recycling and conversion of non-human edible feed	Recycling of crop residues, household waste, swill, and primary vegetation consumption
Land degradation and erosion prevention	Maintenance of vegetation cover
Water quality regulation/purification	Water purification/filtering in soils
Regulation of water flows	Natural drainage and drought prevention, influence of vegetation on rainfall, timing and magnitude of runoff and flooding
Climate regulation	Soil carbon sequestration, Greenhouse Gas (GHG) mitigation
Moderation of extreme events	Avalanche and fire control
Pollination	Yield and seed quality in crops and natural vegetation; genetic diversity
Biological control and animal/human disease regulation	Destruction of habitats of pest and disease vectors; yields (for example, consumption of pest insects by poultry)
Supporting services: ecosystem services that are necessary for the production of all other ecosystem services	
Maintenance of soil structure and fertility	Nutrient cycling on farm and across landscapes, soil formation
Primary production	Improving vegetation growth/cover
Habitat services	
Maintenance of life cycles of species	Habitat for species, esp. migratory species
Habitat connectivity	Seed dispersal in guts and coats
Maintenance of genetic diversity	Gene pool protection and conservation
Cultural services: nonmaterial benefits people obtain from ecosystems	
Opportunities for recreation	Eco/agro-tourism, sports, shows and other recreational activities involving specific animal breeds
Knowledge systems and educational values	Traditional and formal knowledge about the breed, the grazing and socio-cultural systems of the area, information for cognitive development, scientific discovery
Cultural and historic heritage	Presence of the breed in the area helps to maintain elements of the local and/or culture that are valued as part of the heritage of the region; cultural identity, esp. for indigenous peoples
Inspiration for culture, art and design	Traditional art and handicraft; fashion; cultural, intellectual and spiritual enrichment and inspiration; pet animals, advertising
Natural (Landscape) heritage	Values associated with the landscape as shaped by the animals themselves or as a part of the landscape, e.g. aesthetic values, sense of place, inspiration
Spiritual and religious experience	Values related to religious rituals, human life-cycle such as religious ceremonies, funerals or weddings

after: MA, 2005; TEEB, 2010; Oteros-Rozas et al., 2013.

A literature review of more than 100 scientific articles was undertaken in an FAO-Iowa State University project on the values of animal genetic resources with 32 key search terms, e.g. animal production, local breeds, environment, geographical indicators, standards, and value (Ayala *et al*., 2013). The survey revealed that the five commercially most important species cattle, sheep, chicken, pig and goat are most studied, but other species are also covered. The most frequently mentioned products were meat and dairy, followed by ecosystem services (Figure 1).

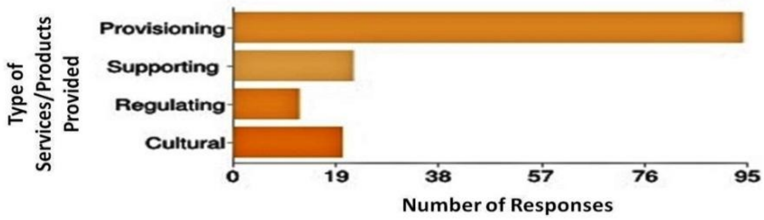
Figure 1. Livestock species and products mentioned in a literature review on the values of animal genetic resources



Source: Ayala et al., 2013.

The ecosystem services are mostly classed as provisioning, stressing food security, followed by supporting and cultural services (Figure 2).

Figure 2. Ecosystem services provided by livestock mentioned in a literature review on the values of animal genetic resources



Source: Ayala et al., 2013.

2.4. Linking breed types to production systems, land cover and climatic zones

The provision of ecosystem services by livestock differs between production systems, as does the type of breed. An open question for some ecosystem services is how they are related to levels of breed diversity, and on how they are produced, maintained, and affected by livestock production systems, or systemic and abiotic changes.

2.4.1. Method

While there is a wealth of information on the ecosystem services provided by livestock in general, it is more difficult to find studies at species level and almost impossible to find studies at breed level. To assess the extent of the provision of ecosystem services at breed level, it was therefore necessary to take an indirect approach. Firstly, land cover and climatic zones were used to classify livestock production systems and to estimate the number of animals occurring in these. Secondly, breed types were assigned to production systems and climatic areas. Breeds were classified according to their level of adaptedness to their production environments ("locally adapted" versus "exotic") and by their geographic distribution ("local" versus "regional transboundary" versus "international transboundary") (FAO 2012a). It can be assumed that locally adapted breeds are either local or regional transboundary breeds, while exotic breeds are international transboundary breeds.

A livestock-oriented classification of farming systems was developed by FAO (1996). The classification defines systems based on the proportion of dry matter feed that comes from crops, the proportion of non-livestock farming activities in the total value of farm production and the stocking rate. It differentiates grassland-based, mixed farming and landless systems. Mixed farming (rainfed and irrigated) and grassland-based systems are also distinguished based on main climatic areas (Table 3).

Table 3. Livestock production system classification

First system breakdown	Second Breakdown	The eleven systems
Grassland-based systems (LG): <10% of dry matter fed to animals comes from crops; and annual average stocking production rates are <10 livestock units (LU) ha-1 agricultural land		Temperate and tropical highlands (LGT)
		Humid/subhumid tropics and subtropics (LGH)
		Arid/semi-arid tropics and subtropics (LGA)
Mixed farming systems (M): >10% of the dry matter fed to animals comes from crop by-products and stubble or >10% of the total value of production comes from non-livestock farming activities	Mixed rainfed systems (MR): > 90% of the value of crops comes from rainfed land use	Temperate and tropical highlands (MRT)
		Humid/subhumid tropics and subtropics (MRH)
		Arid/semi-arid tropics and subtropics (MRA)
	Mixed irrigated (MI): > 10% of the value of crops comes from irrigated land	Temperate and tropical highlands (MIT)
		Humid/subhumid tropics and subtropics (MIH)
		Arid/semi-arid tropics and subtropics (MIA)
Landless (LL): <10% of dry matter fed to animals is produced on the farm; and average stocking production rates are >10 livestock units (LU) ha-1 agricultural land		Landless mono-gastric systems (LLM)
		Landless ruminant systems (LLR)

Source: FAO, 1996; Robinson et al, 2011.
Arid: length of growing period (LGP) less than 75 days, Semi-arid: LGP in the range 75 - 180 days, Sub-humid: LGP in the range 181 - 270 days, Humid: LGP greater than 270 days

For several reasons, the systems as defined by FAO (1996) cannot be mapped directly. Firstly, the classification occurs essentially at the farm level, while the spatial unit of global geospatial datasets is a pixel. Secondly, definitions used in the classification include such elements as “the amount of farm-produced dry matter fed to animals”, which are not available spatially. Therefore Robinson *et al*. (2011) developed a method to map livestock production systems, and FAO recently published new maps of the distribution of the most important livestock species (Robinson *et al*., 2014). The data are publicly available on the web application Livestock Geo-wiki[2] and on GeoNetwork, the FAO geospatial data repository (FAO, 2014b).[3] According to these models, the majority of the Earth’s terrestrial surface is covered by grasslands and tree covered areas (Table 4).

Table 4. Distribution of land cover classes globally (GLC-Share)

Class	Percentage
Artificial Surfaces/Urban	0.6
Cropland	12.6
Grassland/Shrubs/Herbaceous/Sparse vegetation	31.5
Tree Covered Area	27.7
Bare soil	15.2
Snow and Glaciers + Antarctica	9.7
Water bodies/Mangroves	2.7

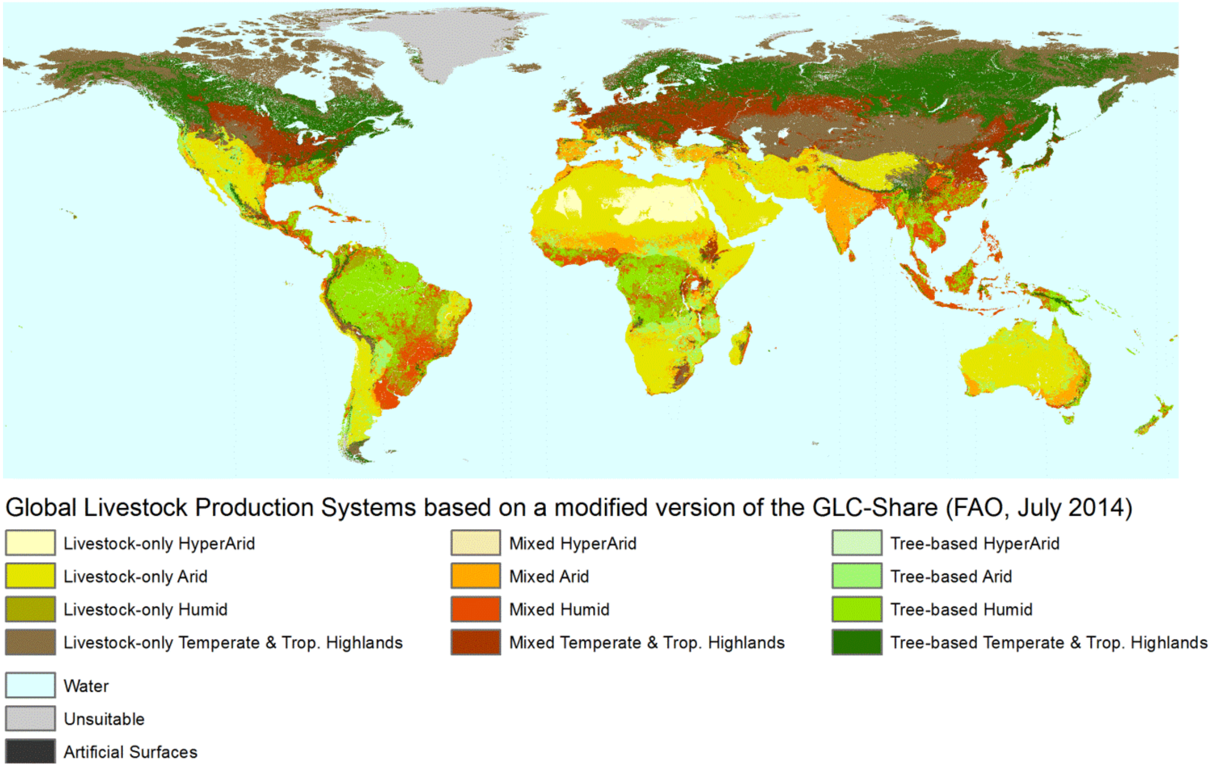
(FAO, 2014b)

For this study, livestock distributions were disaggregated by climatic zone and land-cover category (GLC-Share) (FAO, 2014b) (Figure 3). All terrestrial habitats potentially suitable for livestock were

[2] http://livestock.geo-wiki.org/
[3] http://www.fao.org/geonetwork/srv/en/main.home.

included in the analysis. Mangroves, land covered by snow and glaciers and the whole of Antarctica were excluded.

Figure 3. Global livestock production systems map



It can be assumed that, across all climates and regions, the breeds kept in shrub, sparse and tree-covered areas generally belong to the locally adapted, local and regional transboundary categories. It can similarly be assumed that locally adapted breeds will predominate in herb and grass-covered areas in hyper-arid, arid/semi-arid and humid climates in all regions except in Europe, where they can be assumed to occur only in hyper-arid/arid/semi-arid areas. Exotic, international transboundary breeds are not usually able to thrive in harsh dry environments and tend to suffer under the high disease pressures present in humid tropical grassland and tree systems. Locally adapted breeds can also be expected to be found in mixed rain-fed systems in hyper-arid climates in all regions, whereas in Africa, they occur in hyper-arid, arid/semi-arid areas (Table 5).

Table 5. Schematic allocation of breed types to production systems, habitats and climatic zones

LPS and land cover		**Climate**			
	Hyper-arid	**Arid/semi-arid**	**Humid**	**Temperate**	**Any**
Grassland	LA	LA	LA	LA and E	
Grass and herb	LA	LA	LA*	LA and E	
Shrub and sparse	LA	LA	LA	LA	
Tree	LA	LA	LA	LA	
Mixed rainfed	LA	LA and E**	LA and E	LA and E	
Mixed irrigated	LA and E	LA and E	LA and E	LA and E	
Water					LA and E
Artificial, urban					LA and E

LA locally adapted breeds (local and regional transboundary), E exotic breeds (international transboundary)
*except in Europe, ** In Africa only LA

Locally adapted breeds are generally not used in intensive and industrial systems, as their low output of marketable products makes keeping them economically unviable. Across all climatic zones, breeds of all categories can be found in mixed irrigated systems and in artificial/urban areas, where feed resources are better and animals are often confined. There is also a high probability of finding both locally adapted and exotic breeds in mixed rain-fed systems in arid, humid and temperate climates in all regions except Africa, where they tend to occur only in humid and temperate climatic zones. Similarly, all categories of breeds can be found in grass and herb-covered areas in temperate climates across all regions, and in Europe also in humid climatic areas. The proportions of the livestock population accounted for by locally adapted and exotic breeds in these systems vary, but generally, in all fertile, favourable environments, there is a high probability of finding exotic, international transboundary breeds. The share accounted for by cross-breeds depends largely on the level of intensification.

Based on the literature review, Table 6 contains a schematic allocation of the importance of different ecosystem services in various production systems. It is obvious that landless systems provide mostly provisioning services (private goods), whereas grassland-based and mixed systems provide a range of services, many of which are public goods.

Table 6. Schematic allocation of ecosystem service provided by livestock production systems, taking into account the direct animal effects

	Temporal scale	**Spatial scale**	**Grassland-based**	**Mixed rainfed**	**Mixed irrigated**	**Landless with ruminants**	**Landless with monogastrics**
Provisioning services							
Food, hides, skins and fibres	S	L, R, G	x	xxx	xx	xxxx	xxxx
Draught power	S	L		xxxx	xxxx		
Fertilizer	S	L, R	x	xxx	xxx	xx	xx
Fuel	S	L		x	x	xx	xx
Genetic resources	S, M, L	L, R, G	xxxx	xxxx	xxx	xx	xx
Medicinal resources	S, M, L	L, R, G	x	x	x	x	x
Regulating services							
Waste recycling and conversion of non-human edible feed							
Use of primary vegetation	S	L	xxxx	xxxx	xxxx	x	x
Waste recycling	S	L	x	xxxx	xxxx	x	x
Biological control	S	L	xx	xx	xx		
Land degradation and erosion prevention	M, L	L, R	xx	xx	xx		
Climate regulation	L	G	xxxx	xx	xx		
Regulation of water flow and water quality	M, L	L, R	xxxx	xxx	xxx		
Avalanche and landslide control	S, M	L	xxxx				
Control of bush encroachment and maintenance of fuel breaks	S, M	L	xxxx				
Pollination	S	L	xx	xxxx	xxxx		
Supporting services							
Maintenance of soil fertility	S, M	L	x	xxx	xxx		
Primary production	S, M	L	xx				
Habitat services							

Connecting habitats	M	L, R	xxxx	xx	xx		
Maintenance of life cycle of species	M, L	L	xxxx	xx	xx		
Maintenance of genetic diversity	S, M, L	L, R, G	xxxx	xx	xx		
Cultural services							
Opportunities for recreation	M, L	L, R	xxxx	xx	xx		
Knowledge systems and educational values	M	L	xxxx	xx	xx	xxxx	xxxx
Cultural and historic heritage	M, L	L	xxxx	xxx	xxx		
Inspiration for culture, art and design	M	L, R	xxxx	xxxx	xxx		
Natural (landscape) heritage	M, L	L, R	xxxx	xxx	xx		
Spiritual and religious experience	M, L	L	xxxx	xxx	xxx		

*Note; * low to ****high;*
Spatial scale: L local, R regional, G global;
Temporal scale: L Long-term, M medium-term, S short-term

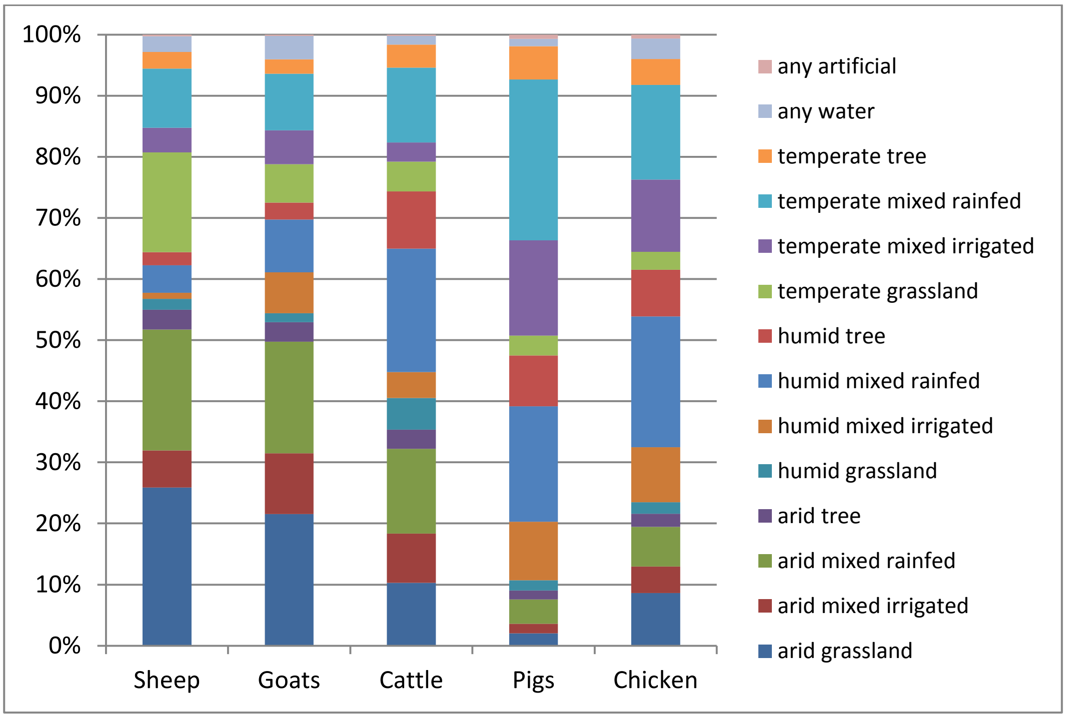
2.4.2. Estimated livestock numbers in production systems

Globally, 51 percent of all sheep, 44 percent of goats, 38 percent of cattle, 21 percent of pigs and 27 percent of chickens are assumed to occur in systems where predominantly locally adapted breeds thrive and grasses and roughages are the major feed resources. In most of these low-input extensive systems, small-scale livestock keepers predominate, with pastoralists widespread in arid rangelands. The recent phenomenon that tropical adapted breeds from Brazil or South Africa are exported to other tropical countries may imply that in future such international transboundary breeds will expand in arid and humid grasslands, as well as rainfed mixed systems.

Globally, 49 percent of all sheep, 56 percent of goats, 62 percent of cattle, 79 percent of pigs and 73 percent of chickens are assumed to occur in systems where both locally adapted breeds, exotic breeds and their cross-breeds thrive and where feed quality tends to increase. Both small-scale and large-scale livestock keepers can be found in these higher-input systems. Details are provided Annex 3. More than half of sheep and goats are found in hyper-arid to semi-arid systems, whereas the share is lower than 10 percent for pigs (Figure 4).

The number of chicken is highest in humid, followed by temperate climatic zones. Pig numbers are low in arid climatic zones (Figure 5). Similar shares of cattle are kept in humid (39%) and arid (hyper-arid to semi-arid) climates (35%), whereas more than half of sheep and goat are kept in arid zones.

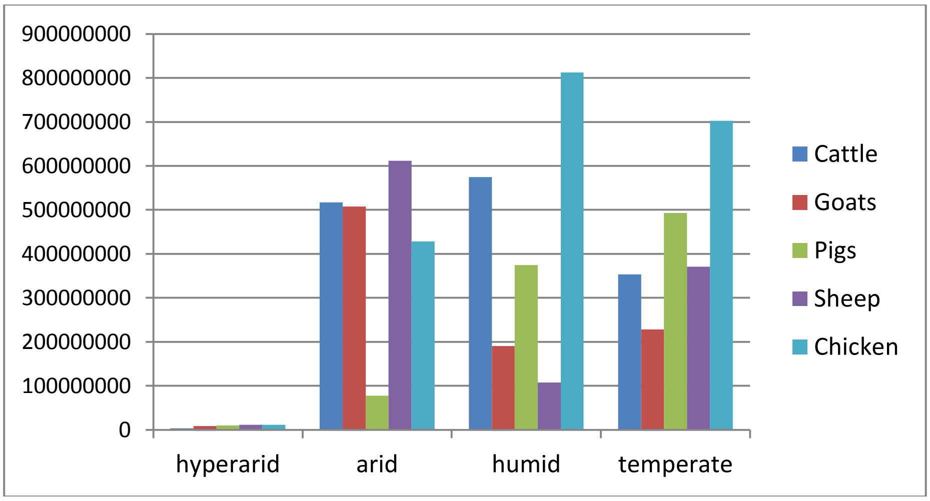
Figure 4. Proportion of livestock populations by climatic zone and production system/habitat



Note: Arid = Hyper-arid, arid, semiarid combined; data source: Robinson et al., 2014.

According to FAO (2006b), 1074 breeds adapted to drylands were identified. In the Near East, 90 percent of all the region's breeds are kept in the drylands. In Africa, 56 percent of all breeds are adapted to drylands, 42 percent in Asia and 19 percent in Latin America. On average, 46 percent of the breeds in the four regions are adapted to drylands, and many of them are transboundary. More than 70 percent of breeds of ass, around 50 percent of sheep and goat breeds, and 30 percent of cattle and horse breeds are reported to be adapted to arid areas.

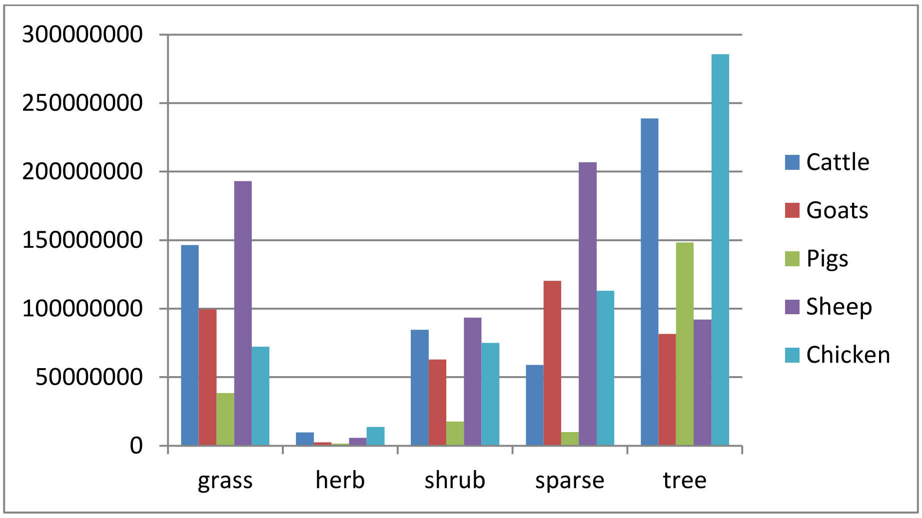
Figure 5. Livestock numbers by climatic zone and by species



Note: Units: cattle, sheep, goats and pigs (heads); chicken (10.000 heads); data source: Robinson et al., 2014.

About half of sheep and goats are kept in areas covered with shrubs and sparse vegetation, followed by grass/herb and lastly, tree covered areas (Figure 6). The situation is different for cattle, of which 44 percent are found in tree covered areas, 29 percent in grass/herb and 27 percent in shrub/sparse vegetation. Within grazing systems, the highest share of pigs is found in tree covered areas, followed by grasslands.

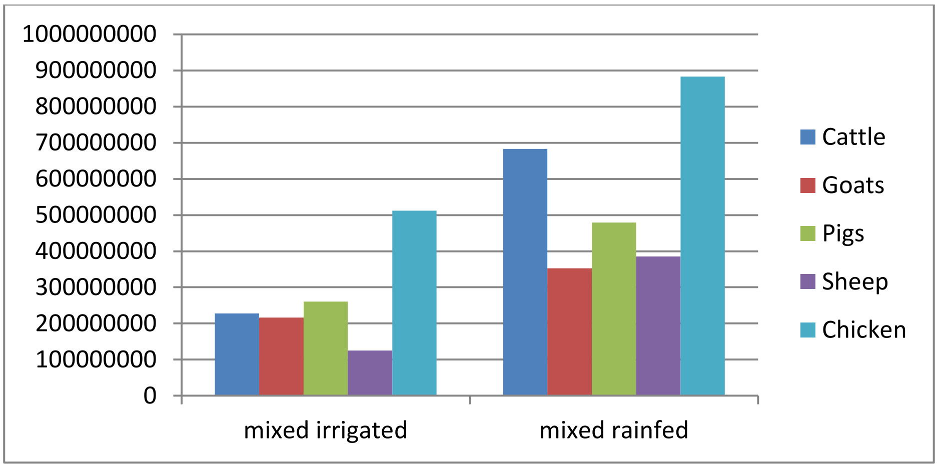
Figure 6. Livestock numbers by land cover class of grazing systems and by species



Note: Units: cattle, sheep, goats and pigs (heads); chicken (10.000 heads); data source: Robinson et al., 2014.

In 2009, about 80 percent of the global cultivated area was rainfed. Rainfed agriculture produces about 60 percent of global crop output in a wide variety of production systems (FAO, 2011b). Globally, the majority of animals across species is kept in mixed systems (76% of pigs and 68% of chicken, 62% of cattle, 58% of goats and 45% of sheep). Within mixed systems, rainfed systems harbour 65 percent of pigs, 63 percent of chicken, 75 percent of cattle, 62 percent of goats and 75 percent of sheep (Figure 7).

Figure 7. Livestock populations in mixed crop-livestock farming systems and by species



Note: Units: cattle, sheep, goats and pigs (heads); chicken (10.000 heads); data source: Robinson et al., 2014.

FAO estimates that in 2010, 55 percent of the global pig population was kept in semi-intensive and industrial systems, and 81 percent of the global chicken population was kept in industrial systems; these animals are most likely high-output international transboundary breeds or their crosses (Gilbert *et al*., submitted).

The figures above do not imply that all livestock in a specific production system provides the relevant ecosystem services. However, they indicate where most livestock are located, and imply the potential of locally adapted breeds that good management could tap into.

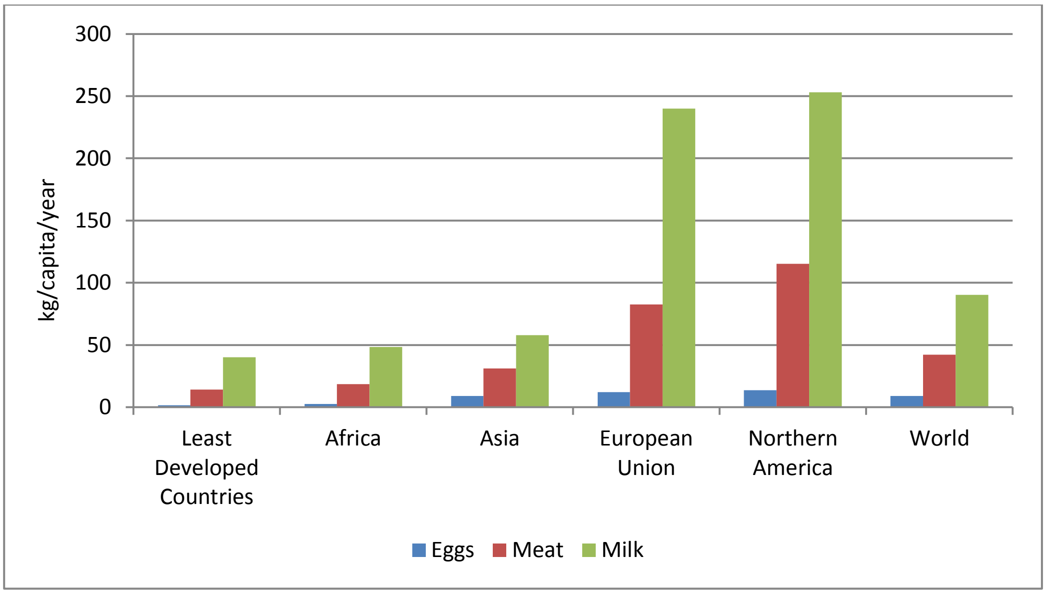
3. Provisioning services

3.1. Food, hides, skins and fibres

Provisioning services – such as the supply of food, fibres and skins – are easier to quantify and value than other ecosystem services, since most have a direct use value and a related market price. Animal source food is an important part of the human diet in many parts of the world and demand for it is growing, driven by rising incomes, urbanization and population growth. Livestock provide approximately 26 percent of human global protein consumption and 13 percent of total calories. Foods of animal origin, such as meat, eggs, milk and dairy products, supply a concentrated variety of essential, highly bio-available nutrients to the diets of people, such as protein, iron, vitamin A, vitamin B12 and zinc, with special nutritional importance for vulnerable populations such as children and mothers. They provide a critical supplement and diversity to staple plant-based diets, and are particularly appropriate for combating malnutrition and a range of nutritional deficiencies.

Animal source foods are highly desired in many cultures, because of their nutritional value and taste. However, consumption is limited in low-income countries, where the diets of people are mainly cereal or tuber-based and micronutrient deficiencies, particularly of vitamin A, iron and zinc, are widespread. These foods, together with other animal source products, such as fish, provide less than 10% of total energy intake in most African countries and Southern Asia, and about 10 to 15% in other Asian countries (Figure 8). By contrast, in affluent or transition countries, energy intake from animal source foods tends to be high and such foods are prominent in the food supply.

Figure 8. Supply of animal sources food by region



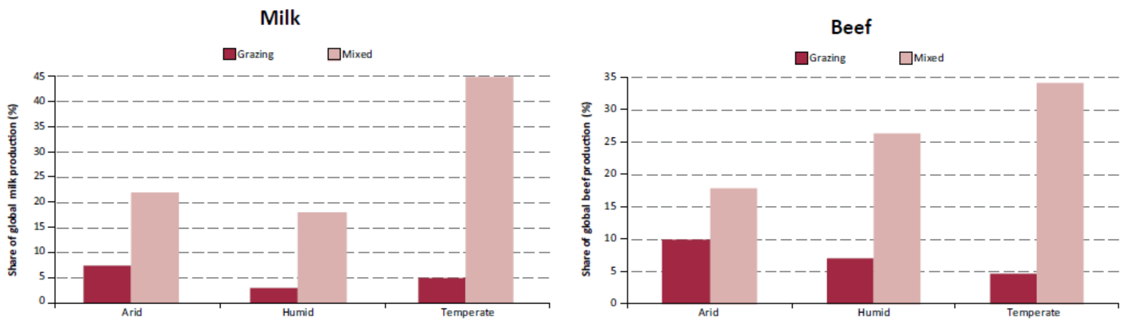
Source: FAOSTAT, 2011.

Between 1980 and 2010, global meat, milk and egg output grew at an unprecedented rate. Globally, this production increase was due to increases in stocks rather than productivity and has been accompanied by rapid structural change and a growing dichotomy between large-scale and small-scale production (FAO, 2010a). However, the global production trends mask high variability between species, breeds and livestock production systems, both within and between regions. The differences are larger in ruminants than in monogastrics, for which industrial systems prevail in both developed and developing regions. Prevailing economic conditions in many countries tend to favour the intensification of production. Incentives such as subsidized inputs are often provided to help countries reach food security goals. An increasing share of global livestock production comes from intensive and industrial production systems, especially in the case of monogastrics. At global level, international transboundary breeds provide the majority of food and fibre.

Due to differences in animal productivity, total livestock production does not correspond to the number of animals in a production system directly. In 2005, the global **cattle** sector produced approximately 508.6 million tonnes of milk and 61.4 million tonnes of beef. According to FAO's Global Livestock Environment Assessment Model (GLEAM), 56 percent of beef was produced by the specialized beef sector and 44 percent by the dairy herd. Grassland-based systems which harbour 37 percent of all cattle (incl. in tree systems; Figure 6) contributed 22 percent of global beef production and 16 percent of global milk production, respectively (Opio *et al*., 2013); with grasslands in arid climates providing about 23 percent of milk and 37 percent of meat in this climatic area (Figure 9). In Africa and the Near and Middle East, grassland-based arid and semi-arid systems accounted for around 20 percent of the ruminant meat production in 2000 (Herrero *et al*., 2014).

Mixed systems play an important role in animal source food production (Steinfeld *et al*., 2006). Mixed livestock production systems, which harbour 63 percent of all cattle (Figure 7), contributed 78 percent of global beef production and 84 percent of global milk production, respectively (Opio *et al*., 2013). About 45 percent of global cattle milk production arises from mixed systems in temperate areas, followed by 22 percent in arid areas (Figure 9).

Figure 9. Contribution to total cattle milk and beef production by production systems and agro-ecological zone



Source: Opio et al., 2013.

Intensive systems are predominantly located in temperate and humid areas and account for 17 percent and 7 percent of, respectively, the beef and veal total production and milk global supply. They include extensive grazing and ranch systems of Latin America, Australia and South Africa. In Latin America, around 20 percent and 10 percent of the ruminant meat and milk were produced in humid and subhumid grazing systems in 2000 (Herrero *et al*., 2014). Industrialization of livestock production is advancing. For example, Brazil is recently experiencing a development of feedlots in the beef industry. These production systems accounted for 13 percent of the production in the country in 2012 (Millen and Arrigoni, 2013). In temperate areas, systems are frequently characterized by relatively intensive production with highly specialized breeds and advances in technology.

The total production from the **small ruminant** sector in 2005 amounted to 20.0 and 12.6 million tonnes of milk and meat, respectively. Goats contribute almost 60 percent of the milk produced by small ruminants, while sheep contribute 62 percent of the meat (Opio *et al*., 2013).

The global **pig** population in 2010 was estimated to be 973 million animals (FAOSTAT), 22 percent more than in 1980. At 37 percent of the total global carcass weight, the pig sector was the biggest contributor to global meat production 2010. According to GLEAM, temperate areas accounted for 56 percent of production in 2005. Backyard, intermediate and industrial systems are considered in GLEAM, with respective contributions to total pig production of 20 percent, 19 percent and 61 percent (Table 7). It can be assumed that exotic breeds and hybrid lines or their crossbreds are kept in industrial and intermediate systems, contributing to 81 percent of production (MacLeod *et al*., 2013).

There is a marked geographical concentration of pigs, with 95 percent of production taking place in East and Southeast Asia, Europe and the Americas. Industrial systems in these regions contributed 61 percent of total production, with industrially kept pigs in temperate areas accounting for 37 percent (MacLeod *et al*., 2013). For instance, in China, the centre of origin of pigs, the proportion of pigs raised in industrial systems in 2005 was 74 percent and overtook the proportion in high income countries (Robinson *et al*., 2011).

Table 7. Global pig production in 2005 by production system

	Backyard	Intermediate	Industrial	All
Million tonnes carcass weight per year	22.9	20.5	66.8	110.2

Source: MacLeod et al., 2013.

The global **poultry** population in 2010 was estimated at almost 22 billion animals, nearly 3 times as much as in 1980, with chickens making up 90 percent (including nearly 6 billion laying hens), 6 percent of ducks, 2 percent geese and 2 percent turkeys. Poultry produced 33 percent of the global meat in 2010. Chicken meat accounts for 88 percent of total poultry meat; turkey, 5 percent; duck, 4 percent and goose, 3 percent. In 2010, total egg production reached 69 million tonnes, hen eggs accounting for 92 percent, with 1.2 billion eggs (MacLeod *et al*., 2013).

Backyard chicken systems, mostly with locally adapted breeds, can be found worldwide and contribute 4 percent of total poultry meat production and 14 percent of total egg production. However, these relatively low figures should not detract from backyard production's critical importance as a source of protein in developing countries. Specialized layer systems with exotic breeds or crossbreds contribute 86 percent of total egg production and 6 percent of total poultry meat production (Table 8). For instance, the proportion of poultry raised in industrial systems in China in 2005 was 90 percent, and overtook the proportion in high income countries (Robinson *et al*., 2011). These selected genotypes require a suitable physical environment, optimal nutrition and efficient protection from the effects of disease. To achieve these, the birds are usually confined, so they need to be provided with all or most of their nutritional requirements. The East and Southeast Asia region dominates egg production, accounting for 42 percent of eggs from layer systems and 35 percent of backyard eggs.

Table 8. Global chicken production in 2005 by production system

	Backyard	Semi-intensive to industrial		All
		Layer	Broiler	
Million tonnes egg per year	8.3	49.7		58
Million tonnes carcass weight per year	2.7	4.1	64.8	71.6

Source: MacLeod et al., 2013.

Chicken meat production has increased tenfold over the past 50 years, in particular in specialized broiler systems with exotic breeds or crossbreds. According to MacLeod *et al*. (2013), they now account for 81 percent of total poultry meat production and are particularly concentrated in Latin America and the Caribbean, North America and East and Southeast Asia. Specialized broiler systems in these regions account for approximately 70 percent of total chicken meat production. As for specialized layer operations, technology developments and advances in breeding have led the poultry industry and the associated feed industry to scale up rapidly, to concentrate themselves close to input sources or final markets, and to integrate vertically (FAO, 2006a).

We can conclude from the above that the contribution of exotic breeds or their crossbreds to pig, egg and chicken meat production in 2005 was more than 80 percent. This indicates an increase of more than 10 percent since 2002 (Steinfeld *et al*., 2006). This trend is expected to increase, especially in the poultry sector where consumption is projected to increase in all developing regions until 2030, followed by the pig sector (FAO 2014a; OECD/FAO, 2014). Poultry represents also the highest growth of demand for animal source food in high income countries, while beef and mutton per capita demand are expected to decrease (FAO, 2014a).

Table 9 shows the livestock products that are easily accessible through FAOSTAT. The increase in production of food, fibres and by-products of livestock has also seen impressive growth rates over the past decades. The high production and trade share of animal by-products, such as edible offals and meat meal used as feed are often neglected contributions of the livestock sector to food security.

Table 9. Provisioning services: Production of animal products (MT)

Item	Year 1990	2000	2010	Total growth % 1990-2010	Annual growth
Food primary					
Meat, cattle and buffalo	55413302	59017455	66562665	20.12	1.01
Meat, sheep and goat	9690158	11541734	13440653	38.70	1.94
Meat, pig	69441148	85917489	107319537	54.55	2.73
Meat, poultry	40996859	68560470	99312500	142.24	7.11
Milk, total	544196424	582091310	724801807	33.19	1.66
Eggs, Primary	37375708	55103793	69555171	86.10	4.30
Honey, natural	1180597	1254830	1547216	31.05	1.55
Food processed					
Butter and Ghee	7842615	7414469	9121329	16.30	0.82
Cheese (all Kinds)	14845241	16594681	20324798	36.91	1.85
Evaporated & condensed milk	4240879	4044385	5043232	18.92	0.95
Skim milk & buttermilk	4280475	3360384	3337266	-22.04	-1.10
Hides, skins and fibre					
Hides, buffalo, fresh	602789	779618	914221	51.67	2.58
Hides, cattle, fresh	6290337	7246527	8031058	27.67	1.38
Skins, goat, fresh	579408	863980	1194988	106.24	5.31
Skins, sheep, fresh	1335968	1772189	1881420	40.83	2.04
Skins, sheep, with wool	431387	529124	620305	43.79	2.19
Wool, greasy	3350508	2311416	2017283	-39.79	-1.99
By-products					
Edible offal	10017000	13330000	15319000	52.93	2.65
Meat meal (feed)	1136959	1807903	1307646	15.01	0.75

Source: FAOSTAT.

In terms of the value of sales and international trade, the most important non-food products are fibres, hides and skins. Global wool production has continued its decline from a peak reached in the early 1990s, and in 2012 it was almost 5 percent lower than in 2004 (FAOSTAT). However, some major wool-producing countries, such as China, Morocco, the Russian Federation and the United Kingdom, have increased their production levels over this period. In other countries, overall declines in wool production have been accompanied by increases in the production of fine, ultrafine and superfine wool (Montossi *et al*., 2013). Demand for finer wool leads to shifts in the use of sheep genetic resources, i.e. changes in breed choice or in breeding goals (ibid.). Over the 2004 to 2012 period, world production of hides and skins from buffaloes, cattle and goats increased, but production of sheepskins fell (FAOSTAT). These figures roughly reflect population trends in these species.

Over the 1990 to 2010 period, trade in animal food products has increased even more than production. The total trade value in 2010 of only the commodity groups presented in Table 10 amounts to US$403 billion. The total value of livestock production in 2010 was US$836 787 million, equivalent to 37 percent of the value of all agricultural production (FAOSTAT).

In the next 20 years, urbanization and rising incomes in developing regions, especially Africa and Asia expect to see an increasing demand (quantity and quality) for animal source foods and changes in marketing and retailing. In parallel, demand for convenience foods, often mass-produced and sold by large retailers, will increase (FAO, 2014a). The rising demand for livestock products drives production system changes that lead to the wider use of a narrow range of breeds (those suitable for use in industrial or other high-input systems) and potential threats to the survival of other breeds because of replacement or, in some cases, indiscriminate cross-breeding.

Table 10. Provisioning services: Export /Trade value of commodity groups (1000 US Dollars)

Item	Year 1990	2000	2010	Total growth % 1990-2010	Annual growth
Live animals, import	9152380	9175621	17951747	96.14	4.81
export	8765307	8938683	17674905	101.65	5.08
Total meat, import	35701844	42361440	102363786	186.72	9.34
export	33219277	41828937	105584376	217.84	10.89
Animal fats, import	1116288	1170522	2834175	153.89	7.69
export	980510	1002208	2941029	199.95	10.00
Dairy and eggs, import	22047055	26570740	64638087	193.18	9.66
export	21239873	26622038	66922413	215.08	10.75
Offals, edible, import	1427219	2339494	5444465	281.47	14.07
export	1170756	2066588	5963462	409.37	20.47
Honey, import	330861	440847	1504379	354.69	17.73
export	321233	438120	1475635	359.37	17.97
Wool, greasy, import	3287749	1850131	2575650	-21.66	-1.08
export	3458089	1547058	2651993	-23.31	-1.17
Skins, total, import	1418322	1105924	1250208	-11.85	-0.59
export	1008540	891239	1196506	18.64	0.93
Hair, fine, import	231211	169363	167560	-27.53	-1.38
export	242298	92337	110605	-54.35	-2.72

Source: FAOSTAT.

However, feed availability and feed price volatility may slow the growth of industrial monogastric production. Social and environmental concerns may start to exert greater influence on consumers' choices of products. A certain level of affluence, as well as changing fashions, may lead to growing interest in speciality food products, including those that may be more traditional or perceived to be so. In many developing countries, long-standing preferences for the taste of products from native breeds continue to influence customer choice. This is already changing the livestock industry, with increasing levels of standards and norms applied to production and processing. A global survey found that private voluntary standards regarding livestock and animal food trade were found to relate mostly to animal welfare, food safety or animal health. Environment/biodiversity on its own was mentioned by 1 percent of respondents, but in 25 combinations with other aspects reached 10 percent of the overall frequency. Also noted were workers' conditions and fair wages, geographic indication or economic development (Hoffmann *et al*., 2014), indicating that wider societal concerns are influencing markets for livestock products. Concerns about health issues and food quality are also increasing in developing countries due to higher purchasing power and new lifestyles (Jabbar *et al*., 2010). While these general tendencies are widely recognized, the scale and precise nature of their effects on animal genetic diversity remain unclear, particularly in developing countries.

Current economic mechanisms primarily value the provisioning services provided by livestock linked to markets, while largely undervaluing or ignoring cultural, supporting and regulating services, such as social functions and the maintenance of genetic diversity. Even provisioning services are not always fully accounted for. For example, milk and meat consumed in the household, rather than sold, are not fully covered in official statistics. The same goes for products sold or traded in informal markets. Moreover, economic statistics do not account fully for the nutritional benefits of animal-source foods, especially for children or lactating and pregnant women. FAO estimates that traditional livestock systems, based mostly on locally adapted breeds, contribute to the livelihoods of 70 percent of the world's rural poor (FAO, 2010a; 2011a). Much of this livelihood contribution takes the form of non-marketed products and services, and often depends on the use of communal resources and ecosystem services. This indicates that the poor rely to a large degree on the continued provision of non-market ecosystem services, and that smallholders' livelihoods will therefore be affected if the surrounding ecosystem deteriorates.

The other provisioning services described below are crucial in mixed systems with their manifold interactions between crop and livestock production.

3.2. Draught power

Draught animal power (DAP) has been the only source of agricultural power, besides human power, for centuries (FAO, 2003). Ramaswamy and Narasimhan (1982) estimated that 2 billion people in developing countries depend on DAP for farming and rural transportation. Even today, working animals play a fundamental role in agriculture and the transport of goods and people in developing countries, and this situation is likely to continue as long as there are significant rural populations without access to motor transport. In many mountainous or otherwise inaccessible regions, DAP is the only feasible source of energy for agricultural work and transport. Following a range of projects, networks and research on DAP in the last decades of the Twentieth century (Starkey and Faye, 1988; Schmitz *et al*., 1991; Starkey *et al*., 1992; Starkey and Kaumbutho, 1999), scientific and development attention seems to have diminished, although the Animal Traction Network for Eastern and Southern Africa (ATNESA) website remains active and contains a wealth of reference material. It can be assumed that locally adapted breeds of the large species are mostly used as draught animals.

There is very little data on working animals across the globe. According to Ramaswamy (1994), about 400 million animals, mostly oxen, followed by buffalo, donkey, horses, camels and mules, were used for agricultural operations in more than half of the cultivated areas of the world in the early 1980s, as well as for hauling 25 million carts. Agricultural operations undertaken with the aid of animals include land preparation, transport, irrigation and threshing. Most of these animals were found in India and China. The Brooke (2014) estimated that in 2011 there were 112 million working equine animals in the world, with 43 million donkeys, 11 million mules and 58 million horses. The majority (95%) of the world's 42.8 million donkeys (2010, FAOSTAT) are most likely used as work and pack animals. In rapidly industrialising countries such as Brazil, China, India and South Africa, donkey populations have declined between 1 and 3 percent per year between 1990 and 2010, whereas they increased in countries such as Ethiopia, Morocco and Pakistan (FAOSTAT). In Mauritania the number of donkey carts has risen from around 1,000 to more than 75,000 in the past 40 years; and in Tanzania the number of draught animals has almost doubled in 20 years (The Brooke, 2007).

In India, the country with most DAP in the world, more than 60 million draught animals were kept in 2003, with numbers declining as they were replaced by tractors. The replacement of draught animals has been estimated to be around 12 to16 bullocks for each tractor introduced, depending on the size of the tractor. The actual replacement was in the order of 3 to 4 animals per tractor, for several reasons: the decrease in size of landholdings; the need to have readily available draught power capacity for tillage at the onset of the rains; and the other functions of draught animals, such as consumptions of crop residues and production of manure that cannot be replaced by tractors (Dikshita and Birthal, 2010). Projections however show an increasing decline of DAP in India, with 37 million animals in 2015 down to 8 million in 2050 (Singh, 2013), and an increase in the number of two wheel tractors of 10 to 15 hp. In China, it is even projected that DAP will mostly be replaced by tractors in 2025. Where farmers replace DAP by motorized power, they use the available crop residues to feed dairy cattle in places with fast developing dairy markets or as a vegetative crop cover for conservation agriculture practices.

The latest FAO estimates (FAO, 2003) show a wide diversity of power sources among countries and regions (Table 11). Draught animals account for shares in total power supply comparable to those of human labour in all regions except sub-Saharan Africa, where human labour predominates. Sub-Saharan Africa and South-eastern Asia are the two regions where draught animals are a significant source of power for farm activities. In Sub-Saharan Africa, draught animals (mostly oxen) are concentrated on rainfed land in the cereal-cotton-based farming systems in the northern parts of West Africa, throughout the maize mixed systems of Eastern Africa and the highland mixed systems of Ethiopia. In Central and the southern parts of Western Africa, however, human power accounts for the majority of harvested areas, since the incidence of tsetse fly makes the forest areas unsuitable for many types of draught animals. In South-East Asia, buffalo and cattle are dominant sources of power in the lowland rice systems and the upland intensive mixed farming systems, where they are used mainly for primary tillage with limited use in secondary operations such as planting or weeding. DAP is also important in the rice and rainfed mixed farming systems of South Asia, and in the mountainous areas of Latin America where the terrain may not be suitable for the use of tractors (FAO, 2003; FAO 2010b). In contrast, tractor power dominates in major parts of Latin America and the Near East/North Africa.

Table 11. Use of different power sources in agriculture

	Percentage of area cultivated by different power sources					
Region	**1997/99**			**2030**		
	Hand	**Draught animal**	**Tractor**	**Hand**	**Draught animal**	**Tractor**
All developing countries	35	30	35	25	20	55
Sub-Saharan Africa	65	25	10	45	30	25
Near East/North Africa	20	20	60	10	15	75
Latin America and the Caribbean	25	25	50	15	15	70
South Asia	30	35	35	15	15	70
East Asia without China	40	40	20	25	25	50

Source: FAO 2003.
Note: Figures have been rounded to the nearest 5 percent.

Smallholders who use animals for soil tillage can cultivate larger areas more efficiently and quickly than with human labour. In all regions, the highest cropping intensities occur in DAP countries. For example in South Asia, cropping intensities on rainfed land and irrigated land are 68 and 79 percent lower in countries using more tractors than in those using more DAP (FAO, 2003).

A more recent study prepared for FAO (Starkey, 2010) provides a systematic region-by-region analysis and a discussion of the factors affecting trends in the use of animal power. Overall, the study shows that use of animal power is declining as mechanized power becomes more available and affordable; confirms the increase in use of DAP in sub-Saharan Africa; and confirms its persistence wherever DAP continues to be profitable and socially acceptable and alternatives are inaccessible or unaffordable. It notes upward trends in the use of some species in some countries (e.g. the use of donkeys in parts of Central Asia) and rapid declines elsewhere (e.g. the use of donkeys in Turkey and some countries of the Near East).

In 2030, 55 percent of the globally cultivated area is expected to be tilled by tractors (Table 11). The sustainability of tractor-based systems is highly dependent on land size, the profitability of agriculture and an infrastructure capable of providing timely access to fuel and inputs for repairs and maintenance. In the absence of such markets and supporting services, it is expected that farmers will retain or even revert to the use of human labour or DAP during the next 30 years (FAO, 2003). The driving forces for the substitution of human and animal labour are part of the development process (e.g. urbanization, off-farm employment) but also reflect more specific factors pertaining to agriculture and particular socio-economic contexts. These include changes in cultivation methods (e.g. spread of no-till/conservation agriculture) and in cropping patterns, as well as other factors affecting the rural workforce, such as the impact of HIV/AIDS, which is an important factor in several countries of sub-Saharan Africa. Only in sub-Saharan Africa will human labour remain the predominant source of power. This is also the only region where draught animals are increasing their share, with tractors expected to be cultivating no more than about a quarter of the total crop area even in 2030 (FAO, 2003; 2010b).

Working animals are multipurpose: they provide draught and load-bearing power, as well as outputs including manure, occasionally milk and to a certain extent, meat and hides. They thus contribute greatly to human livelihoods. Working animals provide both direct and indirect incomes to households and therefore make an important contribution to households' access to food and services. Direct contributions are derived from the transport of goods and people, from being hired out for agricultural work, carting and pack work, and in some cases from selling offspring. Markets for hiring draught animals exist in many developing countries, creating rural employment (FAO, 2014c). Popular hire services include land preparation, planting, weeding, threshing, shelling and transportation. While over 90 percent of the land in some Tanzanian districts was ploughed by oxen in the 1990s, only 30-50 percent of rural households owned cattle. This means that animal hire services have a large market to cater for and at the same time provide benefits to the local community. For the household, the payback period of investment in DAP is quicker when animals are hired out (Shetto *et al*., 1999). Across northern India, it is estimated that 200 000 people and their families own a working male camel and, with their carts, make their living from providing short and medium distance transportation in large cities as well as in remote desert areas (New Agriculturist, 2005).

Box 1. Responses from Country Reports – Draught power

In their Country Reports, 33 countries (including 16 from Africa and 8 from Asia) mentioned draught animal power, referring to a wide range of species (horse, donkey, cattle, buffalo, yak and camels). The main concern, reported by 19 countries, was related to the loss of breed function due to mechanisation, with potential threats to local breeds. A few countries indicated, however, that due to the limited farm size, a large proportion of farmers continues to rely on animal draft power.

Other services (e.g. logging, transport, soil management) provided by draught animals were also mentioned by some countries. In particular, **Democratic Republic of the Congo** reported the implementation of a project in support of the use of draught cattle, bringing together NGOs, governmental and breeding organisations. The project trains livestock keepers and has provided so far 2179 cattle pairs.

Belgium: The Ardennes draught horse could play a greater role in the work of forest (logging) and mowing of nature reserves.

Bhutan notes that although farm mechanization is underway, the country's steep terrains mean that AnGR and their management have been affected only minimally and that future effects are also expected to be low.

Luxemburg notes the promotion and increased use of horse powered traction, e.g. for pasture management in flora and fauna rich vineyards, forests and sensitive soils, as well as the implementation of other sustainable systems (e.g. waste collection in the city by horses), further development of cultural and tourist activities, and social activities (education and rehabilitation with the help of horses etc.)

Philippines: Because of the increasing cost of oil, many farmers still rely on large animals for draught.

Indirect contributions of DAP are obtained through the transport of the household's agricultural produce to markets, or that of farm inputs (feed, seeds, fertilisers) from and to markets or fields. Besides the services to and income generation opportunities for DAP owners, there is a positive impact on the local economy through the local manufacture, repair and maintenance services, the provision of hardware goods and inputs for working animals (Arriaga-Jordán *et al*, 2007; FAO, 2009a). Draught animal equipment often needs to be adapted to specific locations (Ashburner and Yabilan, 1988; Starkey *et al*., 1992). In Tanzania in the 1990s, small-scale farmers who offered hire services, recorded increases in farm incomes of more than 50 percent (Shetto *et al*., 1999). For client farmers, access to DAP hire services can have a big impact on the timeliness of farming operations, as delayed crop planting can result in yield losses of up to 1.5 percent per day of delay, and reduce the possibility of a second crop (FAO, 2012b). In many rural and peri-urban areas of Africa, household water is transported by donkeys from wells and fountains. As with all livestock ownership, working animals serve as savings and a safety net for households, enabling poor households to fulfil social obligations. They have also been used to provide ambulance services for the sick and school transport for children, as well as in community projects, strengthening the social role of their owners in their community. Furthermore, DAP can be a critical coping strategy in the case of shocks or unpredicted changes. The 2008 fuel price rise hike resulted in a temporary increased use of working animals, e.g. in East Africa and northern India. Turkish farmers also reverted to the use of draught animals very quickly (FAO, 2014c). However, this may change as terms of trade change. During natural and human-made crises, such as droughts, floods and civil unrest, working animals can be valuable assets, thus providing an insurance function. Donkeys are used to fetch water and fuelwood, somewhat relieving the workload for women, which is particularly important in the case of drought-affected areas (The Brooke, 2014).

The power available from draught animals depends not only on the species, but also on the general health of the animal, its age, its live weight and its breed (Ashburner, 2000). Power output is also affected by whether or not the animal works in a team or alone, perhaps surprisingly developing less power when working in a team, although it would then be expending less energy and thus would normally be capable of working longer hours. Generally accepted data was collated by Inns (1992), which relate to an animal of a particular weight (Table 12). This weight refers to that which is judged to be a reasonable mean value for the draught animals of a particular region.

Table 12. Power output of animals of different species and weight

Animal	**Typical weight**		**Power Output**
	(kN)	**(kgf)**	**(W)**
Ox	4.5	(450)	450
Buffalo	5.5	(550)	520
Horse	4.0	(400)	500
Donkey	1.5	(150)	200
Mule	3.0	(300)	400
Camel	5.0	(500)	650

Source: Inns (1992). Units: kN = kilo Newton, W = Watt, kgf = kilogramme force. For animals of different weight the power output may be adjusted proportionately.

The productivity of draught animals is also affected by the training of animals and operator skills. FAO has prepared several manuals in this regard (see FAO, 1994). Productivity also depends upon the local availability of appropriate implements (Ashburner, 2002).

Ramaswamy (1994) estimated that each drought animal saves the annual consumption of about 500 litres of fuel. Thus, the outputs of DAP, including livestock's Greenhouse Gas (GHG) emissions, have to be balanced against the fossil fuel consumed by tractors, taking into account the alternative use of the crop residues used to feed the animals. Such a comparative study has not yet been undertaken.

Households reliant on DAP are vulnerable to the loss of their principal power source. In Bangladesh, where cyclones often take a toll on draught animals, DAP has been increasingly replaced by two-wheel tractors. With 80 percent of land prepared by tractors, Bangladesh has the most mechanized agricultural sector in South Asia today (Justice and Biggs, 2010). HIV/AIDS has reduced the workforce in African countries where people are a significant source of power for both household and farm activities, with dramatic impacts on rural livelihoods. In such cases DAP can be one of the solutions.

DAP enjoyed considerable attention from donors in the 1980s and 1990s. Today, the recognition of the role of DAP is a neglected area in development cooperation, as indicated by the lack of figures on DAP, despite the animals' important contribution to agriculture and rural development, food security and gender equity. Locally adapted breeds are often preferred for DAP because of their greater capacity to survive in local conditions (Starkey, 2010). These factors also affect the choice of species. One trend witnessed in parts of the world in relatively recent years has been an increase in the use of draught donkeys. The reasons for this include their relatively low cost, ease of management, resistance to drought and the fact that they are less prone to being stolen (New Agriculturist, 2003). Another trend is an increase in the use of cows or female buffaloes rather than oxen (ibid.). In parts of eastern and southern Africa, the vulnerability of rural livelihoods has been worsened by the decimation of the DAP base caused by the switch from hardy local breeds to cross-breeds, coupled with the failure to carry out regular healthcare practices and an increased livestock susceptibility to disease (such as East Coast fever) (FAO, 2003).

Replacement of animal power by mechanized power is widely recognized as a potential threat to animal genetic diversity. The extent to which this factor is currently contributing to genetic erosion is difficult to estimate. In an earlier survey, replacement of breed functions was mentioned as a threat to breed diversity by 2.2 percent of total respondents. Among respondents who provided information on 87 equine breeds and 212 cattle breeds, "replacement of breed functions" was ranked as the top threat for 32 equine breeds and 10 cattle breeds[4] (FAO, 2009b).

3.3. Manure and urine for fertilizer

The use of organic manures (farmyard manure (FYM), compost, green manure, etc.) is the oldest and most widely practised means of soil nutrient replenishment. Ingredients of FYM are animal droppings, feed left-overs, litter, kitchen residues and ash. Prior to the 1950s, organic manures were almost the only sources of soil and plant nutrition in most countries, and they continue to remain a major source of nutrient and soil fertility. However, manure is not captured in FAO statistics, whereas projections are given for fertilizers (FAO 2003, 2012c). Based on manure production, Potter *et al*. (2010) estimated that in 2000, about 60 percent of global nutrients were introduced by manure. Adjusting for differences in manure collection rates, Liu *et al*. (2010) estimated that Nitrogen (N) input from mineral fertilizer made up about half of the total global N input, whereas N input from manure amounted to 13 percent. In developed countries, it has been suggested that less than 15 percent of the N applied to crops comes from livestock manure. In developing countries, the relative contribution of livestock manure can be high, but is not well documented (FAO, 2011a). A review on improved methods of animal diet and manure management is contained in Hristov et al. (2013).

In the mid-2000s, FAO undertook fertilizer assessments in several countries. Owing to a high animal population, FYM is the most common of organic manures in India, where cattle account for 90 percent of total manure production. The proportion of cattle manure available for fertilizing purposes decreased from 70 percent in the early 1970s to 30 percent in the early 1990s. The average use of FYM is about 2 tonnes per hectare, which is much below the desired rate of 10 tonnes per hectare (FAO, 2005a). As with DAP, manure use in West Africa depends on agro-ecological zones and disease pressure. In Ghana, cattle manure is used in the savanna ecosystems where cattle are kept, whereas poultry manure is used in the forest zones where large commercial poultry farms are found (FAO, 2005b). In Indonesia, chicken manure has been widely used for maize cultivation in some districts and farmers purchase manure from other districts (FAO, 2005c). In Brazil, the commercial use of organic manures is limited to horticultural and perennial crops, including fruit orchards located close to intensive livestock farms. In the case of grain crops, the use of organic fertilizers is uncommon, except in small subsistence and family farming systems or large farms that integrate crop and animal production in confined systems (FAO 2005d). Vitti and Malavolta (1999) estimated that the manure produced in 1997 in intensive livestock systems involved no more than 5 percent of the 144 million cattle in Brazil, contributing only 0.16 percent of the total fertilizer consumption (FAO, 2005d). In South Africa, manures remain an important source of plant nutrients, in addition to their undisputed advantages as a biological agent for improving soil health and productivity. A 1986 survey estimated that approximately 350 000 tonnes of chicken manure are generated, most of which was used as fertilizer. Cattle feedlots also generated considerable quantities of manure, with an estimated 75 000 tonnes of composted cattle manure sold as fertilizer. Assuming reasonable nutrient contents, these manures provided approximately 3 to 4 percent of the total nutrients applied as mineral fertilizer (FAO, 2005e). Manure for fertilizer and urine are derived from locally adapted breeds, as well as from intensive confined systems with international transboundary breeds and crossbreds.

Dung yield varies with breeds, individual animals, age, region and season, and estimates vary from of 4.5 kg fresh weight per day for local cattle and 10.2 kg per day for local buffalo in India (Ravindranath *et al*., 2005) to 24 kg for cattle in Brazil (Vitti and Malavolta, 1999) and 30 kg for high-yielding buffalo in India (Harsdorff, 2012). The majority of nutrients contained in feed are excreted as manure. Studies in West Africa with local zebu cattle revealed that feed quality did not influence the amount of faeces excreted, but urine N excretion increased with protein rich diets (Schlecht *et al*., 1998). An un-

[4] Answers were chosen from a list of options. In both equines and cattle, the most frequently mentioned category of threat was "economic and market-driven threats".

supplemented lactating local Zebu cow produced a total faecal N excretion of 15 kg during the dry season (Rath *et al*., 1998).

In West African grazing systems, livestock are principal vectors of nutrient redistribution across the landscape, with high nutrient transfers from rangeland to cropland, either through overnight corralling of livestock on cropland, or the application of FYM by humans. Corralling returns dung and urine to the soil, and results in better crop yields than dung alone. The average quantity of FYM transported from the homestead to the fields, or dung deposited via night corralling, exceeded the amount provided directly by grazing livestock on average fields (Powell and Valentin 1998; Hoffmann *et al*., 2001, Hoffmann and Mohammed 2004).

The loss of soluble and volatile components during passage through the gastro-intestinal tract and in the compost heap renders FYM more stable in the soil than fresh uncomposted plant materials. Stubble grazing in West Africa provides improved nutrient recycling compared to the direct application of crop residues as organic fertilizer. Farmers use the different decomposition time of different types of manure to ensure a continuous flow of nutrients on the field. Cattle dung decomposes fastest, followed by small ruminant, camel and donkey dung. Therefore there is less nutrient leaching of sheep manure compared to cattle manure (Brouwer and Powell 1998; Hoffmann *et al*., 2001).

Box 2. Shift from cattle to camels as manure-producing animals in Northern Nigeria

With increasing vegetation and feed scarcity, dromedaries are replacing cattle as manure providers in crop farmer-herder manure contracts. The shift from cattle to camels as manure-producing animals has allowed for the utilisation of browse as a feed stratum that still provides sufficient quantities of fodder. The camel is less dependent on herbs and grasses but prefers ligneous browse species, which are still abundant in the region. The night-corralling with camels during the late dry season has a threefold advantage. Firstly, the crop residues are fully available for the farmers' own livestock. Secondly, the impact of manure on the nutrient status of the soil is improved because it is voided right before the onset of the rainy season. Thirdly, given the large part of browse in their diets, it is likely that camel droppings contain less seeds of herbaceous weeds than the dung of cattle and small ruminants (Hoffmann and Mohammed, 2004).

The proportion of manure used as fertilizer depends on the dung collection efficiency and is difficult to estimate, but is probably less than 50 percent in most regions (FAO, 2003; Harsdorff, 2012). Manure is primarily applied as fertilizer to crops, but also to pastures. As the FAO country fertilizer assessments show, farmers' principal management strategy is to concentrate any fertilizers on cash crops rather than food crops, and more to irrigated and favourable fertile lands than to rainfed lands or poor soils. Also Potter *et al*. (2010) found significantly higher application rates for fertilizers and manures in areas with intensive cropland and high densities of livestock. They estimate that nutrient use is confined to a few major hot spots, with approximately 10 percent of the treated land receiving over 50 percent of both fertilizers and manures. In India, six crops consume about two-thirds of the fertilizer applied, and the irrigated area, accounting for 40 percent of the total agricultural area, receives 60 percent of the fertilizer applied (FAO, 2005a). Also, regional studies show that farmers in East and West Africa use manure strategically and in a spatially specific manner (Powell and Valentin 1998; Hoffmann *et al*, 2001; Kirigia *et al*. 2013). However, about half of cultivated area still receives little or no soil amendments, leading to nutrient mining and soil degradation (Potter *et al*., 2010).

Box 3. Responses from Country Reports – Manure

Saint Vincent and Grenadines: Manure from poultry and poultry litter is one of the most used fertilizers (slow release nitrogen) in crop production.

Comoros: Tethered livestock plays an important role in the regulation of ecosystem services, because it allows the production of manure used for the restoration of soils.

Malawi: Livestock manure is used in soil rehabilitation.

Where mineral fertilizer is available, farmers often perceive manure to be a complement to inorganic fertilizer rather than a substitute. The combined application of manure and fertilizer has become an increasingly common practice (Motavalli *et al*., 1994). In South Africa for example, the enrichment of manures (mostly chicken manure) with mineral fertilizer has been general practice for decades, thus combining the benefits of higher plant nutrient concentrations of mineral fertilizers with the benefits of manure (FAO 2005e).

Until a formal market develops for manure, its value will not be captured by statistics. However, manure is traded locally in many countries, e.g. in Thailand where dairy operations sell bagged dried manure to horticulture farmers. The use of manure in African agriculture supports a market system that links pastoral and agricultural communities, but this has been little studied. In West Africa, farmers pay pastoralists for corralling their herds on specific fields for a defined duration under traditional manure contracts. Similarly, in the Godwar area of Rajasthan, camel dung and urine is exchanged with grain for overnight corralling, where it makes an important contribution to the maintenance of soil fertility, while sedentary camel breeders sell camel dung by the cartload or exchange it for grain (Köhler-Rollefson, 2004).

In intensive mixed systems in central Kenya, 81 percent of livestock keeping households are involved in manure trade. Manure from rangelands is marketed to traders or brokers (76%), farmers (20%), and horticultural growers (4.6%). The significantly greater demand for small ruminant manure relative to cattle manure resulted in higher income contributions from the former, and a high mark-up from sales for brokers. Even local governments raise levies on the sale of manure. Other beneficiaries of the manure business include truck loaders (Kirigia *et al*., 2013).

In the Gambia, manure supply ranked as the second most important reason for keeping cows and third for keeping bulls among mixed farmers with fewer than ten cattle. Among farmers with larger herds, manure supply was reported to be the most important livestock function (Ejlertsen *et al*., 2013).

Manure is often more accessible to small-scale farmers than fertilizers, and can be a reason to keep animals that are not otherwise productive. For example in rural Bhutan, unproductive cattle graze in less accessible forest, making them carriers of nutrients from forests to cultivated fields. Such animals are thus retained in the herd for manure production and as a symbol of wealth (Wangchuk *et al*., 2014).

As mentioned above, manure for fertilizer is derived from locally adapted breeds, as well as from intensive confined systems with exotic breeds and crossbreds. In parallel with the growth of the dairy industry in India, the production of dung is estimated to grow from 2 million tons per day to over 3 million tons in 2022 (Harsdorff, 2012).

3.4. Manure and methane for energy

Fuelwood, crop residues and animal manure are the dominant biomass fuels used in rural areas of developing countries, at very low efficiencies. About 20 to 30 percent of the dietary energy contained in feed is not digested by animals and is contained in manure. The energy efficiency of biomass cookstoves is only 8 percent with dung and agricultural residues used in traditional stoves, compared to 50 percent to 60 percent with natural gas, superior kerosene stoves and liquid petroleum gas (IEA, 2007).

While many rural people in developing countries continue to depend on biomass for cooking, India is the country where dung is most used as fuel. In 2005, 668 million people relied on fuelwood and dung for cooking and heating. Assuming an electrification rate of 96 percent in India in 2030, still 60 million rural people will be without access, and 472 million will continue to depend on these fuels in 2030 (IEA, 2007). About 40 percent of the dung collected is used as fuel in cookstoves (Ravindranath *et al*., 2005). Cow dung has a significant income generating effect. Half of the number of jobs in the dairy industry revolves around cow dung as a primary source of income. Harsdorff (2012) thus estimates that the productive use of the total available dung could create nearly 2 million additional full time permanent jobs in dung collection, biogas plants, electricity generation and fertilizer production in rural and peri-urban areas.

Manure and methane for energy (biogas from manure, slaughterhouses etc.) are derived from locally adapted breeds as well as from intensive confined systems with international transboundary breeds and crossbreds. FAO (2013a) found that methane and N_2O emissions from manure storage and processing represent about 10 percent of the livestock sector’s emissions. Methane emissions from manure are a form of energy loss that can be recovered when manure is fed into a biogas digester. The total estimated manure methane emissions are 300 million tonnes CO_2-equivalent per year, about the energy use of Ireland. The wider use of anaerobic digestion for the processing of manure in biogas plants results in lower methane emissions and generates biogas that can substitute other forms of energy. Use of manure in biogas plants would also reduce the premature deaths caused by the indoor use of biomass for cooking and heating. In India, cattle dung use for biogas has large potential for the future, since only 22 percent of the total potential for biogas plants is being utilized and family type biogas plants are being expanded (Ravindranath *et al*., 2005). The addition of biochar to manure in biodigesters increases methane production (Inthapanya *et al*., 2012).

3.5. Genetic resources

With regard to the role of genetic diversity as a provisioning ecosystem service, the greatest relevance of breeds lies in the protection of gene pools and in providing the basis for improvements to food production and agriculture. This service applies across all breed classes. Livestock genetic diversity promotes food security and decreases the vulnerability of production to the effects of diseases and climatic variations. In low-input systems especially, locally adapted breeds often produce higher yields or are more resistant to diseases than breeds selected for high performance under optimal conditions. The value of animal genetic diversity depends on its influence both on mean yields and on variance of yields.

Genetic resources have a considerable economic value. While fully comprehensive data on international gene flows are not available, UN-Comtrade figures[5] indicate that there have been substantial recent increases in the value of global exports in the various categories of live animals and genetic material covered. Between 2005 and 2012, global trade in bovine semen increased by US$0.3 billion, to reach US$0.4 billion in 2012. Reported exports of bovine semen from the United States of America exceeded US$131 million in 2012, compared to US$61 million in 2006. The longer time series of data seem to indicate that, in fact, the rate of growth in international trade accelerated from about 2006 onwards[6]. Bovine semen exports increased at a rate of 8 percent per year during the period 2000 to 2006 and by 21 percent per year in the period 2006 to 2012. Overall, exports of pure bred horses, cattle and pigs, as well as day-old chicken and pigs of less than 50 kg of weight, both of which may include large shares of breeding animals from hybrid breeding programmes, have increased by nearly 500 percent between 2000 and 2012, with a volume of up to 6.4 billion US$ in 2012 (FAO, 2014a).

FAO’s global breed database currently includes 14 869 national breed populations with 8 127 breeds; 7 075 are local breeds and 1 052 are transboundary breeds. Among the transboundary breeds, 507 are regional transboundary breeds (occur in only one region) and 545 are international transboundary breeds (occur in more than one region). A total of 1 788 breeds (17 percent) are currently classified as being at risk, 18 percent are classified as not at risk; 58 percent have unknown risk status and 7 percent are reported to be extinct (FAO, 2014d).

An analysis of DAD-IS data showed a wide range of resilience and plasticity across breeds, indicating that genetic diversity of the world’s livestock provides a range of options that are likely to be valuable in climate change adaptation, including tolerance of climatic extremes such as hot temperatures, adaptation to poor-quality diets or to feeding in harsh conditions, as well as resistance and tolerance to specific diseases. Among the 834 national breed populations with available information on their habitats, 45 percent are reported to be adapted to high mountains, mountains, highlands and hills; and adapted to climatic extremes (Hoffmann, 2013).

Genetic improvement through systematic selection is estimated to contribute between 50 percent (Shook, 2006) and 80 percent (Havenstein *et al*., 2003) to overall productivity increases. Countries with commercial breeding programmes far exceed the production output per animal of the rest of the

[5] http://comtrade.un.org
[6] It is possible that the trend is distorted upwards by more complete reporting in recent years. However, the completeness of figures from preceding years has also been subject to ongoing improvements.

world. Some breeds of the five major livestock species (cattle, sheep, goats, pigs and chickens) have now been developed for a century or more in intensive production systems. These generally provide a single primary product for the market, based on the use of high levels of external inputs. Some of these breeds have spread globally. International transboundary avian and mammalian breeds dominate in the South-West Pacific and North America. Within this transboundary group, a very small number of international transboundary breeds accounts for an ever-increasing share of total production (FAO, 2007b). In species with short generation intervals such as poultry, the majority of genetic material today is supplied by about five globally operating corporations, and a slower but similar concentration trend is observed for pigs; they contribute about 80 percent of global production. Also in dairy breeding, where reproductive technologies allow for the fast spread of genetic progress and large recording populations allow for the use of genomic selection, the breeding industry is consolidating.

The replacement or indiscriminate crossbreeding of local breeds with high-output breeds, taken together with other changes in agricultural structure and practice, has accelerated the erosion of genetic variation (FAO 2009b, 2014a,d). In some cases a small change in habitat area or socio-economic drivers may result in a disproportionate loss in genetic diversity of livestock. This is probably more likely in areas that have already suffered habitat loss and where the remaining populations of particular breeds are quite small (Carson *et al*., 2009).

The loss of genetic diversity associated with more intensive livestock production and related practices may also have deleterious impacts on the non-domesticated plants, animals and micro-organisms in the ecosystem (FAO, 2006a; Steinfeld *et al*., 2010). There is a close connection between the value of biodiversity - breeds in our case - for regulating and habitat services with its value for the resilience of the ecosystems concerned. For the livestock sector itself, a decline in animal genetic diversity has consequences for their genetic vulnerability and their plasticity, for example in response to biotic and abiotic stress. Climate change may also have non-linear effects on breed diversity. Genetic resources will be increasingly important for improved breeding programs, with a wide range of objectives for increasing production, resistance to disease, optimization of processing quality and nutritional value, as well as adaptation to local environments and climate change. Advances in genomics research are opening up a new era in genetic characterization, breeding and conservation.

The World Bank (2009) classified conservation of livestock diversity as a global public good with high degree of non-rivalry and moderate degrees of "globalness" and non-excludability. "Globalness" means that certain features of global public goods are national but cannot be provided adequately through domestic policy action alone. Instead, they require international cooperation to be available locally. The flipside of "globalness" is that many countries need to be involved in the solution whereas the benefits to an individual country's conservation may be only moderate. Because of the special status of agricultural biodiversity derived from previous human efforts to improve breeds, the Global Plan of Action for Animal Genetic Resources's objective is to sustainably manage those resources for food and agriculture in the interest of human kind (FAO 2007c). FAO prepares regular Status and Trends reports (e.g. FAO 2014d), and monitors country implementation of the Global Plan of Action in Synthesis Reports (FAO 2014e) and State of the World reports (FAO, 2007b; 2014a). The indicators and targets developed by the Commission on Genetic Resources for Food and Agriculture for the implementation of the Global Plan of Action for Animal Genetic Resources[7] fall within the scope of *Aichi Target 4*[8] (Governments, business and stakeholders have taken steps to achieve or have implemented plans for sustainable production and consumption and have kept the impacts of use of natural resources well within safe ecological limits) and *Aichi Target 7*[9] (Areas under agriculture are managed sustainably, ensuring conservation of biodiversity). However, definitions of "sustainable production and consumption" and "sustainable management" in the livestock sector remain to be agreed upon.[10] The element of *Aichi Target 13* stating that "strategies have been developed and

[7] CGRFA-14/13/Report, paragraphs 28-32; CGRFA-14/13/4.2.
[8] UNEP/CBD/COP/DEC/X/2 Annex paragraph 13.
[9] UNEP/CBD/COP/DEC/X/2 Annex paragraph 13.
[10] See also Rio+20 Outcome of the Conference, Agenda item 10, The future we want, paragraph 111, 112.

implemented for minimizing genetic erosion and safeguarding their genetic diversity" is particularly reflected in the target for Strategic Priority Area 4.

FAO also collaborates with a wide range of stakeholders to improve the characterization, inventory, breeding and conservation of animal genetic resources.

3.6. Biotechnical/Medicinal resources

The patent landscape report (WIPO, 2014) describes the full range of technologies and innovations that depend on livestock and animal genetic resources. It identified six main themes in the patent data for animal genetic resources:

- Artificial insemination, sex selection and control of estrus;
- Marker assisted breeding (including Quantitative Trait Loci);
- Transgenic animals;
- Cloning animals;
- Xenotransplantation; and
- Animal models.

It found that the creation of transgenic animals using techniques, such as somatic cell nuclear transfer, have increasingly shifted from an initial focus on production for possible consumption to production for medical markets, notably in connection with the production of recombinant proteins in animals (biopharming or the use of animals as bioreactors). Synthetic biology, metabolic engineering, genome engineering and genome editing are emerging areas of science and technology with important implications for developments in food and agriculture, such as the rise of mammalian synthetic biology, or the use of engineered nucleases as molecular scissors to edit the genome of an organism. Animals may be the source of material used in an invention or they may be the target of an invention. For example, animals may be the source of a product such as a recombinant protein or milk with particular properties or they may be the target of an animal feed or therapeutic veterinary product. The vast majority of references in the WIPO report to animal breeds referred to mainstream breeds, such as Holstein cattle or Merino sheep, rather than less common or rare breeds; and no reference was made to the collection of genetic material from a specific country or to traditional knowledge.

4. Regulating and supporting services

Supporting and regulating services are partly interlinked and are inputs to other services, particularly provisioning and cultural services. Regulating and supporting ecosystem services are non-consumptive and in economic terms have only indirect use values or non-use values. Depending on the time horizon, services like soil formation and erosion control, or climate regulation, can be categorized as either supporting or regulating services. Due to this fluidity in the classification system, which is also reflected in the differences between the MA and the TEEB classifications, the following sections present regulating and supporting services as a result of livestock's specific biological functions (see 2.2). Most regulating and supporting services arise from the direct interaction of animals with their environments, and are therefore related to land management practices, especially in grazing systems. From the species' and breeds' feed requirements, and the land-dependency of the production system, they can be grouped as:

- services arising from livestock's ability to convert non-human edible feeds into useful products, through their digestive tracts (waste recycling, use of primary vegetation, weed control, biological control), and
- services arising from livestock's direct interaction with land, vegetation and soil through trampling, grazing and browsing, as well as the production of urine and dung (maintenance of soil structure and fertility, land degradation and erosion prevention, climate regulation, regulation of water flow and water quality, moderation of extreme events and habitat services).

In grazing systems, livestock's mobility and resulting ability to respond to temporal and spatial fluctuations of ecosystems in resource availability is an additional unique function, which provides livestock keepers with a broad range of management options.

In this section, results from the Global and European Surveys and the Country Reports are complemented by findings from the literature. According to Table 13, around 33 percent of Country Reports for the Second Report (FAO, 2014a) indicated that policies, plans or strategies for animal genetic resources management include measures specifically addressing the role of livestock in regulating and supporting ecosystem services. The proportion of countries is larger in Europe (46%) and Asia (35%) than in the other regions.

Table 13. Country responses to the management of animal genetic resources and the provision of regulating and supporting ecosystem services

Regions and subregions	Number of countries	Countries reporting policies, plans or strategies for animal genetic resources management include measures specifically adressing the roles of livestock in the provision of regulating ecosystem services and/or supporting ecosystem services (percent)
Africa	**40**	**28**
East Africa	8	0
North and West Africa	20	35
Southern Africa	12	33
Asia	**20**	**35**
Central Asia	4	25
East Asia	4	25
South Asia	6	33
Southeast Asia	6	50
Southwest Pacific	**7**	**43**
Europe and the Caucasus	**35**	**46**
Latin America & the Caribbean	**18**	**22**
Caribbean	5	20
Central America	5	20
South America	8	25
North America	**1**	0
Near and Middle East	**7**	**14**
World	**128**	**33**

Note: Question: Do your country's policies, plans or strategies for animal genetic resources management include measures specifically addressing the roles of livestock in the provision of regulating ecosystem services and/or supporting ecosystem services?
6.1. If yes, please describe these measures and indicate which supporting and/or regulating ecosystem services are targeted, and in which production systems.
6.2. Please describe what the outcome of these measures has been in terms of: the supply of the respective ecosystem services (including an indication of the scale on which these outcomes have been obtained).

Reported measures aiming at supporting/regulating ecosystem services were diverse, including incentives aiming at a better management of grazing areas (e.g. for maintenance of ecosystems and landscapes, fire control), management of crop residue, or the supply of drought animals. Most countries reported significant and positive impacts of the measures taken in targeted areas, concerning either the conservation of biodiversity and landscapes, the management of environmental risks (erosion, fire, avalanches), the prevention of social conflicts and the improvement of working conditions. It was frequently noted that the implementation of those measures also improved breeding practices, resulting in diversified production, as well as increased productivity and economic viability of livestock populations.

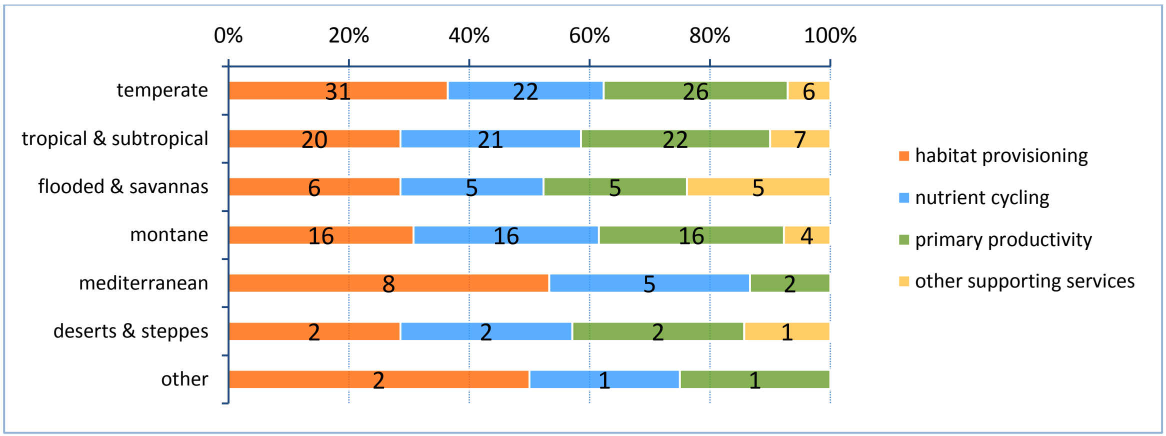
Box 4. Responses from Country Reports – Grazing management

South Africa: The sustainable use of rangeland resources through effective livestock grazing regimes, taking carrying capacity and range condition into account. A pilot rangeland monitoring and improvement program ran for three years and this is currently being formalised as a National Rangeland Monitoring and Improvement Program (NRMIP).

United States of America: The livestock sector, particularly at the species level, provides a broad range of ecosystem services such as, soil nutrient cycling, maintenance of wildlife habitat, vegetation management on public and private lands, and control of noxious weeds. In addition, through grazing plant carbon cycling is stimulated thereby increasing carbon sequestration. However, these services have not been identified as a focus for animal genetic resource management. In the southern plains, goats and to a lesser extent sheep are used to mitigate brush encroachment. Sheep and goats are also used to manage vegetation growth (e.g., trees and shrubs) along electrical power-line easements in mountainous areas thereby reduce the use of herbicides. On mountainous public lands sheep and cattle grazing contributes to vegetation health and plant diversity. Particularly in the Great Plains livestock grazing can stimulate plant vegetative processes that results in increased carbon sequestration. Also in the western half of the U.S. sheep are used as a bio-control for noxious weeds.

In the Global Survey, the provision of supporting services in different types of grassland ecosystems was similarly distributed between habitat provisioning, nutrient cycling and primary productivity (Figure 10), except for temperate and Mediterranean grasslands, where habitat provisioning was more pronounced than nutrient cycling and support of primary production. The prominence of European reports in the sample and the high frequency of Cases B (breeds introduced for ecosystem management) in temperate and Mediterranean grasslands amongst these may explain the stronger focus on habitat services.

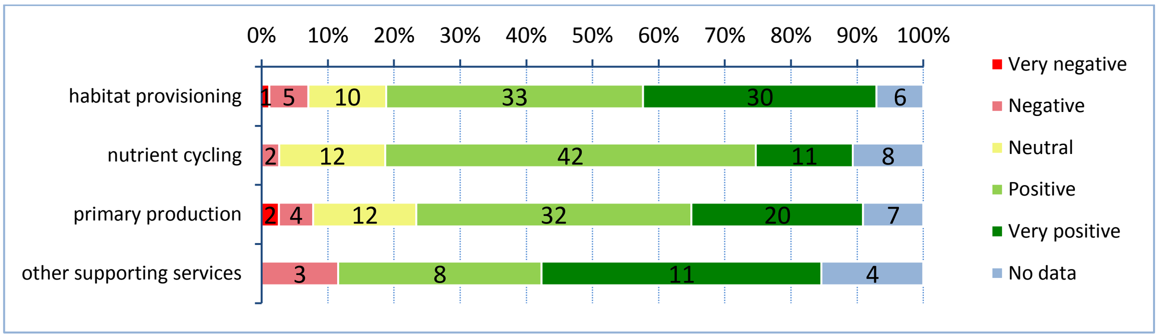
Figure 10. Supporting services in different grassland types



Note: Numbers stand for total responses in each category.

The reported effects of animal genetic resources on the provision of supporting services were mostly positive (44%) and very positive (27%), followed by neutral effects of grazing on the three services (13%) (Figure 11). There were data gaps (10% of respondents) in the evidence for supporting services This indicates the importance of promoting the measurement of the effects of grazing animals on these services.

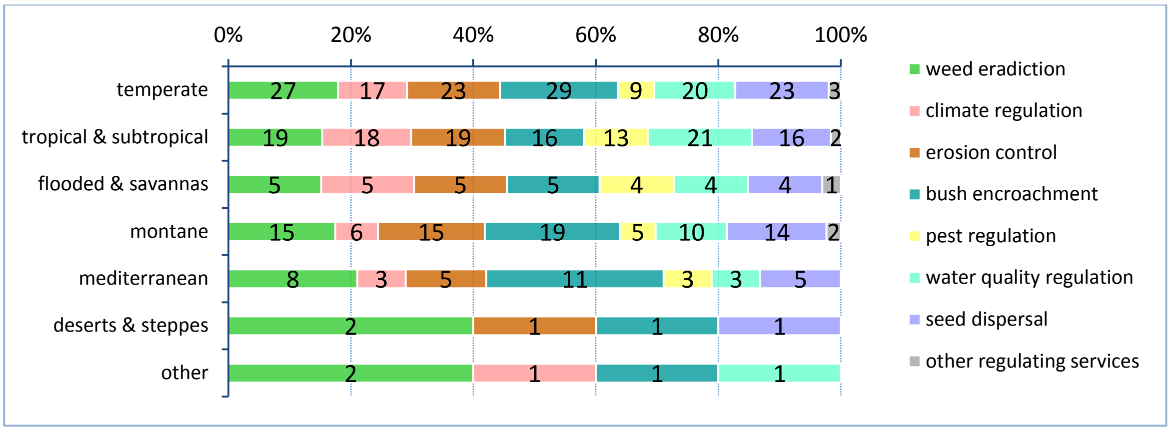
Figure 11. Effects of the breed's grazing on supporting services



Note: Numbers stand for total responses in each category.

The distribution of regulating ecosystem services per grassland type revealed that the different regulating services were provided across all types of grassland (Figure 12). Most frequently reported across all grassland habitats were bush encroachment control (19%) and weed eradication (18%), followed by erosion control and seed dispersal (15% each) and water quality control (13%).

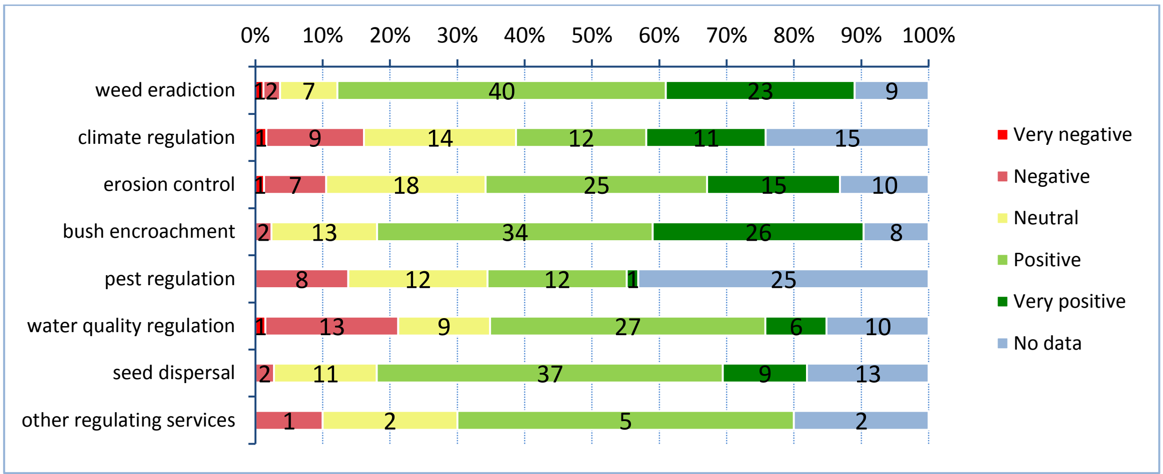
Figure 12. Regulating services in different grassland types



Note: Numbers stand for total responses in each category.

The effects of livestock grazing on regulating ecosystem services were evaluated by 68% of all responses as positive or very positive, and by 21% as neutral (Figure 13). There were also data gaps (22% of all responses) in the evidence given regarding the different services. This highlights the importance of better assessment of the changes in the ecosystems, with special attention to the roles of specific breeds.

Figure 13. Effects of the breed's grazing on regulating services



Note: Numbers stand for total responses in each category.

Knowledge gaps are obvious from the fact that overall 22 percent and 10 percent of all responses indicated a lack of quantitative evidence regarding the different regulating and supporting services. However, respondents frequently stated that livestock keepers were aware of the positive effect of grazing on the diversity of birdlife, small mammals and insects. No available data on the effects of grazing were reported by 11 percent of all cases mentioning bush encroachment, 12 percent on weed eradication, 15 percent on erosion control, 19 percent on water regulation, 22 percent on seed dispersal, 32 percent on climate regulation and 76 percent on disease regulation. This highlights the importance of better assessment of the changes induced by livestock in ecosystems, especially at breed level.

4.1. Services arising from livestock's ability to convert non-human edible feed

These ecosystem services can be provided by all types of breeds, depending on the production system. Livestock's ability to convert non-human edible feed in a range of useful products has been described earlier. From the regulating and supporting services perspective, this ability is particularly useful in grazing systems which make use of the spatial and temporal distribution of livestock.

4.1.1. Use of primary vegetation

In the absence of roughage feed data, livestock consumption data are usually derived from production system and land use models. In 2000, the livestock sector was estimated to have consumed 58 percent of directly used human appropriate biomass globally (Krausmann *et al*., 2008). Herrero *et al*. (2013a) estimate that in 2000, livestock globally consumed about 4.7 billion tons of feed biomass, with ruminants consuming 79 percent. In the United Kingdom for example, grasslands accounted for 69 percent of total forage dry matter used by cattle and sheep (Wilkinson, 2011). Cattle are the main consumers of fibrous feeds. Livestock in developing countries consume the majority of grasses and roughages globally. Grasses comprise about half of the global biomass used by livestock, while other roughages such as crop residues, cut-and-carry forages, legumes and roadside grasses make up about a quarter. Grass is a key feed resource for both grazing and mixed crop–livestock systems. Even though the proportion of grass in the diet of ruminants is higher in grazing systems than in mixed systems, total grass consumption in grazing systems is about half of that in mixed systems due to the lower numbers of animals (Herrero *et al*., 2013a).

Box 5. Responses from County Reports - Feed

Austria: Introduction of low input feed management techniques and appropriate breeds, by supporting research in this field and offering financial support to farmers to reduce dependency on protein imports, could minimise negative environmental impacts by high energy feed and achieve well adapted, independent and resilient breeds.

Ethiopia: Livestock in the highland mixed crop livestock production system allows grazing on crop stubbles and leftovers after harvest. Grazing animals defecate on the crop field in a somewhat distributed manner and add organic matter to the soil, and decrease the amount of biomass that will be available during preparation, which avoids excessive soil burning and reduces the release of carbon dioxide into the atmosphere.

In most developing countries, milk is produced from crop residues, grasses and agro-industrial by-products. Very low levels of cereals are thus used in the diets of dairy animals, suggesting that milk is produced from human-inedible feed resources by the dairy sector in most developing countries. There are, however, differences in rations depending on breed type. While local dairy cows in developing countries receive about 80 percent and local buffalos about 90 percent of roughage, improved breeds of the two species receive more concentrates and compound feed. Improved buffalos receive a higher contribution of grass than low nutritious crop residues (FAO *et al*., 2014).

The predominance of grasses in animal diets stresses the role of grasslands. Including mosaics of grasslands and shrublands, grassland systems are estimated to cover about 32 percent of the world's land area (FAO, 2014b; Table 4). In 40 countries, grasslands cover more than 50 percent of the land area (UNDP *et al*., 2000). Grasslands include rangelands and non-rangeland areas (e.g. mesic pastures). Rangelands[11] extend over all latitudes and are usually characterized by low biomass production due to constraints related to soil, temperature and water availability. Rangeland vegetation is generally dominated by natural plant communities of perennial and annual species, including grasses, shrubs and trees, and therefore covers large parts of low forest cover areas (Table 4). Rangelands are found from the Asian steppes to the Andean regions of South America and from the mountains of Western Europe to the African savannas, where drylands cover 66 percent of the total continental land area (FAO, 2005f; FAO, 2011b).

The extent of and trends in rangelands are difficult to assess. The extent of rangelands changes over time due to conversion of forests into human-made grasslands, the conversion of rangeland into cropland and improved grasslands, and the replacement of abandoned rangeland with forests. FAO (2011b) estimated that the total area of rangelands was 3.43 billion ha in 2000 and decreased slightly to 3.36 billion ha by 2008. The rates of land conversion and the intensity of rangeland use are likely to continue changing over the next decades.

By their very nature rangelands are fragile ecosystems, which, when mismanaged, are readily prone to degradation, loss of biodiversity and water retention capacity, carbon emissions and reduced productivity. Ecology and biodiversity in rangeland ecosystems differs considerably between world regions. In many regions, such as African savannas, North American prairies or Asian steppes, livestock grazing systems have developed on natural rangeland or open woodlands previously grazed by wild ungulates, and today include traditional pastoral systems, as well as ranching systems with fenced-in grasslands. As African landscapes evolved with enormous herds of wild ungulates and are grazing dependent, pastoral management practices involving mobility and fluctuation in herd size that simulates wildlife grazing is more sustainable than constant stocking rates (Hatfield and Davies, 2006). In East Africa, for example, such pastoral systems date back two to three millennia. Most European grasslands were developed from forests many centuries ago. These semi-natural grasslands are valued today as one of the most species-rich ecosystems in Europe, where their conservation and restoration is one of the main objectives of biodiversity policies (EC, 2011, 2013). In the United Kingdom for example, grasslands cover about 68 percent of agricultural land, and 40 percent of grasslands is rough grazing, mostly located in areas of outstanding natural beauty (Wilkinson, 2011). In other regions, especially in Latin America, forest conversion into human-made grasslands or cropland is very recent. Also in Oceania, livestock grazing is a recent phenomenon.

Rangelands make an important contribution to ecosystem functions and biodiversity. In addition to providing feed for livestock, they play an essential role as a habitat for wildlife, for water retention, and for the conservation of plant genetic resources. The flora of rangelands is rich: about 750 genera and 12 000 grass species occur in across all climatic zones. These ecosystems are also important for the maintenance of fauna: e.g. grasslands contain 11 percent of the world's endemic bird areas (White *et al*., 2000), and contribute to the maintenance of pollinators and other insects that have important regulating functions (FAO, 2005f).

Grasslands and rangelands sustain the livelihoods of large numbers of vulnerable people in many parts of the world. Pastoralism, although not unique to drylands, is the only feasible agricultural strategy in many dry areas, particularly when assessed at a landscape scale. Dryland pastoralism depends on herd mobility to respond to the extremely high seasonal variability of vegetation and other resources (Davies *et al*., 2010a). Precise figures are hard to come by, but nomadic and transhumant pastoralists may number between 100 and 200 million people globally. Estimates put the total number of pastoralists and agro-pastoralists worldwide at 120 million in the late 1990s, of which 50 million reside in Sub-Saharan Africa (FAO, 2006c).

Competition for land with other agricultural activities may become an issue in regions where grazing lands have the potential to be used for pasture intensification, food crops and bioenergy crops. However, it is possible to integrate multiple uses in one agro-ecosystem. One of the known examples

[11] The Global Land Cover database of 2000 (GLC2000) categories of rangeland ecosystems are "shrub cover, closed–open, evergreen"; "shrub cover, closed–open, deciduous"; "herbaceous cover, closed–open"; "sparse herbaceous or sparse shrub cover"; and "regularly flooded shrub and/or herbaceous cover".

of such kind of agro-ecosystem is a wood-pasture. According to Devendra and Ibrahim (2004) the appropriate choice of livestock species, production systems and optimum age of trees for integration with livestock in sylvo-pastoral systems are important considerations for the efficient use of natural resources. In a survey of wood-pasture habitats in Europe, Bergmeier *et al*. (2010) suggested that wood-pasture may also provide an avenue for improving the ecological quality of ecosystems and may offer opportunities for integration of ecosystem uses. Broom *et al*. (2013) summarize multiple benefits of agro-silvo-pastoral systems in Latin America. The importance of wood pasture and tree systems at global level was already highlighted in Tables 4 and 6.

4.1.2. Waste recycling and weed control

The total area dedicated to feed crop production amounts to about 33 percent of total arable land, or 4 percent of the land surface of the planet (FAO, 2006a; 2014b, Table 4). However, livestock not only consume feed crops, but also crop residues and a range of wastes from different crops. As agro-ecological potential increases and crop-livestock systems are intensifying, while local breeds are replaced by exotic breeds or crossbreds, the balance of feed resources generally shifts from grass derived from natural pastures to crop residues and by-products, or to planted pastures and forages. Livestock consume a wide range of agro-industrial by-products from oil pressing, beer brewing, wine making and dairy processing, and more recently, distillers grains produced as a co-product from ethanol production from cereals. Feeding pigs and chicken with kitchen residues and swill has been commonplace globally, but has recently been declining in market-based systems due to food safety regulations, resulting in increasing food waste. In India, China, Philippines, Malaysia and Thailand, an estimated 3 million tonnes of fruit and vegetable waste are generated annually, which could be consumed by animals (FAO, 2013b). Waste recycling and weed control are services provided in mixed systems by all types of breeds.

About half of globally available cereal straws and stovers are recycled on croplands to improve soil organic matter. The shares vary regionally depending on the demand for feed and fuel (Liu *et al*., 2010). Straws and stovers are quantitatively by far the most important crop residues in developing countries, in some of which they provide up to 50 percent of ruminants diets (Herrero *et al*., 2013a). In India for example, two-thirds of all crop residues are used as animal feed (FAO, 2005a). However, the low productivity and low feed value of straws and stovers is generally not adequate for any intensification of livestock production systems (World Bank, 2012). Cereal stovers are thus not widely used in developed regions and Latin America (Herrero *et al*., 2013a). In West Africa, the potential of crop residues and agro-industrial by-products remains underexploited (FAO, 2014f).

"Occasional feeds" such as cut-and-carry forages, legumes and roadside grasses, hays and silage, and other by-products occur in much smaller quantities than stovers but are important, because they are less fibrous, have relatively more digestible nutrients, and are often high in protein. Both occasional feeds and stovers are consumed in larger quantities in mixed crop–livestock systems, where stall-feeding is a common practice. Occasional feeds are of importance in mixed systems of developed countries, Latin America and South Asia, where supplementation with fodder crops is widely practised, resulting in diets with higher energy concentrations and higher feed efficiencies (Herrero *et al*., 2013a). FAO country feed assessments are currently aiming to better characterize the different feedstuffs and the quantities used in different production systems (FAO, 2014g).

Weed control and biomass residue management were often mentioned in the Global Survey as functions that different grazing livestock species fullfill, particularly traditional breeds in hard-to-reach and steep areas. Saanen and Anglo Nubian cross-breed goats on Cook Islands were reported to eat invasive plant species, thus minimizing their spread. Grazing by Podolian cattle in Serbia also prevents development of invasive plant species, such as hawthorn, by feeding on the shrub. In Finland, certain weeds such as nettle and dandelion were reported to decrease through grazing by Finncattle.

Smallholder farming benefits from soil improvement using animal dung and manure products, as well as from weed control by grazing animals. Moderate grazing pressures can be compatible with high levels of biodiversity and provide other positive externalities, whereas high intensity grazing performed over short periods can also be used as a tool for weed control (García *et al*., 2012). In a 4-year study, Hatfield *et al*. (2011) concluded that generally any breed, age or background of sheep can be used for summer fallow grazing if weeds are at an immature stage. Not only cattle, but also waterfowl foraging can substantially increase straw decomposition in flooded, fallow, rice fields (Bird *et al*., 2000).

4.1.3. Biological control and animal/human disease regulation

While there are various studies on the resistance to certain diseases of many traditional domestic livestock breeds e.g. Baker (1998) on Red Maasai sheep in Kenya, Paling and Dwinger (2011) on N'Dama cattle; Gauly *et al*., 2010 for review), livestock grazing can also prevent the spread of human diseases and improve farming systems by feeding on pests. Information on this ecosystem service is rare, and available at species rather than breed level.

Box 6. Responses from County Reports – Biological control

In **Malaysia**, beef cattle are being raised in oil palm estates. The estates practicing integration with beef cattle can reduce herbicide and fertilizer use.

Ukraine: Sustainable use by ruminants of big areas, withdrawn from effective economic use, of natural meadows and pastures contaminated with radionuclides of Chernobyl zone is important.

The prevalence of spirochete infection in vector ticks collected from a pasture with low-intensity cattle grazing has been found to be lower than those collected from an ungrazed site (Richter and Matushka, 2006). The authors concluded that the reintroduction of traditional low-intensity agriculture in central Europe may help reduce risk for Lyme disease. Guinea fowl, which in Africa eats a wide variety of arthropods, was found to be appropriate as a means of controlling ticks in low-density housing areas and public areas in New York city, where their noise is unlikely to be a problem and where custodial care is available for the flock (Duffy *et al*., 1992). The authors suggested that guinea fowl alone should not be relied on for the complete control of deer ticks, but rather should be used as one of a range of methods with tick repellents, judicious use of acaricides, and habitat modification. Indigenous chicken as natural predators of livestock ticks were used as part of an integrated tick control plan in cattle-management systems in resource-poor communities in South Africa (Dreyer *et al*., 1997) and Kenya. Hatfield *et al*. (2007) showed the potential for using grazing sheep to control wheat stem sawfly infestations in cereal grain production systems in the United States of America. Rice-duck farming, a traditional farming system, was reintroduced to China's agricultural practice in recent years. Zhang *et al*. (2009) suggested that ducks could replace pesticide use in terms of controlling pest damage without reducing rice yield in a rice-duck system. In a rice-duck farming system, ducklings are released into the paddy field and grow up together with rice (Teo, 2001, Zhang *et al*., 2002). The system has been widely adopted in organic rice production in the Guangzhou area, one of the most economically successful areas in China due to the predation effect of ducks on pests and the reduction of pesticide use (Zhang *et al*., 1997; Zhang *et al*., 2002). In Vietnam, two weeks after the introduction of ducks, most of the common species of weed and insect pests affecting rice had been largely eliminated (Men *et al*., 2008).

Genetic diversity in itself may be related to a decrease in disease emergence and spread. Beyond the individual animal level, the contribution of genetic diversity in populations to the dynamics of pathogen transmission needs further investigation. Mathematical models (Springbett *et al*., 2003) and evidence from plants (Mitchell *et al*., 2002) indicate that high species diversity and high genetic diversity within populations affect both the probability of the occurrence of epidemics and their outcome. In the case of vector-borne diseases, highly diverse host communities show lower infection rates among vectors due to the presence of unsuitable hosts - a mechanism known as the 'dilution effect' (Morand and Guegan, 2008). This highlights the need to maintain biodiversity in agricultural production systems and landscapes (Slingenbergh *et al*., 2010).

4.2. Services arising from livestock's direct interaction with land, vegetation and soil, other than habitat services

Many of the ecosystem services in this group are related to land management in grazing systems, including the spatial and temporal distribution of livestock. These ecosystem services can be provided by all types of breeds, depending on the production system.

4.2.1. *Maintenance of soil structure and fertility*

The nutrient value of manure goes beyond the provision of nitrogen (N), phosphorus (P) and potassium (K) as manure contains organic matter and micronutrients. The organic matter depends on the manure treatment and dilution (e.g. manure with straw bedding vs. slurry). For example, certain manures (e.g. poultry litter) supply more organic matter than others (e.g. swine lagoon effluent).

In soils that are low in organic matter, the organic matter provided by manure is particularly valuable. Low soil nutrient retention capacities are found in Southern Africa, the Amazon area, Central Asia and Northern Europe. In those areas, increased use of fertilizers alone may prove ineffective for increasing crop yields, and additional forms of soil enhancement are necessary (FAO, 2011b). Soil fertility depletion is reaching a critical level in sub-Saharan Africa, especially under small-scale land use. It results from a negative nutrient balance, with at least four times more nutrients removed in harvested products compared with nutrients returned in the form of manure and mineral fertilizer (FAO, 2011b).

The application of sufficient quantities of organic manures is essential to improve soils with naturally low organic matter content, such as in India. In Southern Africa, for example, the improved crop growth under tree canopies could be explained by a combination of factors, such as manure and urine from livestock grazing, and increased nutrient inputs including biological N fixation (Khumalo *et al*., 2012).

In view of global nitrogen recovery rates of about 50-60 percent (Liu *et al*., 2010; FAO, 2011b), a healthy soil is also needed to better bind N. Because N fertilizers are highly water soluble and are rapidly cycled in the soil, much of what is not taken up by the plant may be dissolved as nitrate in solution and find its way into drainage systems, downstream watercourses and into groundwater. Nitrogen is also released to the atmosphere as ammonia or nitrous oxide. The maximum achievable N-use efficiency is around 50 percent, and in practice fertilizer efficiencies are rarely better than 20-30 percent. Organic N, such as provided by manure, becomes available to plants over time, so not all is available during the season it is applied (and not all the N is dissolved as nitrate and susceptible to being carried off in waterways) and the residual effect can be considerable. Measures to promote higher N uptake by plant roots include the use of protected and slow release compounds, which release N progressively at a rate determined by soil moisture content, pH and soil temperature, thus creating a longer period of availability, as well as improvements in soil biological processes that enhance soil fertility (FAO, 2011b).

Less fertilizer may be needed if nutrient cycling becomes more efficient and fewer nutrients are leached from the rooting zone. As soil structure improves, the availability of water and nutrients to plants also improves. Costanza *et al*., (1997) estimated that nutrient cycling provides the largest contribution (51 percent) of the total value of all ecosystem services provided each year.

4.2.2. *Land degradation and erosion prevention*

Recent studies (Nachtergaele *et al*, 2011) have broadened the definition of 'land degradation' beyond soil erosion or loss of soil fertility to the deterioration of a balanced ecosystem and the loss of ecosystem services. Land degradation thus needs to be considered in an integrated way, taking into account all ecosystem goods and services, biophysical as well as socio-economic (LADA, 2010; FAO, 2011b).

Poor land management results in land degradation and on-site soil erosion. Many studies have demonstrated the effect on yields of the loss of nutrients and organic matter, as well as the related deterioration of the water holding capacity of soils. Loss of soil quality and its protective vegetation cover also affects broader ecosystem services by causing hydrological disturbance, loss of above and below ground biological diversity, and reduced soil carbon (C) stocks and associated increases in carbon dioxide emissions.

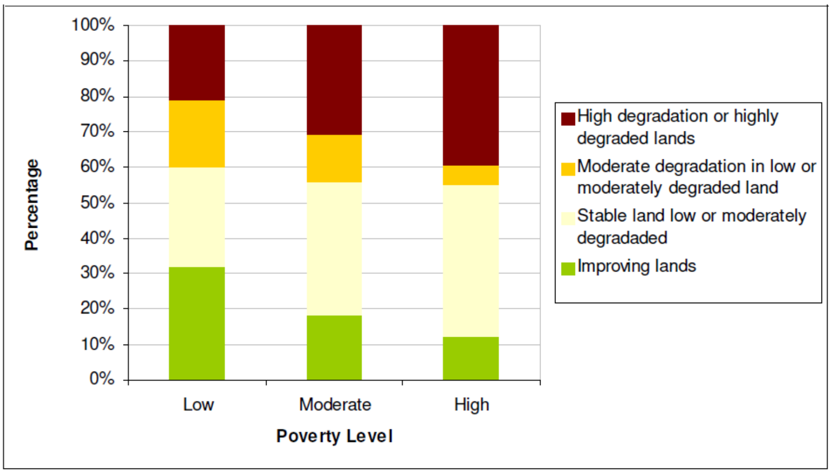
Soil health is declining in many farming systems both in developed and developing countries. The worst situations occur in highland rainfed cropping systems in the Himalayas, Andes, Rocky Mountains and the Alps; in low input, mixed rainfed crop-livestock systems in the Sub-Sahara African savannahs, agro-pastoral systems in the Sahel, the Horn of Africa and Western India; and in intensive systems where nutrients and pesticides can lead to soil and water pollution if not properly managed (FAO, 2011b).

Drylands in the hyper-arid, arid, semi-arid and dry sub-humid zones are considered particularly susceptible to soil degradation. About 20 percent of the world's pastures and rangelands, with 73 percent of rangelands in dry areas, have been degraded to some extent, mostly through land subdivision, lease cropping, as well as overgrazing, compaction and erosion created by livestock action (UNDP *et al*., 2000; MA, 2005b; FAO, 2006a).

The influence of livestock on land degradation and erosion prevention is linked to grazing management. In many drylands, matching the timing of grazing with the phenological state of plants, rather than merely controlling the numbers of animals, needs to be carefully managed. Through livestock mobility, grazing pressure in such non-equilibrium ecosystems can be timed to increase grazing land cover, maximize plant productivity and overall biodiversity (Ellis and Swift, 1988; Behnke et al., 1993; Savory 1999; Dijkman, 2005; Butt and Turner, 2012). Peco *et al*. (2006) and Aboud *et al*. (2012) stress that moderate grazing increases fertility of very poor soils and promotes species richness on local scales, as well as vegetation cover, which contributes to protecting the soil from erosion. It also improves the soils' ability to retain water, which is important for seed germination and seedling establishment in environments where water is the main limiting factor. The vegetation condition and vigor of the constituent species is therefore important. Havstad *et al*. (2007) reported that black grama grass in the USA can be a consistent stabilizer of soil, but when it declines, rangelands formerly dominated by this species are vulnerable to erosion and deterioration.

Land degradation correlates with poverty. Worldwide, 16 percent of the poor and 42 percent of the very poor live in degraded areas (Figure 14). Pastoralists constitute one of the poorest population sub-groups globally. Among African pastoralists, the incidence of extreme poverty ranges from 25 to 55 percent, and in the Horn of Africa it is 41 percent (FAO 2006c). The drylands in particular are affected, as livestock are often the only source of livelihoods for the people living in these areas (FAO 2006c; 2010a).

Figure 14. Relation between land degradation and poverty (2000)



Source: FAO, 2011b.

Concentrations of rural poverty can be linked to marginal lands where tenure of land and water is insecure, combined with poor quality soils and high vulnerability to land degradation and climatic uncertainty. Rangelands, which are usually characterized by low biomass production due to constraints related to soil, temperature and water availability (Nori and Neely, 2009), belong to this kind of vulnerable livestock production systems. A low level of access to land is even a predictor of poverty. Thus improving land and water tenure arrangements, as well as management practices in these areas is likely to have a direct positive impact on food insecurity and poverty (Lipton, 2007). Increased control of indigenous peoples over access to grazing land, water rights and land tenure laws are important instruments in preventing land degradation and ensuring sustainable land use.

Where production systems become harsher as a result of climate change, land degradation, etc., the roles of locally adapted breeds may become increasingly important and demand for them may increase (or decline more slowly). However, major environmental changes may make it more difficult to raise some breeds in the geographical areas where they have traditionally been kept and may even lead to shifts in the species raised in a given area. Developments of this kind may pose a threat to some breeds. Another potential factor affecting breed use in this context is the desire to minimize the environmental degradation caused by livestock keeping. For example, the Country Report from South Africa mentions the example of the Nguni cattle breed, which is considered to be much less harmful to degraded grazing areas than exotic breeds.

Soils have only recently become a global environmental issue, especially in the framework of the three main international environmental conventions. These conventions cover interrelated issues on desertification, climate change and biodiversity loss, especially with respect to drylands. However, few tangible policies have been developed on soil health in drylands, for which organic matter and soil carbon are crucial (Bernoux and Chevallier, 2014). The Global Soil Partnership hosted by FAO is an international effort to coordinate different stakeholders' actions in this field.

Strategies to increase the stock of carbon in rangelands include restoring soil organic matter and root biomass, thereby enhancing soil biota; manure cycling and agroforestry; erosion control; afforestation and forest restoration; optimal livestock densities; water conservation and harvesting; land use change (crops to grass/trees); or setting land aside (FAO, 2013a).

Where pastures and grasslands are actively managed, other practices, which could be used to further increase grassland soil carbon stocks, include the sowing of improved, deep-rooted tropical grass or improved legumes species and improved fire management. The sowing of better quality pasture and better pasture management can lead to improvements in forage digestibility and nutrient quality. This results in faster animal growth rates and lower age at first calving. According to Thornton and Herrero (2010), the replacement of Brazilian native Cerrado grasses with more digestible *Brachiaria decumbens* introduced from Africa has been estimated to increase daily growth rates in beef animals by 170 percent. Better nutrition can also increase cow fertility rates, and reduce mortality rates of calves and mature animals, thus improving animal and herd performances, and reducing the GHG emissions from enteric fermentation (FAO, 2013a,c,d). By improving individual animal performance, reduced stocking rates provide a large mitigation potential (Koslowski *et al*., 2012). Especially the impact of agricultural and pastoral activities on the carbon cycle needs to be taken into greater account. However, significant gaps in knowledge continue to exist on drylands' carbon sequestration potential, acceptable methodologies and cost-benefit analysis of carbon sequestering practices for small-scale rural farmers and pastoralists (FAO, 2009c; 2011b; Stringer *et al*., 2012).

4.2.3. Climate regulation

Restoring degraded grasslands through more sustainable grazing practices and forage production can substantially improve animal feeds and productivity as well, benefiting herders and others who depend on livestock keeping for income and food. By the same token, restoring degraded grasslands can trap large volumes of atmospheric carbon, contributing to the mitigation of climate change. In grasslands that have experienced the excessive removal of vegetation and soil carbon losses from sustained periods of overgrazing, historical carbon losses can at least be partially reversed by reducing grazing pressure. Conversely, there is also scope to improve grass productivity and sequester soil carbon by increasing grazing pressure in many grasslands which are only lightly grazed. Climate regulation is thus linked to the land management practices of livestock production, where increase in soil carbon provides environmental co-benefits including maintenance and quality of immediate and surrounding soil and water resources, air quality, human and wildlife habitat, and aesthetics (Follett and Reed, 2010).

According to the Fourth Assessment Report to the IPCC (Smith *et al*., 2007), 1.5 gigatonnes CO_2-eq[12] of carbon could be sequestered annually, if a broad range of grazing and pasture improvement practices were applied to all of the world's grasslands. The same study estimates that up to 1.4 gigatonnes CO_2-eq of carbon can be sequestered in croplands annually, and much of these are devoted to feed production. In another global assessment, Lal (2004) estimated a more conservative potential for carbon sequestration of between 0.4 and 1.1 gigatonnes CO_2-eq per year. FAO (2013a) estimated that improved grazing management practices in grasslands could sequester about 0.41 gigatonnes CO_2-eq of carbon per year (or 111.4 million tonnes C per year) over a 20-year time period. A further 0.18 gigatonnes CO_2-eq of sequestered emissions (net of increased N_2O emissions) per year over a 20-year time period, was estimated to be possible through the sowing of legumes in some grassland areas. Thus, a combined mitigation potential of 0.59 gigatonnes CO_2-eq was estimated from these practices, representing about 8 percent of livestock supply chain emissions.

Permanent grasslands in the European Union represent a sink of 11.4 ± 69.0 million tonnes CO_2-eq per year, equivalent to 3 percent (± 18 percent) of the yearly emissions of the ruminant sector in the European Union (Soussana *et al*., 2010). In the United States of America, grazing lands have the potential to remove 198 million tonnes of carbon dioxide per year from the atmosphere for 30 years (Follet *et al*., 2001), which would offset 3.3 percent of its CO_2 emissions from fossil fuel and help protect rangeland soil quality. Analysis of grazing practices suggested that light grazing is beneficial to increased soil organic carbon compared to heavy grazing and non-grazing.

Net sequestration/emission of carbon in permanent pasture under stable management practices may thus be significant, but the uncertainty about calculation parameters is such that it cannot be said with certainty whether permanent pastures are a net sink or source of emissions. The relative importance of C sequestration may even be higher in other parts of the world where permanent pastures are much more common and C sequestration potentially higher (e.g. Africa, Latin America and Caribbean) (FAO, 2009c). Better understanding of soil organic carbon dynamics in grasslands and the development of methods and models to monitor and predict changes in C stocks, are required for the inclusion of this mitigation option in global assessments (FAO, 2013a,c,d; Hristov *et al*., 2013). Drought can significantly impact rangeland soil organic carbon levels. In general, carbon storage in rangelands increases with increased precipitation, although there are threshold levels of precipitation where sequestration begins to decrease (Derner and Schuman, 2007).

The impact of better grazing management - defined as the improved balance between forage availability and grazing - on promoting forage production and soil carbon sequestration has been assessed in different countries. The Brazilian government is committed to a carbon sequestration target of 83 to104 million tonnes CO_2-eq through the restoration of 15 million hectares of degraded grassland, between 2010 and 2020, in its Low-Carbon Agriculture Program, which translates to the annual sequestration of 8.3 to10.4 million tonnes CO_2-eq. In West Africa, the impact of better grazing management, e.g. increased mobility and a better balance between vegetation grazing and resting periods, can have a positive impact on forage production and soil carbon sequestration. In China, which has 400 million hectares of grasslands, supportive national policies and measures have been initiated to incentivize the uptake of sustainable grassland management practices such as the Grassland Law of the People's Republic of China; the Grassland Ecology Conservation Subsidy and Reward Mechanism; and the Grassland Retirement Program (Zhang and Hong, 2009; FAO, 2013a).

In the current carbon market system, carbon volumes of agricultural and forestry sectors entering into trading schemes are low compared to those of other sectors (industry, etc.). Carbon crediting schemes that pay projects for reducing greenhouse gas emissions and sequestering carbon do exist, in theory offering farmers the potential to earn money in exchange for adopting practices that help mitigate climate change. But participation of agriculture in carbon markets - including those involving grazing-

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[12] The CO_2 equivalent emission is a standard metric for comparing emissions of different GHGs (IPCC, 2006). It is the amount of CO_2 emissions that would cause the same time-integrated radiative forcing, over a given time horizon, as an emitted amount of a mixture of GHGs. It is obtained by multiplying the emission of a GHG by its global warming potential (GWP) for a given time horizon.

based livelihood systems - has so far been quite small. One reason for this is that carbon markets have so far been focused on monitoring amounts of carbon sequestered, whereas the promotion of recognized carbon sequestration practices would provide a more operational leverage for modifying agricultural practices to protect soils, especially in dryland regions (Bernoux and Chevallier, 2014). Only reliable and affordable approaches for measuring, reporting and verifying carbon sequestration can provide better access to climate funds. Also, a better understanding of institutional needs and economic viability of this option is required before it can be implemented at scale. For example, land tenure is central to the management of schemes and the distribution of benefits.

For reasons outlined above, FAO has collaborated with the Chinese Academy of Agriculture Science, the World Agroforestry Center and China's Northwest Institute of Plateau Biology to develop a grassland carbon accounting methodology. The methodology was designed to support the Three Rivers Sustainable Grazing Project, situated in the Qinghai province of China. The pilot project worked with 271 households of herders of local breeds of yak and sheep and covers an area of more than 22 000 hectares of lightly to severely degraded grazing land. It was found that herders could sequester an average of 3 tonnes CO_2 per hectare of grassland each year over the next 20 years, through the application of improved practices, such as reduction and rotation of grazing pressure on overstocked sites and the sowing of improved pastures and fodder crops close to households.

Box 7. Methodology for Sustainable Grassland Management

The methodology[13] provides procedures to estimate the GHG emission reductions and/or removals from the adoption of sustainable grassland management (SGM) practices on grasslands in semi-arid regions. It allows for either direct measurement of carbon sequestration on sustainably managed grasslands through soil sampling or computer modelling of sequestration based on soil types and farming activities. The use of modelling can substantially reduce costs of measurement.

Eligible project activities include a broad range of SGM activities, such as improving the rotation of grazing animals, limiting the grazing of animals on degraded pastures and restoring severely degraded lands.

The methodology also includes a module with procedures to estimate activity-shifting leakage in project activities where there may be displacement of grazing activity due to the adopting sustainable grassland management practices from the project areas to areas outside the project area. The module provides step-wise procedures to determine whether the lands to which grazing will be relocated are identified or unidentified. It quantifies the GHG emissions due to leakage in identified and unidentified grasslands, forests and/or croplands to which livestock may be relocated and details the parameters that must be monitored by the project.

Source: Verified Carbon standards 2014-VM0026.

This method significantly reduces the costs associated with measurement and verification, greatly facilitating access of small-scale herders to carbon markets, potentially helping to preserve small-scale herder livelihoods and the local breeds that they depend on. The method has won approval by the non-profit Verified Carbon Standard, a voluntary greenhouse gas accounting programme used by projects around the world to verify and issue carbon credits in voluntary emissions markets. Now that the tool has been certified for recognition by international carbon markets, project developers and livestock keepers have a new opportunity to implement grasslands restoration projects on a meaningful scale, improving the productive potential of their grasslands and helping to reverse historic carbon losses. Returns from carbon finance and other mitigation funds can be invested in further restoring the long-term health of the lands upon which herders and grazers depend and in improving marketing associations to improve their incomes, raising families' incomes and improving household food security. The methodology also offers countries a tool that can be adapted and used to support monitoring and verification when developing Nationally Appropriate Mitigation Actions (NAMAs) to reduce GHG emissions. The methodology can be applied worldwide wherever countries work to sustainably feed a growing population while lowering their carbon footprint, especially in grassland-rich countries.

[13] http://www.v-c-s.org/methodologies/methodology-sustainable-grassland-management-sgm

4.2.4. Regulation of water flow and water quality

Due to increasing water scarcity, the regulation of water cycles and quality is an ecosystem service that directly links human populations' welfare to grasslands. Grasslands are a significant ecosystem in many of the world's important watersheds. For example, grasslands comprise more than 50 percent of the land area in the watersheds of the Yellow River in China; the Nile, Zambezi, Orange, and Niger Rivers in Africa; the Rio Colorado in South America; and the Colorado and Rio Grande in North America (UNDP *et al*., 2000). Rangelands serve as watersheds that receive rainfall, yield surface water, and replenish the groundwater throughout the region to the East and South of the western Jordan highlands (Al-Tabini *et al*., 2012).

Grassland cover can capture 50 to 80 percent more water compared to uncovered soils, reducing risks of drought and floods. These attributes are also critical for climate change adaptation and mitigation (FAO, 2011b). An intact vegetation cover shields the soil from the force of raindrops, allows rainwater penetration and reduces runoff. By softening the rain's impact, vegetation protects the ground surface from forming an impermeable seal that ultimately will result in soil movement and water losses (Brauman *et al*., 2007). Therefore forests, woodlands, wetlands and grasslands - systems used for grazing - act like sponges slowing down the movement of rainwater. The soil organic matter content and the depth and density of roots determine the amount of water that soaks into and is retained by the soil.

Vegetation removal, e.g. through human disturbance such as land use change and overgrazing, exposes the soil to increased oxidation, leading to reduced soil organic matter and reduced water holding capacity, and increases the impact of rain and removal by wind. Water and wind erosion are responsible for 45 and 42 percent, respectively, of soil degradation in drylands (UNDP *et al*., 2000). Progressive deterioration of microfauna and -flora, the loss of roots and the battering of rain tend to compact the surface layers and lower porosity until surface runoff begins to occur. The degradation cycle ends in a relatively stable condition of low infiltration and storage capacities of the watershed, and excessive rates of surface runoff (Wilm, 1957). Finally, the frequency, severity and unpredictability of floods increases and floods erode stream channels, lower water quality, and degrade aquatic habitat.

The influence of livestock on water flow regulation is linked to grazing management. Grazing can affect water cycles positively if properly managed, and negatively if the livestock distribution over time and space is conducted without considering the environmental impacts of the animals on the water balance of the grazing site, as well as adjacent sites, especially in areas with direct access for animals to water bodies. Therefore, preventing overgrazing in sensitive areas is an important land and water management strategy (FAO, 2011b). Hubbard *et al*. (2003) highlighted the importance of good management practices protecting the soil surface from erosion, sediment transport and nutrient loadings that might negatively affect water bodies and whole watersheds.

There seem to be no findings on the roles of specific livestock breeds on water aspects. Adaptability of traditional animal genetic resources to particular environments, however, is likely to be advantageous in remote and extensively used grazing lands.

Box 8. Responses from Country Reports – Water regulation measures

Lesotho: The ecosystems targeted are the rangelands and measures undertaken support water production, prevention of siltation in water bodies and provision of adequate grazing land. The destocking of rangelands, rotational grazing, protection of wetlands and prevention of veld fires all lead to the prevention of siltation in water bodies and provision of adequate grazing land.

Samoa: Rotational grazing to overcome overgrazing and degradation of land; use of manure for bio-gas, farming buffer zone 100 m away from water catchments, agro-forestry grazing - small scale land area available for grazing, tropical tolerant breeds who can graze on low nutrition pastures.

Soil and vegetation management practices in North American rangelands can have significant effects on hydrologic processes (Havstad *et al*., 2007). The relative amount available in support of ecological services depends on water quantity and its partitioning. A series of watershed studies from Californian rangelands reported that livestock grazing did not significantly increase nutrient and sediment levels in stream water, but the faecal coliform standards could be exceeded during storm events (Dahlgren *et al*., 2001). The results of another study in California on forest lands suggested that cattle grazing, recreation and provisioning of clean water can be compatible goals across national forest lands (Roche *et al*., 2013). In California, controlled grazing in a detailed grazing management plan and planting of local plants along creeks assisted with stream bank stability and increased sediment entrapment, leading to improved water quality and more regular water flows (Schohr, 2009).

Moderate grazing in Spain was found not only to increase floristic and functional diversity and improve carbon balance, but also to improve water infiltration rates (Carvalho *et al*., 2011). In the northern Ethiopian highlands, community-based integrated watershed management and more effective water harvesting measures resulted in better use of water resources for biomass and livestock production, and helped to restore up to 40 percent of the rangelands (Descheemaeker *et al*., 2010). A community-based conservation program in Zimbabwe that used intensive Holistic Management Planned Grazing to restore lost habitat and re-establish natural vegetation found that concentrating livestock on ephemeral stream standing pools resulted in water quality and riparian ecosystem structure similar to the use of water resources by wildlife only (Strauch *et al*., 2009).

The New York City watershed programme used grasslands to reduce nutrients, sediments and other toxic materials from New York's water supply. The animals' access to river banks was reduced, and rotational grazing and brush removal were used to encourage an even distribution of the animals in order to improve manure and nutrient distribution on pasture. Grasses facilitate the uptake of N from manure, and grass filter strips slow down water flow and filter out pollutants (Flaherty and Drelich, no year).

Manure management can have implications on water cycles (FAO, 2006a). Pote *et al*. (2003) showed that incorporating poultry litter into the soil instead of applying it to the surface significantly reduced nutrient concentrations and mass losses in runoff. By the second year of treatment, litter-incorporated soils had greater rain infiltration rates, water-holding capacities, and sediment retention than soils receiving surface-applied litter. These soils also showed a strong tendency to increase forage yield.

Livestock's influence on water quality is related to concentration in the landscape, either of water points where animals gather, or pollution from manure and fertilizer for feed crops or both. Wetlands are particularly important for removing fine sediments and other pollutants from runoff: they can remove 20-60 percent of heavy metals. Peatlands are useful in absorbing various pollutants, including herbicides. Both of these habitats are important grazing areas in many countries.

4.2.5. Moderation of extreme events

As many of the areas at risk of extreme events are either dry or montane, any services related to the moderation of extreme events are most likely to be provided by locally adapted breeds rather than exotic breeds. It appears that in particular environments (such as steep mountain ranges), where only certain species and breeds can graze, these breeds fulfil the roles of guardians of intact vegetation, and prevent soil erosion as well as avalanches, provided their numbers are properly managed.

Control of bush encroachment and creation or maintenance of fuel breaks

This service is closely related to habitat services in the sense that these relate to management interventions with livestock targeted at a specific vegetation outcome. However, in this case the desired outcome is the reduction of unwanted vegetation to minimize extreme events, instead of increasing biodiversity.

Many of the world's rangelands contain substantial woody vegetation. Hence, browsing species constitute an important resource to keep rangelands open. Although it is not realistic to expect shrub-dominated rangelands to support sustainable livestock production, they will continue to be grazed (Estell *et al*., 2012). While grazing on bushes may not constitute a substantial diet for livestock, in many areas, especially in remote montane areas, species and breeds with different abilities for browsing can contribute to maintaining fuel breaks and controlling bush encroachment.

Ecosystems with a long history of grazing become tolerant and even dependent on grazing for ecosystem functions and services (Bassi and Tache, 2008). In Europe for example, many areas of high-nature value grasslands have been used throughout history for low-intensity livestock grazing (Bignal and McCracken 2000). Apart from biodiversity loss, shrub encroachment can threaten a traditional diverse mosaic landscape, compromising the recreational value of open woodlands and meadows and use by domestic or wild animals (Bernués *et al*., 2011). It is thus important to control the successional change towards woodland and shrubland and create structural heterogeneity in the vegetation composition (Tallowin *et al*., 2005). Generally, the fundamental difference between mown and grazed grasslands is that in the latter the behaviour of grazing animal leads to enhanced structural heterogeneity of the sward canopy, often of a highly dynamic nature (Rook *et al*., 2004). Therefore grazing animals can be an effective tool to modulate vegetation dynamics in sensitive areas (Casasús *et al*., 2007). Moderate grazing can also be a useful tool to limit the expansion of shrubs, for example in the mountain pastures of the Pyrenees, resulting in the enhancement of the environmental and recreational values of the area (Casasús *et al*., 2007). Tocco *et al*. (2013) studied the effects of grazing on shrub encroachment via dung beetle abundance and diversity as an indicator of grassland ecosystem functioning improvement. After livestock grazing reduced bush encroachment, an increase in the beetle species abundance and diversity indicated that meso-eutrophic grassland can be restored. About 1000 ha of Swiss Alpine pasture is annually overgrown by shrubs, mostly Green Alder (*Alnus viridis*). A symbiosis with N-fixing bacteria favours the fast spread of Alder, outcompeting natural reforestation and leading to N leaching and NOx emissions. Sheep do not eat the bark and leaves of Alder, with the exception of Engadiner sheep, which are very efficient in controlling Alder (Arnold, 2011). The same applies for traditional cattle such as Eringer, whose high intake of leaves and young branches of Alder controls the further dispersion of this woody species (Meisser, 2010).

The European Survey received many examples of breeds keeping pasture areas open as a positive regulating service, particularly in mountain areas: Herens and Engadiner sheep breeds in Switzerland, Castellana sheep in Spain, several sheep breeds in Portugal (e.g. Campaniça, Churra Algarvia, Merina Branca, Merina Preta and Saloia), Abondance and Tarentaise cattle breeds in France, Valdostana cattle in Italy, and Parda de Montaña and Pirenaica cattle in Spain. Grazing by Cika cattle in Slovenia contributed to keeping pastures open up to the elevation of 1680 m.a.s.l. It was mentioned, however, that there was little scientific evidence published. Several of these cases were also mentioned as a valuable method for the control of avalanches.

Box 9. Responses from Country Reports – Bush encroachment and fuel breaks

Costa Rica: In some area of the National System of Conservation Areas, cattle is introduced to graze at certain times of the year to lower the amount of pasture biomass, to reduce the risk of forest fires during the dry season.

France, Montenegro and **Spain** mention livestock's role in vegetation clearing and fire control in the Mediterranean region.

Switzerland: The government co-funds projects in the field of ecosystem services provided by different species/breeds. Examples of projects are e.g. controlling of alpine pastures contributing to reduction of scrub on alpine pastures, keeping forest within its borders, avalanche control. It is still early to describe outcomes regarding animal genetic resources, but we hope that in the future, the number of animals of specific breeds used for ecosystem services will slowly increase.

Livestock grazing has frequently been used as one of the management techniques to prevent bush encroachment and control fuel breaks, especially in forest ecosystems (Ruiz-Mirazo *et al*., 2009). Grazing by goats can be useful in controlling bush encroachment in the veldts of Southern Africa (Saico and Abul, 2007). Livestock grazing in some areas in California reduces the presence of shrubs and, by removing biomass, reduces the spread and occurrence of wild and deliberate fires (Huntsinger *et al*., 2012). It also has potential to control weed proliferation and prevent succession to forests by limiting the invasion by woodland species. Goats and horses were found capable of controlling gorse re-growth and limit the accumulation of combustible phytomass in Spain (García *et al*., 2013). In a three-year experiment in Andalusia, Spain, livestock grazing decreased the risk of wildfires in sagebrush steppe (Ruiz-Mirazo and Robles, 2012). Grazing and fire are important factors for the persistence of South Brazilian Campos (Overbeck *et al*., 2007). Moderate grazing of sagebrush rangelands in Australia increases the efficiency of fire suppression activities (Davies *et al*., 2010b). The European Survey revealed one example where environmental programmes are linked to a specific breed: the Segureña sheep in the Andalusian Network of Grazed Fuel Breaks in Spain.Special attention should be given to flexible grazing management techniques adapted to the potential multiple uses and the ecological dynamics of forests (Etienne, 2005). To reduce the threat of fire, grazing management should be focused on stimulating dry forage intake and shrub browsing, and should also be adapted to the structure and spatial organization of fire prevention management plans. In a study of fire management using historical approaches, which were mainly based on aerial photographs taken at different intervals during the last 50 years, Etienne (2005) found a strong interaction between grazing management, rangeland allocation and shrub encroachment in both temperate and Mediterranean conditions.

Avalanche and landslide control

If properly managed, livestock grazing does not pose a threat to the conditions of the soil and biomass, which can loosen the ground and increase the risks of avalanches or landslides in hilly and steep areas. A five year study of cattle-trail erosion and sedimentation rates in oak-woodland stream channels in California (George *et al*., 2004) found a significant increase of bare ground, but no erosion of stream banks resulted from any grazing level applied. Nevertheless, the location of the watering points is an important issue to consider for preventing excessive trailing. In Central America, grazing animals can affect the depletion and erosion of the soil in the hilly areas, reducing landslide risks (Esquivel-Mimenza *et al*., 2011). In the Northern French Alps there is a favourable impact of grazing on the maintenance of open pastures. This can also contribute to reducing the risk of avalanches (Fabre *et al*., 2010; Lambert-Derkimba *et al*., 2010). The mechanism in Alpine areas is that livestock grazing leaves grasses short, causing more friction between the land and the snow. If grasses are not grazed, they decay and the snow flattens the dead matter, which becomes very slippery. This is especially important in ski resorts, where animal spatial management needs to be adapted to the botanical composition of pastures and livestock’s feeding preferences (Casasús *et al*., 2013).

4.3. Pollination

Plant pollination by insects is essential for human health, food webs and the protection of biodiversity. The decline of pollinators is caused by agricultural intensification and urbanization, and invasive plant species resulting in a lack of sufficient habitats for pollinators. There is evidence that managed grazing can not only minimize negative impacts, but can provide positive benefits to floral resources in certain rangelands, especially where shorter flowering plants are suppressed by taller grasses (Black *et al*., 2007). Incorporating pollinator needs into grazing management could therefore result in habitat for pollinators.

Although bees are not included in DAD-IS, except for Poland, bee diversity is critical for pollination. It is estimated that about one third of all plants or plant products eaten by humans are directly or indirectly dependent on bee pollination (Klein *et al*., 2007). Directly dependent crops require pollinators to produce a fruit, while indirectly dependent crops require pollinators to create seeds, but not the crop itself (Calderone, 2012). Honey bees and other insects pollinate species that are directly dependent on insects for pollination, such as apples, almonds, blueberries, cherries, oranges and squash, and species that are indirectly dependent on insects, such as alfalfa, sugar beets, asparagus, broccoli, carrots and onions (ABF, 2014). Bee pollination not only results in a higher number of fruits, berries or seeds, it may also give a better quality of produce. Good fruit weight sometimes depends on the pollination and development of all seeds in a fruit (e.g. strawberry). In addition, many food crops, and forage crops are grown from seeds of insect-pollinated plants (FAO, 2009d). In oilseeds, sufficient pollinators will ensure that all plants in a field are pollinated in the same period, allowing seeds to ripen at the same time. This permits harvest of a uniform crop, with less green and unripe seeds among the ripe ones, giving farmers a higher price.

Unfortunately, there appears to be no published data available on differences between managed honey bee subspecies in their ability and propensity to pollinate different crops.

4.3.1. Valuation of pollination

In Northern Europe, it is estimated that 75 percent of all wild blooming plants depends on insect pollination, with most species pollinated by honeybees and bumblebees. All the crops, fruit trees and wild flowers blooming before midsummer are dependent on bees to be able to develop their seeds, berries and fruits. The economic value of bee pollination in nature and the great ecological importance of that cannot be counted, but is certainly far greater than the financial cost of crop pollination. The value of bee pollination in Western Europe is estimated to be 30-50 times the value of honey and wax harvests in this region. In Africa, bee pollination is sometimes estimated to be 100 times the value of the honey harvest, depending on the type of crop. In Europe, Australia, New Zealand and North America, almond, fruit and berry growers, as well as white clover growers pay beekeepers to bring bees for pollination in the blooming season (FAO, 2009d). In 2000 the value of bee pollination for Australian horticulture and agriculture were valued at 1.7 billion Australian Dollars (Australian Government, 2009) and was estimated at US$14.6 billion in the United States of America (Morse and Calderone, 2000). In 2010, the value of directly pollinated crops in the United States of America was estimated at US$16.35 billion, while the value of indirectly dependent crops was US$12.65 billion. More specifically, honeybees pollinated US$12.4 billion worth of directly dependent crops and US$6.8 billion worth of indirectly dependent crops in 2010 (Calderone, 2012).

4.3.2. Honey bees and wild pollinators

Both managed honey bee populations and wild pollinators play a great role in pollination of crops and wild plant populations (Klein *et al*., 2007). It has been estimated that more than 70 percent of pollination is provided by managed honey bee populations (Klein *et al*., 2007; Carré *et al*., 2009; Breeze *et al*., 2011; Schulp *et al*., 2014), although this is highly dependent on the crop species, the geographic location and landscape parameters. In recent years a lively debate has emerged on the relative importance of managed honey bees (*Apis mellifera*) versus wild pollinators for the pollination, fruit set and yield of pollinator-dependent crops (Aebi *et al*., 2012; Ollerton *et al*., 2012; Schulp *et al*., 2014).

Ollerton *et al*. (2012) questioned the widely accepted paradigm that honey bees are essential pollinators both in agriculture and in maintaining natural biodiversity. They argued that there was evidence to show that even though honey bee abundance was declining, yields of pollinator-dependent crops were in fact rising (e.g. Breeze *et al*., 2011), thus indicating that honey bees were not the exclusive pollinators of these crops. Aebi *et al*. (2012) in response, pointed out that there may be a number of confounding factors leading to Ollerton's conclusion. Furthermore, they stressed that interactions between managed honey bees (or bumble bees) and wild pollinators can have a great positive effect on pollination effectiveness (see also Greenleaf and Kremen, 2006; Brittain *et al*., 2013). In 41 crop systems worldwide, Garibaldi *et al*. (2013) found that wild insects pollinated crops more effectively than honey bees and that pollination by managed honey bees supplemented, rather than substituted for pollination by wild insects.

Schulp *et al*. (2014), in a study mapping the supply and demand of pollination in the EU, concluded that the complete absence of pollinators would lower the returns of pollinator-dependent crops (which represent 31 percent of the EU income from crop production) by 10 percent. To ensure optimal returns, farmers have two options in areas with high pollinator demand and low supply: either take measures to increase the abundance of wild pollinators or use managed pollinator populations (usually honey bees). The latter is a fairly convenient and cheap option. But this practice is currently threatened by global declines in honey bee colonies (e.g. Potts *et al*., 2010 and references therein). Even though wild bees will be affected by the same threats as managed honey bees, it is likely that, due to their solitary lifestyle, they will be less susceptible to pathogens and parasites (Schulp *et al*., 2014). Conservation of pollinators should therefore aim to focus not only on either wild pollinators or managed populations, but try to integrate the two (Aebi *et al*., 2012). New practices for the integrated management of both honey bees and diverse wild insects will enhance crop yields (Garibaldi *et al*., 2013).

4.4. Habitat services

Habitat provisioning is one of the main ecosystems services linking the effects of livestock grazing to the biodiversity of the host ecosystem. Out of 120 responses of the Global Survey, habitat provisioning was mentioned in 85, highlighting the importance of grazing for the associated diversity of ecosystems. Habitat services are mostly non-consumptive, and in economic terms have only indirect use values or non-use values. Most supporting, regulating and habitat services arise from the direct interaction of animals with their environments, and are therefore related to land management practices, especially in grazing systems. Land-based production systems that have both plant and animal components need co-management of the various components of biological diversity, including soils, crops, rangelands and pastures, fodder crops and wildlife. If animal movements are appropriately managed and regulations, including property regimes that foster sustainable land management, are in place, it is likely that overgrazing can be prevented and that extensive grazing can have a positive effect on the vegetation community, associated biodiversity, wildlife and other ecosystem services.

The importance of grasslands for biological diversity is evident from the biological distinctiveness index developed by the World Wildlife Fund (WWF). This index considers species richness, species endemism, rarity of habitat type and ecological phenomena, amongst other criteria. For North America and Latin America, 10 of 32 regions and 9 of 34 regions respectively rated as “globally outstanding” for biological distinctiveness are in grassland ecosystems (UNDP *et al*., 2000). Twenty six percent of all World Heritage Sites, which aim to protect the world’s cultural and natural heritage, are located in drylands (Davies *et al*., 2012). Europe’s agricultural settlement and development history dates back several millennia, having led to a co-evolution of agriculture and what remains from pristine nature. In a cross-European study, three public goods (agricultural cultural landscapes, biodiversity and prevention of forest fires in Mediterranean areas) were found to be inherently linked to certain agricultural practices. The farming systems with the highest potential to deliver these public goods are: extensive outdoor livestock and silvo-pastoral systems, and extensive mixed arable/pastoral systems (Cooper *et al*., 2009). This is why 53 out of the 224 habitat types of the Annex I of the EU Habitats Directive depend on, or are associated with, agricultural activities, mostly in connection with grazing and mowing (Caballero *et al*., 2009; EEA, 2010, 2012).

The impacts of land use changes on rangeland biodiversity remain poorly understood. Ecosystem benefits, especially regulating services such as water infiltration and purification, climate regulation (e.g. carbon sequestration) and pollination, have begun to be assigned an economic value, and systematic data gathering in rangelands of both developed and developing countries should be a global priority (LADA, 2010; FAO, 2011b).

Since most habitats with high biodiversity or conservation value are located in marginal, mountainous, dry or forested areas, these are mostly grazed by locally adapted breeds. The most important clusters of habitat services provided by livestock are those that contribute to the creation of mosaic landscapes and mini-habitats that sustain biodiversity, those that support the maintenance of species life cycles (creation or maintenance of habitat, especially for migratory species) and those related to the connection of habitats (seed dispersal in guts and on coats). The positive effect that such systems have on biodiversity contrasts with that of many high external input farming systems which have, with their machines, agrochemicals and intensive sown pastures, led to drastic declines in biodiversity (Finck *et al*., 2002). The effects of deterioration of habitat services may only become visible in case of grazing abandonment, and their restoration then becomes the target of so-called conservation grazing. This is one reason why the European and Global Surveys distinguished between breeds traditionally present in the grazing area (Case A) and those recently introduced for ecosystem services and vegetation management (Case B).

4.4.1. Nature conservation and protected areas

Protected areas are fundamental elements of many national and international conservation strategies, supported by governments and international institutions such as the Convention on Biological Diversity (CBD) and the International Union for the Conservation of Nature (IUCN). They are the main tools of protection for at-risk and threatened species, and are increasingly recognized as essential providers of ecosystem services and biological resources; key components in climate change mitigation strategies; and in some cases as vehicles for protecting threatened human communities or sites of great cultural and spiritual value (Dudley, 2008). At global level, the total share of protected areas has increased and amounted to 13 percent of total land in 2010. However, this value is still below the Aichi Biodiversity Target 11 of at least 17 percent protection of terrestrial and inland water area by 2020.

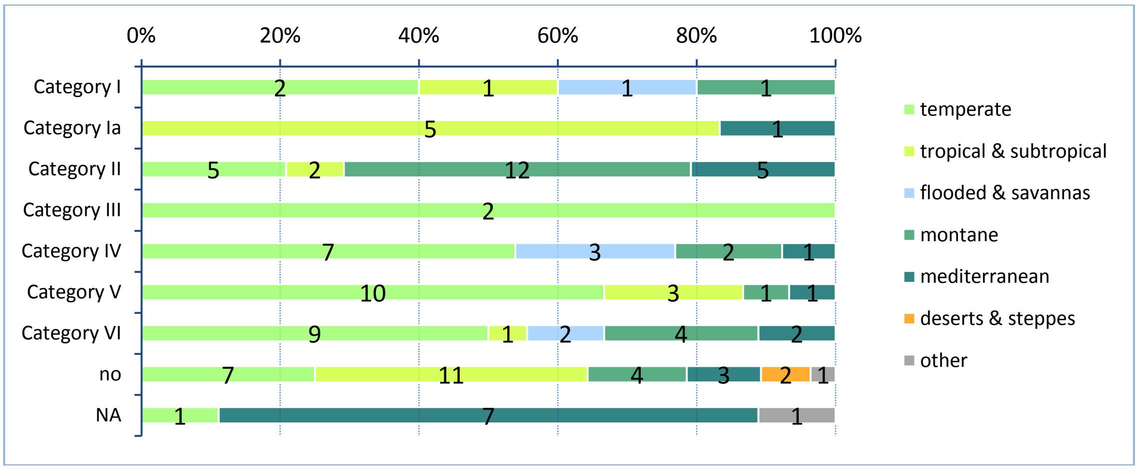
Not only in Europe or the United States of America, where strong policy support of environmental protection measures are available, are conservation actions involving livestock being put into wider practice. Also in India, for example, establishment of protected areas and wildlife sanctuaries, national parks and other types of protected areas can be combined with traditional management of local breeds in order to preserve indigenous lifestyles and management strategies (Köhler-Rollefson *et al*., 2013). Conservation management has also become an issue in the USA (Schohr, 2009) and Australia (Smith and Ash, 2006). As biodiversity provides important ecosystem services for the grazing industry, maintaining the integrity of existing biodiversity becomes vital for this land use. Biodiversity is also an integral part of other rangeland uses, such as harvesting of bush foods and outback tourism in Australia (Bastin, 2008).

An analysis of 167 Country Reports submitted for the first FAO State of the World's Animal Genetic Resources found that 37 percent of the reports mentioned protected areas in relation to conservation of biodiversity in general, 13 percent referred to protected areas as means to conserve wild relatives of domesticated animals or wild game species, and 9 percent revealed that the use of livestock diversity was actively encouraged through programmes involving protected areas (Rosenthal, 2010).

Although the responses to the Global and European Surveys may represent a biased sample, the results indicate the potential for using nature protection areas for grazing, as well as the dependence of specific habitats on continued grazing. In the Global Survey, 70 percent of the 120 respondents mentioned that livestock grazing takes place in protected areas. Most respondents were able to identify the protection status assigned to the described grazing area, according to the IUCN classification. Forty percent of the grazing areas featured in the survey responses lie within IUCN categories IV, V and VI, 21 percent in categories II and III, and 9 percent in strictly protected areas (IUCN I) (Figure 15). It was not specified whether the grazing takes place within or in the buffer zones around strictly protected areas.

Temperate grasslands are most represented across the protection classes, except tropical/subtropical grasslands that are most frequent in wilderness areas (IUCN Ia), and montane and Mediterranean rangelands that are most frequent in national parks (IUCN II) (Figure 15).

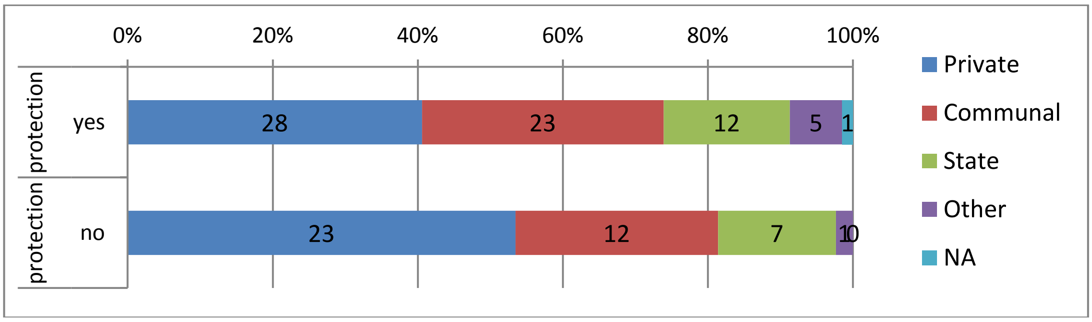
Figure 15. Protected areas by grassland ecosystem



Note: Numbers stand for total responses in each category.

More than half (53%) of unprotected land was privately owned. Protected areas were more communally owned that unprotected areas (33 vs. 28%). The reported share of state-owned land was the same for protected and unprotected areas (16%) (Figure 16).

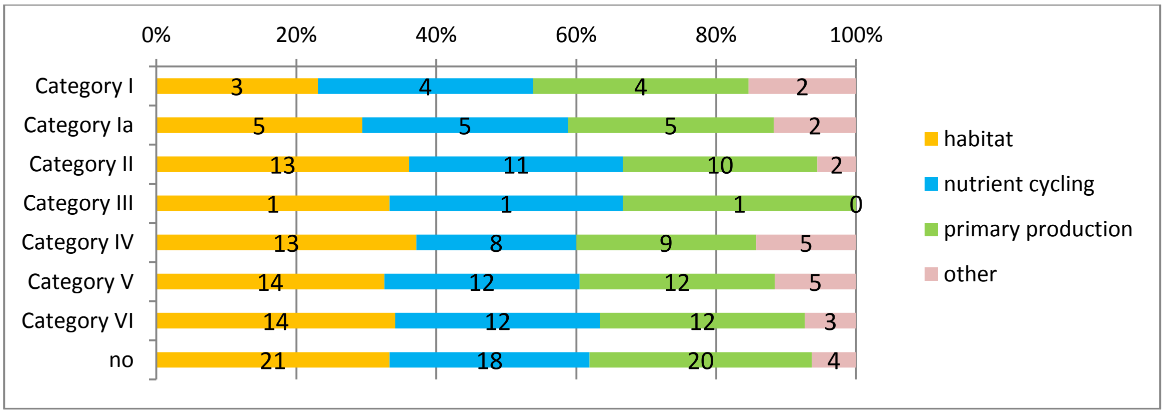
Figure 16. Protected areas by land ownership



Note: Numbers stand for total responses in each category.

Across all protection types, the highest shares of habitat services were reported for IUCN categories II and IV (37%) (Figure 17).

Figure 17. Supporting services by IUCN protected area type



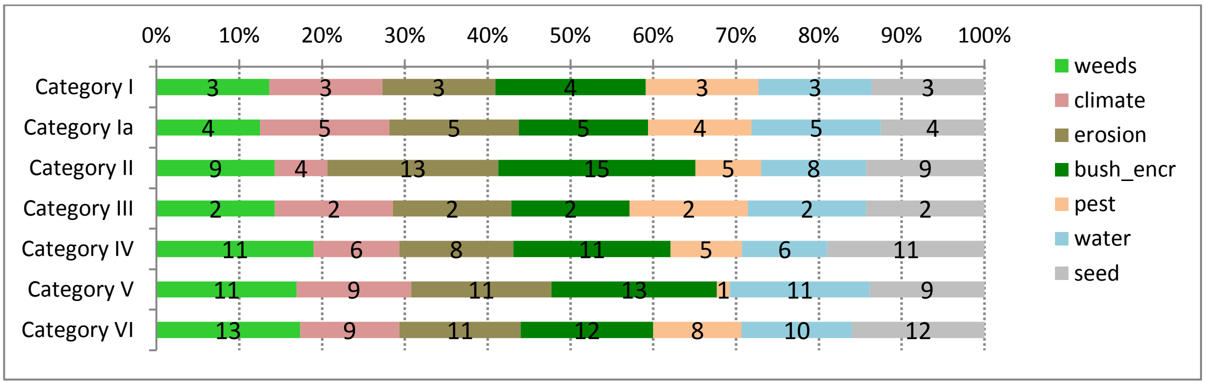
Note: Numbers stand for total responses in each category.

The European Survey found a close overlap between breed conservation, HNV farmland and nature conservation. The 29 grazing areas cover 28 IUCN protected areas and 21 Natura 2000 sites, 3 UNESCO-MAB Biosphere Reserves, 5 National Parks, and 3 Ramsar Wetlands of International Importance. Under the IUCN categories, such grazing areas are most frequently located in protected landscapes (IUCN V category), followed by equal numbers of habitat/species management areas (IUCN IV) and national parks (IUCN II)[14]. The European Survey also found that most of the breeds grazing in protected areas were locally adapted or at-risk breeds, indicating the possibility of linking breed conservation with nature conservation.

For natural parks (IUCN II), bush encroachment and erosion control were the most frequently mentioned regulating services (23 and 20%) (Figure 18). This may be due to the high share of montane and Mediterranean grasslands covered by the IUCN II category. In IUCN IV to VI categories which were more in temperate grasslands, weed and shrub control and seed disbursement were mentioned with similar frequencies (16-19%).

[14] http://www.iucn.org/about/work/programmes/gpap_home/gpap_quality/gpap_pacategories/

Figure 18. Regulating services by IUCN protected area type



Note: Numbers stand for total responses in each category.

Several country reports submitted as part of the reporting process for the Second Report indicate that improved collaboration between sectors and coordination between sectoral policies and programmes are needed in order to allow potential benefits of this kind to be fully captured.

4.4.2. Conservation of charismatic species

Wildlife value is particularly significant in Africa, but extends to Asia, to a lesser extent South America and is relevant in Europe, particularly Eastern Europe. Wildlife populations are often not viable if confined to protected areas because they utilise and rely on pastoral lands as an integral part of their existence (Niamir Fuller *et al*., 2012). The value that can be assigned to pastoralism in the context of wildlife tourism is significant. In addition, there is now substantial literature that shows that livestock grazing confers significant benefits to wildlife in terms of maintaining or enhancing biodiversity, and the ecosystem services that support such biodiversity, including water and nutrient cycles (Hatfield and Davies, 2006). Some of the world's most iconic protected areas have profound links with pastoralism. The Maasai Mara Game Reserve in Kenya, and the Serengeti National Park and the Ngorongoro Conservation Area in Tanzania are all located in ecosystems that co-evolved with pastoralism.

Habitat or dietary overlaps have often been used to claim wildlife-livestock competition in East Africa. Butt and Turner (2012) argue that feed competition is mediated through vegetative responses to grazing that vary across heterogenous landscapes in time and space, and that facilitative effects outweigh competitive effects. Evidence exists for mutually beneficial uses of common rangeland resources by wildlife and livestock (Homewood and Rogers, 1986). Land-use decisions that exclude grazing wildlife from pastoral lands or livestock from protected areas will therefor increase the vulnerability of the overall system (Little, 1996).

The animals kept by pastoralists and smallholder farmers are often important to wildlife conservation. Relationships between domestic and wild biodiversity have rarely been studied in detail, except for the transmission of diseases. But evicting livestock from wildlife reserves may lead to an exodus of predators, or result in habitat changes that make it less attractive for wildlife. In the Kumbalgarh Wildlife Sanctuary in Rajasthan, India, for example, leopards and wolves (for which the sanctuary was established) prey almost exclusively on the sheep and goats pastured there (Robbins and Changani, 2005). In the Gir Forest National Park and Wildlife Sanctuary in neighbouring Gujarat, Asia's last remaining lions depend on livestock for part of their diet. Expelling pastoralists from the sanctuary has induced the lions to leave as well (Casimir, 2001). And in the Keoladeo National Park, India, a ban on grazing by buffaloes led to uncontrolled growth of a water weed (*Paspalum distichum*), which in turn prevented Siberian cranes from accessing plants tubers, their main food source. This led to a dramatic decrease in the numbers of cranes in the park (Pirot *et al*., 2000; Lewis, 2003).

Box 10. Responses from Country Reports – Nature conservation and conservation grazing

Austria: In the current Austrian Agri-Environmental Programme two measures deal with specific ecosystem services: Management of mountain meadows, Alpine pasturage and shepherding. The measures target control of weeds, maintenance of wildlife habitats and avalanche control via grazing of mountain pastures. The production systems participating in the measures are ranching and rural mixed farming systems. The national Agri-Environmental Programme could contain combined measures like, for example, pasture management and the use of rare breeds to multiply the effect on protection of genetic resources. Public as well as private land holders could introduce grassland management programs on fallow land like high water dams, water retention area and extensive pasture land, which is endangered by shrubs. This would reduce the costs of land management and offer additional grazing to farmers for small rents or even for free.

In order to advance the Declaration of Rio+20 "The Future We Want", the **Plurinational State of Bolivia** launched the Mitigation and Adaptation Mechanism for the Integrated and Sustainable Management of Forests and Mother Earth. Its aim is to put into effective practice a way of simultaneously meeting the goals of climate change mitigation and adaptation, and as a proposal for non-commodification of forests and promoting integrated and sustainable management of forests in synergy with the protection of other components of Mother earth (land, forests, air, water and biodiversity) and the development of sustainable systems, including livestock production. In parallel, silvo-pastoral systems are being promoted in most of the country's ecosystems, particularly in the Bolivian Chaco where the establishment of shade tolerant pasture, such as *Panicum maximum* var. tricoglume has had significant impacts on livestock development through mitigating forest degradation.

Finland: Grazing and browsing livestock are kept in traditional rural biotypes and cultural landscapes to keep these rare ecosystems open. Cattle and sheep are the most common species that are used for these purposes. However, the management of landscapes through grazing should be increased in Finland to prevent loss of biodiversity. A few endangered, valuable landscapes have been saved. In Southern Finland and in national parks, the use of grazing animals in preservation of cultural landscape is done currently on the regular basis. In Koli National Park in eastern Finland, native cattle and sheep breeds do valuable jobs to maintain the Finnish cultural landscape. On some islands of the Finnish Gulf, the native sheep breeds are used to keep the landscape open.

Nepal: Promoting local breeds in low input and harsh environment (semi-intensive production system). Yak/Chaury, sheep and mountain goats in higher hilly and mountainous areas (extensive production system) is very environmentally friendly.

Peru: Besides being an important economic resource for Andean peoples, camelids and their products are considered flagship species and products (alpaca and vicuña). In parts of the highlands of Peru, this has allowed ecological services and experiential tourism, including knowledge of the breeding of domestic camelids (alpaca and llama) and/or the viewing of wild camelids (mostly vicuña and guanacos), usually in nature reserves. These species have significant potential in providing ecosystem services, especially for the scenic beauty. In addition, maintenance and breeding of these species in ecosystems favours Puna grassland conservation, as their behaviour and grazing help to maintain the viability of grass and soil, unlike other species such as sheep and cattle. Therefore, keeping of camelids is encouraged for the recovery of degraded areas, rather than raising exotic or naturalized breeds.

Over the centuries a range of bird species have become associated with transhumance and the open landscapes that grazing practices maintain in Alpine landscapes (Gregory *et al*., 2010, Nelson, 2012). For example, grazed areas provided good hunting grounds for predators such as the Golden Eagle (*Aquila chrysaetos*); livestock carcasses provided a readily available food supply for vultures and other scavengers; and grazed areas with an abundance of livestock dung provided good foraging opportunities for invertebrate-feeders like the Chough (*Pyrrhocorax pyrrhocorax*) and the Alpine Chough (*Pyrrhocorax graculus*) (Pain and Dunn, 1996). The bearded vulture (*Gypaetus barbatus*) is a scavenger of mountainous areas in Italy, Spain and France, feeding mostly on the remains of dead animals that are provided by extensive livestock farming (Pain and Pienkowski, 1996). In the Cantabrian Mountains in Spain, transhumance positively influences the abundance of scavengers and supports the sustainable management of griffon vulture populations (Olea and Mateo-Tomás, 2009; Margalida *et al*., 2011).

4.4.3. Maintaining the life cycles of animal and plant species, especially in co-evolved landscapes

Without grazing, grassland ecosystems might undergo inevitable succession processes, which will transform the vegetation communities (Diaz *et al*., 2007, Wrage *et al*., 2011). Especially human-made biotopes such as dry grassland, heath and meadows, and the avian, insect and predator (e.g. bat) diversity that depend on them, are maintained by traditional land management practices such as livestock grazing and hay-making (Bradbury *et al*., 2004; Van Swaay *et al*., 2006). For example, most European grasslands are sub-climax communities, but due to the disappearance of traditional practices, the overall status of European grassland habitats is in progressive decline, and grasslands are under particular pressure in intensively farmed regions (EEA, 2009, 2010).

Land use changes in many countries, especially abandonment of grazing lands, represent a serious threat to the multi-functionality of landscapes, which is often closely connected to their perception of the environment as a cultural landscape (Raudsepp-Hearne *et al*., 2010). Abandoned grassland may revert to scrub and woodland, thereby losing much of its current habitat value (Blaschka and Guggenberger, 2010), while grassland areas, even under conservation, can be used by livestock keepers for their traditional agricultural practices. Specific practices may make pastoralism and nature conservation more compatible (Heikkinen *et al*., 2012). Permanently stocked pasture, for example, can require less work from farmers and allow livestock keepers to transfer animals less frequently (Pavlu *et al*., 2003). Maintenance of infrastructure such as watering points and shelter for shepherds and livestock is important in large grazing areas (Beaufoy *et al*., 1994). It is important to optimize livestock pressures, as moderate grazing maintains a greater biodiversity of vegetation (Barać *et al*., 2011). Besides maintaining habitat diversity and the associated species of fauna and flora, the indirect effects help to control fires, improve water balance and conserve cultural landscapes (Bunce *et al*. 2004).

In Europe, where few areas have been left in a pristine natural state, it was recognized that conservation of biodiversity cannot be only linked to protected areas but depends on the continuation of semi-natural farming systems. Baldock *et al*. (1993) and Beaufoy *et al*. (1994) introduced the term 'high nature value farmland' (HNV). In many European countries, policy measures recently became an important tool in environmental instruments for ensuring sustainable use and conservation of natural resources. Countries are required to identify and protect ecologically valuable grasslands within protected sites. Today, the Natura 2000 network encompasses more than 25 000 sites covering 17 percent of the EU's territory with diverse land use types under different degrees of human management. In addition, 16 percent of the EU's land is protected under national regulations, with some overlaps between these schemes (EEA, 2009).

Box 11. High nature value farmland in Europe

HNV refers to farming activities and farmlands that support high levels of diversity of species and habitats of conservation concern (EEA, 2010, 2012). Extensive (i.e. low-input and large scale) agriculture systems contribute substantially to HNV areas (Caballero, 2007; Caballero *et al*., 2007) and can support the conservation of habitats and species (Bignal and McCracken, 2000). Large-scale grazing has several important ecological impacts, for example for the development of open and semi-open landscapes in the forest regions of Europe. These landscapes offer habitats for many nowadays rare or even endangered animal and plant species (Niemeyer and Rieseth, 2004). Farmlands with a high proportion of very species-rich semi-natural vegetation with high conservation value include large parts of the low-intensity livestock grazing systems that are still practiced in the less-favoured upland and mountainous regions across Europe and in the arid zones of Southern and Eastern Europe. Some intensive farming systems may even have components of HNV, if they support high concentrations of species of conservation concern, e.g. migratory waterfowl in certain more intensively farmed areas in lowlands. HNV farmlands are often found in areas with some protection status, from National Parks to Natura 2000 network sites, but are also widespread in other areas of the countryside where for geographical, social or economic reasons intensification has not been possible (yet) or reversed (EEA, 2009). The conservation and development of HNV farmland systems has been highlighted as a priority in Council Decision EC No 2006/144. The HNV farmland indicator is one of 35 indicators that incorporate environmental concerns into the EU Common Agricultural Policy (CAP) (EC, 2013). Farmers can receive agro-environment payments under the rural development pillar. Survey responses from several European countries (e.g. France, Hungary and Latvia) note that increased interest, at policy level, in the protection of permanent meadows and other grassland habitats has created opportunities for keeping locally adapted breeds.

Similarly in the United States of America conservation takes place on farmland. So-called conservation easements are voluntary legally binding agreements that limit certain types of uses or prevent development from taking place on a piece of property now and in the future, while protecting the property's ecological or open-space values. The landowner who grants a conservation easement continues to privately own and manage the land and may receive significant state and federal tax advantages for having donated and/or sold the conservation easement. Easement values are determined by appraisal and typically are about one-third of the property's full market value (US Fish and Wildlife Service). In 2003, 2.1 million ha were protected by local and regional land trusts through conservation easements (The Nature Conservancy).

Many studies that demonstrate the diversity of traditional grazing activities on biodiversity, and the roles of animal genetic resources in particular, come from European countries. This may be partly due to the availability of funds for research to allow evidence based policy-making. Semi-open pastures were re-introduced in Germany to preserve the biodiversity of traditional wood-pasture landscapes. This involves the management of robust livestock breeds, which can be kept in a 'semi-wild' manner all year round (Bergmeier *et al*., 2010). Peco *et al*. (2006) found that floristic composition of Dehesa systems in Central Spain changed dramatically with abandonment, while the total number of species in abandoned zones did not significantly differ from grazed zones. Policy-makers and land managers should therefore be aware of the value of extensive grazing and the risk of abandoning traditional grazing lands.

Grasslands butterflies are considered to be representative indicators of trends observed for most other terrestrial insects. Populations of grassland butterflies in Europe have fallen by 60 percent since 1990 and continue to decline. Agricultural intensification is the most important threat to butterflies in the intensively farmed lowland areas of Western Europe, while lack of sustainable grazing and abandonment are the main threats in Southern and Eastern Europe, particularly in mountainous areas or areas with poor soils. Grassland butterflies mainly survive in traditionally farmed low-input systems as well as nature reserves, and on marginal land such as road verges and amenity areas (EEA, 2013). No impact of breed diversity (traditional vs. commercial) on butterfly and grasshopper diversity was found in a comparison of grazing sites in the United Kingdom, Germany and Italy (Wallis de Vries *et al*., 2007).

Birds have been the focus of many studies carried out on nature conservation aspects of farming activities. The ease with which birds can obtain food from grasslands seems to be a critical factor influencing the number and diversity of farmland birds (Rook, 2006). For example, the productivity of barn swallows in Switzerland depends on the characteristics of the micro- and macro-habitat (Grüebler *et al*., 2010). Populations of farmland birds in Europe have declined by around 50 percent (EEA, 2009). About one third of 175 evaluated bird species included in the Annex I of the Bird Directive were considered as positively influenced by extensive grazing (Caballero *et al*., 2009).

Through alteration of vegetation structure, grazing can have impacts on associated diversity of grasslands, such as nesting birds. Light grazing can increase plant species richness and the abundance of species for which grasslands serve as typical habitats, such as butterflies, grasshoppers and ground-dwelling arthropods (Wallis De Vries *et al*., 2007). Verhulst *et al*. (2004) found the most bird species in extensive grasslands, whereas intensively grazed fields had lower bird species diversity and density. Ornithological studies in the Biebrzanski National Park in Poland indicated that extensive grazing of cattle contributed to the improvement of bird nesting conditions. The positive effect of grazing was a result of the creation of a habitat structure through vegetation height mosaics, which constituted an optimum for nesting birds (Metera *et al*., 2010).

In Australia's arid and semi-arid zone, bird species diversity was higher in low input systems and declined in response to the intensification of livestock grazing (Davies *et al*., 2010b). Through trampling and other disturbances, livestock can affect nest survival directly. A study on grazing effects on bird survival in Canada found that very few nests were directly destroyed by cattle, but nest destruction was positively correlated with grazing pressure (i.e., stocking rate or grazing intensity) (Bleho *et al*., 2014). Blanco-Fontao *et al*. (2011) reported that cattle numbers were negatively related to the presence of an endangered, distinctive population of Wood grouse *(Capercaillie)*. Since changes in farming systems, grazing patterns, landscape heterogeneity and climate may have different effects on grassland habitats, these changes may affect habitats of grassland bird species in a complex way.

Close mowing or grazing increased the attractiveness of farmland for shorebirds and was suggested to be a feasible management option to provide habitat for wintering shorebirds (Ogden *et al*., 2008). In French coastal marshes, wet grasslands support large populations of waders. Models showed that without an appropriate level of grazing intensity and the indirect effects of grazing on habitat quality, it was not possible to maintain wader bird populations (Tichit *et al*., 2005; Sabatier *et al*., 2010). In a nature reserve in the Gulf of Finland it was found that birds, especially water birds, waders and birds nesting in the seaside meadows reduced in number following the decline of grazing, which leads to the spread of reeds and less diverse vegetation. The tall vegetation increases light competition and short, often classified rare, plants have less possibilities to grow. Twenty-three percent of the plants typical to coastal meadows in Finland are classified as threatened and in need of monitoring. Grazing with Finn cattle and Finn sheep reduced high vegetation and light competition and was beneficial for waders; the Lapwing (*Vanellus vanellus*) and the Common Redshank (*Tringa totanus*) have started nesting in the area after a long break, and the number of waders visiting the area during migration has increased. The same two breeds maintain the landscape open in the Kolin National Park in Finland, thus providing habitat for the plant and butterfly species typical for glade meadows (Lohilahti and Pajari, 2007; Hinska, 2008).

Grazing and amphibian conservation in Sierra Nevada meadows in the USA seem compatible in a landscape used by cattle and Yosemite toads. During the early season, when habitat use overlap was highest, overall low grazing levels resulted in no detectable impacts on toad occupancy (Roche *et al*., 2012). Grazing with Scottish Highland cattle in the Swiss Sürch Nature Reserve led to an increase of species numbers of light-sensitive plants, grasshoppers (158 individuals with grazing as compared to 15 with mowing), and several rare frogs and newt species. By contrast, neophytes such as Goldrute (*Solidago gigantea*) and Sachalin-Staudenknöterich (*Reynoutria sachalinensis*) were reduced (Moser and Wild, 2010). The latter case exemplifies the general principle that while low-intensity grazing may positively affect overall biodiversity and species abundance, and certain species in particular, it may negatively affect other species.

Ant diversity in semi-arid American rangelands is more dependent on vegetation and soil properties than grazing pressure (Bestelmeyer and Wiens, 2001). In Spain, population density of the most abundant grasshopper species was independent from the breed grazing (Jauregui *et al*., 2008).

In the Sava floodplain in Croatia, grazing by pigs, horses and cattle has a variety of positive effects on biodiversity: livestock disperse seeds through their dung; rooting by pigs creates mini-habitats that allow threatened plant species to germinate; and the depressions left in the soil by the pigs and by animals' hooves create tiny pools where amphibians can reproduce (Poschlod *et al*., 2002). In Ethiopia, traditional land management by Borana pastoralists has similar effects (Bassi and Tache, 2008).

In North America, grazing maintains native plant and invertebrate diversity in ephemeral wetlands. By contrast, non-native annual species invaded habitats after the exclusion of cattle grazing, reducing native plant cover and wetland inundation periods. A range of threatened animal species are affected negatively by thick ground cover. The Californian Cattlemen's Association, in collaboration with the California Rangeland Trust and other conservation organizations, has established wildlife habitats on working ranches that led to increases in protected animals such as the tiger salamander, red-legged frog, callipe silverspot butterfly, flycatcher, a range of bird (esp. waterbird) species, raptors, bald eagles, racoons, mountains lions and deer (Schohr, 2009).

Herbivory can be a key factor for plant evolution, control of vegetation growth and a stimulus for plant productivity (Bunce *et al*., 2004). Herbivores can influence competition between plant species and introduce more heterogeneous structure of the grass sward. The main mechanisms in this respect are selective grazing, nutrient redistribution, treading and seed distribution (Wrage *et al*,. 2011). Selective defoliation as a result of dietary choices results in sward heterogeneity (Rook *et al*., 2004). Treading and grazing opens up regeneration niches for gap-colonizing species, upon which wild herbivores may depend, or provide access to food for wild animals (feed facilitation). However, if the intensity of grazing increases, animals may become less selective in their feeding behaviour, which can lead to more homogenous defoliation of plants (Dumont *et al*., 2007). The effects of grazing can be further modified by the levels of nutrient input (fertilization; supplementary feeding) or the use of other vegetation strata, such as browsing or tree lopping (Hoffmann and Mohammed, 2004).

Grazing intensity is a critical issue in conservation and management of grassland diversity in terms of vegetation diversity, composition and associated diversity. In order to achieve the expected results, animal species, breeds and methods of pasture management should be chosen taking into account the local environmental conditions and conservation goals of each particular area (Derner *et al*., 2009). While there were multiple studies conducted on the effects of grazing on different parameters of vegetation diversity, De Bello *et al*. (2010) mentioned the importance of other biodiversity drivers' measurements (e.g. number of grazing animals, fire frequency, soil parameters and landscape fragmentation). The effects of grazing on vegetation are complex and it is important to have different measurements, as well as information on the various drivers of biodiversity loss/increase, as grazing pressure and soil moisture can vary with time, and single measurements will not reveal long-term effects (Metera *et al*., 2010).

Generally, low-intensity grazing can create highly diverse mosaic landscapes and habitats that harbour rare animals and plants. It also has the potential to facilitate the restoration of diverse swards and to support reasonable individual performances of grazing animals (Isselstein *et al*., 2005, Tallowin *et al*., 2005). Moderate grazing can be a useful tool to limit the expansion of shrubs, as shown by Casasus *et al*. (2007), in mountain pastures of the Pyrenees, resulting in the enhancement of the environmental and recreational value of the area. Through its effect on vegetation composition and structure, it allows more light to reach lower strata (Wilson *et al*., 2012, Borer *et al*., 2014). Extensively managed grasslands are more useful in terms of regeneration from the soil seed bank than intensive-managed ones (Reiné *et al*., 2004). In woodlands, cattle was found to be capable of creating structural diversity and in grasslands, heaths, and marshes it could encourage conditions that favour floristic diversity and micro-habitats for invertebrates, mammals, and birds (Bignal and McCracken, 2000).

In the Global Survey, Bhutan reported that Nublang cattle contribute to controlling the encroachment of *Yushania microphylla* bamboo species in areas above 2400 m.a.s.l., where this species reduces competition and vegetation regeneration. A response from South Africa noted that in order for normal succession in grasslands to take place, livestock grazing can be performed, among others, by Nguni, Bonsmara, Drakensberger and cross-breeds of cattle. In Switzerland, if Green Alder (*Alnus viridis*) covers more than 50 percent of the area, the diversity of other plants, insects and birds is significantly reduced (Bühlmann *et al*., 2013). Eringer cattle and Engadiner sheep keep pasture areas open and control the further dispersion of Alder (Meisser *et al*., 2009; Meisser, 2010; Arnold, 2011). The examples of a range of breeds keeping landscapes open in mountainous areas (chapter 4.2.5) are relevant here as well.

In Spain, Cashmere and Celtiberic goats modified vegetation composition and structure differently on Cantabrian heathland, with herbaceous vegetation and plant species richness enhanced by the local breed (Celaya *et al*., 2007). Grazing by Celtiberic goats caused a higher reduction of shrub cover (Jauregui *et al*., 2008). Shrub cover and plant canopy height decreased with increasing grazing pressure, leading to higher herbaceous plant cover compared to lower stocking densities (Riedel *et al*., 2013).

The BurrenLIFE project in Ireland found that flower-rich grasslands, scrub and woodlands are important for butterflies, moths and pollinators such as bees (Parr *et al*., 2009). The continuation of winter grazing – and the removal of plant material accumulated over summer - was an important part of maintaining the Burren's calcareous grasslands and their favourable conservation status.

If livestock is purposely introduced for vegetation management, this is called conservation grazing. In Germany, conservation grazing is supported by the Federal Nature Conservation Agency. Examples include the use of goats to control blackberry growth; sheep to keep vegetation open and maintain nesting habitats for migratory birds; and sheep, cattle and donkeys to re-establish sand-dune vegetation (Redecker *at al*., 2002).

In conclusion, both the plant and animal associated diversity in many grassland areas depends upon levels of grazing. In order to achieve beneficial results of grazing for biodiversity, it is important to monitor and adjust grazing pressure in different grassland ecosystems, especially in vulnerable areas experiencing particular pressures of human activities and climate change. Too much grazing can lead to land degradation and the loss of biodiversity, while too little grazing can lead to succession from grassland to woodland and the loss of grassland habitats (Watkinson and Ormerod, 2001).

4.4.4. Connecting habitats

Many annual herbaceous and shrubby species produce hard seeds as a defence against harsh climatic conditions. Germination of such seeds can be favoured by ruminant digestion. By moving their herds seasonally, pastoralists connect different ecosystems. Locally, transhumance routes act as important source of spatial heterogeneity and a reservoir for a large number of plant species, while at larger scale, they support structural and functional continuity, increasing potential connectivity at the regional level (Azcárate *et al.*, 2012). Migratory sheep flocks provide a means by which plants can move from one ecosystem to another, with each animal transporting thousands of seeds. Experiments in Spain (Manzano and Malo, 2006) showed that seeds attached to the fleece of transhumant sheep were transported over long distances and that substantial numbers were dispersed up to several hundred kilometres from their points of origin. With changing climates, this promises to be an important way to enable plants to move into new habitats, and thereby to prevent their extinction. A drawback is the distribution of unwanted species (ibid.). Livestock keepers sometimes make conscious efforts to disperse the seeds of preferred plants. Pastoralists in the Islamic Republic of Iran pack seeds in little bags and hang these around the necks of their sheep. During grazing the seeds drop out through little holes in the bags and are worked into to the ground by the sheep's hooves (Koocheki, 1992; FAO, 2009e,f).

4.5. The role of breeds in the provision of regulating and supporting services

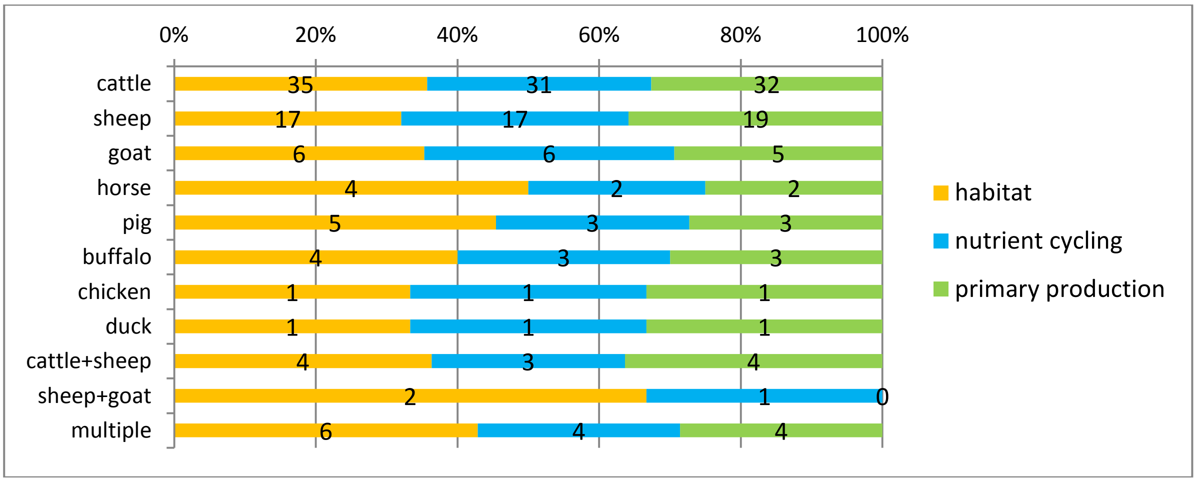
Most studies related to the provision of habitat and regulating services by livestock refer to species only. Evidence for breed-level differences is secondary to that at species level. Where breeds are mentioned, these are mostly locally adapted breeds. Overall, the effects of species and stocking densities, and of spatial and temporal livestock management, seem to have a larger effect on the provision of regulating and supporting ecosystem services than the specific breed used.

Species differences exist in adaptation to extreme environments. For example, Bactrian camels and dromedaries thrive in water scarce environments with extreme climates. Yaks are highly adapted to high-altitude environments where domestic cattle get high-altitude sickness. Yaks and domestic cattle diverged from a common ancestor about 4.5 million years ago. Qui *et al*. (2012) found that genes involved in responding to low oxygen levels and to extracting the most nutrition from sparse grazing were evolving more rapidly in yak than in cattle ancestors. Within species differences to extreme environments also exist. For example, Wuletaw *et al*. (2011) found breed differences in high altitudes (>3500 m) in Ethiopia, with locally adapted Simien cattle having a lower range of oxygen saturation than temperate breeds; they concluded that Simien cattle are genetically adapted to high altitude by largely eliminating the hypoxic pulmonary vasoconstrictor response. Crosses of the local breed with Holstein and Jersey also did not show high altitude pulmonary hypertension. Bedouin goats are able to graze without need for shelter thanks to a greater ability to control their body temperature, whereas other breeds originating from northern climes loose appetite and body weight if not given shade (Mualem et al., 1990). Literature regarding climate and other adaptation of species and breeds has been reviewed by Hoffmann (2010) and Hoffmann (2013). Thus, the provision of ecosystem services in extreme environments depends on the species and breeds adapted to such conditions.

Grazing effects on grassland ecosystems can vary according to species used. When heathland vegetation was the predominant resource available, goats had better productive responses than sheep, and horses better than cattle (García *et al*., 2013). These authors also suggested that the impact of goat grazing on vegetation varied depending on breed and stocking rate, and promoted greater vegetation structural complexity than sheep or cattle grazing, benefiting a wider variety of herbaceous and arthropod species. Goats also proved to be the best complement to other animal species for an efficient use of natural vegetation in a study on heathlands by Ferreira *et al*. (2013), who identified the need to better assess the interactions between grazing behaviour and animal performance.

The Global Survey showed an equal distribution of the three main supporting services across all ruminant species (Figure 19), whereas horses and flocks composed of sheep and goats were slightly more frequently mentioned to provide habitat services.

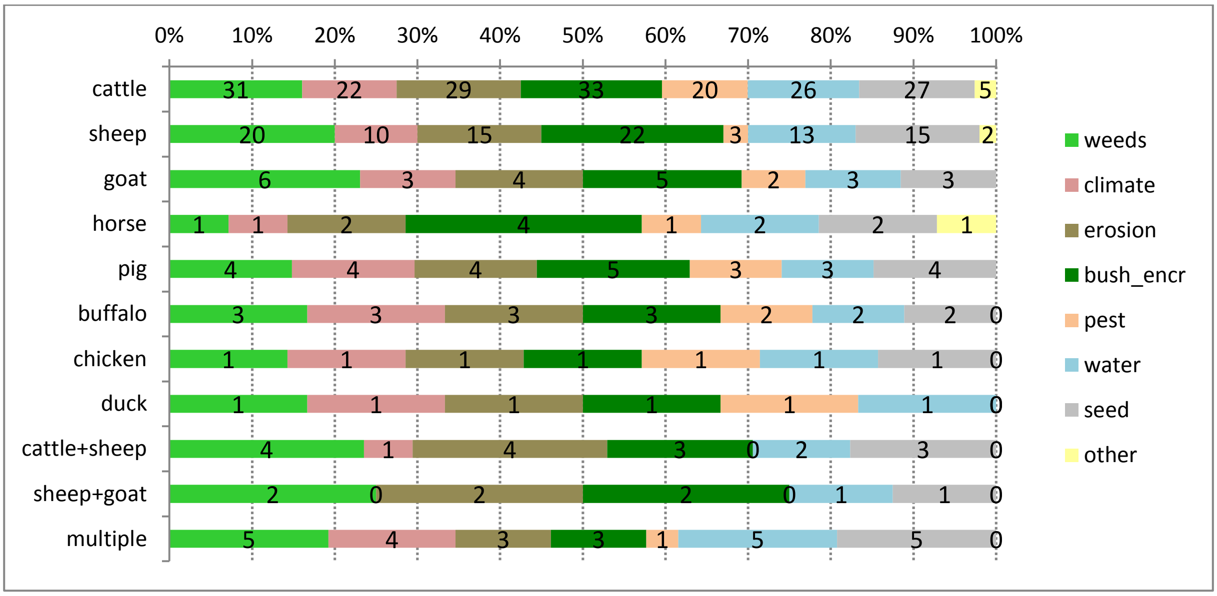
Figure* 19. *Effects of the breed's grazing on supporting services, by species



Note: Numbers stand for total responses in each category.

The regulating services were reported to be provided across all species; small ruminants were mentioned in high frequency as providers of weed control (Figure 20).

Figure* 20. *Effects of the breed's grazing on regulating services, by species



Note: Numbers stand for total responses in each category.

However, beyond the choice of species, there are indications that hardiness, pasturing behaviour and dietary choice play a role, in addition to the size and weight of the animals – traits that differ between breeds. Such traits are particularly advantageous in the provision of services in environments that are harsh or challenging (e.g. those at high elevations or characterized by steep slopes, rugged terrain or extreme climates). A global analysis found that breeds well adapted to temperature extremes, harsh environments and coarse and scarce feed resources are mostly found in mountain regions or semi-arid rangelands (Hoffmann, 2013). Environments with low productivity of vegetation require low stocking rates and breeds with low feed requirements. Particularly on dry pastures, only breeds that have low fertility and low performance can be sustained. On degradation-prone soils, the weight of the animals, their use of the terrain and their spatial mobility are important.

In their extensive review, Rook *et al*. (2004) assume that species and breed differences in the botanical composition of diets can largely be explained by differences in body size, food intake, digestibility and selectivity, and that evidence for breed differences in grazing behaviours and impacts on extensive habitats is mostly anecdotal. The choice of the breed, apart from size and weight, seemed generally to be of less importance in cattle on mesic pastures (Isselstein *et al*., 2007), but breed effects have been reported for sheep and goats (Osoro *et al*., 2007). Other studies found diet selection differences between breeds grazing nutrient-poor pastures (Frazer *et al*., 2009; Jauregui *et al*., 2008). Particular feed preferences were ascribed to individual breeds, which made them appropriate for certain environments (Du Toit, 1998; Blench, 1999). Selective grazing was also a reason why Scottish Highland cows could maintain N intake better than Brown Swiss cows on unimproved Alpine pasture (Berry *et al*., 2003). In the same environment, differences in diet selection and composition were found between different breeds (Winder *et al*., 1996), and between individuals within a breed (Winder *et al*., 1995).

Box 12. Responses from Country Reports – Breeds

Austria: Due to traditional grassland management and grazing practices many extensively managed habitats like steep mountain slopes, high altitude grazing planes or dry meadows are still protected by Austria’s livestock farmers. As a greater part of these habitats are characterized by rough topography, in most cases rare breeds of ruminants are the appropriate choice to manage these lands. They are small framed, flexible to all types of terrain and can cope with low energy feed.

The **Plurinational State of Bolivia**: The Criollo cattle, with their lower body weight, multipurpose use and their physiological ability to browse (consume fodder from trees such as the various species of *Acacia*) and digest forages of lower nutritional quality, are by far a more appropriate alternative for the provision of ecosystem services than the introduced breeds with heavier body weight, which demand better quality forages. Therefore Criollo is promoted in regions where their population is important as in the Chaco region, Mesothermic Valleys and the Altiplano.

Poland: There are certain links between species or even a given breed and the provision of specific environmental services. One example includes the utilisation of Polish Koniks in vegetation control in the Biebrza National Park. It is impossible to use other species to perform this service, such as sheep due to the presence of wolves. Only horses adapted to free range grazing can manage to do well under these circumstances. Another example includes Swiniarka sheep, the breed that is used to graze xerothermic grasslands in the south of Poland. These very fragile grasslands can only be grazed by animals of a light body weight and which require very little care.

United States of America: All ecosystem services are species specific and are not based upon the utilization of a specific genotype. No breed types have been identified as having the ability to mitigate adverse environmental effects of livestock production. Mitigation has been achieved through management actions.

Breed differences were found in terrain use and spatial mobility. Breeds that originate in mountainous terrain use steep slopes and travel farther vertically from water compared to breeds originating from gentle terrain (Bailey *et al*., 2001; Von Wagoner *et al*., 2006). Especially in mountainous environments or transhumance systems, long treks and vertical movements cause high energy requirements. In combination with low herbage quality, this results in low animal performances or even loss of body reserves during summer grazing. Slow growth rate is linked to the ability to sustain body condition and reproduction (Mills, 2008), which differs between breeds, especially under harsh conditions (D’hour *et al*., 1998; Casasús *et al*., 2002; Berry *et al*., 2003; Frazer *et al*., 2009; Morgan-Davies *et al*., 2014).

Livestock’s learning to feed in early life affects foraging skills and intake of relatively undesirable forages (Flores *et al*., 1989; Distel and Provenza, 1991). Consequently, sheep, cattle and goats placed in unfamiliar and complex environments spend more time eating, but ingest less food than animals experienced in these environments (Provenza and Balph, 1987; L’Ecrivain *et al*., 1996). This may particularly be the case on diverse grasslands and harsh rangelands (Bailey *et al*., 2010). Cattle brought into the New Forest in the UK had difficulties to cope with the very short swards in the area, but it was not clear whether this is a genetic or learning effect (Sanderson, 1998).

It appears that there are little breed differences on mesic or grassy pastures, but differences occur on low quality pastures and rugged and higher altitude terrain. Due to the difficulties to separate genetic effects from environmental effects, particularly prior experience of biodiverse pastures during early life (Rook *et al*., 2004), Bailey *et al*. (2010) recommend to use genetically adapted breeds and provide an environment in which animals can learn to adapt. In very harsh environments this should include the retention of a core group of females adapted to the environmental conditions to ensure the production of their own replacements.

Other studies show that several breeds of similar adaptive type are able to provide the same service. What makes the traditional breeds distinctive is their role in the cultural and socio-economic systems of livestock keepers. In the United Kingdom, for instance, a rare and a commercial breed, Belted Galloway and Limousin cross are able to utilize forage similarly (Fraser *et al*., 2013). Few cases in the European Survey reported on good vegetation and biodiversity outcomes where non-native breeds (e.g. Scottish Highland cattle and German Heidschnucke sheep in Switzerland) perform the same ecosystem function as the traditional local breed. However, despite delivering the same or similar regulating and supporting ecosystem services, such breeds cannot replace the cultural value of the traditional breed in the short to mid-term. Several studies stress the important role of traditional breeds in cultural heritage and education, and the public perception of their services (Zander *et al*., 2013; Oteros-Rozas, 2013; Martin-Collado *et al*., 2014). People tend to conserve what they are familiar with and understand, but this is an evolving perspective (Pauly, 1995). In the future, Scottish highland cattle in the Piemontese Alps or Heidschnucke in the Swiss Alps, for example, may have become a familiar feature to the public.

Overall, there seems to be a further need and opportunity for further investigating the roles of traditional breeds and the possibilities for integrating the outcomes of such studies in grazing strategies.

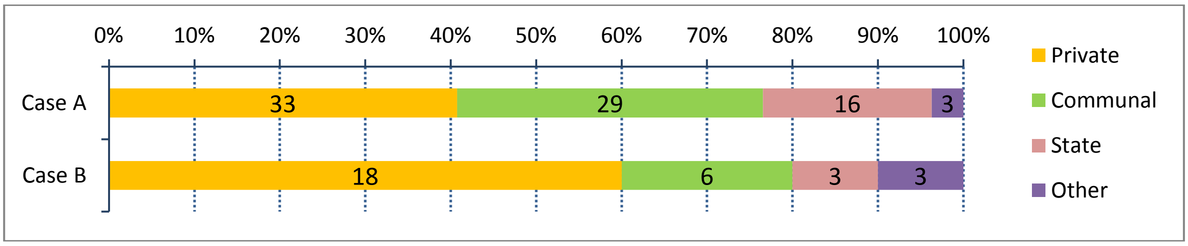
4.6. The role of livestock and land management in the provision of regulating and supporting ecosystem services

Both the Global and the European Surveys asked respondents for information on livestock and grassland management. They also distinguished between cases with breeds historically present in the grazing areas (Case A) and breeds introduced recently for the provision of ecosystem services (Case B). Since management depends, among others, on land ownership, the Global Survey included several related questions.

Privately owned land made up 43 percent of all responses, followed by communal land (29%) and state-owned land (16%). Among private land, areas larger than 100 km² made up 31 percent of the responses, followed by equal numbers (25% each) of very small (<1 km²) and medium (10-50 km²) lands. More than half of the communal land was larger than 100 km², whereas state land was relatively evenly distributed over the land size classes.

Breeds introduced for the provision of ecosystem services (Case B) were most frequently (60%) reported to be found on privately owned land, whereas breeds historically present in the area were mostly kept on communal (36%) and state-owned land (20%) (Figure 21).

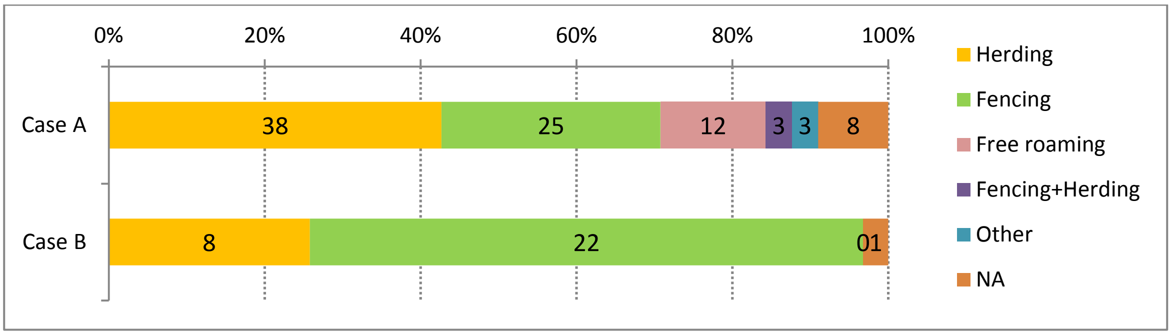
Figure 21. Land ownership in cases with breeds historically present (Case A) and introduced recently for the provision of ecosystem services (Case B)



Note: Numbers stand for total responses in each category.

Livestock management strategies varied depending on the size of the area. Overall, fencing and herding were the most frequently reported methods of animal management (43% and 42%), followed by free roaming (11%) (Figure 22). In cases B, animals were reported to be primarily fenced (67%) or herded (24%). In cases A, herding was reported as the most frequent management tool, followed by fencing and free roaming, thus covering all management intensities. Small grazing areas were reported to be mostly fenced, while in grazing areas of 1-10 and 10-50 km² both fencing and herding were equally practiced (Annex 2). In larger grazing areas (> 50 km²) herding was reported to be most common, while the frequency of free roaming was reported to higher than in small grazing areas. This could be explained by the fact that the animals are rarely left totally alone; even when they are moving freely during certain periods, pasture rotation to less grazed areas is still managed by herders.

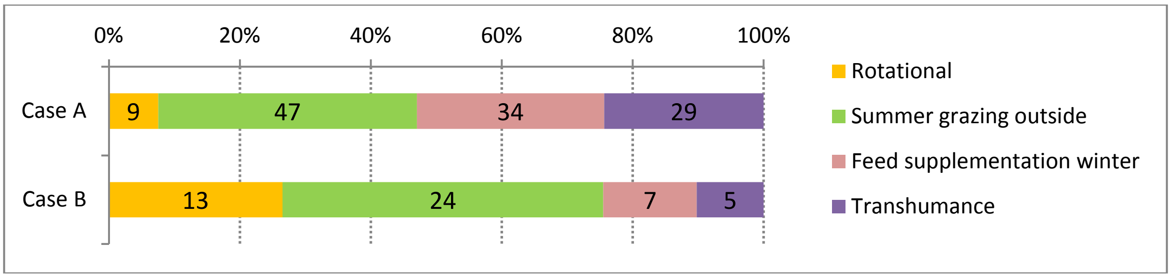
Figure 22. Spatial livestock management in cases with breeds historically present (Case A) and introduced recently for the provision of ecosystem services (Case B)



Note: Numbers stand for total responses in each category.

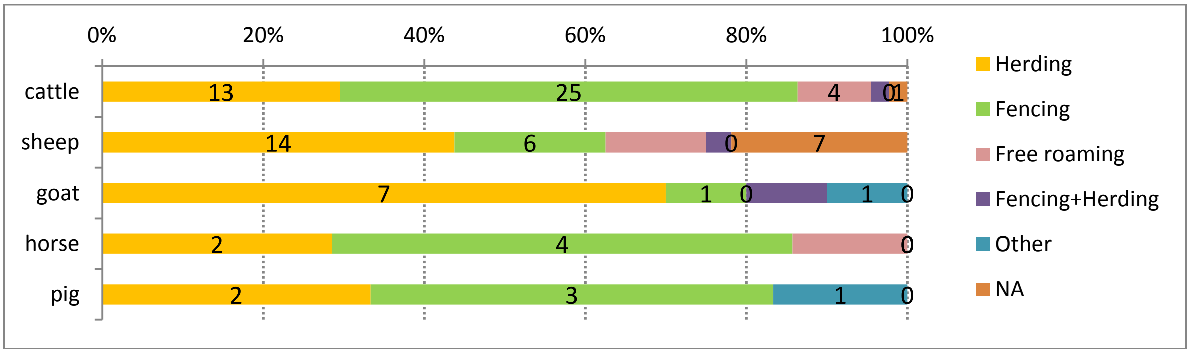
The feeding management choices in Figure 23 are not mutually exclusive. The majority of cases B reported that animals graze during the summer and pastures are managed by rotation. In cases A, with their higher share of communal and state-owned land, rotational grazing played a minor role, whereas transhumance was practiced in 24 percent of the cases. The higher share of winter supplementation (29%) in cases A than cases B (14%) may be due to the higher frequency of keeping the animals grazing outside also in winter, as was indicated in responses to the European Survey. Winter feeding of the animals was mostly linked with private land ownership.

Figure 23. Grazing and feeding management in cases with breeds historically present (Case A) and introduced recently for the provision of ecosystem services (Case B)



Note: Numbers stand for total responses in each category.

Figure 24. Spatial livestock management by species



Note: Numbers stand for total responses in each category.

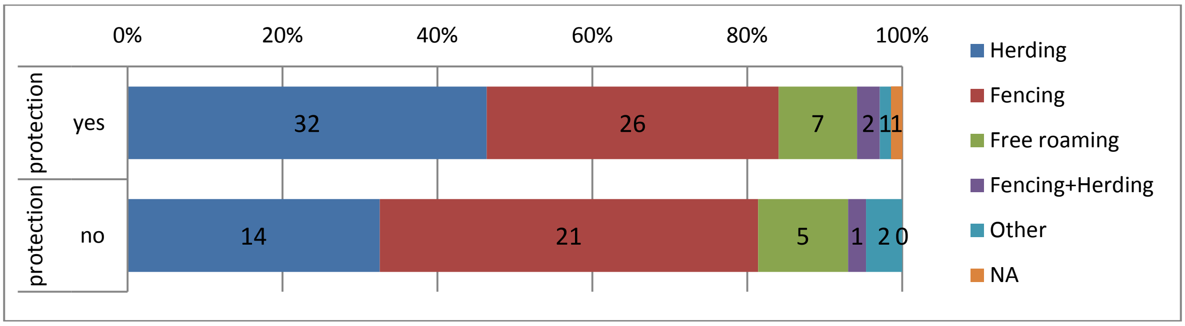
Goats, followed by sheep, were most frequently mentioned to be herded, wheras larger (cattle, horses) or less mobile species (pigs) were more frequently kept in fenced areas (Figure 24).

Transhumance was more frequently reported to occur in montane and temperate grasslands and in communal rather than privately owned lands (15% vs. 10%). Transhumance was also more frequently reported for national parks (IUCN Category II) than for protected landscapes and areas (IUCN Categories V and VI), whereas grazing during the summer was similar across areas under IUCN Categories II, IV, V and VI (see Annex 2). The history and the current ecological advantages of transhumance in a developed country were highlighted by Manzano and Casas (2010).

Grazing area management strategies were reported to be linked to land ownership, with herding more prevalent on communal lands and fencing on private lands (see Annex 2).

Herding was also found to be the most frequent livestock grazing management (46%) in protected areas, followed by fencing (38%). The order is reversed in non-protected areas, with fencing (49%) and herding (32%) respectively (Figure 25). The frequency of free roaming was found to be similar in protected and non-protected areas.

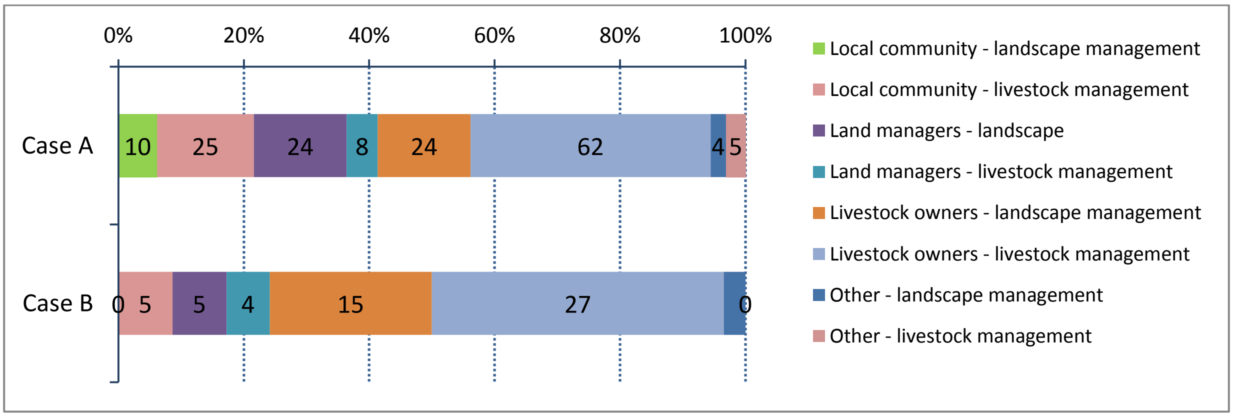
Figure 25. Spatial livestock management by protection status of the grazing area



Note: Numbers stand for total responses in each category.

Stakeholder roles in grazing area management were distributed as follows. In the responses, livestock owners perform both livestock (41%) and landscape management roles (18%) across both cases (Figure 26). Land managers were more often described as performing landscape management (13%) rather than livestock management (5%) across both cases. Local communities performed livestock management in 14% of the responses, which indicates the importance of traditional livestock farming. However, local communities were only indicated as landscape managers in 5% of all cases. This may partly be a result of a lack of recognition of local communities' customary roles in landscape management.

Figure 26. Involvement of different stakeholders in management of livestock and landscape



Note: Numbers stand for total responses in each category.

Little and only incomplete information was provided in the Global Survey on more detailed aspects of grazing management, such as age and sex classes of livestock, or stocking rates. In the European survey, information on the type of grazing animals was usually given as number of animals and number of herds, without detailed indication on spatial distribution or management of the animals. Although most cases listed adult animals, some respondents indicated that herds also included young stock. The calculated stocking density averages 0.3 livestock units per hectare in cases A across species where they refer to the average number of animals present on pastures for the whole grazing period. In cases B, shorter term grazing periods and rotations come with slightly higher stocking rates to ensure removal of unwanted vegetation. However, stocking rates are below 0.5 livestock units per hectare, which is below the limit most countries set for HNV farmland.

5. Cultural services

The reasons for small-scale livestock keepers and pastoralists to keep livestock, and livestock's significant contributions to rural livelihoods are manifold (FAO 2009e,f; FAO 2012c, e; Herrero *et al*., 2013b). In Namibia, livestock is not only kept to provide meat, milk and animal draught power, but it also serves as a form of wealth and status (Auerbach *et al*., 2013).

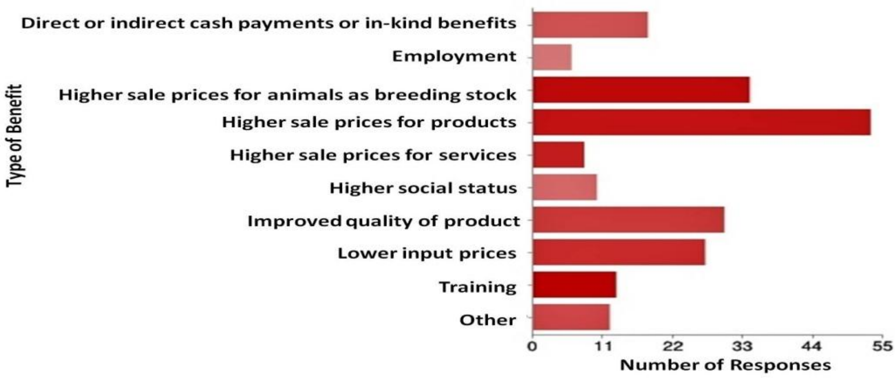
Box 13. Reasons of pastoral communities for breeding animal species

- Cattle: economic benefits of provision of milk and beef come along with payments of dowry, hides for shelter and bedding, draught power, blood as food, making traditional products such as sandals, bedding, manure, use of skins for clothing. Many traditional cattle breeds in pastoral communities are also used in traditional ceremonies and funerals.
- Camels: meat and milk for food, payment of dowry, hides for shelter, traditional sandals, bedding. Such innovative uses of camel products as making ice-cream from camel milk or paper from camel dung became new income opportunities for livestock keepers (Köhler-Rollefson *et al*., 2013).
- Sheep and goats: direct source of income for the family, provision of milk, blood and meat, payment of dowry, sheep's fat for medicine, skins for clothing.
- Donkeys: cheapest means of transport, bride price, milk for medicines to treat tuberculosis and general chest infections.

Note: after Köhler-Rollefson and Wanyama (2003).

An extensive literature review revealed a wide range of economic and non-economic benefits of animal genetic resources (Ayala *et al*., 2013) (Figure 27).

Figure 27. Benefits provided by livestock mentioned in a literature review on the values of animal genetic resources



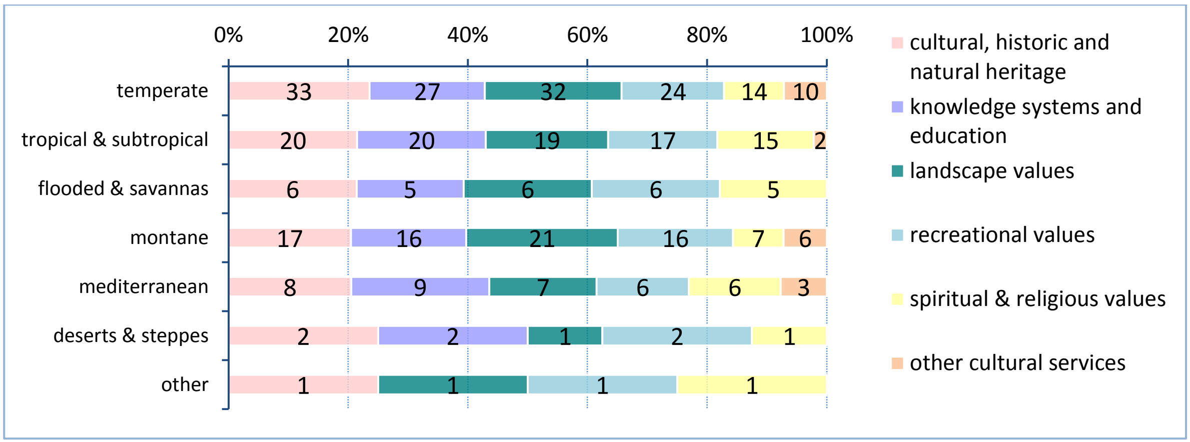
Source: Ayala et al., 2013.

From playing an important role in various religious ceremonies, to positively affecting the cultural and recreational image of grazing areas and attracting visitors, many livestock breeds are a vital component of livestock keepers' livelihoods. Cultural services were mentioned in 83% of all responses as positively and very positively affected by the presence of livestock breeds, and as neutral by 15% (Figure 29). This finding supports the reasons for the guardianship of pastoralists and smallholder livestock keepers of animal genetic diversity (FAO, 2009e,f).

The most frequently mentioned cultural services in the Global Survey were cultural, historic and natural heritage, and landscape value (22% each), followed by knowledge systems (20%), recreation

(18%) and spiritual and religious values (12%) and other values (6%). Landscape, heritage and recreational values of grazing areas are often highly connected to the presence of specific local breeds. Cultural services were distributed fairly equally throughout the various grassland ecosystems (Figure 28), indicating that cultural services are an important component of livestock grazing systems regardless of the grassland type.

Figure 28. Cultural services in different grassland types

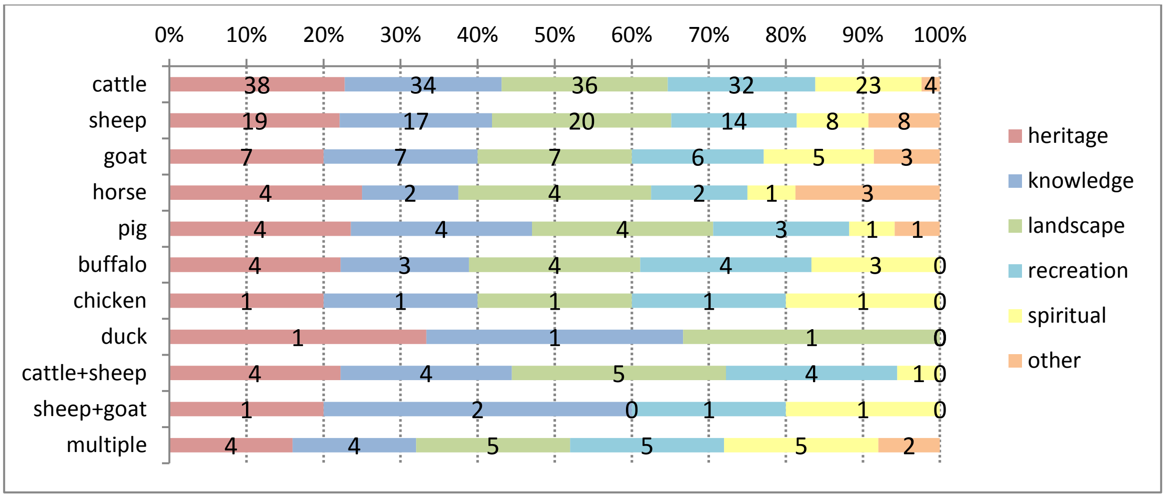


Note: Numbers stand for total responses in each category.

The pattern of distribution of cultural services was similar in Case A and Case B. Landscape and cultural, historical and natural heritage values were mentioned slightly more in Case B (24%) than in Case A (21%) (see Annex 2). This could be because these ecosystem services are the main motivation for introducing or re-introducing breeds for grazing in specific regions. For example, grazing for improving landscape values has been introduced in many European countries.

The entire range of cultural services was reported in the Global Survey as being provided by all livestock species (Figure 29).

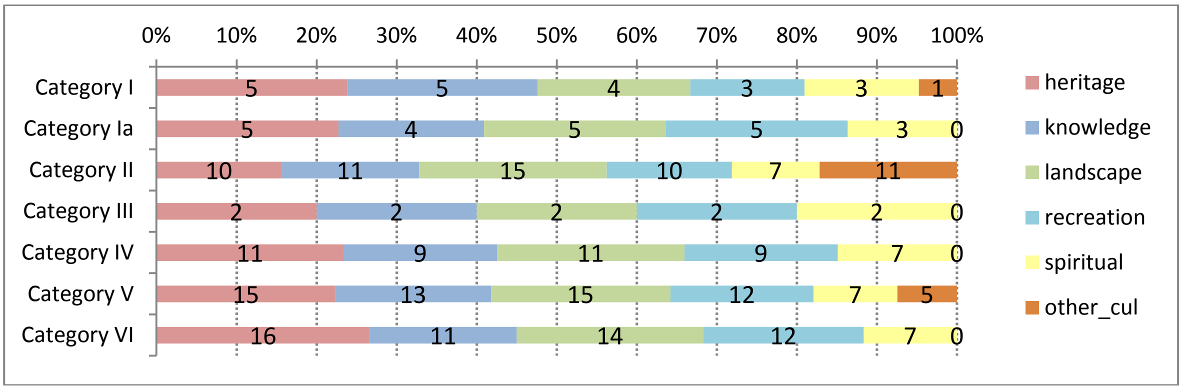
Figure 29. Effects of the breeds' grazing on cultural services, by species



Note: Numbers stand for total responses in each category.

In all protection classes except II, the heritage value was mentioned in 20 to 27 percent of responses in each category. Landscape values were mentioned in 23 percent of responses in natural parks (IUCN II), and IUCN IV to VI protected areas. It is interesting that IUCN II category has the highest share of all protection categories of "other" cultural values. As expected, the share of spiritual value is highest (20%) in the natural monument/feature (IUCN III) category.

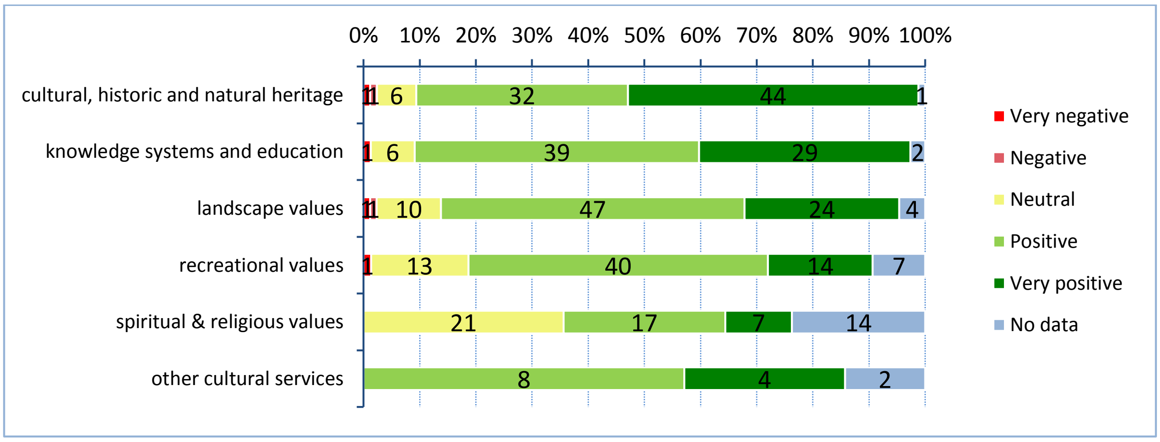
Figure 30. Cultural services by IUCN protected area type



Note: Numbers stand for total responses in each category.

Traditional livestock production systems include animals as an integral part, where livestock plays an important role in many religious rituals and in the knowledge systems of the herders. Compared to supporting and regulating services (Figures 11 and 13), cultural services received the highest share of positive and neutral assessments, and a lower level of "no data", indicating that relatively more evidence is available for cultural services (Figure 31).

Figure 31. Effects of the breed's grazing on cultural services



Note: Numbers stand for total responses in each category.

Distinctive features of traditional breeds, which play an important role in daily life of many pastoralist communities and their cultural significance, should not be underestimated. This has implications on scientific assessments, which often overlook livestock's multiple roles and livelihood functions.

5.1. Livestock as a part of cultural heritage and spiritual/religious values

In many countries indigenous breeds are important for cultural, spiritual and social activities. To date, cultural services provided by numerous traditional breeds are determining factors for small farming systems, and livestock owners rarely keep their animals for income purposes only (Weiler *et al*., 2014). In the Rajasthan province of India, camels are an important part of cultural identity, the landscape and a significant element in promoting ecotourism (Köhler-Rollefson *et al*., 2013). In Kenya, chicken are used in a number of social, cultural and spiritual activities including funeral gifts, entertainment, spiritual cleansing, and as a biological clock (Magothe *et al*., 2012). Besides the value that the Yakutian Cattle in Russia might have for breeding, the cattle are also a means to preserve a traditional way of life and strengthen the cultural heritage and identity of Sakha people (Ovasaka and Soini, 2011). The social significance of livestock among East African dryland pastoralists includes, but is not limited to, the following: rainmaking ceremonies, cleansing of families, communities or livestock, protection against curses or disease outbreaks, oral traditions, customary law and values, treating sick persons, naming ceremonies, initiation ceremonies and rites of passage, sacrifices as per the community's cultural beliefs, as a source of life, without which life has no meaning, as a measure of wealth, use in bull dances and other festivals, social sharing of livestock breeds by exchanging males and females to enhance social links, source of dowry, bride wealth, birth celebrations and other life cycle ceremonies such as funeral feasts (Hesse and MacGregor, 2006). Madura cattle in Indonesia participating in cultural events were valued at prices that were 2–3.5 times higher than Madura cattle not participating in cultural events (Widi *et al*., 2013). Farmers mentioned the unique values of Madura cattle as their motivations to keep them: financial security (saving), income, providing manure, utilization of crop by-products, raising the social status of their owner, cultural events, insurance against draught events and hobby purposes.

Changes in the cultural roles of livestock are expected to have impacts on breeds and their management. This may explain the data gap of 23 percent of responses on spiritual and religious values, the highest among the cultural services (Figure 31). It is interesting to note that those Country Reports mentioning downward trends in cultural roles of livestock were from developing countries, while eight out of ten countries reporting upward trends were developed countries (FAO, 2014a). Where downward trends are described, the reason in most cases is reported to be a decline in traditional cultural roles (Box 14). Other reasons mentioned in the Country Reports are related to the replacement of breed functions (e.g. savings) or animal welfare concerns (fighting animals).

Box 14. Responses from Country Reports – Cultural services

Togo mentions that a decline in traditional beliefs has led to a loss of interest in maintaining culturally significant livestock breeds, particularly of chicken. Similarly, **Bhutan** notes that the rearing of animals for use as sacrifices or offerings is dying out. In the report of **Guinea-Bissau**, economic reasons are reported to have led to a decline in the practice of slaughtering large numbers of animals at funeral ceremonies.

Ethiopia: There is a change in the cultural role of livestock, mainly in pastoral areas. Livestock used to serve as compensation in case of settlement of disputes, but there is increasing tendency to use the legal system. Instead of livestock, cash payments are replacing other cultural roles of livestock. But this has no significant effect on the livestock genetic resources and it is also unlikely to have sizeable effect in the foreseeable future.

The cultural roles of livestock in **Liberia**, such as wealth in the case of cattle, feast and ceremonies, traditional marriage payment and providing emergency funds, are not expected to change in even in the long term.

Peru: In general, cultural patterns have been maintained over time. The livestock sector plays an important role not only in commercial and food security; it also helps in recreational activities such as bullfights, cockfights, various activities related to horses (exhibitions, contests, rides), exhibitions and competitions of domestic camelids and guinea pigs, among others. The latter two native species are part of Andean culture and constitute an ancient ancestral cultural legacy. The Association of Owners and Breeders of Fighting Bulls Arequipa organizes three championships a year. There is also a Breeders Association of Knife Fighting Cocks of Peru. Events such as Yawar Fiesta (Feast of Blood), cockfights and bullfights are increasingly getting more attention and regulations, especially in the context of the global trend to ensure the protection and welfare of animals. For example, the Provincial Municipality of Concepción, Junín, banned bullfights ending with the death of these animals. In addition, there were two legislative initiatives against bullfighting in Congress.

Slovenia: Traditional events from the past (livestock exhibitions, festivals …) are becoming more attractive to the wider public.

Sri Lanka notes that provision of livestock at the time of marriages used to be a widespread practice and that this helped to distribute livestock and maintain their diversity, but that this practice has disappeared. It also notes that concerns about animal welfare have led to some animal sports (e.g. cock fighting) being prohibited by law and that sacrificing animals at religious events is in decline because of societal disapproval, with the consequence that breeding of the types of animal used in these events is in decline.

Uganda: In different parts of the country, cultural aspects of livestock have not changed at all, while in other parts the changes are marked, especially in areas where exotic breeds are kept. For example, in Central Uganda cattle are no longer being used as bride-price, whereas in the western and the north eastern parts of the country, this practice goes on.

With regard to livestock’s savings function, a few country reports (e.g. **Guinea-Bissau** and **Mali**), in response to a general question about changes in livestock functions, note that livestock’s savings and insurance functions are in decline. Other reports, however, specifically note that these functions remain important (e.g. **Swaziland, Uganda, Tajikistan** and **Zimbabwe**).

Animal genetic resources play important roles in the natural and cultural heritage of traditional farming societies and have a diversity of spiritual and religious values in these communities. These values should be better incorporated into different evaluation techniques of livestock production systems, since these non-economic values are irreplaceable parts of the lives of livestock keepers. Recognizing cultural diversity and the different ways keepers of local breeds make decisions, is crucial for the successful development and implementation of animal genetic resources conservation policies and programmes (Soini *et al*., 2012; Bernues *et al*., 2013; Morgan-Davies *et al*., 2014).

5.2. Knowledge systems and educational values

Over the centuries, traditional livestock keeping communities have accumulated valuable knowledge on the coexistence of nature, humans and livestock, including on ecosystem functioning and the management of supporting and regulating ecosystem services. These links between livestock and local communities, and the knowledge systems associated with these, may be lost due to the lack of recognition of the role of livestock or lack of understanding by decision-makers of the roles that animal genetic resources play, especially for pastoral communities (FAO, 2009e,f). The fascinating historical cultural elements associated with transhumance, for example, have been developed over many centuries and are results of accumulated knowledge of livestock keepers. The indigenous knowledge accumulated by pastoralists over many generations seems too valuable to be just neglected or omitted (Kreutzman, 2011). Indigenous knowledge on animal genetic resources plays an important role in ensuring continuous management of traditional breeds in many Asian countries, despite political and environmental changes (Namgay *et al*., 2013). Modern agricultural practices aimed primarily at increasing income and livestock production may contribute to losses of this important knowledge on the traditional livestock breeds and thus the educational values of farming practices could be diminished.

One of the ways to preserve the knowledge of pastoral communities is the use of biocultural community protocols (LPP and Life Network, 2010; Box 14) which are based on customary norms and laws of communities and set out clear terms and conditions to governments, the private and research sectors for accessing community resources and engaging communities. They can act as a repository of information about history, culture, use and non-use values of animal genetic resources, as well as best practices of the ecosystem management in relation to pastoralism. Biocultural community protocols facilitate conservation and sustainable use of biodiversity by ensuring that decisions regarding communally managed resources rest firmly with the communities who have served as stewards of these resources over many generations. Close interactions among people, nature and livestock are made possible if knowledge on traditional farming practices is preserved and transmitted to younger generations. Biocultural community protocols can also be linked to special marketing chains and labels as discussed in chapter 7.3.

Box 15. Biocultural community protocol of Raika people, India

"Through our interaction with the forests, gauchar and oran, and through selective breeding over generations, we have created breeds that are particularly hardy, able to forage and digest rough vegetation, withstand the dry Rajasthani environment and to walk long distances – all attributes that "high performance" exotic breeds do not have. Their genetic traits and our traditional knowledge associated with these will also be of use in breeding for disease resistance, and may provide us with other diverse economic opportunities under the forthcoming International Regime on Access. We have traditional customs that ensure the genetic diversity of our breeds, such as the rotation of bulls between villages for stud. We have also developed extensive local treatment systems (ethno-veterinary knowledge) with which to care for wounded or ill animals, and much of this traditional knowledge is held by both the men and women of our community. Our breeds are more than just a livelihood. They form an integral part of our social fabric and are interwoven with spiritual meaning. A number of important holy days involve rituals that involve our animals and underscore the sacred ties between our livestock, the environment and our traditional knowledge."

Source: http://www.pastoralpeoples.org/biocculturalprotocols.htm (2009).

Farmers preserving the knowledge about their breeds do not tend to select their animals based on productivity criteria only. In Ethiopia, farmers knowing the aggressive temperament of Sheko cattle prefer to keep local Zebu cattle, even if the latter has lower performance (Desta *et al*., 2011). Neuquén criollo goats in Patagonia, Argentina form a core component of the transhumance culture and identity of the north of Neuquén Province (Lanari *et al*., 2003; Tempelman and Cardellino, 2007), and the knowledge of transhumance practices should be preserved to protect the link to people's identities. Morgan-Davies *et al*. (2014) found that hill beef farmers in Scotland appear to not only choose breeds and adapt their production systems according to their current bio-physical and financial circumstances, but also from personal experience and preferences. Different farmer types were identified with different management systems, decision-making processes and cattle breeds kept. These farmer types differed significantly in their views regarding breed hardiness, suitability and reasons for their choice of breed.

Knowledge is dynamic and partly linked to specific natural environments and institutional setups. For example, a recent increase in consumer demand for grass-fed beef and organic chicken influences the standards and conditions of livestock production (see Box 18). In the rangelands of California, ranchers are advised on at-risk species conservation and maintaining the environmental health of their lands by the California Rangeland Trust. Ranchers, as members of the Trust, voluntarily take steps to protect rangeland, ensure clean water, habitat for wildlife species, scenic views and promote other benefits of open landscapes. The examples given by Schohr (2009) from California show that the management of livestock and grazing habitats to ensure a range of ecosystem services is knowledge-intensive and requires a mix of local and scientific knowledge and innovations. A wide range of stakeholders, from ranchers and their organizations to nature conservancies, research organizations and non-governmental organizations (e.g. Holistic Management) is needed to achieve and monitor satisfactory outcomes.

Also the BurrenLIFE project in Ireland addressed sustaining the traditional Burren landscape through collaboration of scientists, farmers, conservationists and development authorities. Changes in the management of these grasslands need economic and scientific validations to continue contributing to livelihoods and tourism in the region (Parr *et al*., 2009).

In workshops among conservation specialists, the establishment of grassland stewardship and sustainable ranching were identified as possible tools in the conservation of natural grasslands (Bilenca and Miñarro, 2004). Verdu *et al*. (2000) proposed a reintroduction of traditional grazing of sheep and goats throughout ecological, cultural and economic measures, which would include guidelines and regulations.

In conclusion, as Dong *et al*. (2009) highlighted, there seems to be a need to form a network of interested researchers, professionals and others to promote a balanced view of traditional management systems and innovations to policy-makers, educational institutions, project planning and implementation organizations.

5.3. Livestock as part of natural heritage, and landscape and recreational values

Traditional farming has formed unique landscapes, such as rice fields in Asia, mountainous grazing in the Alps or vast rangelands in the Americas. Cultural landscapes are defined as the result of the interaction between people and their natural environment. The quality of landscape experience has been highlighted as a part of cultural and symbolic significance values of the landscape (Körner and Eisel, 2004; Konold, 2008). Cole and Philipps (2008) describe the close relationship of English breeds and landscapes and conclude that the beauty of the landscape should be included in landscape planning and management activities. The "wide open spaces" of ranch landscapes in the United States of America are important aesthetically, and many other ecosystem services depend upon the extensive and undeveloped land (Huntsinger, 2013). The scenic value used as an indicator variable explained the role of ecosystem services in Wyoming landscapes (Bastian *et al*., 2002).

While grazing is an important process in shaping ecosystems that developed in co-evolution with human practices, domesticated livestock populations have also become visually associated with landscapes during the course of history. Abandoning these practices would have detrimental effects on traditional landscapes (Box 15). While environmental benefits of such systems tend to be local and preservation of traditional lifestyles is a choice of each community (Mendelsohn, 2003), it is still important to ensure that environmental roles of animal genetic resources are acknowledged as contributions to regional and global diversity. UNESCO, since 2007, has taken a more proactive approach towards including pastoralist sites in the World Heritage List, mainly under its cultural landscapes sub-category (Lerin, 2010). The list currently includes 15 sites that are directly and indirectly associated with pastoralism.[15] [16]

Box 16. Examples of the effects of decreasing traditional grazing practices

Mérinos d'Arles sheep grazing in the hills of the Provence in France was the major factor influencing the traditional landscape. Now thick scrub and evergreen oak forests cover completely landscapes formerly dominated by grasslands and are the most demonstrative example of the phenomenon of grazing abandonment causing landscape transformation (Bunce *et al*., 2004).

The classic Northeastern landscape of rolling green valleys surrounded by forested hills in the United States of America would be lost if the dairy industry is lost (Mendelsohn, 2003).

Provision of cultural services through habitat management has only begun to be explored (see links in section 4.4). However, the possibilities are extensive (Fiedler *et al*., 2008). In traditional and extensive farming systems, local breeds often play an important cultural role and therefore have a high value as evidence of the history of farming (Gandini and Villa, 2003). Where indigenous peoples live in landscapes affected by a number of environmental, social or economic changes, the conservation of native plants and animals for medicinal, cultural, or religious purposes is often critical for livelihoods and, at the same time, contributes to habitat management goals.

The Maremmana cattle breed in Italy is important for maintaining the characteristic Maremma landscape in Tuscany, consisting of patchy areas of grasslands and bush fragmented by corrals (Zander *et al*., 2013). The Borana Conserved Landscape is a large community conserved area in Southern Ethiopia, managed with Boran cattle according to indigenous governance. Although it is not yet formally recognised, the Borana Conserved Landscape provides the habitat for a variety of important, globally threatened, range restricted and biome specific wild species (Bassi and Tache, 2008).

Cultural landscapes formed by grazing activities are often valued and recognized by tourists. As with wildlife, aesthetically valued landscapes are of great value to the tourist industry and can be enhanced and protected by pastoralism. Pastoralist societies have also gained popularity and attract initial and repeat visits to East Africa. The Maasai, and their iconic image, for example, are at the heart of Kenya's and Tanzania's identity towards visitors from abroad. Northern tour operators and their East African affiliates regularly use pastoral imagery to sell their products and a range of other industries including airlines, car manufacturers and mobile phone companies also use similar marketing practices (Hesse and MacGregor, 2006). The annual value of pastoralist land uses to the wildlife-based tourism industry in northern Tanzania was estimated at approximately US$83.5 million (Nelson, 2012). Mato Grosso do Sul in Brazil became an important Brazilian tourism destination, especially with regard to its natural resources and strategic location (Mariani *et al*., 2011). Tourists are offered opportunities to broaden their travel experiences, like food festivals based on lamb meat. In the Brazilian Pantanal region where seasonal flooding causes migrations of animals, tourism niches for local farmers are created (Pinto de Abreu *et al*., 2010). In Lesotho there is an opportunity for ecological tourism involving riding Basotho ponies (Tempelman and Cardellino, 2007). The Country Report from Albania notes that in mountainous areas, infrastructural developments associated with tourism have inadvertently allowed breed conservation to flourish.

Several responses of the Global Survey mentioned that certain livestock breeds have a high potential for use in tourism and recreation activities in grazing areas. Products of Shami cattle in Jordan attract tourists, as well as horse populations close to Kaapsche Hoop in South Africa. The Bentheimer sheep breed is kept within Germany's North Rhine-Westphalia nature reserve and is a popular tourist attraction.

[15] http://whc.unesco.org/en/list/
[16] http://www.worldheritagesite.org/tags/tag926.html

Box 17. Responses from Country Reports – Landscape and recreation

Albania: In projects that have conservation and management of protected areas as objectives, activities of conservation and sustainable use of animal genetic resources are foreseen too. For example in the project for the protection of the natural park and ecosystem of Prespa Lake, conservation and sustainable use of native cattle breed "Illyric Dwarf Cattle - Prespa Cattle" is one of the objectives.

Croatia: Maintaining the native and protected breeds of domestic animals in the Republic of Croatia, in their original environment (*in situ*), is a primary form of protection. By maintaining a constant contact with the environment (habitat, humans), native breeds maintain their own adaptability, they adapt their productivity, nurture bio-diversity of the habitat, maintain the relationship with humans and become integrated into the activities of rural areas (folklore, tourist, etc.). The Nature Protection Act has only recently introduced the category for protected domesticated taxa under which such an endangered inherited animal breed can fall, which was developed as a result of traditional breeding and is a part of Croatian natural heritage. Strategic goal: To preserve and enhance the existing genetic diversity of native and threatened domestic animal breeds and cultivated plants by appropriate conservation methods (*in situ, ex situ, inter situ*). Examples: in karst areas, sheep and goats maintain landscapes by grazing, which reduces numbers of wildfires. Slavonian Syrmian Podolian cattle is efficient in the prevention of degradation of pastures (repression of the plant Amorfa).

Spain: In recent years, Spain has shown a growing interest in the protection, sustainable use and enhancement of genetic resources and their roles in the conservation of our biodiversity, ecosystems, rural development, etc. As a result of this, Spain enacted Law 42/2007 on Natural Heritage and Biodiversity, which establishes the basic legal framework for the conservation, sustainable use, restoration and enhancement of natural heritage and biodiversity in Spain. This is part of the duty and goal to guarantee the constitutional right of people to an appropriate environment for their welfare, health and development. The Act aims to raise awareness about the value of genetic resources and their importance in maintaining existing ecosystems and biodiversity.

Togo: Rehabilitation of forests and protected areas for wildlife protection areas will result in the denial of access to certain areas with high potential of forage for cattle herds.

Quantification and improved understanding of landscape management (Petrov and Voronina, 2008; Rieken and Kaule, 2008; Roser, 2011) and landscape interactions could help in the design and evaluation of spatial policies related to the provision of multiple goods and services by landscapes (Willemen *et al*., 2010). The recent works on ecosystem services bundles address trade-offs between ecosystem services within landscapes (Raudsepp-Hearne *et al*., 2010; Martín-López *et al*., 2012).

Clear and enforceable tenure regimes are critical for the continued management of traditional landscapes and the breeds developed in them (Ostrom, 1990; Bromley, 1998; Bassi and Tache, 2008; FAO, 2007a,b). Togo for example provided an example of land use conflicts (Box 16). The economic value of pastoralists' contribution to wildlife conservation highlights the importance of the need for prioritizing measures that promote communal rangeland management and support traditional land use practices in Tanzanian policies on land, livestock, tourism and wildlife (Nelson, 2012).

6. The roles of small-scale livestock keepers and pastoralists in the provision of ecosystem services

It is difficult to assess the number of small-scale livestock keepers world-wide (FAO, 2009f). FAO has estimated that there are more than 500 million family farms, making up over 98 percent of global farming holdings, and that 84 percent of farms are smaller than 2 hectares (this latter category account for about 12 percent of global farmland) (Lowder *et al*., 2014). Family farmers also work on a significant portion of the world's farming land, with substantial regional differences: 85 percent in Asia, 62 percent in Africa, 83 percent in North and Central America, 68 percent in Europe and 18 percent in South America. Although not all family farms are smallholdings, it can be assumed that the majority of family farmers in Asia, Africa and South America are smallholders and that most keep a few livestock.

As mentioned earlier, grasslands and rangelands sustain the livelihoods of large numbers of vulnerable people in many parts of the world, and nomadic and transhumant pastoralists were estimated to number between 100 million and 200 million people globally (FAO, 2006c). Their absolute numbers are much lower than those living in mixed farming (Herrero *et al*., 2012). However, their presence is predominant in extensively managed grassland ecosystems, and they are found in all regions of the world.

Based on the analysis presented in chapters 3 to 5 of this document, it can be concluded that the majority of regulating, habitat and cultural services are provided in systems, particularly grazing systems, where small-scale livestock keepers and pastoralists predominate and where mostly locally adapted breeds are kept (see Table 6). The large areas covered by these production systems, the importance of grasslands to biological diversity and the link between livestock grazing and nature conservation affirms the role of small-scale livestock keepers and pastoralists as guardians of biodiversity beyond the management of their breeds. However, the extent to which small-scale livestock keepers and pastoralists actually deliver these ecosystem services depends on a range of institutional and political factors, as well as differences in cultural management practices between different peoples, communities and locations.

The above indicates the strong correlation of the presence of pastoralists and small-scale livestock keepers in the management of grassland systems most relevant for the delivery of ecosystem services. What factors explain this correlation? As mentioned in the study's introduction (chapter 1.2), the likelihood that a given ecosystem service is maintained depends on people's perspectives of its values. These are determined by economic systems (subsistence and/or market-oriented) and the directness of livelihood dependence on ecosystem services, as well as social, moral and spiritual aspects of people's cultures. Even though small-scale livestock keepers and pastoralist embody a wide range of cultures, a tendency can be discerned that their traditional cultures and lifestyles embody a much higher appreciation of ecosystem services other than provisioning ones, compared to modern (urban) lifestyles. This affects their collective and private everyday decision-making on natural resource management, and their maintenance of non-provisioning ecosystem services in particular.

Especially in marginal and vulnerable environments, where livelihood dependency on ecosystem services is high and the consequences of ecological mismanagement can threaten human survival directly, small-scale livestock keepers and pastoralists have developed, through accumulated experience, knowledge systems that allow them to understand and monitor ecological processes and changes, including regulating and supporting ecosystem functions, in relation to their own management choices. These knowledge systems tend to be very finely tuned to specific ecosystems and are maintained through oral traditions, forms of education and instruction, ceremonies and other cultural and spiritual practices.

Customary norms and laws on access to and use of natural resources reflect both the value systems and social norms for sharing the benefits of ecosystems among members of communities. These institutions allow traditional livestock-keeping communities to provide both positive and negative incentives (sanctions).

Their knowledge and value systems underpin the care for regulating and supporting ecosystem services by small-scale livestock keepers and pastoralists, underlining the significance of cultures and cultural diversity *for* the management of breeds and ecosystem services, as distinct from – although closely related to – the cultural services *of* ecosystems. Although many, but not all, populations of small-scale livestock keepers and pastoralists are identified as indigenous peoples, the majority shares their distinct features. FAO's Policy on Indigenous and Tribal Peoples (FAO, 2010c) recognizes the role of indigenous peoples' cultures in sustaining the natural resource base that underpins food security.

Many small-scale livestock keepers' and pastoralists' management practices are eroding quickly, due to several factors, which often converge: absolute and relative poverty, resources scarcity and competition, driving the adoption of unsustainable livelihood alternatives; insecure land and natural resources tenure; policies and programmes driving sedentarization, land-use changes and cultural changes; political marginalization and low levels of participation in decision-making; exclusion from protected areas; as well as negative stereotypes and low status.

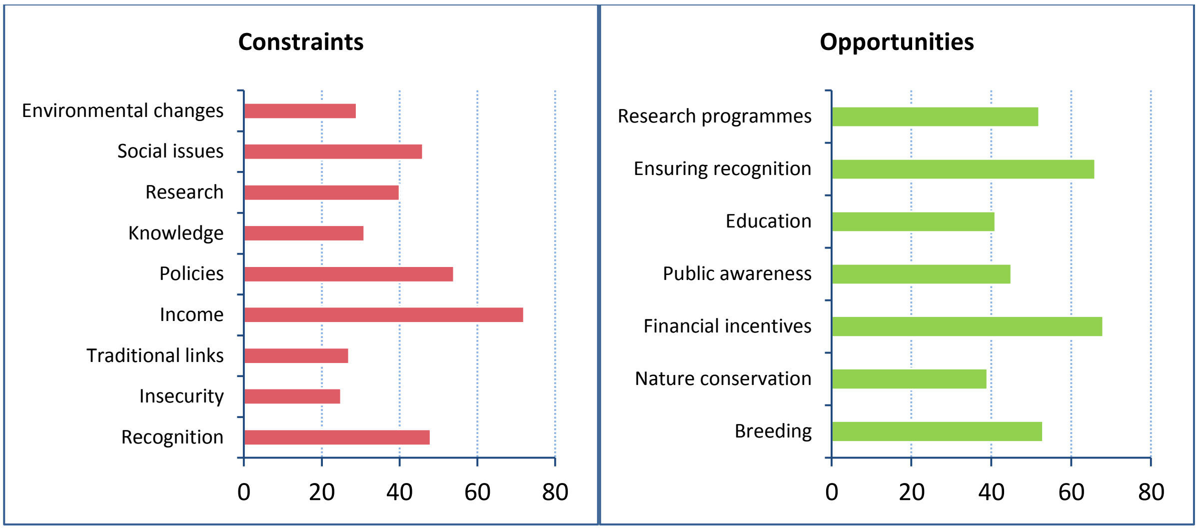
From a livelihoods perspective, two main characteristics of locally adapted breeds are highlighted as being particularly relevant to women livestock keepers (FAO, 2012f). Firstly, locally adapted breeds tend to be easier to care for than exotic breeds. Therefore, keeping these breeds can be more easily combined with household and child-rearing tasks. Secondly, locally adapted breeds are normally better able to access and utilize common property resources (because of their ability to negotiate the local terrain and make use of local feeds) than exotic breeds. This capacity tends to be particularly important for women because of the major gender inequalities that exist in terms of landownership.

The current study found no quantitative data on the contributions of small-scale livestock keepers and pastoralists to the provision of ecosystem services, indicating a need and opportunity for further investigation.

7. Constraints and opportunities

This chapter focuses on the non-provisioning services, most of which are economically invisible. It takes the responses to the Global Survey on constraints and opportunities as a starting point for a wider discussion. Constraints were identified together with opportunities for the continuation of ecosystem services provided by animal genetic resources (Figure 32 and Table 14). The most common constraint identified in the Global Survey was the lack of sufficient income generation from livestock (C4), followed by the absence of supporting policies and regulations (C5), a lack of recognition of the services (C1) and by wider social issues (C8). More detailed challenges include the loss of social prestige of pastoralists, and the decrease in grazing activities in grassland ecosystems worldwide. Linked to the social status are economic reasons: there are few economic incentives for livestock keepers to provide ecosystem services other than provisioning services, making it not profitable to keep breeds with lower market production. In cases where local breeds are kept for conservation grazing, recurrent costs of keeping, managing and transporting the animals need to be considered, and appropriate infrastructure has to be put in place. Insufficient property rights, lack of access to land and water, and the exclusion of livestock from nature conservation areas were also mentioned as constraints.

Figure 32. Total number of selected constraints and opportunities



Among opportunities, financial support/economic incentives (O3) and ensuring recognition of ecosystem services among policy-makers (O6) were the most frequently mentioned. More detailed opportunities include the continued role of livestock as a livelihood for the poor and in marginal areas, and the emerging market opportunities for grass-fed and organic livestock products. These are related to the opportunity of sustainable grazing management, since moderate grazing pressure generally maintains higher levels of biodiversity.

It is interesting to note that the constraints on lack of income (C4) and supporting policies (C5) were most frequently mentioned in combinations with ensuring recognition of ecosystem services among policymakers (O6) and financial support/economic incentives (O4) (Table 14). This stresses the role of policy-making and incentives in the continued support of ecosystem services. Constraints C2 (Insecurity or conflicts that limit access to grazing land), C3 (Loss of traditional links between livestock and the local community) and C9 (Threats to the traditional production environments of the livestock population caused by climatic or other environmental changes) appeared to be secondary and less linked to specific observed opportunities.

Opportunities for the continuation of ecosystem services provided by species and breeds such as public awareness, recognition, knowledge management, education and research, support to animal breeding and nature conservation programmes can be considered as non-monetary support to livestock keepers of a more technical nature, although they require an enabling policy environment to flourish. Opportunities such as supportive land tenure regimes and markets, and improved integration of sectoral approaches, the development of supportive policies and regulations and the monetary mechanisms that ranked high under the constraints and opportunities all fall in the policy realm. In the following sections, these topics are reviewed.

Table 14. Combinations between constraints and opportunities

	C 1. Recognition	C 2. Insecurity	C 3. Traditional links	C 4. Income	C 5. Policies	C 6. Knowledge	C 7. Research	C 8. Social issues	C 9. Environ. changes
O 1. Breeding	29	14	17	30	32	25	21	30	17
O 2. Nature conservation	19	9	18	28	25	15	17	20	14
O 3. Financial incentives	30	17	17	45	37	20	31	31	23
O 4. Public awareness	18	7	18	35	24	12	21	25	14
O 5. Education	20	10	16	25	27	17	27	27	17
O 6. Ensuring recognition	38	16	19	46	41	20	27	34	22
O 7. Research programmes	26	17	16	37	29	18	27	28	17

Note: Total number of responses in each category.
Constraints: *C1 Existing livestock management is not based on the recognition of the ecosystem services provided by the livestock; C2 Insecurity or conflicts that limit access to grazing land; C3 Loss of traditional links between livestock and the local community; C4 Lack of sufficient income generation from the livestock; C5 Absence of supporting policies/regulations; C6 Loss of knowledge on the management of the described livestock population; C7 Lack of research activities on the topic; C8 Social/political issues that affect livestock management; C9 Threats to the traditional production environments of the livestock population caused by climatic or other environmental changes.*
Opportunities: *O1 Livestock breeding programmes targeting specific characteristics that are relevant to the provision of ecosystem services; O2 Nature conservation programmes; O3 Financial support/economic incentives; O4 Raising public awareness; O5 Introducing educational programmes for livestock keepers and/or breeders; O6Ensuring recognition of ecosystem services among policy-makers; O7 Introducing/supporting research programmes on ecosystem services provided by animal genetic resources.*

7.1. Recognition of ecosystem services

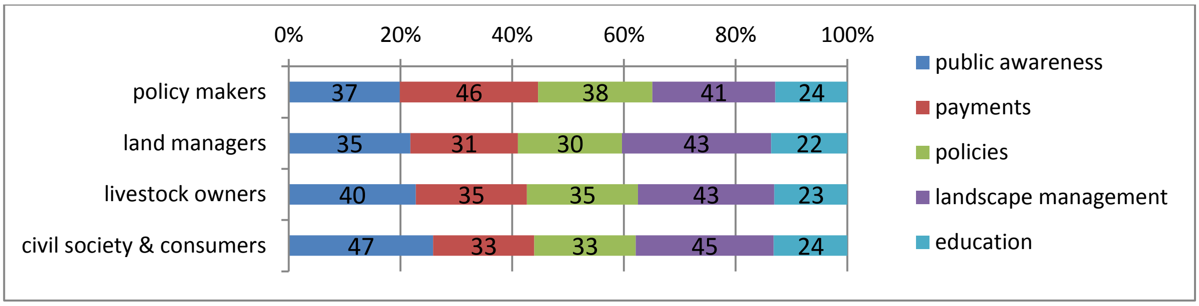
The Global Survey contained several questions on recognition of ecosystem services. Forms of recognition ranged from public awareness of livestock roles in the provision of ecosystem services to agro-environmental incentives to farmers. In total, ecosystem services were reported to be recognized by 87 percent of the respondents ("yes" and "some"). The respondents noted that even though no official recognition exists of the services provided by the breeds, the livestock keepers and local population were aware of the positive role animals play in positively affecting one or more ecosystem services.

The most frequently mentioned form of recognition was through landscape/nature conservation management programmes (25%), followed by economic incentives and public awareness (both 22%).

Policies/strategies and actions that support the role of the livestock population in the supply of ecosystem services (18%) along with educational programmes (13%) were less common answers.

Stakeholder groups influence the form of recognition (Figure 33). Civil society and consumers recognize the roles of animal genetic resources primarily in the form of public awareness and through landscape/nature conservation programmes. Policy-makers recognize ecosystem services chiefly through economic incentives, as well as through landscape management measures and nature conservation programmes. Landscape management and nature conservation programmes are mentioned in high frequency by all stakeholder groups, indicating a convergence of opinion on this matter, whereas educational programmes were consistently mentioned to a lesser extent by all groups.

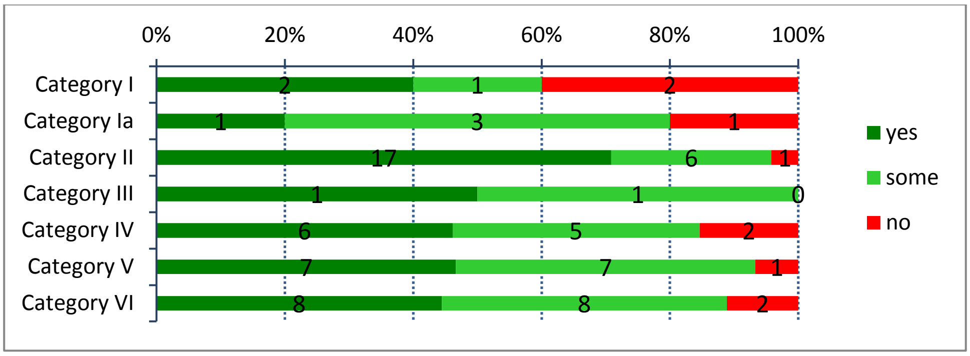
Figure 33. Types of recognition of ecosystem services by stakeholder group



Note: Total number of responses in each category.

The protection status of the area influenced the recognition of the services: the majority (56%) of respondents fully recognized ecosystem services provided by breeds in protected areas. The reverse was the case in non-protected areas, for which 53 percent of respondents recognized "some" ecosystem services (see Annex 2). The highest share of fully positive recognition was reported for natural parks (IUCN II), whereas the highest share of "no" recognition was in strict nature reserves (IUCN I) (Figure 34). In protection categories that explicitly allow agricultural activities (IV to VI), "yes" and "some" recognition reached between 80 and more than 90 percent.

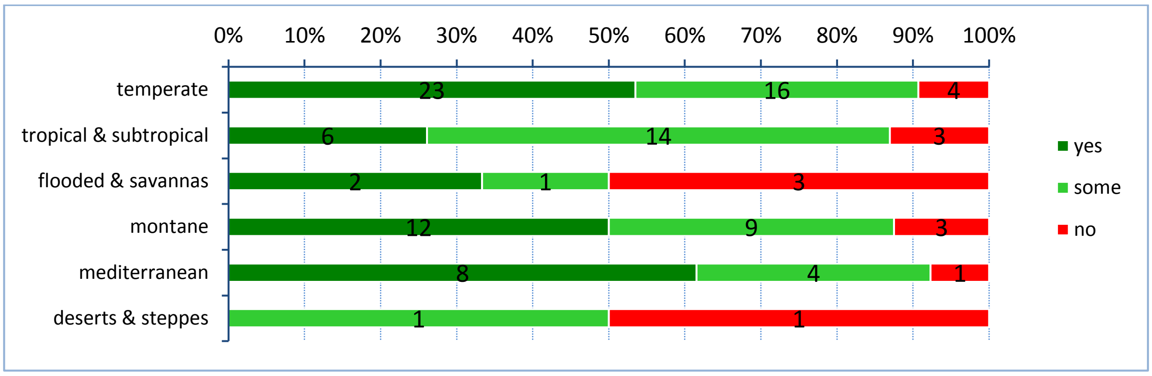
Figure 34. Types of recognition of ecosystem services by IUCN protected area type



Note: Total number of responses in each category.

Equally, the type of grassland habitat influenced recognition of ecosystem services (Figure 35). In all habitats except tropical flooded grasslands/savannas, and deserts/steppes, 85 percent of respondents recognized ecosystem services ("yes" and "some"). In temperate and Mediterranean grasslands there was more definite positive recognition of ecosystem services (53 and 61%), whereas in tropical and subtropical grasslands the share of "some" recognition was highest (61%). This may be related to the high number of respondents from Europe with temperate and Mediterranean grasslands, where increasingly affluent societies attribute a high importance to cultural and regulating services.

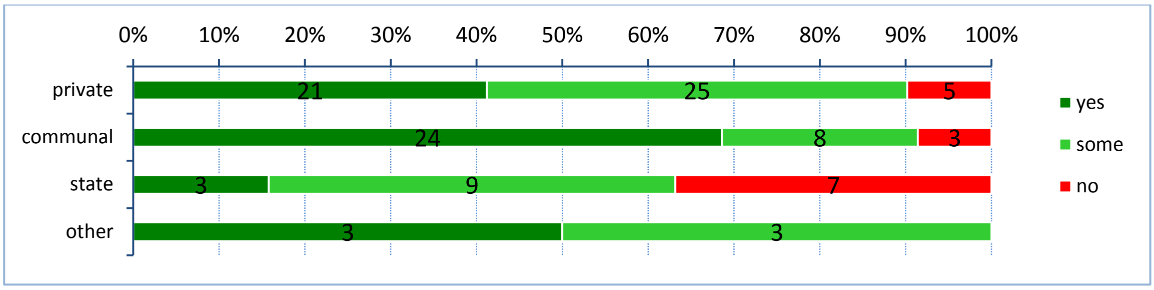
Figure 35. Recognition of ecosystem services by grassland ecosystems



Note: Total number of responses in each category.

Land ownership also affected the recognition of ecosystem services provided by the breeds in grasslands (Figure 36). The highest frequency of positive recognition (69%) was reported for communal lands, whereas private land showed similar frequencies of positive and "some" recognition. The highest frequency of "no" recognition was reported for state-owned lands.

Figure 36. Recognition of ecosystem services by land ownership



Note: Total number of responses in each category.

Public awareness as well as landscape and nature conservation programmes were mentioned across stakeholder groups as important types of recognition. Nature conservation in protected areas and communicating the value of such areas to visitors has become a successful tool for increasing awareness of biodiversity roles. Raising awareness is also an important means for increasing consumer awareness and support of locally produced milk, cheese, meat and other products, as well as promoting rural development for livestock herding communities (De Groot *et al*., 2010). This would also add to human well-being through integrating animal genetic diversity in the conservation of grassland ecosystems by creating higher landscape, cultural and educational values of agro-ecosystems, and acknowledging the roles of genetic diversity for ecosystem functioning and sustainable use of available natural resources. Promotion of eco-tourism and facilitation of learning, as well as capacity development (Wilkes *et al*., 2006) can also help address the improvement of production in such systems.

7.2. Knowledge management, stakeholder inclusion and policies

7.2.1. Knowledge gaps/management and research

The importance of this study was often noted by the respondents in the communication about the Global Survey. Knowledge and data gaps are indicated by the fact that in 22, 10 and 8 percent of all responses regarding, respectively, regulating, supporting and cultural services, respondents were unable to provide available sources of evidence. However, many of the respondents mentioned that despite the fact that often no "hard" data is currently available on the indicators of change in ecosystem services affecting the state of grasslands, livestock owners and local communities are aware of the diversity of roles that their animals play in ecosystem functioning and how they contribute to the socio-cultural well-being of communities and add value to landscapes.

A review of literature on ecosystem services in grasslands found that habitat services and biodiversity were the focus of most studies, followed by cultural services linked to landscapes, and a range of regulating services, mostly climate regulation (Rodríguez-Ortega *et al*., 2014). Their review did not include breed related information. Finding information about the roles of breeds in the provision of ecosystem services is not an easy task. In the European Survey, about half of the respondents indicated that scientific evidence is available, and there was more evidence for Cases B, where often the (re)introduction of livestock for the provision of ecosystem services was accompanied by research projects. Such evidence is often available in national language scientific journals or in the journals of the national breed associations, and therefore not easily internationally accessible. This lack of accessible research is more pronounced in developing countries where even traditional knowledge may not be well documented.

Research on ecosystem services provided by livestock also suffers from lack of interaction between academic disciplines. Studies describing breeds generally provide information on the main uses of animals, such as transportation and work power or as a source of income, as well as on their roles in peoples' lives, or their genetic characteristics, but lack description of their roles in the provision of ecosystem services, including direct and indirect effects on ecosystem functioning (see also Rodríguez-Ortega *et al*., 2014). By contrast, studies on different aspects of grazing cover the impact of grazing management on vegetation composition and health or its potential for improving soil nutrient balance, but do not consider breed effects on the provision of ecosystem services.

In Finland, research into ecosystem services incorporates agriculture and livestock farming. Rudebjer (2007) suggested that also African universities and colleges need to integrate and mainstream agro-biodiversity in higher education programmes to increase environmental awareness in the agricultural sector, including the role of people in the management of genetic resources.

Additionally, there are many conceptual and methodological constraints yet to overcome. Several methods are used to describe biodiversity; they include species richness and species abundance, classifications of the various hierarchical levels of biodiversity, evolutionary diversity assessed by neutral markers, functional or adaptive trait diversity assessed by single-nucleotide polymorphisms. Molecular genetic methods are applied globally across taxa and countries. Other methods cover interaction webs (pollinator, trophic, host-parasite), or composite measures. The biodiversity indicators most frequently used for global assessments are red lists of threatened species, mostly charismatic or key species, species abundance or ecosystem extent. The relative Mean Species Abundance (MSA) is an indicator of naturalness or biodiversity intactness used as a proxy for the CBD indicator on trends in species abundance. It is defined as the mean abundance of original species relative to their abundance in pristine, undisturbed ecosystems. An area with an MSA of 100% means a biodiversity that is similar to the natural situation. An MSA of 0% means a completely degraded ecosystem, with no original species remaining (CBD, 2010; Leadley *et al*., 2010; Alkemade *et al*., 2013). Although the MSA indicator is helpful in many ways, it does not capture all taxa or the inherently dynamic nature of ecosystems, especially in co-evolved grasslands.

Because of the complexity of interrelated aspects, which each require different methods of measurement, Salles (2011) noted that "*approaches to build a value concept on objective information, such as energy-equivalent or ecological footprint, have not really succeeded to produce a usable framework that links conceptually empirical observations with normative social objectives*". Thus, effects of land use changes on greenhouse gas emissions are easier to assess than on biodiversity, which hampers the assessment of trade-offs between the two (Teillard *et al*., 2014).

Extensive grassland based livestock production systems, which provide most regulating and supporting ecosystem services, are often blamed for high GHG emissions per kg of livestock product because livestock productivity is low and methane emissions from enteric fermentation are high due to low digestible feed. However, Moran and Wall (2011) indicate that there are huge differences between farms in terms of animal productivity and environmental performance, which indicates the difficulties in generalizing the results of GHG accounting. Integration of new research methods provides an opportunity for reflection of the value of ecosystem services provided in livestock systems. The negative effects of livestock on climate change appear less dramatic if multi-functionality and cultural roles are integrated into the evaluation of emissions from livestock production. For example the carbon footprints of milk and meat depend on many assumptions and the boundaries of the analysis (Wolf *et al*., 2010; Ripoll-Bosch *et al*., 2013; Weiler *et al*., 2014). Weiler *et al*. (2014) recommended that life-cycle assessments (LCAs) of smallholder systems should account for the multi-functionality provided by livestock in those systems. GHG emissions per kg of milk were half that of food allocation if a livelihood allocation method was applied. A recent study conducted in four different regions of extensive dairy systems showed that the system in Mali can be more efficient than intensive systems on Reunion Island, and just as efficient as semi-intensive systems in western France (Vigne, 2014).

Studies on ecosystem services should be transparent about which specific services are considered, and how these are measured and valued (De Groot *et al*., 2002). Thus research and documentation is one of the main tasks, and a first step in ensuring the provision of all types of ecosystem services by species and breeds.

7.2.2. Stakeholder inclusion

Knowledge management, and the way research is done which underpins political decision-making, raises issues about stakeholder inclusion. The integration of several agricultural and environment sectors requires the cooperation among stakeholders. For example the National Research Action Plan in Zambia in the 1990s described problems of lack of attention to the interaction among crops, livestock, and agro-forestry (Bezuneh *et al*., 1995). Gandini *et al*. (2010) suggested that information on local cattle farming should not be restricted to the farming society, but should be extended to the whole society in order to increase general knowledge, awareness and appreciation of the work done by keepers of local breeds. According to Barać *et al*. (2011), nowadays, traditional livestock keepers are not only shepherds, but also the keepers of common knowledge, skills and heritage. Pastoralists in Australia hold status both as owners and managers of a large proportion of grazing landscapes; they must be considered key partners in managing the landscapes for conservation outcomes and not only for production purposes (Kearney *et al*., 2012). Collaboration between livestock and wildlife communities thus needs to be strengthened (Joost *et al*., 2011). This requires both conceptual frameworks that allow stakeholders to communicate with each other, and participative methodologies that are inclusive and fair.

Box 18. Responses from County Reports – Stakeholder inclusion

Czech Republic: Holistic support means the close collaboration among all relevant stakeholders of various backgrounds and interests within the livestock sector. The holistic view should thus reflect the concerns of breeding, agricultural and food production, conservation programmes for at-risk breeds, the issues of sustainable utilisation, soil, water and air protection and other environmental and even maybe social aspects. At this level, the cooperation among institutions is not sufficient, which could be due to limited administration and financial capacities but also a lack of political will.

Germany: Generally, common interests and goals are facilitating the collaboration between the different sectors of biological diversity. The main constraints is the partly disconnection of the sectors in training and education (completely different lessons for animal breeding, plant breeding, forestry, aquatic resources management and environmental protection) and consequently in the remaining separation in animal, plant, forest, plant and environmental protection sectors. If animal genetic resources management shall play an effective role in environmental protection measures, research is needed to show how animal genetic resources management could do that.

Senegal: With the pastoral code under development, measures could be better specified with indicators to assess results and management of wildlife. There are measures to improve wildlife habitat, and thus indirectly wildlife itself. These measures include reforestation, development of ponds and social measures to encourage local people (education, health, income generation through ecotourism etc.). To remove the constraints, there is a need to build bridges between different policies / sectoral programmes, consider complementary legislation, sensitize and involve all stakeholders in genetic resource management, develop a market for the valuation of ecosystem services, strengthen the financial capacity of stakeholders and define a national strategy to put in place the identified management models.

Survey responses provide examples of successful integration of grazing in landscape management programmes. In an example from Austria, support and profit from sheep grazing in mountain regions involves a number of different stakeholders. A ski resort and a tourism company provided additional funds and labour, since they were profiting from the increased landscape value of the mountains with grazing sheep. Another important issue in the acknowledgment of ecosystem services provided by traditional breeds is the presence of a dialogue and cooperation among all stakeholders beyond just nature conservationists and livestock keepers. In several African countries, pastoralists are becoming recognized in economic development planning (e.g. economic policies in Kenya, Ethiopia and Tanzania), and the need for special attention to drylands development is also captured (Notenbaert *et al*., 2012). Dong *et al*. (2009) describe how policy-makers should be aware of the importance of the involvement of local farmers and the incorporation of traditional livestock management systems into planning and decision-making processes.

The many challenges that grassland-based livestock production systems are facing often become the reason for abandonment of traditional grazing activities. It is therefore important to identify the potential threats and inform stakeholders about the unique roles that indigenous breeds play in grassland ecosystems. There is a clear need for further research, training programmes for livestock keepers, improving financial support mechanisms and raising public awareness of opportunities which could ensure the conservation and sustainable use of both habitats and local breeds.

7.2.3. Policies

In view of complex emerging challenges such as biodiversity decline and climate change, there are both challenges stemming from and opportunities for improvements in policies, institutions and agricultural research. Especially under the conditions of climate change, it is important to increase grazing systems' capacity of adapting to new situations. Barnes *et al*. (2012), for example, suggested that active interventions to adapt to climate change in Namibia should include shifts in livestock and rangeland policy, encouragement of the adoption of more flexible and resilient systems, and the inclusion of efforts to make rangeland use less rigid. Adaptation to climate change in Namibia should include the promotion of natural resource-based land uses, so that the implementation of the Namibia Rangeland Management Policy could provide incentives to invest in sound rangeland management and support traditional breeds.

Case studies on tenure and rangeland governance were compiled by Herrera *et al*. (2014). Hesse and Thebaud (2006) argue that while the pastoral laws adopted in several West African countries during the 1990s and early 2000s include a number of positive features, their complicated bureaucratic mechanisms, and sectoral approaches that artificially separate different aspects of local livelihood systems, have the potential to disempower pastoralist communities and undermine their grazing-based livelihood strategies. Legal frameworks and policies in West Africa have, nonetheless, been described as "more favourable" to pastoralism than those in East Africa, which reportedly tend to favour sedentarization (Inter-Résaux, 2012) and are often based on negative stereotypes and out-dated conceptions of pastoralism. With the extra-budgetary support from the Federal Government of Germany, FAO is establishing a pastoralist knowledge hub to improve the capacity of pastoralist livestock keepers and facilitate communication among them.

Policies are required to manage societal trade-offs. Due to the livestock sector's vast spatial extent, one of the main challenge policy-makers face relates to finding the best ways to combine livestock production with other land uses, especially nature conservation goals. It is interesting to note that the total share of protected areas, which amounted to 13% of total land in 2010, increased faster between 1990 and 2010 than that of agricultural areas (3% vs. 0.8%), while agricultural and livestock production continued to increase (FAOSTAT), indicating increased land use and production efficiency.

Most ecosystems have been converted to human-dominated systems to some extent or are otherwise affected by human activity (MA, 2005a). Biodiversity is a continuum in which the wild and fully domesticated can only be told apart at the extremes of the spectrum. Typically, grassland ecosystems have co-evolved with human practices and contain a mix of interlinked wild and domesticated elements. In many cases, landscapes are dominated by so-called "socio-ecological mosaics", patchworks of intensively managed to unmanaged areas within the same landscape. The conversion of natural areas into cropland and pasture, and the effects resulting from agricultural activities are among the main causes of biodiversity loss, depletion of critical ecosystem services and increased levels of greenhouse gases (MA, 2005a; FAO, 2006a; EEA, 2009; PBL, 2012).

The increasing anthropogenic land use and the subsequently limited space for biodiversity led to the land-sparing versus land-sharing debate that aims at identifying the best strategy for biodiversity and ecosystem services outcomes (Fischer *et al*., 2008). The outcomes of land-sparing and land sharing will be different, as lower yields in lower input farming systems result in a trade-off between land for agriculture and land for maintaining wild biodiversity. These indirect land-use changes often result in a displacement of effects on biodiversity if demand for food remains stable. Intensification of livestock production, with its shift from pastoral systems requiring vast grazing areas to mixed and landless production systems, implies that more food crops will be used to feed livestock. However, the crop areas required are relatively small compared to the grasslands abandoned (Teillard *et al*., 2014).

Fully sustainable agricultural production and production intensification can only be achieved if biodiversity management is included in production management. There is increasing consensus that by incorporating the challenges of land-sparing versus land-sharing in spatial planning at landscape level, synergies can be found and trade-offs be dealt with (Bignal and McCracken, 2000; Tscharntke *et al*., 2005; Scherr and McNeely, 2008; Brussaard *et al*., 2010; PBL, 2012; Garnett *et al*., 2013). High external input, high-yielding land-sparing technologies could be located in favourable environments with fertile soils that are well suited to agricultural production, or areas that have been converted to cropland since long. Low external input, relatively low productive, ecologically oriented land-sharing technologies and approaches could be used in less-favoured areas, areas with environmental restrictions or highly valued ecosystems (Bullock *et al*., 2011). The latter production systems can contribute especially to ecosystem services other than provisioning ones. The Global Survey, the Country Reports and the review of the literature reveal that the relationship between livestock systems, and species and breeds with biodiversity conservation goals is rather more complex. Especially extensive free-ranging livestock systems can be net-facilitative to biodiversity conservation, as well as to the delivery of all types of ecosystem services.

The Country Reports and Survey responses indicate that societies' perceptions and valuations of ecosystem services depend on the value system of stakeholder groups and change in the course of economic and societal development. More than half of Survey respondents from temperate, montane and Mediterranean type grasslands fully recognized the provision of ecosystem services by grazing livestock (Figure 32); a large share of these respondents came from Europe, where increasingly affluent societies attribute high importance to cultural and regulating services. Similarly, the Country Reports found that countries reporting upward trends of perceived cultural roles and values of traditional breeds were developed countries, whereas countries mentioning downward trends were developing countries (FAO, 2014a). Within societies, the recognition of ecosystem services depends on livelihood and lifestyle, among other factors. In Spain for example, farmers and citizens viewed pasture-based mountain livestock differently: farmers gave more importance to regulating and provisioning ecosystem services that are related to their farming activity and local circumstances; whereas citizens gave more importance to cultural services, showing more global concerns (Bernués *et al*., 2013).

Other studies on "ecosystem services bundles" show that the valuation of specific services within the bundle by different stakeholders depends on age, gender, level of formal education or local knowledge, spatial proximity to the ecosystem service and lifestyle (e.g., rural or urban) (Raudsepp-Hearne *et al*., 2010; Martín-López *et al*., 2012; Bernués *et al*., 2014). Studies from Spain and Canada show that there are trade-offs between provisioning services on the one hand and regulating, supporting and most cultural services on the other, but that multifunctional landscapes are better at producing regulating services and have more option values (Raudsepp-Hearne *et al*., 2010; Martín-López *et al*., 2012). For policy makers from developing countries this implies, that although food security and provisioning services are an immediate priority, the other ecosystem services have to be maintained because of future demands of more affluent, urbanized citizens.

Under conditions of high uncertainty and when ecosystem change is irreversible or only reversible at prohibitive cost, the critical natural resources should be treated as exhaustible and policy should be guided by “safe-minimum-standard” and “precautionary approach” principles (TEEB, 2010; Salles, 2011; Silvis and van der Heide, 2013). Under such conditions, monetary valuation is limited.

With regard to the genetic resources services provided by breeds, the erosion of domestic animal diversity due to natural causes and human activity will become a serious concern if current production levels are to be sustained and future market demands are to be addressed. From an economic point of view, the aim of conserving culturally significant breeds, often with specific adaptation traits, is regularly perceived to be contrary to the objective of increasing livestock productivity. Apart from increasing awareness of farmers and promoting of the roles of indigenous breeds among consumers and policy-makers, one measure to mitigate against such erosion is through incentives for agro-biodiversity conservation services that may increase private benefits from utilizing local animal genetic resources on farms through voluntary reward mechanisms, with a view to sustain on-farm conservation (Narloch, 2011; Narloch *et al*., 2011; Krishna *et al*., 2013).

Most countries in the European Union use agri-environment payments to encourage livestock keepers to conserve traditional at-risk breeds. A regional assessment found that in many regions of Europe, especially Eastern Europe, breeds at-risk are kept as long as the farmers receive the financial support as otherwise it is not profitable for the livestock keepers to manage animals with lower production potential (Bernués *et al*., 2011; Kompan and Klopcik, 2013). In many non-European countries, on the other hand, there is often no policy framework supporting the roles of breeds in the provision of ecosystem services, and no breed specific support policies or payments for breed conservation exist. However, in the Country Reports for the second State of the World report, 52 countries out of 128 indicated that incentives for keeping at-risk breeds were provided either by the private or public sector. Barbados, Bhutan, Bolivia, Costa Rica, Indonesia, Lesotho, Mexico, Peru, Thailand and South Africa mentioned financial and technical support measures for breeding, breed conservation and/or environmental services (FAO, 2014a, Table 15), although the support measures were often not specified.

Table 15. Responses from Country Reports of developing countries on support methods for* in situ *breed conservation and ecosystem services

	Africa	Asia	Latin America & the Caribbean	Total
Breed conservation	21	9	6	36
technical support	10	4	3	17
technical/institutional support	3		1	4
technical support/restocking	3			3
technical support/infrastructure	2			2
technical/financial support	2	4	2	8
marketing support	1	1		2
Ecosystem services			6	6
technical support			1	1
technical/financial support			1	1
financial support			4	4
Total	**21**	**9**	**12**	**42**

Note: Question 22: Please indicate which of the following methods are used as elements of in situ conservation programmes in your country and which operators are managing them.

In most cases, technical support was related to breeding activities, and institutional support to breeders and producers organizations. Restocking was mentioned by three countries (Djibouti, Togo, Guinea), with funds from foreign donors, including from FAO. Senegal mentioned that payments for ecosystem services have so far been explored for the forestry sector only, but should be considered in the review of the national biodiversity conservation strategy. Thailand and Ethiopia mentioned the promotion of niche markets to sustain breed conservation efforts. Support to ecosystem services only was merely provided in Latin America.

7.3. Incentives for ecosystem services

Significant non-market and/or public good values associated with livestock breed conservation have often been ignored in economic analysis. Such values relate to the use of livestock breeds in supporting agro-ecosystem resilience, in maintaining evolutionary processes and global option values, as well as maintaining landscapes, socio-cultural traditions, local identities and traditional knowledge (Mendelsohn, 2003; Smale and Drucker, 2007; Narloch *et al*., 2011). Increasing awareness of the fact that the market has failed to fully account for the value of a wide range of livestock functions (Drucker and Anderson, 2004), particularly those associated with public goods, has led to conservation interventions with a view to maintaining these values for society (Martin-Collado *et al*., 2014).

Under the current competitive conditions for agricultural products derived from provisioning services, livestock keepers cannot be expected or even afford to sufficiently maintain regulating and supporting ecosystem services, as well as the conservation of breeds, at socially desirable levels. Under such conditions, the development of incentive mechanisms to reward farmers for producing significant public good values may be justified (Martin-Collado *et al*., 2014).

Incentives cover a wide range of motives and measures, from personal to social incentives, and they can be moral/spiritual or material/financial. The respondents of both surveys and the Country Reports also identified non-monetary recognition, market based incentives and public financial support as opportunities, giving them roughly equal weight. Non-monetary incentives such as research and education have been described in chapter 7.2.

Studies have been undertaken to assess the economic value of pastoralism (Hatfield and Davies, 2006; Rodriguez, 2008) and the value of temperate grasslands (Heidenreich, 2009) - topics related to this study. Both find that few country case studies exist, and that global understanding of the total economic value of the goods and services provided by these systems is virtually non-existent. This lack of understanding will continue to threaten the long-term ecological viability of these systems. A recent study, combining socio-cultural and economic valuation methods was able to assess the total economic value (TEV) for pastoral agro-ecosystems in Mediterranean mountains (Bernués *et al*., 2014).

Proper assessment of the full range of functions provided by livestock, as expressed in terms of their TEV, can support decision-making in livestock conservation and sustainable use (Drucker *et al*., 2001). Improved understanding of the TEV of the ecosystem services provided by livestock species and breeds and the relative weights of the different components can be used to help determine which kinds of interventions and incentive mechanisms might be most appropriate for ensuring their long-term survival (Martin-Collado *et al*., 2014).

7.3.1. Markets

Mainstreaming biodiversity within sectors is more likely to succeed if and where biodiversity is aligned with the core interests of stakeholders in main value chains and where negative environmental externalities are reflected in prices of provisioning services or some cultural services (e.g. ecotourism; see chapter 5.3). Policies, as well as collaborations with the private sector, scientists, landscape managers and other stakeholders provide opportunities for better awareness raising on the topic and attracting other stakeholders in recognizing the environmental roles of local breeds, and ensuring their conservation and sustainable management. A Survey response from Portugal, for example, noted that intensification of agricultural systems and of livestock management contributed to a strong decrease in extensive pig production. As a result, indigenous pig breeds represented only about 2 percent of total pig population in 1986. However, a recent increase in consumer interest and support of agriculture has resulted in new opportunities. The Alentejo pig breed, in particular, is highly valued and associated with a traditional production system where animals graze under oak or chestnut trees. Decision-makers can influence the creation of tools supporting such traditional farming systems and their produce by promoting and adding value to such products.

In addition, increased uptake of certification schemes that address biodiversity issues may be options for producers, although most current certification schemes are less concerned with breed diversity than wild biodiversity. Certifying livestock products according to their origin represents potential for adding value and raising awareness not only of the importance of the conservation of traditional livestock breeds, but also their environmental roles. Examples are provided in LPP *et al*. (2010). Improved product differentiation and marketing may be necessary for high-quality traditional produce to reach a wider consumer clientele. It is expected that besides origin, other attributes such as animal welfare, grass-fed or “organic” will increasingly become part of labels and other voluntary standards (Hoffmann and Baumung, 2013; Hoffmann *et al*., 2014).

Through labels and specific marketing chains, farmers can valorize the originality of a product and breed linked to a traditional production system, increasing farming profitability. Niche markets generally emerge in more affluent economies and targeting them normally requires a relatively high level of organization among producers, a reliable marketing chain, well-organized marketing campaigns and, for some types of product, an effective legal framework. Their significance in developing countries has therefore been limited so far.

Box 19. Voluntary schemes for grass-fed meat

In **Australia**, a voluntary beef quality standard scheme assesses, among other quality traits, the tropical breed content of the carcass as a measure to guarantee the most accurate eating quality grade (MLA, no year.) For producers already accredited under the Meat Standards Australia, the Cattle Council of Australia initiated the Pasture-Fed Certification Assurance System in Queensland. Now distributed through retailers, producers get premium prices and having grass-fed beef labelled as such will help it be recognised as a clean and green product. A range of labels sell beefs of specific breeds raised on pasture (ABC Rural 2014; Meat and Livestock Australia; http://primecutmeats.com.au/beef)

The programmes of Uruguay and the United States of America do not make reference to specific breeds but do cater for consumer concerns.

The main components of the voluntary Certified Natural Meat Program of **Uruguay** are food safety, traceability, animal welfare, and environmental sustainability; it includes claims on grass fed and open range keeping http://www.choicesmagazine.org/2007-1/foodchains/2007-1-03.htm (Fox *et al*., 2005).

In the **United States of America**, a national voluntary standard for grass/forage fed marketing claims exist (USDA, 2007); however, without references to breeds. In 2014, a USDA Grass Fed Program for Small and Very Small Producers was launched, which includes a less costly application and verification process tailored to meet the needs of small-scale producers. The certification will add value to their products, creating new economic opportunities and keeping small-scale producers competitive in today’s marketplace (USDA, 2014).

In the European Survey, 28 breeds were found to be connected to 22 protected designations of origin (PDO) or protected geographical indications (PGI). Although other regions have less geographic indications than Europe,[17] the legal survey for the Second Report (FAO 2014a) received responses from other countries. Brazil’s survey response indicates that by the end of 2013 geographical indications had been granted to two types of cheese (Canatra and Serro) and one type of beef (Pampa Gaúcho). The potential use of Pantaneiro cattle for organic beef production had been discussed earlier (Sereno, 2002). The survey response from Nepal mentions the labels established for pashmina scarfs and for carpets made from the wool of native sheep breeds. Köhler-Rollefson *et al*. (2013) showed that it is possible to describe the options which can ensure that the camel herding system can exist as an integral part of a National Park, attract visitors interested in ecological tourism and provide a diversity of camel products such as camel milk, camel milk soap and camel dung paper.

In addition to initiatives targeting niche markets which are more or less external to the local area, it is quite common for local consumers to have long-standing preferences for food products supplied by the traditional breeds of the local area and to be willing to pay a premium price for these products. Where this is the case, the breeds in question provide their keepers with relatively high-value products to sell and also contribute to the local culinary culture.

[17] http://ec.europa.eu/agriculture/quality/schemes/index_en.htm

Box 20. Responses from Country Reports - Marketing

The Plurinational State of Bolivia: Management policies run during the last decade on animal genetic resources have had an important component of environmental protection. The programs that were developed to implement policies, for example in the management of Llamas and Alpacas, have supported the development of alternative technologies that complemented the traditional knowledge – ancient in some cases – through technological innovation. Its main results translate into supplying organic products that, compared to conventional ones, achieve higher prices and have contributed in positioning the meat, fiber and leather among urban consumers. Today, you can get Llama meat in the main hotels in the city of La Paz. The supply of Llama meat and fibre grew to 17 thousand tons, whereas the fibre supply stagnated at 960 tons produced mainly by Alpacas. Regarding its population growth, the National Agricultural Survey (ENA 2008) reveals that the annual growth of Llamas and Alpacas in the last decade was 2.52 percent, an acceptable value considering that the extraction rate increased from 12 to 16 percent during the same period of time.

Cyprus: An emerging trend for healthy, organic, lactose-free and other specific products is apparent and is expected to be even more prominent in the next decade. This may benefit the management of animal genetic resources in low-input production.

Bulgaria: Within the Swiss-Bulgarian project "Linking Nature Protection and Sustainable Rural Development" 12 projects for on-farm processing and direct sales are in preparation for sheep, goat, buffalo and cattle milk and organic honey.

Luxemburg: To ensure long-term protection of endangered breeds, more opportunities such as promotion of products (milk, meat, wool) from these breeds (identification and visualization by a PDO, PGI, introduction of a label "transfrontalières" for local breeds in danger) should be created.

Slovenia is a country of a great biodiversity as well as for its tradition and customs, which is also reflected in the variety of local and traditional agricultural products and foodstuffs. Promotion of niche marketing is increased for autochthonous breeds (local markets). In Slovenia there are four quality schemes, which enable the protection of agricultural products and foodstuffs: Protected designation of origin, Protected geographical indication, Traditional speciality guaranteed and Designation of higher quality. Today there are 19 Slovenian products protected at EU level. Further activities for enhancing value through ties to geographical origin or cultural significance are necessary. One factor that can be important for marketing is the uniqueness of the product, particularly with respect to its place of origin (regional foods with strong historical identities).

The **United States of America** reported that the establishment of new local or regionally based markets will create opportunities for product branding that supports the use of at-risk breeds. It also notes that in the case of layer chickens, consumer demand for “naturally” grown meat has affected the development of new lines, enhancing diversity at commercial level, and that, in some states, animal-welfare regulations may lead to the development of new genetic lines for cage-free production.

Kenya: Indigenous chickens are increasingly being raised for organic poultry meat production.

Choice experiment surveys on the threatened Alistana-Sanabresa cattle breed in Spain (Martin-Collado *et al*., 2014) and two threatened cattle breeds (Modicana and Maremmana) in Italy (Zander *et al*., 2013) revealed direct use values of only around 20 percent of the breeds’ TEV. This implies that niche product markets aimed at enhancing the private good values associated with conservation could form elements of a conservation and use strategy for these breeds, but will not generate sufficient funding for achieving the conservation goals alone. However, in both studies, cultural (esp. landscape maintenance), existence and future option values of the breeds make up more than 80 percent of their TEVs. Both studies indicate that respondents were willing to pay around three to four times as much for the existence and cultural values than direct use values. As most respondents support breed conservation, their stated willingness-to-pay appears to justify public support (Zander *et al*., 2013; Martin-Collado *et al*., 2014).

7.3.2. Payments for ecosystem services

Although the use of market opportunities can stimulate livestock keepers to invest in regulating, supporting and habitat services, complementary measures are frequently needed to reward indirect use and non-use values. Payments for environmental or ecosystem services (PES) are frequently mentioned as potential tool for improving environmental outcomes (Fischer *et al*., 2008). Payments for ecosystem services are one component of payments for environmental services.

Due to the public or common good characteristics of regulating and habitat services and their spatial and temporal dimensions, the provider of a service may differ from the beneficiary of that service. If the value for the provider is lower than for the beneficiary, incentives may be needed to allow the provider to continue the provision of the service in question. If farmers are not paid for the environmental services they deliver, they suffer displacement by other economic activities. The price in a PES mechanism is expected to reflect the opportunity costs to farmers of fulfilling some ecological or cultural target or limiting their ecosystem use (Salles, 2011). The emerging literature on payment for environmental or ecosystem services (e.g. Pagiola *et al*., 2004; Lipper *et al*., 2006; FAO, 2007a; Silvestri *et al*., 2012) and especially on incentives and payments for agro-biodiversity services (FAO, 1999; Pascual and Perrings 2007; Narloch, 2011; Narloch *et al*., 2011; Krishna *et al*., 2013) deals with this topic. In many cases, secure property rights are essential for the continuation of ecosystem services in which people are involved (e.g. Ostrom, 1990; Bromley, 1998; Anderson and Centonze 2006). Incentive policies and PES schemes may lead to new property regimes (Salles, 2011).

Grasslands provide ecosystem services estimated to be worth US$18.4 trillion per year (Costanza *et al*., 2014; Table 16), a value that has increased about 13-fold since 1997. Alkemade *et al*. (2013) estimated that between 10 and 60 percent of grasslands globally are grazed; this can be higher locally, as for example more than 85 percent of publicly owned lands in the Western United States of America are grazed (Follett and Reed, 2010). Thus livestock is a contributor to a large share of this value.

Table 16. Area, unit values and aggregate global flow value of ecosystem services

Biome	**Area (e6 ha)**	**Unit value (USD/ha/yr)**		**Aggregate global flow value (e12 2007 USD/yr)**	**Percent of total value of terrestrial biomes**
		1997	**2007**		
Grassland/rangeland	4418	321	4166	18.4	25
Cropland	1627	126	5567	9.3	12

Source: Costanza et al., 2014.

An earlier study (Costanza *et al*., 1997) estimated that nutrient cycling provides 51 percent of the total value of all ecosystem services each year; the 1997 value of 17 trillion US$ may be up to eight times higher when expressed in 2007 US$ (De Groot *et al*., 2012; Costanza *et al*., 2014). Assuming that 25 percent of cropland in developing countries is prepared with DAP (Table 11), and that manure is applied on 50 percent of cropland in developing countries at very low rates and on another 10 percent at sufficient rates, livestock also contributes significantly to both ecosystem services arising from croplands and to nutrient cycling.

According to Bernués *et al*. (2011), grassland based livestock farming systems can satisfy societal demands for public goods or ethical concerns about food production and are less vulnerable to market changes. Many of today’s grassland areas offer a potential for nature conservation and rehabilitation, and C-sequestration. For the sustainable use of such areas and the improved livelihoods of their managers, the potential for the introduction of PES needs to be explored. As mentioned earlier, there are often co-benefits in terms of improved livestock production or increasing the value of livestock production (Dutilly-Diane *et al*., 2007; Milne and Niesten 2009; Silvestri *et al*., 2012).

Table 17. Monetary values for ecosystem services in most important grazing areas (values in Int.$/ha/year, 2007 price levels)

	Provisioning	**Regulating**	**Habitat**	**Cultural**	**Total**	**Min.-Max.**
Grassland	1305	159	1214	139	2871	124-5930
Woodland	253	51	1277	7	1588	1373-2188

Source: De Groot et al., 2012.

In grasslands and woodlands, provisioning services are estimated to account only for 45 and 16 percent of the TEV (Table 17). A recent paper calculated the TEV of mountain agro-pastoral systems based on socio-cultural and economic valuation, at a local scale. In this study, both farmers and citizens clearly recognized cultural services (particularly the aesthetic and recreational values of the landscape), supporting services (biodiversity maintenance) and some regulating services (particularly fire risk prevention). The TEV of the systems was three times the current value of support by agro-environmental policies (Bernués *et al*., 2014).

A review was recently completed of 50 payments for environmental services schemes in grazing lands from developed and developing countries[18] (ADB, 2014). The largest number of schemes targeted multiple or unspecified services, focusing on overcoming negative externalities, as well as increasing provision of positive externalities. Biodiversity was the most frequently specified service, followed by C-sequestration and water regulation. Most schemes were process-oriented and paid land users for performing certain land management practices, which are assumed to lead to positive environmental outcomes, and very few of the schemes were outcome oriented, rewarding the delivery of ecosystem services according to measured indicators. Research on outcomes is poor, and even in the USA with its well-established research, the environmental benefits of these programmes could not be accurately assessed (Briske, 2011). Of the 50 schemes reviewed, about half received funding from national state budgets and one-third received funds from sub-national government budgets. About 40 percent of schemes involve private payments for environmental services in one way or the other.

However, few PES schemes specifically involve livestock keepers (Silvestri *et al*., 2012). Herrero *et al*. (2013) note that opportunities for grazing and mixed crop–livestock systems to access PES schemes are mainly driven by carbon markets schemes, but also include biodiversity, water conservation and hydrological services. In grazing systems, restoration of degraded lands, sustainable grazing land management and biodiversity conservation also present potential for carbon sequestration. PES could contribute to promoting ecological and socio-economic sustainability in grazing systems and hence the maintenance of the associated breeds.

Box 21. Responses from Country Reports – Incentive schemes

Costa Rica: Costa Rica has increased its forest cover to 52 percent and most of the owners of land, conservation of forest and silvopastoral systems are farmers. 40 000 hectares silvopastoral, 60 000 hectares in agroforestry systems and 400 000 hectares of forest are on cattle farms. They are the largest contribution after conservation areas. Silvopastoral systems are supported by payments for environmental services that pay US$ 1.40 per tree planted in livestock farms, either in pasture or hedges, up to 3600 trees per producer. This project is funded through the Program of Payment for Environmental Services (PPSA), the National Forestry Financing Fund (FONAFIFO). Systems on-farm tree planting have established biological corridors, which has increased the feline population and birds in the country, leading to a better balance in ecosystems.

Ireland: The Rural Environmental Protection Scheme (REPS) and Agri-Environment Options Scheme (AEOS) have provided an opportunity for farmers to adopt a number of measures aimed at the conservation of animal genetic resources coupled with the implementation of agri-environmental measures on their lands.

Finally, PES schemes' success depends critically on secure tenure and clear property rights over ecosystem components (land, water and biodiversity). Even if the reality of PES is usually very far from an efficient market, implementing PES schemes implies to some extent designing new property rights. New property rights may even create new responsibilities and appropriate incentives (Salles, 2011). Most PES programmes are location specific and difficult to scale up. For most PES programmes, the income generated from the environmental benefit will remain small compared with the income from livestock production (FAO, 2007a). Also the ADB (2014) review concluded that in many developing countries, market imperfections, land tenure issues and broader development needs of land users may make PES challenging, and PES may be less relevant than more general investments in production systems and livelihoods.

[18] Australia, Brazil, Canada, China, Colombia, Costa Rica, Ecuador, France, Germany, India, Kenya, Mexico, Mongolia, Nicaragua, Paraguay, Portugal, Romania, South Africa, Sweden, Tanzania, The Netherlands, Zimbabwe

8. International measures favouring the acknowledgment of the roles of breeds and their keepers in the provision of ecosystem services

The analysis presented in this study shows that a large share of the world's locally adapted ruminant breeds are kept by small-scale livestock keepers and pastoralists in arid climates or in grazing systems where the vegetation is of poor nutritive value, and that these systems provide the majority of livestock's regulating, supporting, habitat and cultural ecosystem services. These are also areas where poverty rates are high and where livestock keepers' livelihoods depend on the continued provision of diverse ecosystem services by their animals and the surrounding ecosystems. Intervention measures thus need to take into consideration the close links between ecosystem services and the livelihoods of small-scale livestock keepers and pastoralists. Labelling and the development of specific marketing chains for products and services such as ecotourism can allow livestock keepers to valorize the originality of products linked to traditional production systems, regions or breeds, and thereby increase the profitability of their activities. However, other forms of recognizing, encouraging and safeguarding the roles of livestock keepers in the delivery of ecosystem services have complimentary roles to play.

Strategic Priority 5 (Promote agro-ecosystems approaches to the management of animal genetic resources) and Strategic Priority 8 (Establish or strengthen *in situ* conservation programmes) of the Global Plan of Action highlight links between breeds and agro-ecosystems. In the words of the Global Plan of Action, agro-ecosystems "*depend on human management practices, knowledge systems, cultural norms, values and beliefs, as well as social relationships and livelihood strategies*". Strategic Priority 8 recognizes that encouraging the development and implementation of *in situ* conservation measures "*may include support, either directly for breeders of threatened breeds, or measures to support agricultural production systems that manage areas of importance to breeds at risk, the encouragement of breed organizations, community-based conservation organizations, non-governmental organizations and other actors to participate in conservation efforts provided that such support or such measures are consistent with existing international agreements*".[19]

In the county reports prepared for the second report on *The State of the World's Animal Genetic Resources* (FAO, 2014a), 33 percent of countries reported policies, plans or strategies for animal genetic resources management that specifically address the provision of regulating and/or supporting services. Many responses also noted that the implementation of these measures has improved livestock-keeping practices, leading to diversification of production, as well as increases in the productivity and the economic viability of breed populations.

The United Nations Permanent Forum on Indigenous Issues, at its Seventh Session,[20] welcomed the adoption of the Global Plan of Action. It requested FAO to give priority to the Global Plan of Action's Strategic Priority 6 (Support indigenous and local production systems and associated knowledge systems of importance to the maintenance and sustainable use of animal genetic resources) and to further develop relevant approaches, including rights-based approaches and payment for services that support the custodianship of local breeds by indigenous peoples. It also recommended the provision of technical and financial support to protect and nurture indigenous peoples' natural resource management, environmentally friendly technologies, biodiversity and cultural diversity, and low-carbon, traditional livelihoods (e.g. pastoralism). FAO's Policy on Indigenous and Tribal Peoples (FAO, 2010c) recognizes the role of indigenous peoples' cultures in sustaining the natural resource base that underpins food security.

UNESCO, since 2007, has taken a more proactive approach towards including pastoralist sites in the World Heritage List, mainly under its cultural landscapes sub-category (Lerin, 2010). The list currently includes 15 sites that are directly and indirectly associated with pastoralism.[21,22]

[19] Global Plan of Action for Animal Genetic Resources, Action 2, Strategic Priority 8.
[20] E/2008/43, E/C.19/2008/13 paragraph 85.
[21] http://whc.unesco.org/en/list/
[22] http://www.worldheritagesite.org/tags/tag926.html

The Conference of Parties (COP) to the Convention on Biological Diversity (CBD) has recognized the important role of indigenous and local communities in achieving the three objectives of the Convention and acknowledged the many important contributions of indigenous and local communities, including farmers and livestock keepers, to the conservation and sustainable use of agricultural biodiversity. In 2008, the COP invited "*Parties, other Governments, relevant international and regional organizations, local and indigenous communities, farmers, pastoralists and plant and animal breeders to promote, support and remove constraints to on-farm and in situ conservation of agricultural biodiversity through participatory decision-making processes in order to enhance the conservation of plant and animal genetic resources, related components of biodiversity in agricultural ecosystems, and related ecosystem functions*" (Decision IX/1). In 2010, Parties to the CBD adopted the Strategic Plan for Biodiversity 2011–2020, including Aichi Biodiversity Targets (CBD, 2010). FAO contributes to the implementation of several targets under the Strategic Plan for Biodiversity 2011-2020 through its new Strategic Framework and Medium Term Plan. In particular, FAO will provide leadership on the implementation of Target 13 (By 2020, the genetic diversity of cultivated plants and farmed and domesticated animals and of wild relatives, including other socio-economically as well as culturally valuable species, is maintained, and strategies have been developed and implemented for minimizing genetic erosion and safeguarding their genetic diversity) with the provision of indicators developed under the Commission on Genetic Resources for Food and Agriculture. FAO will also contribute to Target 7 (By 2020 areas under agriculture, aquaculture and forestry are managed sustainably, ensuring conservation of biodiversity) and Target 14 (By 2020, ecosystems that provide essential services, including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable).

In Decision X/2, the development of positive incentives is included under Strategic Goal A (*Address the underlying causes of biodiversity loss by mainstreaming biodiversity across government and society*) of the Strategic Plan for Biodiversity 2011-2020 (CBD, 2010), especially Aichi Target 3 (By 2020, at the latest, incentives, including subsidies, harmful to biodiversity are eliminated, phased out or reformed in order to minimize or avoid negative impacts, and positive incentives for the conservation and sustainable use of biodiversity are developed and applied, consistent and in harmony with the Convention and other relevant international obligations, taking into account national socio economic conditions).

In general, the use and management of agro-ecosystems by humans will depend critically on existing policy and incentive frameworks at local, national and international levels. The Global Survey and the Country Reports (FAO, 2014a, 2014e) indicate that countries have made steps to improve the management of ecosystems and locally adapted breeds. Among regions, for example, the European Union's Biodiversity Strategy towards 2020 (EC, 2011) aims at reversing biodiversity loss and speeding up the EU's transition towards a resource efficient and green economy. The African Union Interafrican Bureau for Animal Resources's Strategic Plan 2014 – 2017 (AU-IBAR, 2013), under Programme 2 (Animal Resource Production Systems and Ecosystem Management), includes the sustainable utilization, management and conservation of animal resources and their ecosystems, and aims to effectively exploit opportunities for animal resources to bring livelihood benefits through payments for ecological services. At global level, the post-2015 global development agenda will contain a number of sustainable development goals likely to target poverty eradication, food security, genetic resources, biodiversity conservation and sustainable agriculture, as well as sustainable consumption and production.

At the Rio+20 Conference in 2012, a Ten-Year Framework of Programmes on Sustainable Consumption and Production was adopted to enhance international cooperation to accelerate the shift towards sustainable consumption and production in both developed and developing countries (United Nations 2012). Food systems are a priority area of interest. The Sustainable Food Systems Programme (SFSP), established by FAO and UNEP in 2011, with the support of the Government of Switzerland, catalyses, through the Agrifood Task Force[23], partnerships among United Nations agencies, other international agencies, governments, industry and civil society, whose activities can promote the necessary transition of food systems to sustainability. The overall objective of the SFSP is to add value by bringing together various initiatives and workstreams, inside of FAO and with partners, to build capacity for the uptake of more sustainable consumption and production practices across food systems, as well as develop new multi-stakeholder engagement to build synergies and cooperation towards mutual objectives.

On the production side, innovative approaches such as PES or C-sequestration schemes are already employed worldwide and offer opportunities to mainstream the value of nature within the agricultural sector. On the consumption side, labelling schemes provide opportunities to strengthen product identity and advertise quality. However, direct use values obtainable in marketing schemes may not cover the breeds' total economic values.

Many of today's marginal areas, in which locally adapted breeds thrive, offer potential for nature rehabilitation and conservation. FAO (2007a) has concluded that if farmers are to provide a better mix of ecosystem services, better incentives will be required. In order to promote the sustainable use of ecosystems and improve the livelihoods of the people that manage these, the potential for introducing payment for environmental services (PES) could be explored. PES could contribute to promoting ecological and socio-economic sustainability in grazing systems and hence the maintenance of the associated breeds. For most PES programmes, the income generated from the provision of environmental benefits will remain small compared to that generated from livestock production. However, improved rangeland management also leads to improved livestock productivity. Options for increasing carbon sequestration and biodiversity management through better grazing management could therefore be explored. The roles of specific breeds in such measures would need to be considered, as would the potential for integrated approaches to soil carbon sequestration, livelihood objectives, conservation of wild biodiversity and sustainable use of animal genetic resources (CBD, 2009).

Institutional problems such as land-use rights and secure access to resources need to be solved to enable the diverse and often marginalized livestock keepers to partake in decision-making and develop and adopt or maintain sustainable rangeland management practices. The African Union's Policy Framework for Pastoralism in Africa (African Union, 2013) notes positive trends in pro-pastoral policies and legislation in Africa, but recognizes that major challenges remain. Appropriate legislation – accompanied by institutional and operational measures – is recognized as an essential component of efforts to improve pastoral policies. Specifically, it is recognized that there is a need to secure "*access to rangelands for pastoralists through supportive land tenure policies and legislation, and further development of regional policies to enable regional movements and livestock trade*".

The Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security (Voluntary Guidelines) (FAO, 2012d) are an important component of efforts to improve resource access for livestock keepers. They aim to promote secure tenure rights and equitable access to land and forests, as a means of eradicating hunger and poverty, supporting sustainable development and enhancing the environment. They make specific references to pastoralists, who maintain a wide range of highly adapted breeds, but whose breeds and sustainable management practices are threatened by a lack of functioning institutions, socio-political instability and poor livestock-sector policies (FAO, 2009b). According to the Voluntary Guidelines, states and other parties should contribute to the understanding of transboundary tenure issues affecting communities, such as those related to rangelands or seasonal migration routes of pastoralists that lie across international boundaries.[24] A technical guide on implementing the Voluntary Guidelines in

[23] The Agrofood Task Force on SCP comprises representatives of States (Barbados, Brazil, China, Costa Rica, Ghana, India, Indonesia, Kazakhstan, Morocco, Netherlands, New Zeeland, Switzerland, UK, South Africa, USA), UN Agencies and Programmes (FAO, IFAD, UNCTAD, UNEP, UNIDO), the European Commission, civil society organizations (WWF, IUCN, ISEAL, World Farmers' Organization), and international business organizations representing 325 firms (SAI, CropLife International) as well as the European SCP Round Table.
[24] Voluntary Guidelines, paragraph 22.2 (http://www.fao.org/docrep/016/i2801e/i2801e.pdf).

pastoral rangelands is being prepared. It should do justice to the full range of tenure arrangements in pastoral rangelands in different regions of the world, including those in industrialized countries.

The Committee for Food Security (CFS), in its Forty-first Session, requested the High Level Panel of Experts to undertake a study on “Sustainable agricultural development for food security and nutrition, including the role of livestock” to be presented to the CFS Plenary in 2016 and a study on “Sustainable forestry for food security and nutrition” to be presented to the CFS Plenary in 2017. Both studies offer opportunities to highlight the breadth of ecosystem services provided by livestock.

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Annex 1. Questionnaire of the global survey on the roles of animal genetic resources in providing ecosystem services in grasslands

GENERAL INFORMATION

1. Please indicate the country of your case study.

____

2. Please indicate the livestock species (cattle, sheep, goat, horse, buffalo, chicken, etc.) If other, please specify.

____

3. Please provide the name(s) of the livestock breed(s) involved.

____

4. Please select one of the two following cases.

- Case A: the breed(s) has/have been historically present in the grazing area
- Case B: the breed(s) has/have been introduced into the area specifically for use in grazing management to provide one or more ecosystem services

Please provide further information or comments

____

GRAZING AREA

5. Please indicate the location of the grazing area.

If it has a recognized name (e.g. the name of a national park or a range of mountains) please provide this name. If possible please provide geographic coordinates. Otherwise, please describe where the grazing area is located (e.g. specify that it is located between particular villages or towns or geographical features such as rivers).

____

6. Please indicate the size of the grazing area.

- Under 1 km² (<10 ha)
- 1-10 km² (10-100 ha)
- 10-50 km² (100-5000 ha)
- 50-100 km² (5000-10000 ha)
- Larger than 100 km² (>10000 ha)
- If you know the exact size, please, in addition, specify it in km² _______________________

7. Please indicate the ecosystem type and the characteristic vegetation of the grazing area.

- Temperate grasslands, savannas and shrublands (e.g. meadow, steppe, heathland)
- Tropical and subtropical grasslands, savannas and shrublands (e.g. cerrado, bushveld)
- Flooded grasslands and savannas (e.g. wet meadow, salt marsh)
- Montane grassland and shrublands (e.g. alpine and subalpine meadows)
- Mediterranean shrublands (e.g. matorral, maquis)
- Deserts and xeric shrublands (e.g. sagebrush steppe)
- Tundra (dominating vegetation consisting of shrubs, sedges, mosses, lichens)
- Other (please specify in the text box)
- Please provide further information on the main vegetation types of the grazing area.
- ____

PROTECTED AREA TYPE

8. Is the grazing area under any kind of protected status?

- Yes
- No

- Please add a comment if, for example, there are plans to expand existing protected area(s) in the region so that they will include the grazing area.

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9. Please indicate the type of protected area.

According to the International Union for Conservation of Nature, there are several international categories of protected areas. Please select the relevant category from the list. If a different classification is used in your country, please select the most appropriate according to the description. Please also name and describe the national type of protected area category in the text box.

- Category I: Strict Nature Reserve (strictly protected areas set aside to protect biodiversity and also possibly geological/geomorphical features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values)
- Category Ia: Wilderness area (large unmodified or slightly modified areas, retaining their natural character and influence without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition)
- Category II: National park (large natural or near natural areas set aside to protect largescale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible, spiritual, scientific, educational, recreational, and visitor opportunities)
- Category III: Nature monument or feature (specific natural monument, which can be a landform, seamount, submarine cavern, geological feature such as a cave or even a living feature such as an ancient grove. They are generally quite small protected areas and often have high visitor value)
- Category IV: Habitat/species management area (protect particular species or habitats and management of the area reflects this priority)
- Category V: Protected landscape/seascape (in a protected landscape interaction of people and nature over time has produced an area of distinct character with significant, ecological, biological, cultural and scenic values and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation)
- Category VI: Protected area with sustainable use of natural resources (areas which conserve ecosystems and habitats together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level nonindustrial use of natural resources, compatible with nature conservation, is seen as one of the main aims of the area)
- Name and description of national type of protected area.______________________________

LAND OWNERSHIP AND MANAGEMENT

10. Please indicate the type of land ownership that operates in the grazing area.

- Private ownership
- Communal ownership
- State ownership
- Other
- If other, please specify.______________________________________

11. Who manages the grazing area and what roles do they play (livestock and/or landscape management)?

- Local community/ethnic group
- Landscape manager/park manager
- Commercial farmers/livestock keepers
- Other
- Please indicate other stakeholders and provide further details.__________________________

12. How is the spatial distribution of animals managed?

- Herding
- Fencing
- Free roaming
- Other (please specify)
- Please provide further details. ___________________________________

GRAZING MANAGEMENT

13. Please indicate the size and characteristics of the herd(s) (e.g. species mix, breed, sex, age groups). _________________________________

14. Please indicate the average number of animals belonging to the breed(s) you are describing present in the grazing area over the course of the year. ___________________________________

15. Please indicate the number of weeks and stocking rates in each season of the year.

Add comments on the livestock management in each season (supplementary feeding, confinement, indoors, shoeing, etc.).

- Spring: __________________________________
- Summer: _________________________________
- Autumn: _________________________________
- Winter: __________________________________

If these seasons are not applicable in the location where the grazing area is situated, please provide the information on the local seasons and the stocking rates and types of livestock management practiced in each.

SUPPORTING ECOSYSTEM SERVICES

Supporting services (e.g. primary production, habitat provision, nutrient cycling) are essential to the functioning of ecosystems. Supporting services do not directly affect human well-being, but are important for the provision of all other ecosystem services. Please indicate how the livestock population you are describing affects the provision of supporting ecosystem services in the grazing area.

16. Is there evidence that the livestock population you are describing affects the provision of supporting ecosystem services in the grazing area?

Please indicate the impact that the livestock have on the provision of each of the following ecosystem services.

- Habitat provision (e.g. abundance of rare plant, insect, bird or animal species influenced by grazing)
- Impact (very negative, negative, neutral, positive, very positive, no data)
- Nutrient cycling (e.g. use of manure for grassland or crop production)
- Impact (very negative, negative, neutral, positive, very positive, no data)
- Support of primary production (e.g. improving vegetation growth/cover)
- Impact (very negative, negative, neutral, positive, very positive, no data)
- Other (please specify) ____
- Impact

Please provide references and comments. ____________________________________

REGULATING ECOSYSTEM SERVICES

Regulating services are services obtained from regulation of ecosystem processes. Some regulating services can also be regarded as supporting services (e.g. nutrient regulation, support of nutrient cycling). Indicate how the livestock population you are describing affects the provision of regulating services in the grazing area.

17. Is there evidence that the livestock population you are describing affects regulating ecosystem services in the grazing area?

Please indicate the impact that the livestock have on the provision of each of the following ecosystem services.

- Control of crop residues/eradication of weeds (e.g. removal of excessive biomass growth)
- Impact (very negative, negative, neutral, positive, very positive, no data)
- Climate/air quality regulation (e.g. carbon sequestration)
- Impact (very negative, negative, neutral, positive, very positive, no data)
- Erosion/avalanche control (e.g. regulation of the vegetative cover and stabilizing the soil)
- Impact (very negative, negative, neutral, positive, very positive, no data)
- Bush encroachment/fire control (e.g. removal of shrubby plants by grazing and browsing)
- Impact (very negative, negative, neutral, positive, very positive, no data)
- Pest and disease regulation (e.g. destruction of disease vectors or pest habitats)
- Impact (very negative, negative, neutral, positive, very positive, no data)
- Water quality/cycling regulation (e.g. helping to maintain permanent vegetation cover and thereby maintain water quality)
- Impact (very negative, negative, neutral, positive, very positive, no data)
- Seed dispersal (e.g. spreading seeds on coats or in guts)
- Impact (very negative, negative, neutral, positive, very positive, no data)
- Other (please specify in the text box)
- Impact (very negative, negative, neutral, positive, very positive, no data)

Please provide references and comments. ___________________________________

CULTURAL ECOSYSTEM SERVICES

Cultural services are non-material benefits that people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences. Please indicate how the livestock population you are describing affects the provision of cultural ecosystem services in the grazing area.

18. Is there evidence that the livestock population you are describing affects cultural ecosystem services in the grazing area?

Please indicate the impact that the livestock have on the provision of each of the following ecosystem services.

- Cultural, historic and natural heritage (e.g. presence of the breed in the grazing area helps to maintain elements of the local landscape and/or culture that are valued as part of the heritage of the region)
- Impact (very negative, negative, neutral, positive, very positive, no data)
- Knowledge systems and educational values (e.g. traditional knowledge about the breed and the grazing and sociocultural systems of the area)
- Impact (very negative, negative, neutral, positive, very positive, no data)
- Landscape values (values associated with the landscape as shaped by the animals themselves or as a part of the landscape, e.g. aesthetic values, sense of place, inspiration)
- Impact (very negative, negative, neutral, positive, very positive, no data)
- Recreational values (e.g. eco/agrotourism, sports, shows and other touristic activities involving specific animal breeds)
- Impact (very negative, negative, neutral, positive, very positive, no data)
- Spiritual and religious values (e.g. the role of the animals or their products in local customs such as religious ceremonies, funerals or weddings)
- Impact (very negative, negative, neutral, positive, very positive, no data)

- Other (please specify in the text box)
- Impact (very negative, negative, neutral, positive, very positive, no data)
- Please provide references and comments. ___________________________________

RECOGNITION OF ECOSYSTEM SERVICES

It is important that future actions by livestock keepers, breeders and conservationists account for the ecosystem services provided by livestock.

19. Is there any recognition of the ecosystem services provided by the livestock population you are describing?

Recognition of ecosystem services can take various forms: from public awareness and payments for ecosystem services to market support for products supplied by breeds that provide ecosystem services.

- Yes
- Some
- No

20. By whom are the ecosystem services recognized?

- Policy-makers
- Land managers
- Livestock owners
- Civil society, consumers, general public
- Other (please specify) or comment on above. _____________________________________

21. Please indicate which of the following forms of recognition exist.

Please select all that apply.

- Public awareness of the role of the livestock population in the supply of ecosystem services
- Payments/economic incentives based on ecosystem services Policies, strategies and actions that support the role of the livestock population in the supply of ecosystem services (e.g. improving infrastructure for herders in hard-to-reach grazing areas)
- Landscape management/nature conservation programmes based on the recognition of the ecosystem services
- Educational programmes
- Other (please specify) or comment on above. _______________________________

CHALLENGES AND OPPORTUNITIES FOR THE FUTURE

22. What constraints may prevent the livestock population you are describing from providing ecosystem services in the grazing area in the future?

Please select the three most important ones from the list below.

- Existing livestock management is not based on the recognition of the ecosystem services provided by the livestock
- Insecurity or conflicts that limit access to grazing land
- Loss of traditional links between livestock and the local community
- Lack of sufficient income generation from the livestock
- Absence of supporting policies/regulations
- Loss of knowledge on the management of the described livestock population
- Lack of research activities on the topic
- Social/political issues that affect livestock management

Threats to the traditional production environments of the livestock population caused by climatic or other environmental changes

Please describe any other constraints. ________________________________

23. What opportunities do you see for ensuring that ecosystem services provided by the livestock population are recognized and utilized?

Please select the three most important ones from the list below.

- Livestock breeding programmes targeting specific characteristics that are relevant to the provision of ecosystem services
- Nature conservation programmes
- Financial support/economic incentives
- Raising public awareness
- Introducing educational programmes for livestock keepers and/or breeders
- Ensuring recognition of ecosystem services among policy-makers
- Introducing/supporting research programmes on ecosystem services provided by animal genetic resources
- Please describe any other opportunities. ________________________________

Thank you for submitting the survey!

Annex 2. Results of the Global Survey on the roles of animal genetic resources in providing ecosystem services in grasslands

1. Methodology of the study and analysis of received responses

In preparation for this study, a questionnaire was designed and delivered to experts working in the field of animal genetic resources. Prior to the Global Survey, a pilot survey on the environmental benefits of breeds grazing within Europe in 2013, was jointly undertaken by FAO, the European Regional Focal Point for Animal Genetic Resources, the European Federation of Animal Science's Working Group on Animal Genetic Resources and the Universities of Wageningen and Milan (European Survey). The European Survey was distributed though the European Environmental Agency and various expert networks to a range of stakeholders, including National Coordinators for the Management of Animal Genetic Resources, relevant experts in governments, academic institutions and non-governmental organisations. It primarily addressed the environmental roles of animal genetic resources, especially supporting, regulating and habitat services; management of livestock; and the opportunities and challenges faced by breeds and stakeholders. The European Survey received 29 responses covering 57 breeds. Responses identified as sufficiently complete quantitatively were analysed together with the results of the Global Survey. Textual responses, predominantly in relation to the diversity of breeds of particular species, were also used for the qualitative analysis of the Global Survey.

Building on the experience with the European Survey, the Global Survey was distributed via FAO's Domestic Animal Diversity Network[1] (DAD-net) and various other expert networks. The respondents included relevant experts in governments, academic institutions and non-governmental organisations, and National Coordinators for the Management of Animal Genetic Resources. The design of the Global Survey pre-identified the most relevant ecosystem services and the indicators to measure changes in the state of each service. Examples were provided within the survey to assist respondents in identifying the ecosystem services delivered by the grazing areas within the remit of their knowledge and expertise (see Annex 1). The definition of "grazing area" included both single management units (e.g. a nature reserve under unified management or an individual farm) and a geographical area encompassing a number of management units (e.g. a mountain range containing a number of farms or a communal grazing area used by a number of livestock keepers). Respondents had to select the size of the area. To address the different geographical regions, main grassland ecosystem types were identified and examples provided. Protection and conservation status had to be specified for each grazing area. Respondents were provided with the descriptions of the categories under the protected area classification of the International Union for Conservation of Nature[2]. They were asked to select the most appropriate category if a different classification was used in their country. The respondents were also asked to define whether their response referred to breeds historically present in the grazing area (Case A) or breeds recently introduced for the provision of ecosystem services (Case B).

The respondents were asked to indicate the land tenure status of grazing areas (e.g. privately owned, communal or state-owned). The management of animals was assessed through the identification of the roles played in livestock and landscape management by local communities/ethnic groups, landscape managers/park managers, commercial farmers/livestock keepers. Spatial distribution of the animals was identified by selecting herding, fencing and free roaming options (or a combination of those) within the survey. Respondents provided, if possible, information on herd characteristics, such as species mix, breed mix, sex and age group mix, as well as an indication of the average number of animals belonging to each breed. Stocking rates and number of grazing weeks per season were also specified. Respondents were asked to evaluate the changes in the provision of specific ecosystem services, scoring them on a scale from "very negative" to "very positive", with the added response options "neutral" effect and "no data".

[1] https://dgroups.org/fao/dad-net
[2] http://www.iucn.org/about/work/programmes/gpap_home/gpap_quality/gpap_pacategories/

The survey then focused on the state of recognition of the ecosystem services: firstly, whether there was any recognition of the various roles of the livestock populations, and; secondly, which stakeholders were the agents of such recognition (e.g. policy-makers, land managers, livestock owners, or a group composed of civil society, consumers and general public). In two final questions, the respondents were asked about the barriers and constraints to the provision of ecosystem services by livestock populations, as well as about existing opportunities to recognize and stimulate the future delivery and utilization of ecosystem services.

The questionnaire, constructed using Adobe Livecycle Designer, was distributed via DAD-net and several contact lists of scientists and experts working in grassland-related fields. Submitted questionnaires were loaded in a Microsoft Excel spreadsheet. Questionnaires were checked for completeness, and respondents were contacted in order to gather missing information.

The 120 completed questionnaires were used for quantitative analysis in Microsoft Excel. The number of responses to individual questions was recorded to be able to distinguish between the number of responses to the survey as a whole and the number of responses to each individual question. Responses describing multiple breeds were analyzed qualitatively in order to avoid misinterpretation of individual breed effects. Since the questionnaire of the European Survey differed slightly from the Global Survey, the differing responses were used for qualitative analysis of the data, such as the identification of breed specific ecosystem services.

2. Overview of responses

2.1 Geographic distribution and general trends

A total of 120 responses were received from 47 countries[3], providing information on more than 150 breeds (several responses contained information on multiple breeds) (Figure 1). The majority of responses (53%) originated from the Asian, African and American regions. The remaining 47 percent of responses came from European countries. Most responses described livestock populations historically present in the grazing area (Case A). In Northern and Western Europe there were slightly more responses describing the roles of animal genetic resources introduced with the aim of providing specific ecosystem services (Case B).

The high proportion of responses from Europe is a result of the inclusion of the European Survey responses. In Europe, agri-environmental measures of the Common Agricultural Policy are a main tool for promoting grazing for the conservation of grassland ecosystems, supporting traditional grazing practices and nature conservation, as well as at-risk breeds. They raise the interest of farmers, researchers and policy-makers in better utilization of natural resources. Therefore, the level of European research and institutional support in those areas is relatively high. In contrast, ecosystem services are less embedded in the agricultural policies and research agendas of many non-European countries, although the main part of this study shows a trend of increasing awareness.

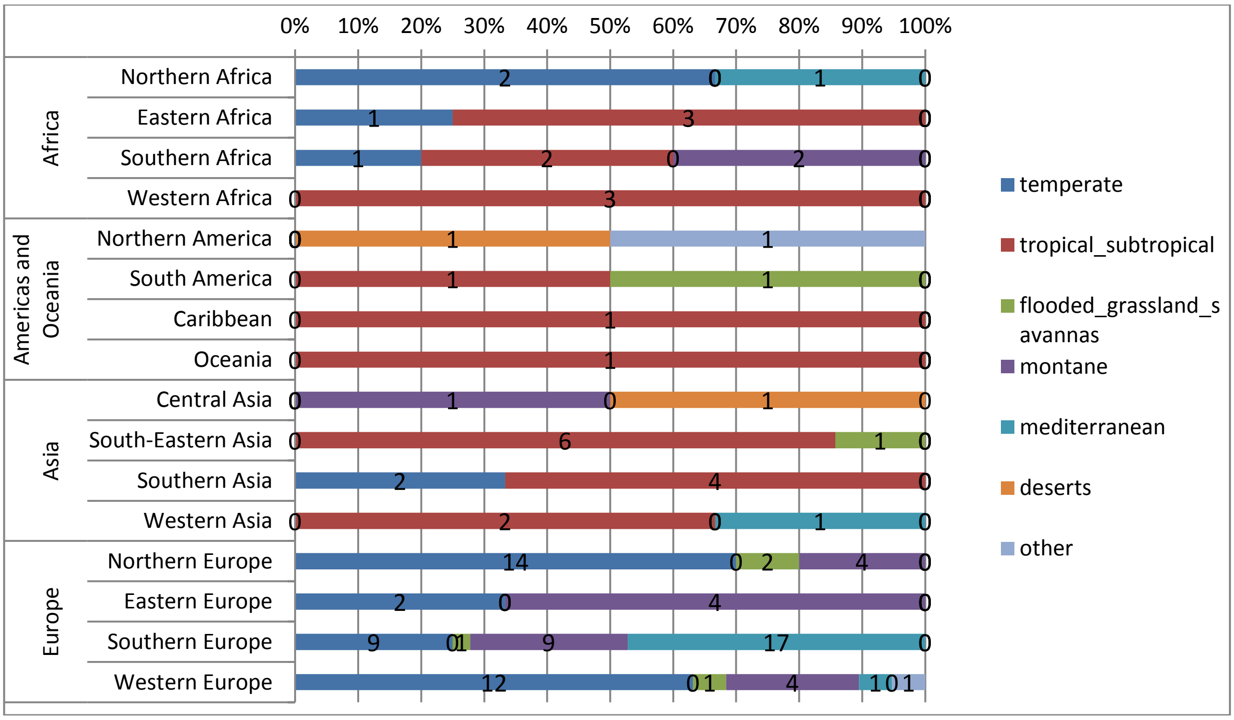
The distribution of responses across different grassland is presented in Figure 2. Temperate grasslands, reported in 35 percent of responses from countries on three out of four continents, formed the majority of responses from European countries. Montane grasslands (21%), tropical and subtropical (19%) and Mediterranean grasslands (17%), which are especially prevalent in Southern Europe, were covered to a lesser extent. Flooded savannas and grasslands, as well as steppes and deserts, were only occasionally covered in the responses.

[3] List of countries: Algeria, Austria, Bhutan, Brazil, Cook Islands, Croatia, Denmark, Egypt, Finland, France, Germany, Ghana, Iceland, Iran, India, Ireland, Israel, Italy, Jordan, Kenya, Kyrgyzstan, Mali, Martinique, Namibia, Nepal, Netherlands, Nigeria, Norway, Portugal, Russian Federation, Serbia, Slovakia, Slovenia, South Africa, Spain, Sri Lanka, Sweden, Switzerland, Tajikistan, Thailand, Tunisia, Ukraine, United Kingdom, United Republic of Tanzania, United States of America, Viet Nam, Zimbabwe

Figure 1. Geographic distribution of responses

Note: Numbers stand for total responses in each category.

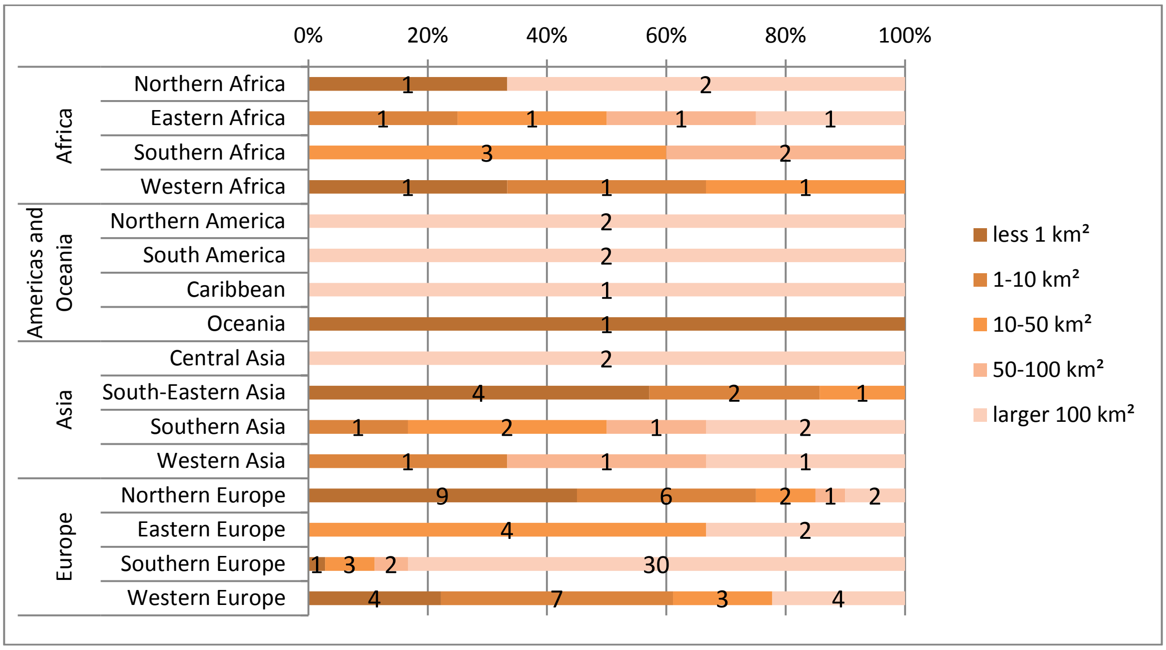
Figure 2. Geographic distribution of responses according to the grassland type



Note: Numbers stand for total responses in each category.

Figure 3 illustrates the distribution of grazing area sizes over the regions. In Southern Europe, Spain and Portugal specifically reported several livestock breeds grazing over large geographic regions in mountain ranges and natural parks (Case A). Predominantly small grazing areas were reported in Northern Europe. This proportion may be a reflection of the characteristic mosaic of small areas of grassland used for pasture that is found in the region, and may also be due to the relatively high share of Case B responses from Northern and Western Europe. The reported areas from the Americas and Central Asia were all larger than 100 km².

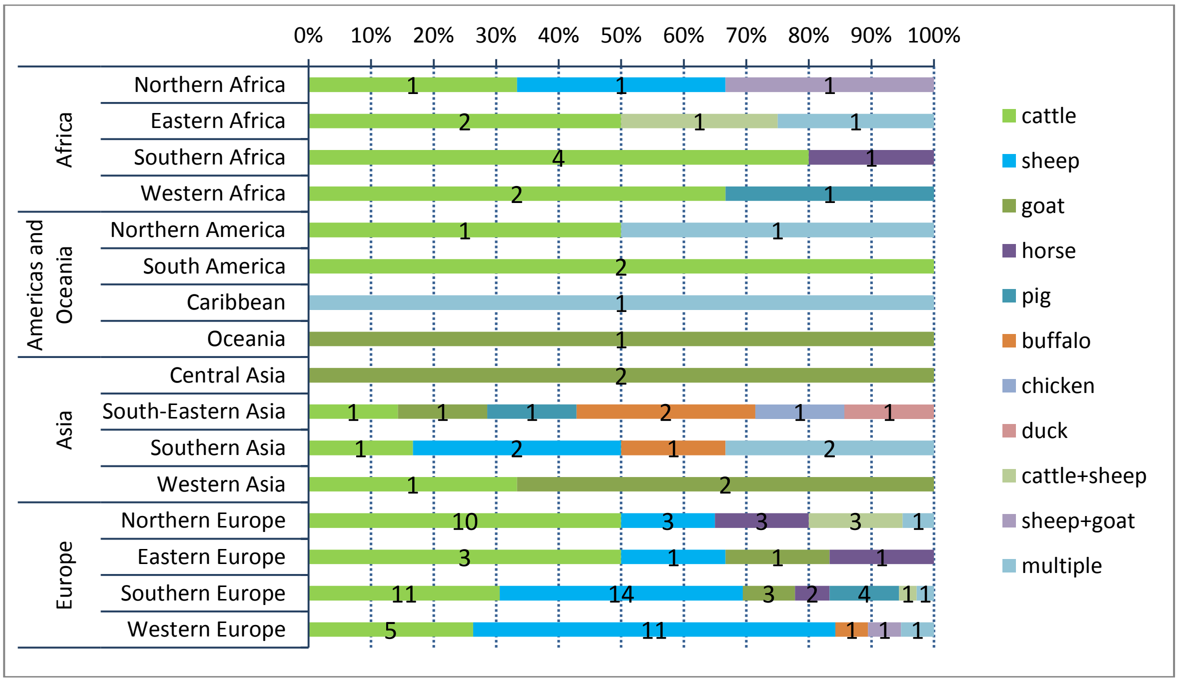
Figure 3. Geographic distribution of responses per size of livestock grazing area



Note: Numbers stand for total responses in each category.

Cattle and sheep were the most commonly described species by respondents at 37 percent and 27 percent, respectively (Figure 4). Several responses described joint grazing of one area by several species.In these cases, the breeds were representative for the specific grazing area or for a number of different sites in a specific geographical area. For example, Pantaneiro cattle and Pantaneiro horse breeds were described for the Pantanal region of Brazil. Four responses reported grazing by sheep and cattle followed by joint grazing by sheep and goats. Further responses reported pig, chicken, duck and water buffalo grazing.

Figure 4. Geographic distribution of responses according to livestock species



Note: Numbers stand for total responses in each category.

European countries provided the majority of responses in relation to sheep grazing. Asia provided more diverse responses in terms of described livestock species. In Europe, reports of cattle grazing were more prevalent in Northern and Eastern Europe, whilst in Western Europe sheep grazing was more frequently reported. Southern Europe reported an equal mix of sheep and cattle grazing examples.

Responses are further discussed disregarding the geographic distribution, in order to concentrate on the main characteristics and trends in provision of ecosystem services, their recognition, management aspects of livestock populations, as well as constraints to and opportunities for the delivery of ecosystem services by livestock species and breeds.

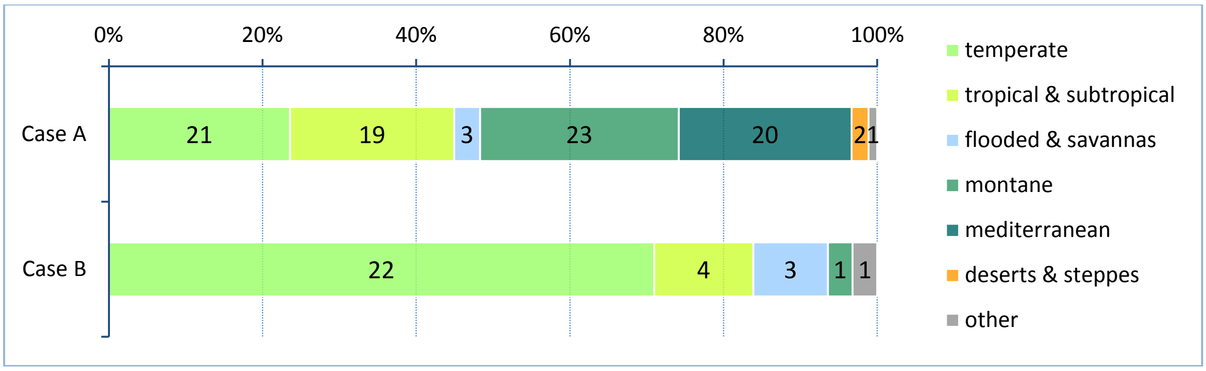
2.2 Characterization of the grazing areas

Respondents described grazing locations and provided information on the type of grassland, size of the area, protected status and type of the protected status, if available. The distribution of responses to each question was differentiated between Case A and Case B.

Grassland ecosystem types and extent of the grazing areas

The distribution of responses per grassland type in Case A and Case B (Figure 5) revealed that Cases A equally covered the main grassland types represented in the survey. The majority of Cases B responses on temperate grasslands originated from European countries.

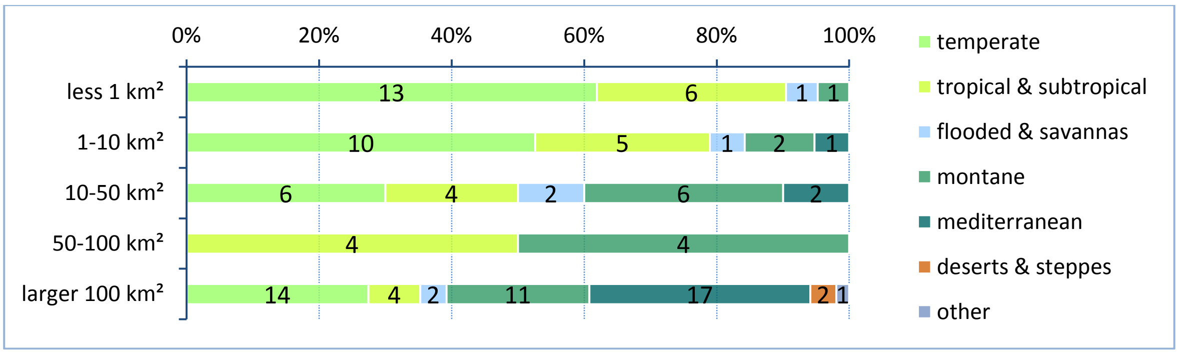
Figure 5. Responses in Case A and Case B per type of the grassland ecosystem



Note: Numbers stand for total responses in each category.

Looking in detail at the sizes of grazing areas described, the largest number of responses on vast grazing areas (>50 km²) were reported from Mediterranean, montane and tropical/subtropical grasslands (Figure 6). This indicates the differences in the use of the grazing lands and their accessibility. Smaller grazing areas (less than 10 km²) mostly occur in temperate and tropical/subtropical grasslands. In European countries, which dominate the responses for temperate grasslands, agricultural landscapes are characterized by high heterogeneity.

Figure 6. Size livestock grazing areas in different grassland types



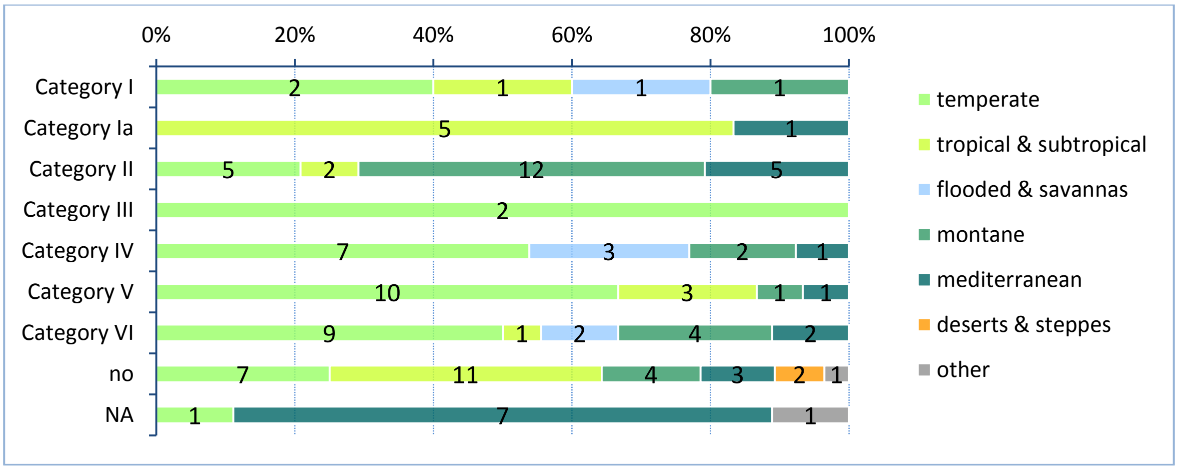
Note: Numbers stand for total responses in each category.

Large grazing areas in Mediterranean grasslands were reported from Portugal and Spain, where respondents noted that the grazing area extends over the whole territory of nature parks in both countries. However, the actual size of the specific pastures in use may well be smaller and animals may have to be moved between pastures. In such cases, where livestock populations are spread over larger geographical areas, which include nature parks, significant interactions between livestock and wildlife often occur.

Protected status

Protected areas are fundamental elements of many national and international conservation strategies, supported by governments and international institutions. Grazing areas reported as unprotected or with unknown protection status comprised 30 percent of all responses (Figure 7). Many responses reported that grazing lands were located within designated protected areas or were contained within larger protected areas. Most respondents were able to identify the protection status assigned to the described grazing area, according to the IUCN classification. The highest share of all grazing areas (40%) lay within IUCN categories IV, V and VI, followed by 21 percent in categories II and III, and 9 percent in strictly protected areas (IUCN I).

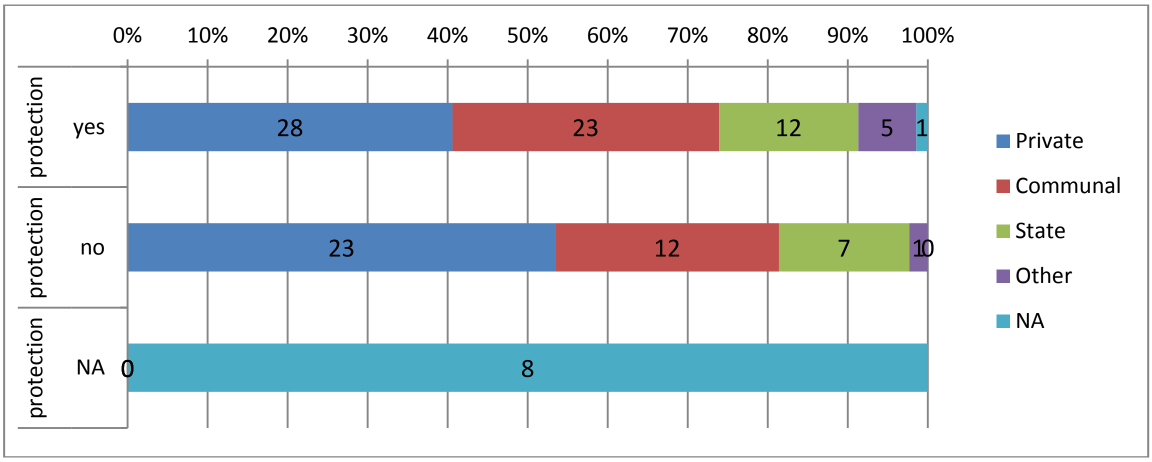
Figure 7. Protected areas in different grassland ecosystems



Note: Numbers stand for total responses in each category.

The fact that the majority of responses (70%) reported some kind of protected status indicates a current and future potential for integrating livestock grazing into protected are management, and finding synergies between nature conservation and grazing management goals. If animal movements are appropriately managed and regulations, including property regimes, fostering sustainable land management are in place, it is likely that overgrazing can be prevented and that extensive grazing can have a positive (facilitative) effect on the vegetation community, associated biodiversity, wildlife and other ecosystem services.

Figure 8. Protected areas by land ownership



Note: Numbers stand for total responses in each category.

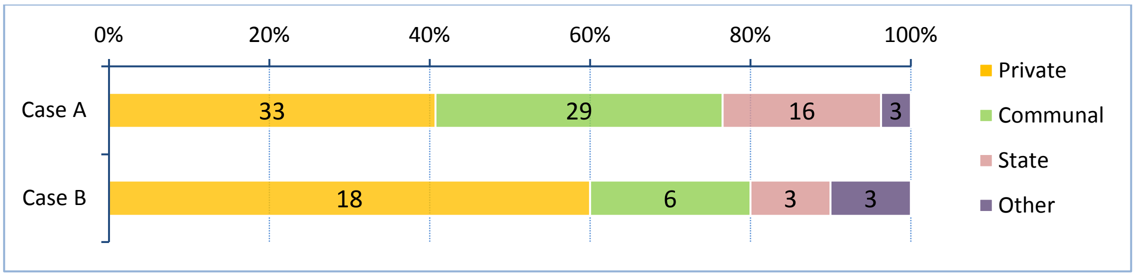
More than half of unprotected land was privately owned, whereas protected land was mostly privately and communally owned (Figure 8). The share of state-owned land was similar across the protection status.

Land ownership and management

The representation of responses on land ownership is presented in Figure 9 and varied according to the case type (A or B). Privately owned land constitutes 43 percent of all responses, followed by communal land (29%) and state-owned land (16%). Most of the grazing sites under Case B (60 %) were privately owned. Responses for Case A indicated significant communal grazing areas, across the regions, including in Asian and African countries where smallholder farmers and pastoralists graze their animals on communal lands. The reported cases of state-owned land often covered conditions where livestock keepers were allowed to graze their livestock in protected areas.

Among the reported instances of private land, areas larger than 100 km² made up 31 percent of the responses, followed by equal numbers (25% each) of very small (<1 km²) and medium (10-50 km²) lands. More than half of the communal land was larger than 100 km², whereas state land was relatively evenly distributed over the land size classes.

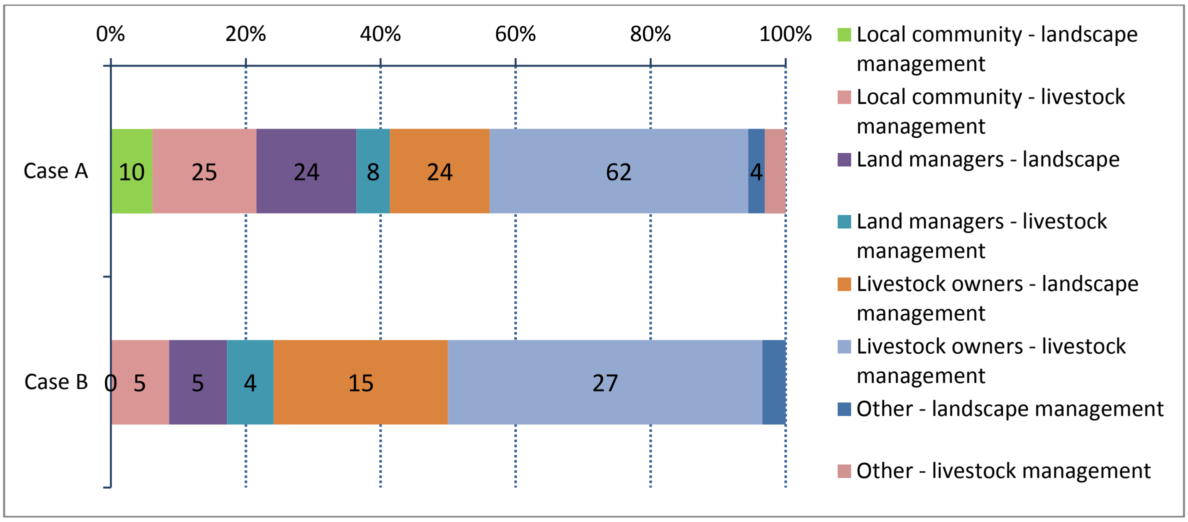
Figure 9. Representation of land ownership in Case A and Case B



Note: Numbers stand for total responses in each category.

Stakeholder roles in grazing area management were distributed as follows. In the responses, livestock owners perform both livestock (41%) and landscape management roles (18%) across both cases (Figure 10). Land managers performed landscape management (13%) rather than livestock management (5%) across both cases. Local communities performed livestock management in 14% of the responses, which indicates the importance of traditional livestock keeping. However, local communities were only indicated as landscape managers in 5% of all cases. This may partly be due to a lack of recognition of local communities' customary roles in landscape management.

Figure 10. Involvement of different stakeholders in management of livestock and landscape

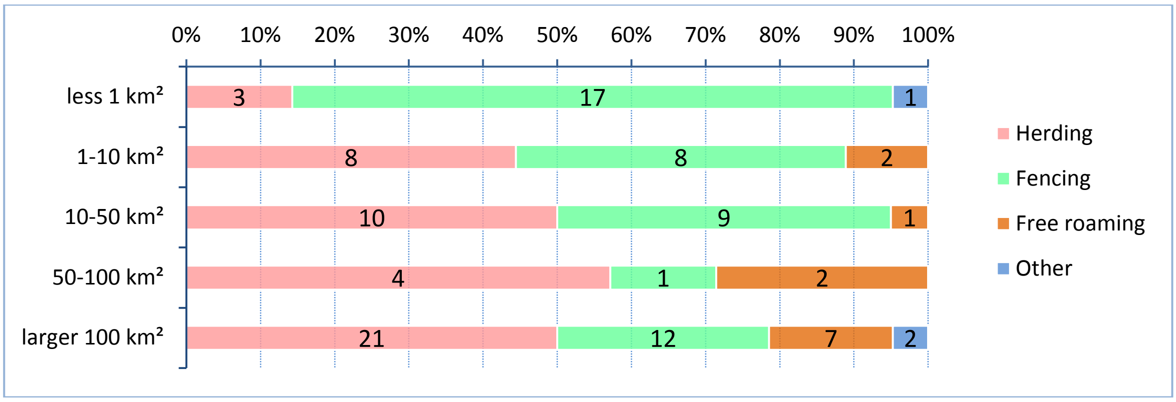


Note: Numbers stand for total responses in each category.

Area management and grazing management

Livestock management strategies varied greatly depending on the size of the area (Figure 11). Fencing and herding were the most frequently reported methods of animal management (43% and 42%, respectively), followed by free roaming (11%). Small grazing areas were mostly fenced, while in the grazing areas of 1-10 and 10-50 sqkm both fencing and herding were equally practiced. In larger (>50 km²) grazing areas, herding was reported as being most common and the frequency of free roaming was higher than in small grazing areas. This could be explained by the fact that the animals are rarely left totally alone; even when they are moving freely seasonally or during certain briefer periods, pasture rotation to less grazed areas is still managed by herders.

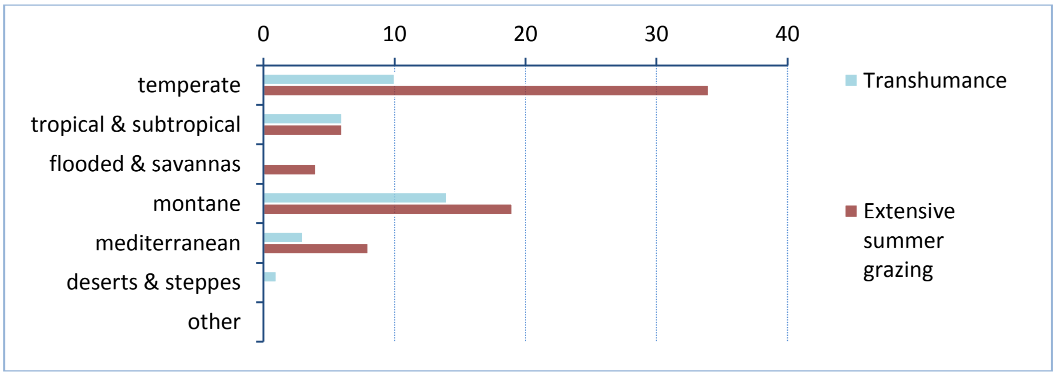
Figure 11. Land management in the grazing areas of different size



Note: Numbers stand for total responses in each category.

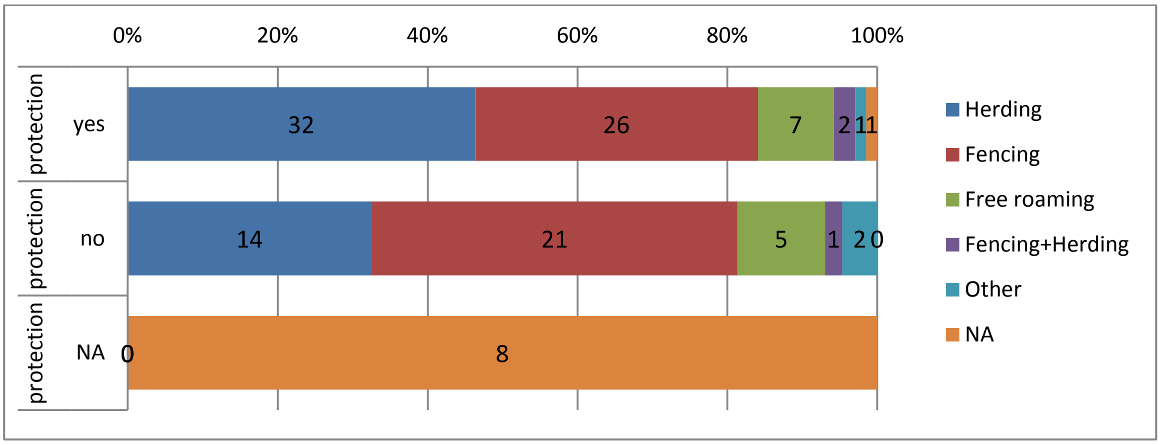
In montane, tropical/subtropical and temperate grasslands, many responses noted that livestock movement is typical for transhumant grazing (Figure 12). Many responses also mentioned explicitly that the animals are grazing on pastures during the summer periods only.

Figure 12. Transhumance and extensive summer grazing in different grassland types, number of responses



Herding is the most frequent livestock grazing management (46%) in protected areas, followed by fencing (38%). The order is reversed in non-protected areas, where fencing represents 49 percent and herding 32 percent (Figure 13). The frequency of free roaming is the same in protected and non-protected areas.

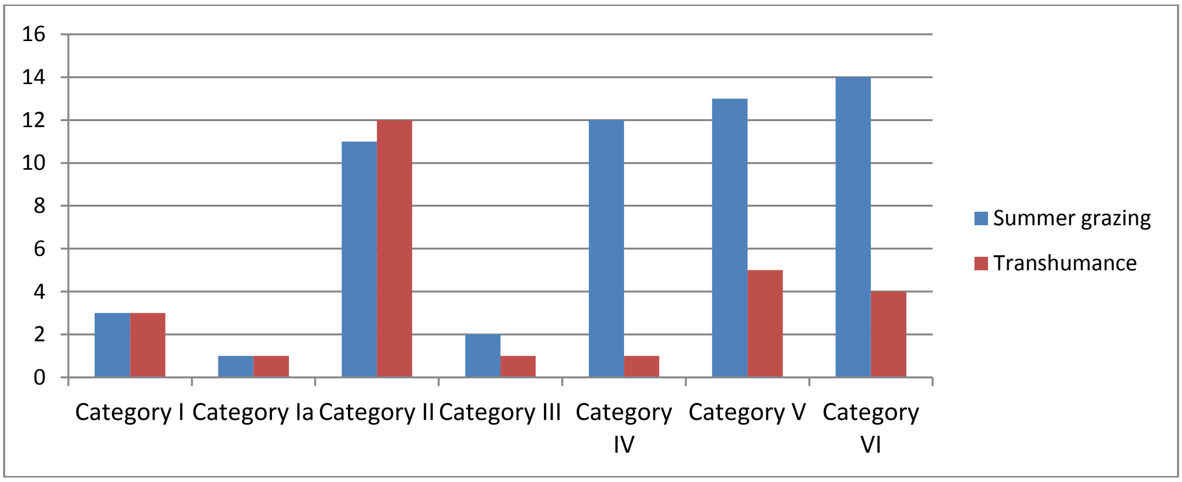
Figure 13. Grazing land protection level and grazing management



Note: Numbers stand for total responses in each category.

Transhumance was reported to be more frequent in national parks (IUCN Category II) than in protected landscapes and areas (IUCN Categories V & VI), whereas grazing during summer was similar across areas under IUCN Categories II, IV, V and VI (Figure 14).

Figure 14. Grazing land protection level and livestock mobility



Note: Numbers stand for total responses in each category.

Several grazing area management strategies were found to be linked to land ownership (Table 1). Herding was most frequently mentioned in combination with communal lands, and fencing on private lands, whilst other combinations of livestock management and land ownership did not reveal any relations.

Table 1. Combinations between land ownership and grazing area management

	Herding	Fencing	Free roaming	Fencing&Herding	Other
Private	12	32	4	2	1
Communal	24	6	4	0	1
Other	3	2	0	0	1
state	7	7	4	1	0

Note: Numbers stand for total responses in each category.

In conclusion, land ownership and the protected status of the grassland ecosystems, in both Case A and Case B, influenced the different strategies of livestock and land management, as well as the degree of livestock mobility. While many responses showed similarities in the combinations of livestock and area management, the initial conditions such as land ownership, protected status, location of the grazing site and other factors (e.g. infrastructure, traditional ways of farming and/or political situation in the region) are important to consider when evaluating and describing the roles of animal genetic resources in the provision of the ecosystem services.

2.3 Ecosystem services affected by grazing in grasslands

Livestock production plays a significant role in economies and people's livelihoods in many regions. Animal genetic resources were reported as affecting the socio-economic, cultural and environmental well-being of pastoralist societies in many responses. In addition to contributing to agricultural production, ecosystem services provided in grassland systems support biodiversity and are significant for long-term sustainable land and livestock management.

In addition to the options provided in the survey, respondents also provided comments on further roles and uses of traditional livestock breeds. For example, Cika cattle in Slovenia are adapted to the local grazing conditions (hilly and steep terrains), bred traditionally and valued for milk quality as well as for their contribution to the characteristic beauty of the landscape. Encouraging livestock owners to support Cika cattle breeding in connection with alpine dairy farming is considered important for the conservation of Slovenia's natural and cultural heritage.

In India, Kangayam cattle, Mayilambadi and Mecheri sheep breeds were reported to contribute to the regulation of the water table, to the habitat of the region, as well as the preservation of the local culture and the lifestyles of livestock keepers. The Korangadu pasturelands in the Southern Indian state of Tamil Nadu are co-dependent on the grazing of livestock of land-owning and landless livestock keepers. This system does not only provide income security to local livestock keepers, but also conserves domestic animal diversity and favourable environmental conditions in the region.

In Spain, the number of Churra Tensina sheep decreased due to the transition to cattle grazing. Thus, many areas have gone through a re-vegetation process. Traditionally open areas maintained by sheep grazing prevented bush encroachment, which has now led to succession, altering the nature and value of the landscape. Nowadays, forest is more abundant in the Pyrenees (Lasanta et al. 2006). In the Netherlands, the use of the traditional Drenthe Heath Sheep has been recognized by various stakeholders as a successful strategy to maintain open heathlands and to provide multiple ecosystem services (Box A1).

Box A1. The roles of Drenthe Heath Sheep in The Netherlands

- Maintaining the cultural and historical heath landscapes
- Keeping heathland open
- Providing high biodiversity values in heathlands
- Ensuring heathland mosaics after grazing period
- Ensuring slow adaptation of vegetation to new stadia

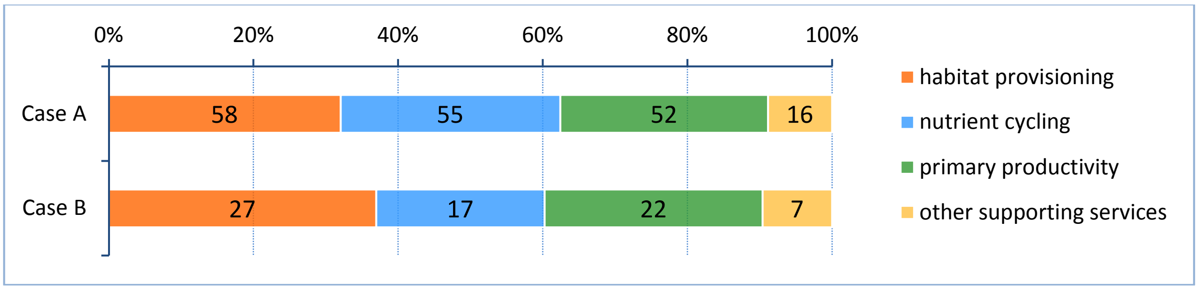
Several respondents mentioned local management choices facing livestock keepers and conservationists alike. For example, a response from Brazil describing cattle, sheep and horses of the Pantaneiro breeds, mentioned that the stocking rate greatly affects the impacts of grazing on the ecosystem. It also noted that Pantaneiro breeds play an important role in the local socio-economic system and traditions, reflected in the Gaucho culture.

2.4 Supporting ecosystem services affected by grazing of livestock breeds

Figure 15 shows that three main supporting ecosystem services of livestock species and breeds in grasslands, in effect habitat provisioning, nutrient cycling and support of primary production, were given prominence and roughly equal weight (approximately 30% each) by the respondents. Slightly more responses under Case A noted the support of nutrient cycling in grazing areas (30% vs. 23 % of Case B), whereas slightly more noted the support of habitat services under Case B (37% vs. 32 % of Case A). This can be explained by the fact that most instances of Case B have ecosystem services provision and habitat conservation as goals.

For the Segureña sheep breed from Spain it was reported that its grazing contributes to establishing and maintaining the characteristic vegetation composition and associated fauna diversity of its home region. In the response from Namibia on Sanga and Nguni cattle breeds, support of primary production was attributed to the cattle grazing, which improves botanical composition and dry biomass production of grasslands. However, the high rainfall levels during the reporting period may also have contributed to the reported improvement of biomass production in the ecosystem.

Figure 15. Supporting services in Case A and Case B

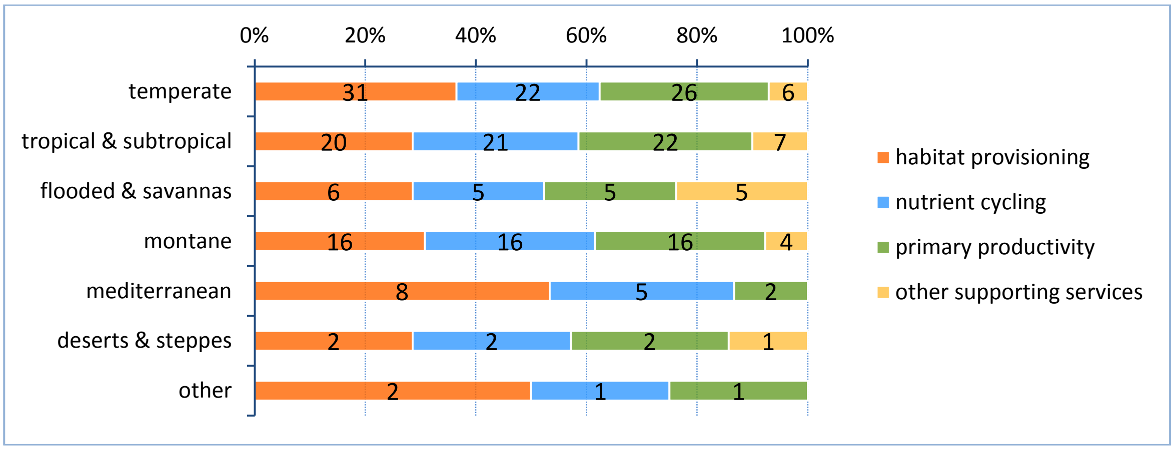


Note: Numbers stand for total responses in each category.

"Other supporting services" included positive changes in vegetation composition after grazing, the introduction or regeneration of certain plant species, as well as positive effects of re-introducing grazing after abandonment of a grazing area. Some responses noted the prevention of the spread of invasive plant species in the grazing area as an additional service.

The provision of supporting services in different types of grassland ecosystems was similarly distributed between habitat provisioning, nutrient cycling and primary productivity (Figure 16) except for temperate and Mediterranean grasslands, where habitat provisioning was more pronounced than nutrient cycling and support of primary production. The prominence of European responses in the sample and the high frequency of Cases B for temperate and Mediterranean grasslands amongst these, may explain the stronger focus on habitat services.

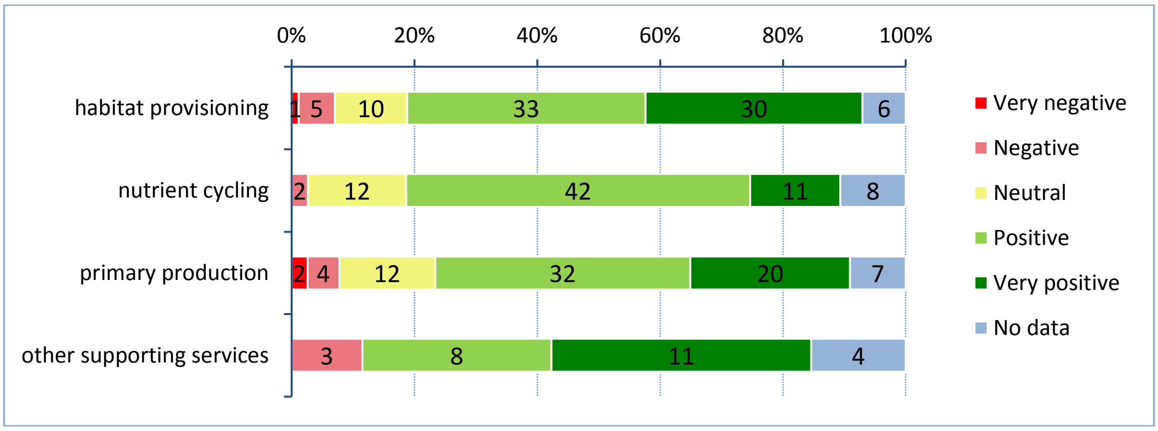
Figure 16. Supporting services in different grassland types



Note: Numbers stand for total responses in each category.

The reported effects of animal genetic resources on the provision of supporting services were mostly positive (44%) and very positive (27%), followed by neutral effects of grazing on the three main services (13%) (Figure 17). While 10 percent of respondents mentioned that there are no scientific data available on the state of biodiversity in the grazing area, it was frequently mentioned that livestock keepers were aware of the positive effects of livestock grazing, for example on the diversity of birdlife, small mammals and insects. This indicates the importance of promoting the scientific measurement of the effects of grazing animals on these services.

Figure 17. Effects of the breed's grazing on supporting services



Note: Numbers stand for total responses in each category.

Nutrient cycling

Dung and manure use were mentioned frequently as having a positive effect on supporting services. In traditional and more extensive agricultural systems, livestock is often encouraged to feed on crop residue, contributing to the improvement of nutrient cycling. Manure of the Churra tensina sheep breed in Spain is used as a fertilizer for cultivating crops. Chillingham cattle in the United Kingdom and other breeds were also mentioned to be positively affecting nutrient redistribution. In India, the Raika people prefer to use camel dung as opposed to mineral fertilizers. This is also the case for the Zebu cattle owners in Kenya and Fipa, Ankole, Mpwapwa and Iringa red cattle breed keepers in Tanzania.

Support of primary production

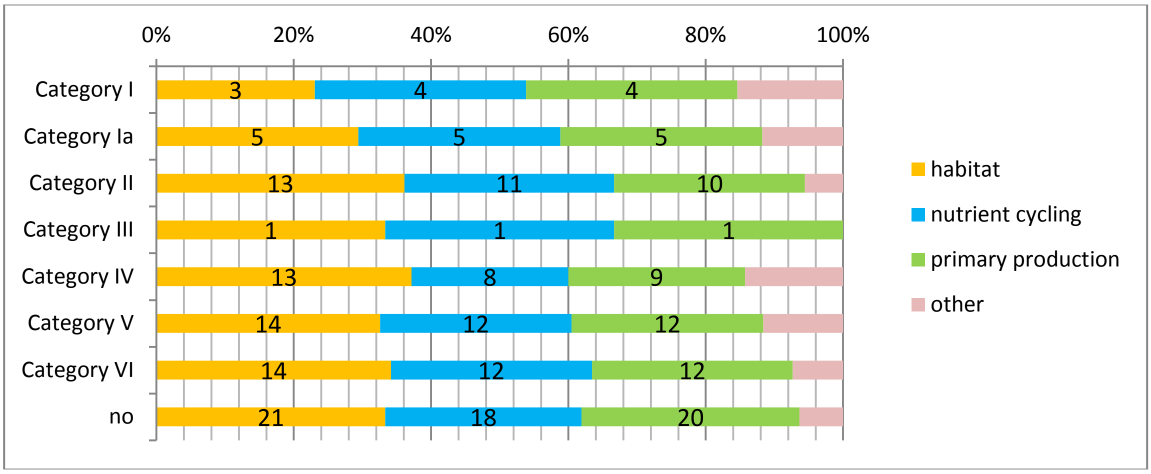
Primary production within an ecosystem depends mainly on the nutrient status of the soil and availability of water. Grazing in grassland ecosystems, if properly managed, can positively affect the primary production through the redistribution of nutrients by livestock, combined with allowing periods of rest for the vegetation to allow the growth of biomass and avoiding overgrazing. In Germany, grazing by Bentheimer and Weiße Hornlose Heidschnucke sheep was reported to contribute to an increase in the proportion of heath in the grazing area, as well as the reduction of invasive and unwanted plant species, such as pine trees. Grazing by Bonsmara cattle in South Africa improved the soil conditions in terms of bare ground reduction and contributed to grass growth, provided the animals were not allowed to graze for too long in one area.

2.5 Habitat provisioning

Habitat provisioning is one of the main ecosystems services linking the effects of grazing to the biodiversity of the host ecosystem. Out of 120 responses, habitat provisioning was mentioned in 85, highlighting the importance of grazing for the associated diversity of ecosystems. In the responses from the European Survey, more details on the status of associated diversity were provided. The response from France regarding Landes de Bretagne sheep and Chèvre des Fossés goats, reported that after four years of grazing (Case B), birdlife and flora diversity increased by 50%, the occurrence of the invasive species *Fallopia japonica* was reduced and bush encroachment by *Fraxinus excelsior*, *Quercus robus and Betulda verrucosa* was significantly reduced. In another Case B from Finland, grazing of Eastern Finncattle and Eastern Finnsheep opened up water meadows and allowed the re-establishment of water birds. In short, grazing had large positive impacts on the diversity of bird and plant species.

Other habitat services mentioned in the responses included ecosystem services enjoyed by the bat populations feeding on the insects that feed on cattle dung and manure, in the case of Devon cattle (Red Ruby Devon breed) in the United Kingdom. In a project for reviving grazing by sheep on montane pastures in Switzerland (Case B), grazing by Valais Blacknose and Roux de Valais, as well as three other sheep breeds (Bündner Oberländnerschaf, Spiegelschaf, Deutsche Heidschnucke) supports threatened plant and animal diversity, including orchid species (Männertreu, Schwärzliches Knabenkraut, Grüne Hohlzunge), dusky large blue butterfly *(Maculinea nausithous)* and grey bush cricket (*Platycleis albopunctata*). There was no difference in reported supporting services between protection types of the grazing area (Figure 18).

Figure 18. Supporting services by IUCN protected area type

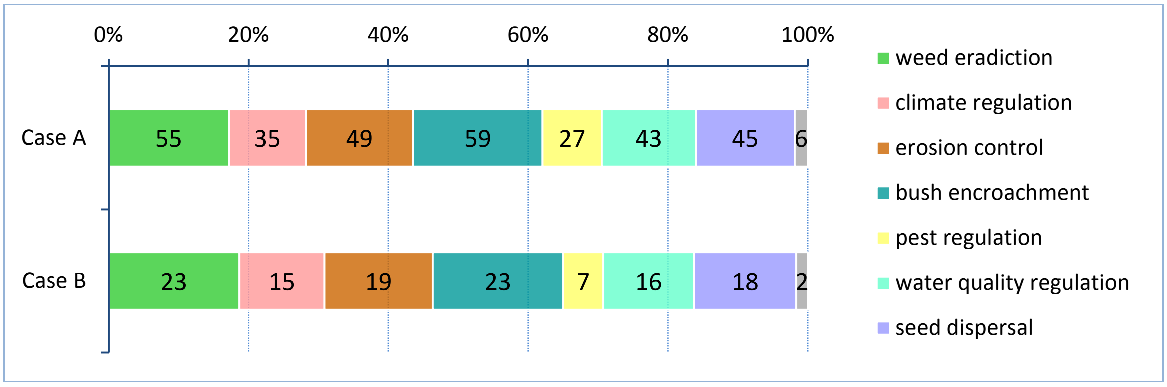


Note: Numbers stand for total responses in each category.

2.6 Regulating services

Many responses contained information on the roles of livestock grazing beyond the positive effects on nutrient cycling and habitat for associated biodiversity. Multiple livestock breeds covered by the responses were noted to be particularly adapted to certain environments and to positively affect a number of regulating services in grassland ecosystems.

Figure 19. Regulating services in Case A and Case B

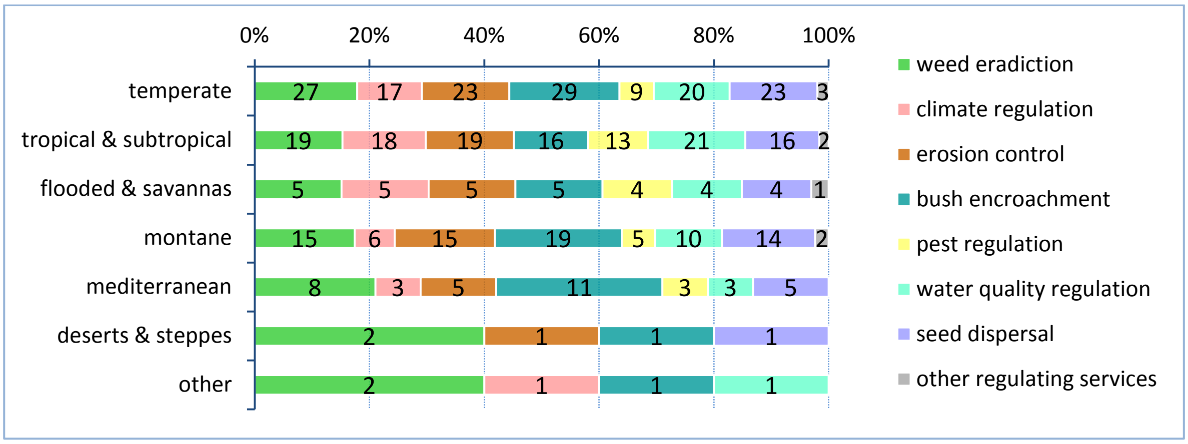


Note: Numbers stand for total responses in each category.

The different regulating services showed a similar, fairly evenly distributed, pattern between Case A and Case B, varying per regulating service from 8 to about 20 percent of the responses in both (Figure 19). There were slightly more responses regarding the effects of livestock grazing on weed eradication and control of crop residues, as well as on climate and air quality regulation in Case B, while pest and disease regulation were mentioned more frequently in responses where livestock breeds were historically present (Case A).

The distribution of regulating ecosystem services per grassland type revealed that the different regulating services were provided across all types of grassland (Figure 20). Most frequently reported across all grassland habitats were bush encroachment (19%) and weed eradication (18%), followed by erosion control and seed dispersal (15% each) and water quality control (13%).

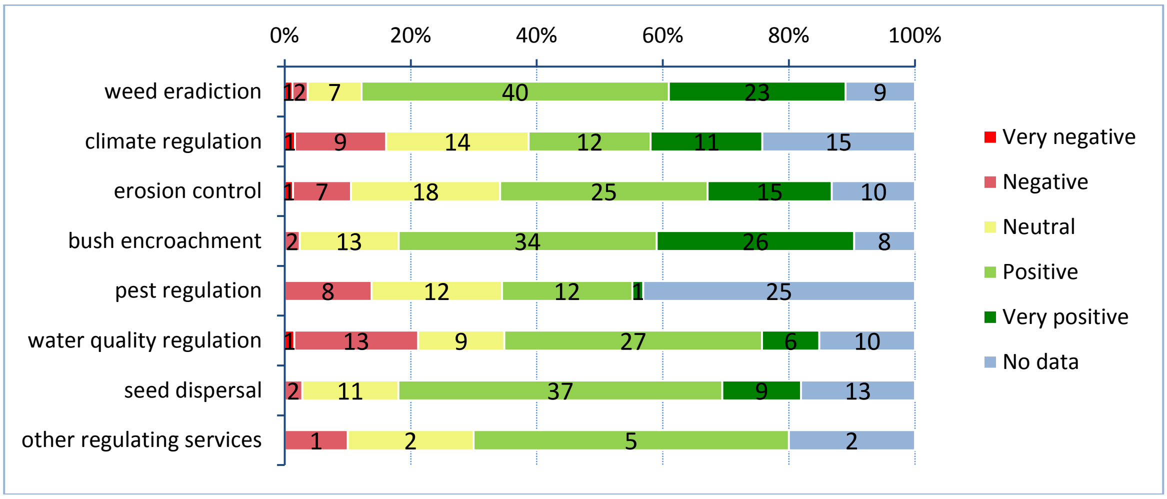
Figure 20. Regulating services in different grassland types



Note: Numbers stand for total responses in each category.

The effects of livestock grazing on regulating ecosystem services were evaluated by 68% of all responses as positive or very positive, and by 21% as neutral (Figure 21). There were also data gaps (22% of all responses) in the evidence given regarding the different services. This highlights the importance of better assessment of the changes in the ecosystems, with special attention to the roles of specific breeds.

Figure 21. Effects of the breed's grazing on regulating services



Note: Numbers stand for total responses in each category.

Generally, the negative effects of livestock grazing on regulating services were attributed to poor spatial management of the animals, resulting in overgrazing. Also, if livestock's access to water is not properly adjusted to the environmental conditions or the water points are not well organized, the animals tend to contribute to erosion by transporting soil material into the water, contributing to lower water quality. Reported pest, disease and climate regulation services were accompanied by the lowest level of provided evidence, followed by seed dispersal and water quality/cycling regulation, pointing to a need for research in these areas.

Control of crop residues and eradication of weeds

Twelfe percent of respondents mentioning weed eradication indicated that there was no available data. Several respondents mentioned that livestock species, especially in developing countries, can be perfectly integrated with crop production systems by including crop residues and food waste into feeding. Goats of the Saanen cross-breed and the Anglo Nubian mix on the Cook Islands eat invasive plant species, thus minimizing their spread. Grazing by Podolian cattle in Serbia also prevents development of invasive plant species, such as hawthorn, by feeding on the shrub. In Finland, certain weeds such as nettle and dandelion decreased through grazing by Western Finncattle, Eastern Finncattle, Northern Finncattle on an organic farm in Konnevesi.

Climate and air quality regulation

Thirty-two percent of respondents mentioning climate regulation indicated the absence of available data, pointing to research gaps. Several respondents mentioned concerns about greenhouse gas emissions from livestock production. However, the negative effects of livestock grazing on climate change might appear less dramatic if multi-functionality and cultural roles of traditional breeds were better integrated into the evaluation of emissions from livestock production (Wolf et al. 2010; Weiler et al. 2014). A positive example of grazing effects on soil carbon accumulation in peat lands was mentioned in a response from Germany, where Bulgarian Landrace water buffalo contributed to the regulation of reed encroachment.

Erosion and avalanche control

Fifteen percent of respondents mentioning erosion control indicated gaps in available data. The use of livestock grazing for the regulation of erosion and control of avalanches was mentioned frequently by the respondents, provided livestock numbers and grazing pressure were controlled. According to the keepers of Ghezel sheep in Iran, these sheep contribute positively to the mitigation of erosion and are an irreplaceable part of the traditional farming system. Grazing by Cika cattle in Slovenia contributed to keeping pastures open up to the elevation of 1680 m.a.s.l. It was mentioned, however, that there was little scientific evidence published. Engadiner sheep in Switzerland were also mentioned as a valuable method of the control of avalanches and bush encroachment. In the response from Bhutan on Nublang cattle, this breed was reported to contribute to controlling the encroachment of the *Yushania microphylla* bamboo species in areas above 2400 m.a.s.l., where this species reduced species competition and improved the regeneration of vegetation.

Bush encroachment and fire control

Eleven percent of all responses mentioning bush encroachment reported a lack of available data on measurable impacts. Control of bush encroachment and regulation of firebreaks were frequently mentioned as regulating services provided by cattle, sheep, goat and horse grazing. Several responses reported that grazing by combinations of species, such as sheep and cattle or sheep and goat, was also practiced in some regions to maintain firebreaks. Keeping pasture areas open was mentioned as a positive regulating service provided by the Herens sheep breed in Switzerland, Castellana sheep in Spain, and several sheep breeds in Portugal (e.g. Campaniça, Churra Algarvia, Merina Branca, Merina Preta and Saloia).

A survey response on the Abondance and Tarentaise cattle breeds from France mentioned that the decrease of regular grazing activities has led to a decrease in soil quality and the invasion of bushes and less digestible grass species. Similar processes were mentioned in Italy, where bush encroachment was absent in areas where Valdostana cattle were still grazing. In Austria, continued grazing by mountain sheep positively affected the presence of herb species in the vegetation composition. Furthermore, it was reported that mowing or completely removing shrubs (e.g. *Rhododendrum ferrugineum*) would have contributed to an increased risk of erosion. In Spain, grazing by Parda de Montaña and Pirenaica cattle was reported as positively affecting the shrub growth dynamics and enhancing the environmental and recreational value of the grazing area. Firebreaks were maintained in the environmental plan through measures that include extensive livestock farming. Studies from South Africa showed that in order for normal succession in grasslands to take place, livestock grazing can be performed, among others, by Nguni, Bonsmara, Drakensberger and cross-breeds of cattle.

Pest and disease regulation

In Sri Lanka, controlled grazing by indigenous swamp buffalo and Moorah, an indigenous cross-breed of buffalo, was reported to reduce the propagation of weed and insect populations. In the traditional rice cultivating systems in Viet Nam, ducks graze on the rice paddy fields and contribute to better pest control and reduce the need for the application of pesticides. A lack of available data on impact was reported by 76 percent of all cases mentioning pest and disease regulation, which indicates a need for further research.

Water quality and water cycling regulation

Regulation of water quality was mentioned to be positively affected by livestock, provided the grazing areas were large and stocking densities low. When the vegetation cover was maintained and overgrazing avoided, grazing by Sanga/Nguni cattle breeds in Namibia were suggested to positively affect water quality. However, no direct measurements were performed. A lack of available data on impact was reported by 19 percent of all cases mentioning water quality and water cycling regulation. Several respondents noted a need for more research on the role of different livestock breeds in water quality regulation.

Seed dispersal

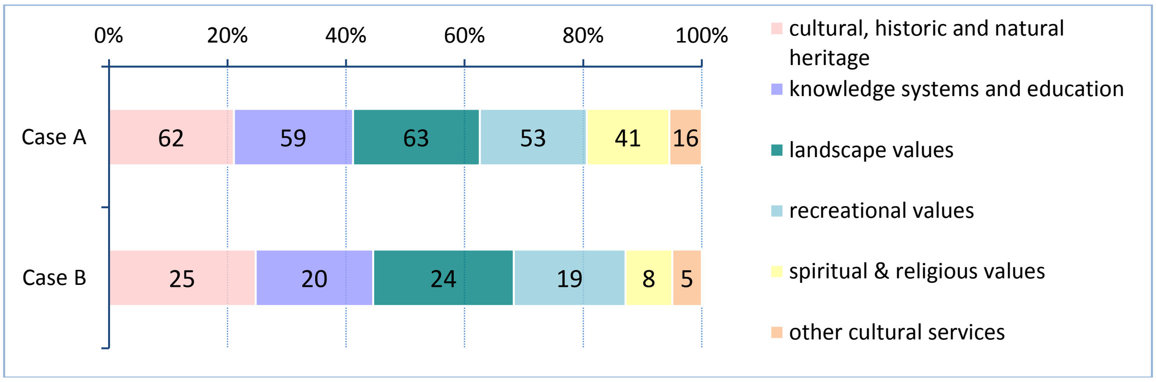
The effects of seed dispersal by livestock, such as diversifying the vegetation composition, were mentioned frequently by respondents. A survey response on the Korangadu farming system in India reported that Acacia seeds profited from dispersal by animals and better germination after a period of exposure in the dung. A lack of available data on impact was reported by 22 percent of all cases mentioning seed dispersal, which indicates a need for further research.

2.7 Cultural services

From playing an important role in various religious ceremonies to positively affecting the cultural and recreational image of the grazing areas and attracting visitors, many livestock breeds are a vital component of livestock keepers' livelihoods (Figure 22). The most frequently mentioned cultural services were cultural, historic, natural heritage and landscape values (22% each), followed by knowledge systems (20%), recreation (18%) and spiritual and religious values (12%).

Livestock by-products, such as skins, horns and feathers are also used in different cultural ceremonies and are also given as gifts or dowry. Healing practices of indigenous pastoralist communities sometimes include the use of animal products. Some breeds are even valued for their medicinal purposes or used in traditional crafts, which can be regarded as "heritage" products.

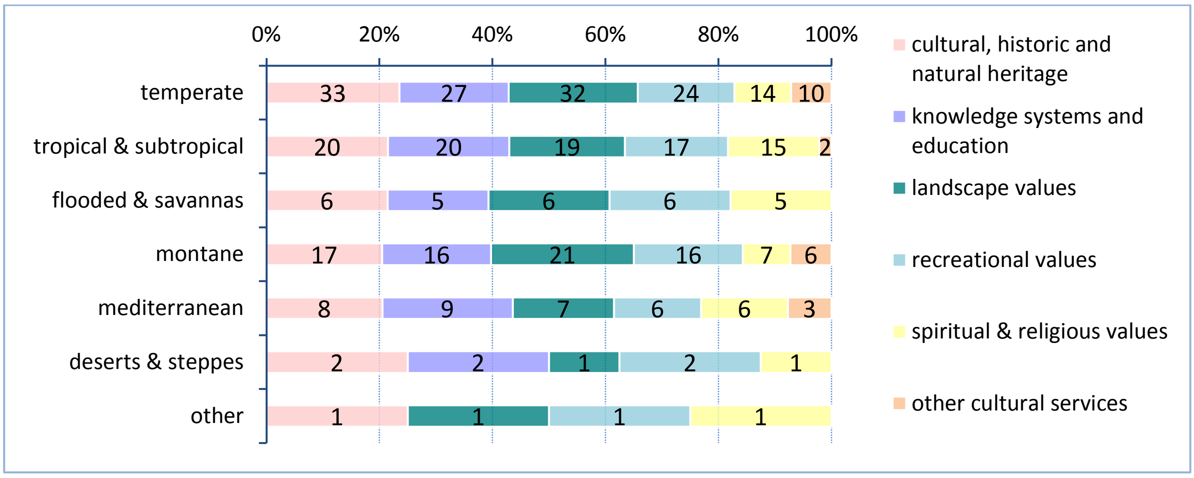
Figure 22. Cultural services in Case A and B responses



Note: Numbers stand for total responses in each category.

Cultural services were distributed fairly equally throughout the various grassland ecosystems (Figure 23), indicating that cultural services are an important component of livestock grazing systems regardless of the grassland type.

Figure 23. Cultural services in different grassland types

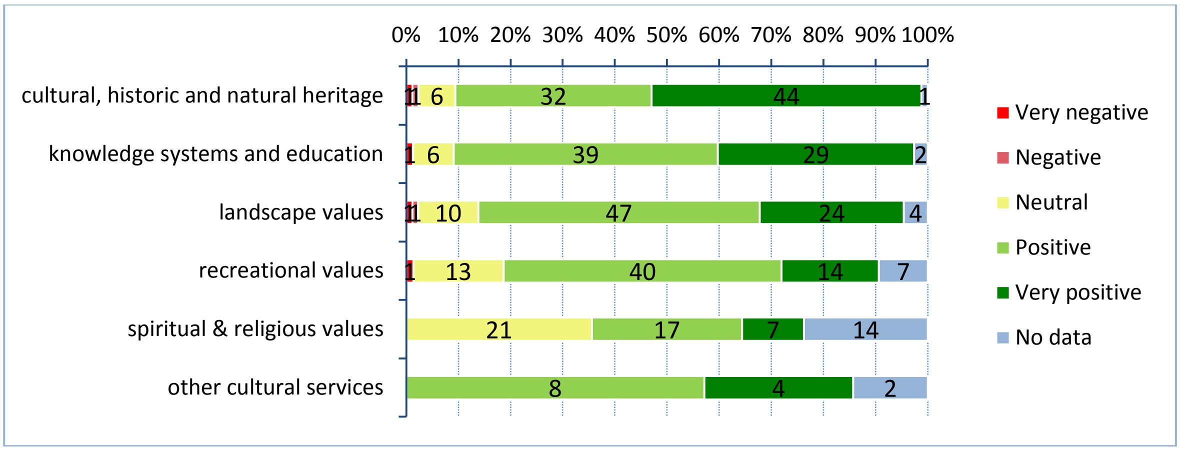


Note: Numbers stand for total responses in each category.

The pattern of distribution of cultural services was similar in both Case A and Case B. Landscape and cultural, historical and natural heritage values were mentioned slightly more in Case B (24%) than in Case A (21%). This could be because these ecosystem services are the main motivation for introducing or re-introducing breeds for grazing in specific regions. For example, grazing for improving landscape values has been introduced in many European countries, explicitly aiming to increase the cultural landscape values of regions.

Traditional livestock production systems include animals as an integral part, in which livestock plays an important role in many religious rituals and in the knowledge systems of the herders. Cultural services were mentioned in 83% of all responses as positively and very positively affected by the presence of livestock breeds, and as neutral by 15% (Figure 24). Compared to supporting and regulating services, cultural services received the highest share of positive and neutral assessments, and a lower level of "no data" indicating lack of evidence.

Figure 24. Effects of the breed's grazing on cultural services



Note: Numbers stand for total responses in each category.

Cultural, historical and natural heritage, landscape and recreational values

The socio-cultural roles of many livestock breeds were reported as contributing to the cultural, historical and natural heritage values of grazing areas. The heritage, landscape and recreational values of areas were often highly connected to the presence of a specific breed. For example, Churra tensina sheep and Tudanca cattle breeds in Spain have a distinctive socio-economic role, as have Fipa, Ankole, Mpwapwa and Iringa red cattle breeds in Tanzania.

Several responses mentioned that certain livestock breeds have a high potential for use in tourism and recreation activities in grazing areas. Products of Shami cattle in Jordan attract tourists, as well as horse populations close to Kaapsche Hoop in South Africa. The Bentheimer sheep breed is kept within Germany's North Rhine-Westphalia nature reserve with species-rich conservation areas and is a popular tourist attraction.

Knowledge systems

Traditional livestock farming is an important source of knowledge on each breeds' role in socio-economic and environmental systems of many regions, particularly remote areas. Several respondents mentioned that information on certain breeds was included in research and environmental education (e.g. in Finland on Eastern Finncattle and Eastern Finnsheep). In Germany, tourists visiting the grazing area of Weiße Hornlose Heidschnucke are educated about the outstanding role sheep play in forming the typical heath landscape.

Spiritual and religious values

A lack of available data on impact was reported by 23 percent of all cases regarding spiritual and religious values of livestock breeds. Many respondents mentioned that the animals can have a high religious value along with their use as draught animals, as a source of income and insurance (e.g. Zebu cattle in Kenya are used as dowry and in traditional cultural celebrations such as rites of passage).

Social and economic security and further values

Through specific marketing chains and labels, farmers can add value to their produce on the basis of the origin of a product, for example a certain breed linked to a traditional production system in a specific location, increasing farming profitability. The popularity of some breeds is associated with specific value chains where certain quality characteristics are highly valued by consumers. In Italy, a new local fast-food chain called “Chianino”, advertises the local Tuscan Chianina cattle breed meat, which is used for the preparation of hamburgers. All other ingredients used are advertised as regional as well. The Podolian cattle of Italy have an image as cattle raised in natural pastures, which is essential for the quality of popular dairy products such as Caciocavallo and Ricotta cheese. Pantaneiro cattle offer excellent quality beef for the Brazilian organic animal production system and are typical for the Pantanal region (Sereno, 2002).

Traditional livestock breeds play many roles in herding systems across many regions. The keeping of Segureña sheep and Tudanca cattle in Spain contributes to sustainable rural development through investments in improved infrastructure for herders and therefore for the whole region. The breeding of the Bisaro pig in Portugal contributes to maintaining the human population in the rural zones. A survey response from Bhutan reported the need for conservation of the Nublang cattle breed (Box A2).

Box A2. Conservation of the Nublang cattle breed and its habitat in Bhutan

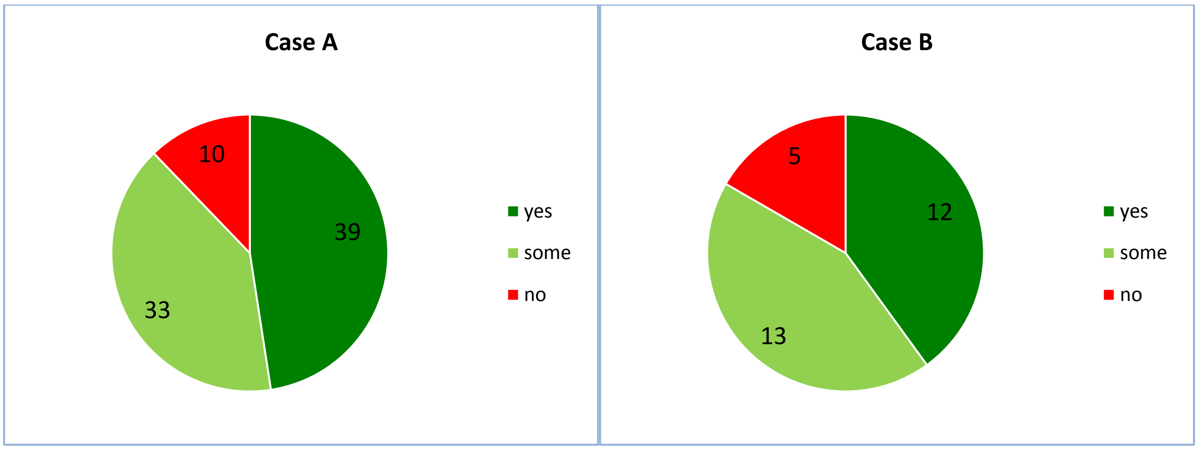
In **Bhutan** the Nublang cattle breed was granted support through the Integrated Livestock and Crop Conservation Project from 2007 to 2012. There was, however, no policy for conservation and protection of the habitat of the breed. Bhutan's Biodiversity Action Plan (2009) outlined some of the measures for conservation and utilization, however, there is a need for a strong policy to conserve and protect the habitat of Nublang. Possibilities are the improvement on Nublang product branding such as milk and meat, further development of niche products, and highlighting links between Nublang and its area of origin with the tourism sector, exploiting the existing Toorsa Strict Reserve and Nobtshonapata trail for Nublang landscape tourism and Nublang park (farm) and declaration of Sombaykha valley - the breeding tract - as Nublang heritage site with detailed management plan on conservation and utilization.

Tourism, farmer and community incomes are still the primary reasons why many breeds are being kept. Thai Brahman, Tak cattle and swamp buffalo in Thailand, as well as Martinique and Creole goats on Martinique are examples of this. Many ethnic groups in African countries are traditional pastoralists, relying on livestock as important elements of their livelihood and as a measure of wealth.

2.8 Recognition of ecosystem services

Available ways of recognizing ecosystem services range from public awareness of livestock roles in the provision of ecosystem services to agro-environmental incentives for farmers to help meet environmental and socio-cultural goals. In total, ecosystem services were reported as fully recognized by 46 percent of the respondents. “Some” recognition was mentioned in 41 percent of the responses (Figure 25). However, the role, type and degree of recognition differed among responses. Frequently, the respondents noted that, even though no official recognition of the services provided by the breeds existed, the livestock keepers and local population (especially smallholder farmers) were aware of the positive role animals play in affecting one or more ecosystem services.

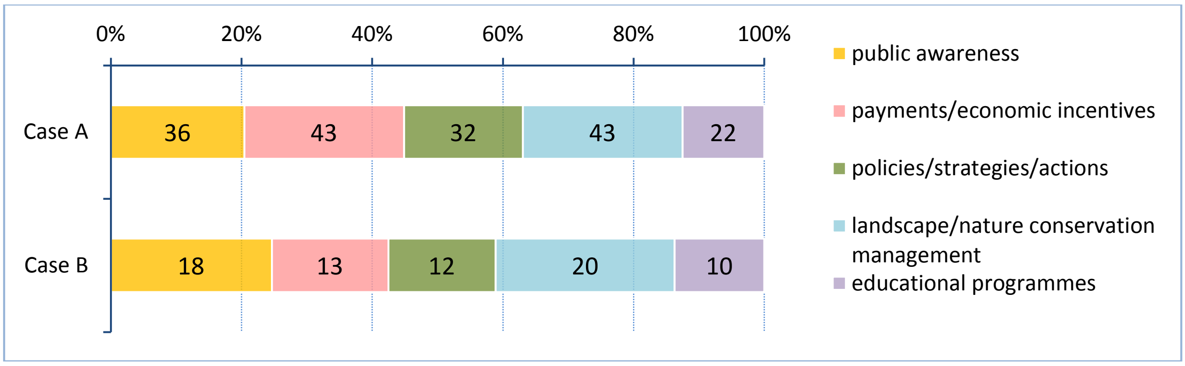
Figure 25. Recognition of ecosystem services in cases A and B



Note: Numbers stand for total responses in each category.

Many respondents provided comments indicating that some recognition of the role of animal genetic resources in the provision of ecosystem services exists among the different stakeholders (Figure 26). The most frequently reported form of recognition was through landscape/nature conservation management programmes (25%), followed by economic incentives and public awareness (both 22%). Policies/strategies and actions that support the role of the livestock population in the supply of ecosystem services (18%) along with educational programmes (13%) were less common forms of recognition.

Figure 26. Forms of recognition of ecosystem services



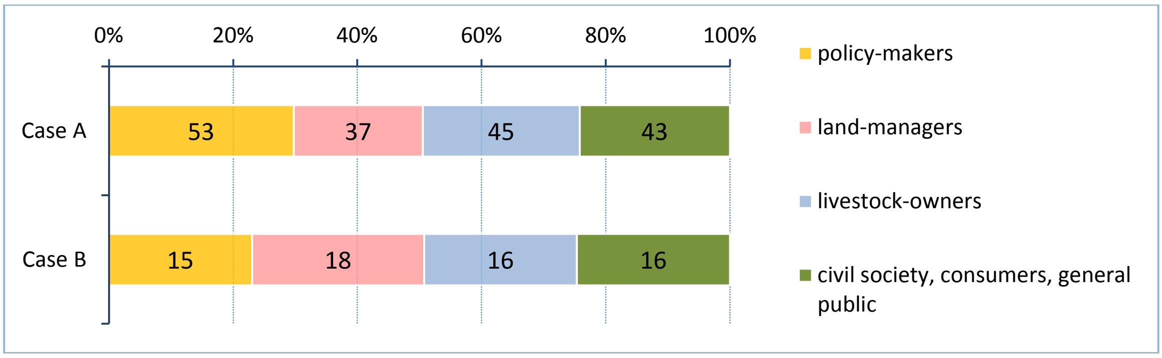
Note: Numbers stand for total responses in each category.

A response from Bhutan on Nublang cattle mentioned that there is no recognition of the vegetation management services provided by the breed and the extent of this remains unevaluated. Furthermore, Bhutan’s Forest and Nature Conservation Act does not allow grazing in certain areas; animals are blamed for destroying the environment regardless of the lack of supporting evidence. In South Africa however, landowners providing grazing land recognize the visible changes in vegetation composition affected by the grazing of Bonsmara cattle. However, it was reported that policies encouraging conservation grazing are still lacking.

Many responses from European countries mentioned incentives to farmers of traditional breeds within protected nature areas, such as Sortbroget Jydsk Malkekvæg cattle in Denmark, Western Finncattle, Western Finnsheep, Western Finnhorse in Finland, Valdostana cattle in Italy, and Lojeña sheep in Spain. In Portugal, livestock keepers of many traditional cattle, sheep, goats and other livestock breeds receive support for contributing to the conservation of habitats and the traditional breeds themselves with yearly payments determined according to the breeds risk status. The Chillingham cattle in the United Kingdom have been included in Environmental Stewardship policies since 2005. Agri-environmental schemes include a "Grazing supplement" for cattle in England and "Encouraging native breeds" in Wales. A response from Spain on Parda de Montaña cattle reported that EU, national or local subsidies sometimes target specific breeds and/or ecosystems. In Germany, in the Vogelsberg Nature Park, a contract exists with farmers prescribing that only animals of a certain (traditional) breed native to the area can graze on the land.

In our study, overall, the various stakeholder groups had similar shares (23-28%) between Case A and Case B in recognition of the roles of animal genetic resources (Figure 27).

Figure 27. Stakeholders recognizing the provision of ecosystem services



Note: Numbers stand for total responses in each category.

Agri-environmental schemes have been implemented in many European countries. EU subsidies for rare breeds were mentioned in the responses from several countries (eg. Spain, Slovenia, Italy, Portugal). Other forms of recognition were mentioned in the United Kingdom where the Chillingham Cattle Association involves different stakeholders.

Table 2 shows relations of the respective stakeholder groups and different forms of recognition. Civil society and consumers recognize the roles of animal genetic resources primarily in the form of public awareness and through landscape/nature conservation programmes. Policy-makers recognize ecosystem services chiefly through economic incentives, as well as through landscape management measures and nature conservation programmes. Landscape management and nature conservation programmes are mentioned in high frequency by all stakeholder groups, indicating a convergence of opinion on this matter, whereas educational programmes were consistently mentioned to a lesser extent across all groups.

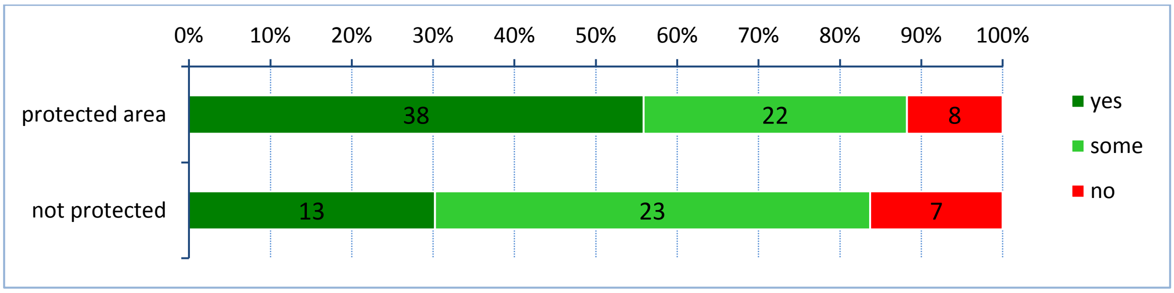
Table 2. Relations between forms of recognition and different stakeholders

	Policy-makers	Land-managers	Livestock-owners	Civil society & consumers
Public awareness	37	35	40	47
Payments/economic incentives	46	31	35	33
Policies, strategies and actions	38	30	35	33
Landscape management & nature conservation programmes	41	43	43	45
Educational programmes	24	22	23	24

Note: Numbers stand for total responses in each category.

Respondents mentioned different opportunities for increasing the recognition of ecosystem services provided by traditional livestock breeds. In Italy, there is a willingness of consumers to pay a higher price for Fontina cheese produced from the milk of the Valdostana cattle. In Spain, support measures exist for extensive production systems. Although the recognition of ecosystem services of the breed is not direct, the Aragon region receives special funding for the maintenance of fire-break areas in forests where Churra tensina sheep graze traditionally. The Aragon region also supports provision of appropriate infrastructure for the herders. In Finland, the Koli park, where Eastern Finncattle and Eastern Finnsheep graze, was awarded a certificate for its role in sustainable tourism. Visitors to the park, among other activities, can enjoy views of traditional breeds grazing on the land. In our study, the majority (56%) of respondents recognized ecosystem services provided by breeds in protected areas. The reverse was the case in non-protected areas, where 53% of respondents recognized "some" ecosystem services (Figure 28).

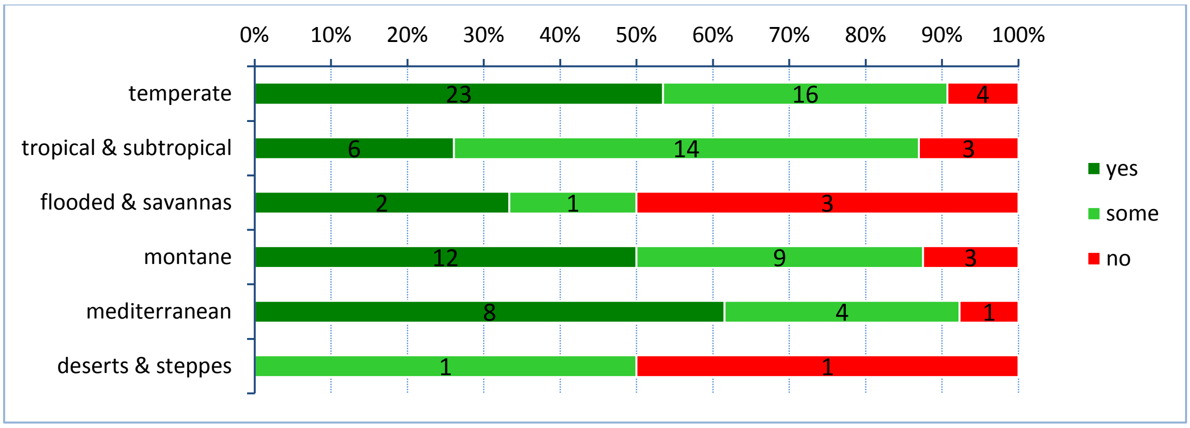
Figure 28. Recognition of ecosystem services vs. nature protection status



Note: Numbers stand for total responses in each category.

Depending on the grassland habitat, there were also differences in recognition of ecosystem services influenced by the presence of the breeds in the landscape (Figure 29). In all habitats except flooded areas, savannas, deserts and steppes, 85% of respondents recognized ecosystem services ("yes" and "some"). In temperate and Mediterranean grasslands, there was more definite positive recognition of ecosystem services (53% and 61%), whereas in tropical and subtropical grasslands the share of "some" recognition was highest (61%).

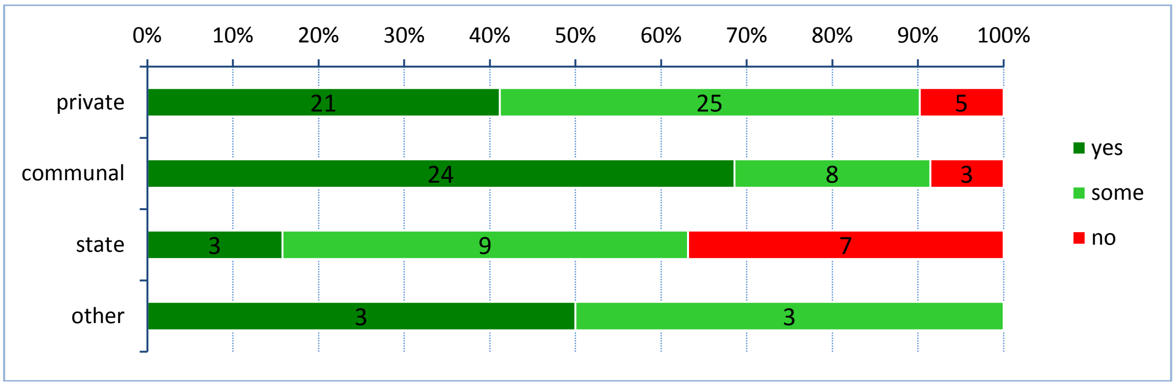
Figure 29. Recognition of ecosystem services in different grassland ecosystems



Note: Numbers stand for total responses in each category.

Land ownership also affected the recognition of ecosystem services provided by livestock breeds in grasslands (Figure 30). The highest frequency of positive recognition (69%) was in communal lands, whereas private land showed similar frequencies of positive and "some" recognition. The highest share of "no" recognition was reported for state-owned land.

Figure 30. Recognition of ecosystem services depending on land ownership



Note: Numbers stand for total responses in each category.

Along with traditional uses of livestock animals and their products, many traditional breeds are an important part of socio-cultural systems, which should be acknowledged and included in evaluations of the environmental impacts of livestock. This was a frequently mentioned comment from respondents. In overview, the results of the survey suggest that combining incentives for conserving traditional breeds and the provision of ecosystem services resulting from their grazing are favoured. This would ensure that traditional breeds are not only kept for their rare status, but are also utilized in a sustainable way for managing regulating and supporting services, landscapes and biodiversity.

Research and education are additional available tools to support the recognition of the environmental roles of animal genetic resources. Successful implementation is reported in some countries such as Finland, where research into ecosystem services incorporates agriculture and livestock farming. Such programmes support further dissemination of knowledge, research activities and education of both farmers and the public.

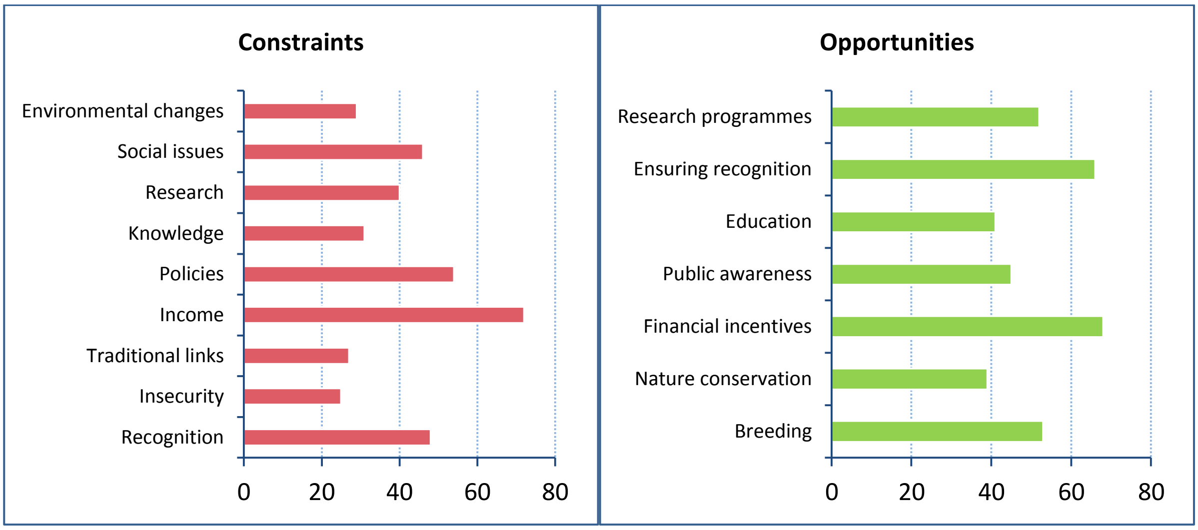
2.9 Constraints and opportunities

The positive roles of livestock grazing in the provision of ecosystem services, especially within sustainable agricultural practices, can be seen against a background of challenges, such as negative effects of overgrazing, climate change and land use competition, including between food and biofuels. Sustainable mixed farming systems are under threat by changes in consumer demand and by interactions with the natural resource base on which livestock production depends. In Portugal, for example, intensification of agricultural systems and of livestock management contributed to a strong decrease in extensive pig production. As a result, indigenous pig breeds represented only about 2 percent of total pig population in 1986. However, a recent increase in consumer interest and support for agriculture has resulted in new opportunities. The Alentejo pig breed, in particular, is highly valued and associated with a traditional production system in which animals graze under oak or chestnut trees. Decision-makers can influence the creation of tools supporting such traditional farming systems by promoting and adding value to their products.

However, there are also concerns that policy-makers using the term “ecosystem services” in speeches may not understand the real meaning and importance of the term. This was also mentioned in the survey responses describing Sarda and Sarda Modicana cattle breeds in Italy.

Common constraints were identified alongside opportunities that respondents considered beneficial to the continuation of ecosystem services provided by animal genetic resources (Figure 31 and Table 3). The most frequently reported constraint was the lack of sufficient income generation from livestock (C4), followed by the absence of supporting policies and regulations (C5) and the lack of recognition of ecosystem services (C1), i.e. ecosystem services considerations do not inform management decisions. Financial support/economic incentives (O3) and ensuring recognition of ecosystem services among policy-makers (O6) were named most frequently as opportunities.

Figure 31. Total number of selected constraints and opportunities



Note: Numbers stand for total responses in each category.

Table 3 indicates that the highest numbers of responses were received on constraints C4 (lack of income generation from livestock), C5 (absence of supporting policies) and C8 (Social/political issues that affect livestock management) in combinations with the most frequently selected opportunities: ensuring recognition of ecosystem services among policy-makers (O6) and financial support/economic incentives (O4). This stresses the role of policy-making in the continued support of ecosystem services. Constraints C2 (Insecurity or conflicts that limit access to grazing land), C3 (Loss of traditional links between livestock and the local community) and C9 (Threats to the traditional production environments of the livestock population caused by climatic or other environmental changes) seem to be secondary and less associated with specific observed opportunities.

Table 3. Combinations between constraints and opportunities

	C 1. Recognition	C 2. Insecurity	C 3. Traditional links	C 4. Income	C 5. Policies	C 6. Knowledge	C 7. Research	C 8. Social issues	C 9. Environ. changes
O 1. Breeding	29	14	17	30	32	25	21	30	17
O 2. Nature conservation	19	9	18	28	25	15	17	20	14
O 3. Financial incentives	30	17	17	45	37	20	31	31	23
O 4. Public awareness	18	7	18	35	24	12	21	25	14
O 5. Education	20	10	16	25	27	17	27	27	17
O 6. Ensuring recognition	38	16	19	46	41	20	27	34	22
O 7. Research programmes	26	17	16	37	29	18	27	28	17

Note: Numbers stand for total responses in each category.
Constraints: *C1 Existing livestock management is not based on the recognition of the ecosystem services provided by the livestock; C2 Insecurity or conflicts that limit access to grazing land; C3 Loss of traditional links between livestock and the local community; C4 Lack of sufficient income generation from the livestock; C5 Absence of supporting policies/regulations; C6 Loss of knowledge on the management of the described livestock population; C7 Lack of research activities on the topic; C8 Social/political issues that affect livestock management; C9 Threats to the traditional production environments of the livestock population caused by climatic or other environmental changes.*
Opportunities: *O1 Livestock breeding programmes targeting specific characteristics that are relevant to the provision of ecosystem services; O2 Nature conservation programmes; O3 Financial support/economic incentives; O4 Raising public awareness; O5 Introducing educational programmes for livestock keepers and/or breeders; O6 Ensuring recognition of ecosystem services among policy-makers; O7 Introducing/supporting research programmes on ecosystem services provided by animal genetic resources.*

In their textual answers, many respondents elaborated on factors affecting grazing activities and the provision of ecosystem services, and suggested opportunities for improvements, including beyond the preselected options described above. This survey report has organized these responses around seven main issues.

Main reasons for the decrease of grazing by traditional livestock breeds in grassland ecosystems

A number of challenges were identified by respondents as the reasons for the decrease in grazing activities in grassland ecosystems worldwide. These included economic conditions and poverty, political conditions, armed conflicts, land conflicts and competition, including with other agricultural uses and wildlife conservation, and climate and environmental changes that may prevent livestock keepers from continuing managed grazing activities.

In Sri Lanka, one of the major concerns reported was the presence of unauthorized cultivation and hunting in the traditional grazing areas of an indigenous swamp buffalo breed. These areas were not threatened by overgrazing, however, this highly damaging human activity was leading to the deterioration of the ecosystem. A survey response from the Korangadu region of India identified environmental changes as a constraint to the continuation of traditional grazing activities. The grazing area of the Ramnad white sheep breed in India was predominantly threatened by the competition for land by intensive cropping systems and other land uses for non-agricultural purposes. A survey response on the Nguni cattle in South Africa highlighted stock theft and loss of knowledge on operating livestock management systems as threats.

In Martinique, the keeping of Martinique and Creole goat breeds, Martinique sheep, Creole cattle, and Naked neck chicken is under threat from diminishing traditional ties to these animals. In Thailand, natural disasters such as flooding threaten the traditional resting habitat of the Thai Brahman swamp buffalo. In Brazil, competition from cropping, primarily Soybean and Eucalyptus plantations, are threatening natural grasslands by encroaching on the grazing areas of Angus and Hereford crosses.

Another reported concern and threat to traditional production systems is the loss of social prestige of being a livestock keeper or pastoralist. This was mentioned in multiple responses, such as on Boran cattle and Red Maasai sheep in Kenya, as well as Asturian cattle and traditional Merino sheep in Spain. In France, the traditional transhumance activities of livestock keepers of the Abondance and Tarentaise cattle breeds also experienced a decrease in social prestige, in addition to high land costs and increasing alternative land use demands.

Need for improving financial support mechanisms

Many respondents raised concerns regarding the need for proper understanding and a monetary valuation of the environmental roles of indigenous breeds. These should be recognized by livestock keepers and other stakeholders, and expressed as environmental values of livestock products. Animal products from the Bisaro pig in Portugal, for example, need ‘certification of origin’ to support their proper valuation. Full understanding and monetary evaluation of environmental roles of Valdostana cattle and its product (Fontina) cheese was also highlighted in the response from Italy. In several responses from France, the delivery of certain ecosystem services in lieu for breed specific subsidies were mentioned. Additionally, the market value of original cheeses from the region were reported to be high and in demand by consumers. Therefore, public recognition along with improvement of financial support mechanisms can be an important tool, also to raise consumer awareness of the unique roles of local livestock breeds. Sometimes creative multi-stakeholder mechanisms can be used to source financial support. In an example from Austria, support and profit from sheep grazing in mountain regions involves a number of different stakeholders. A ski resort and tourism company provided additional funds and labour as they were profiting from the increased landscape value of the mountains with grazing sheep.

Most countries in the European Union use payments to encourage livestock keepers to manage traditional breeds. A response from the United Kingdom mentioned that the future management of the Exmoor pony could be threatened by a decrease in EU or national funding for agri-environmental payments. A regional assessment found that in many regions of Europe, especially Eastern Europe, breeds at risk are kept as long as the farmers receive financial support. Without such support it is not profitable for the livestock keepers to manage animals with lower production potential (Kompan and Klopcik, 2013). This is directly linked to the lack of reward provided by regular market mechanism for the provision of ecosystem services other than provisioning services. A response from the United States of America on Brangus, Brahmans and Angus cattle breeds highlighted that there were few economic incentives for ranchers to provide ecosystem services other than the production of commodities (beef).

Improving livelihoods

Small ruminant and chicken keeping was frequently mentioned as particularly important for improving the livelihoods of the poor. This highlights the importance of supporting the traditional livestock keeping of chickens, goats, ducks and other small domestic animals. In the Indian Korangadu region, landless farmers and farmers owning land cooperate by creating communal grazing areas. This encourages the conservation of local breeds and provides opportunities to utilize their diversity to meet consumer demands. It can also serve as insurance against environmental changes, socio-economic and cultural changes and improve the livelihoods of livestock keepers through improved food security, nutrition and income.

Reviving grazing activities and improving infrastructure

Several survey responses from European countries mentioned reviving grazing activities through local livestock breeds. These also noted that in addition to appropriate landscape management plans and their implementation, operational issues need to be taken into consideration by decision-makers and livestock keepers alike.

One frequently raised concern referred to the level of support for infrastructure development in rural areas, including the requirements for keeping and managing local breeds and their related costs. When pasture areas are located such that animals are required to be transported (for example in Germany with Bentheimer and Graue Gehörnte Heidschnucke sheep breeds), manual labour is often more expensive than vehicles. Therefore, it is necessary that such needs and costs are also taken into account in mechanisms improving infrastructure, such as missing driveways.

In Germany, a response describing the Weiße Hornlose Heidschnucke sheep breed also noted a dependence on infrastructure (such as shelter for livestock and water points), as well as good access to pastures. In the United Kingdom, where awareness and financial support for grazing by English Longhorn cattle exists, a bridge needs to be built for the cattle to avoid their passage through an adjacent saltmarsh ecosystem. Lack of livestock keepers’ income from landscape management despite agri-environmental payments compared to the all year-round operational costs of maintaining grazing activities, was also mentioned. It was highlighted that the values of livestock grazing systems should be better recognized by society. One measure to improve the level of recognition and prestige for shepherds could be to train different stakeholders on the environmental benefits of grazing. Education and infrastructural measures could help ensure that grazing activities continue in a sustainable way, as well as potentially expand to other (protected) areas.

Improving the sustainability of land use

Concerns regarding the sustainable nature of grazing and communication with the specialists working in the field of livestock were highlighted in many responses. Improving the sustainability of grazing activities has been approached in various ways across all regions, relating to the current challenges that the livestock keepers face. In South Africa, for example, a group of livestock keepers are implementing a holistic management approach to grazing. Their approach initially faced a lack of support among fellow farmers. However, after demonstrating the success of such management strategies on soil and vegetation conditions, holistic grazing of Bonsmara cattle rapidly gained popularity among the farmers.

A survey response from Algeria, for example, provided information on the negative effects of the Ouled-Djellal sheep breed in the region of El Bayedh introduced because of its superior zootechnical (meat production) characteristics compared to the original Hamra sheep breed. The grazing by Ouled

Djellal sheep caused significant damage to the ecosystem and is currently replacing the original breed population. It was highlighted by the respondent that there is a lack of political awareness of and interest in the problem. Therefore the ecosystem is further degrading, while the traditional breed is endangered. Meat production, in this case, should not be the sole objective of livestock keeping and the choice of breed, but the system should be evaluated from different perspectives, including from a sustainability point of view.

The historic farming systems in Germany of traditional sheep grazing contribute not only to unique cultural landscapes (such as high Alpine pastures), but are also environmentally sustainable if properly managed. In India, traditional grassland systems have not yet been fully incorporated in the mainstream watershed development programme. Nevertheless, promotion of the “Korangadu” pastureland can provide not only income security to resource poor families while enhancing conservation of traditional livestock breeds, but also function in a sustainable way where the farmers share grazing lands and make sure that overgrazing is avoided.

Access, property rights and competition with other uses

A respondent on the Kumbhalgarh region in India, reported that the government plans to declare a significant part of the traditional camel grazing areas of the Raika people as an exclusive nature area, in the absence of evidence that the herds pose a threat to the area’s natural values. This measure is expected to lead to greater concentrations of herds outside the area with related sustainability impacts, losses of livelihood, and losses of the area’s agro-ecological and socio-cultural heritage values. Responses from other countries (e.g. Slovenia, Spain), reported similar difficulties with the interface of pastoralism and wildlife conservation which are also well kown in East Africa

A response from South Africa raised the concern that feral horses, which are free roaming on state owned land, cause traffic accidents on the roads passing through it. The Department of Agriculture, Forestry and Fisheries, which is the management authority of the Forest Nature Reserve where the animals are grazing, became in fact responsible for such incidents and drivers’ claims. This indicates that on state-owned or communal grazing lands, it is particularly important to define the roles and responsibilities of all parties in order to protect the animals, their owners’ and other users’ rights, and to protect the ecosystem.

A response from Egypt provided an example on the Pastoral Bedouin Farming System that faces many challenges. Land ownership was granted since 1920 at the tribal level, but this ownership is still not clearly defined. The agricultural and livestock policies in the region have started to address the formation of cooperatives and associations, incentives for rain fed barley, fig and olive trees, as well as, access of the livestock owners to export markets, especially sheep for the Arabic Gulf states. There are also various policies on water harvesting, supplies and infrastructure, land tenure and farming production, since rangelands went through severe degradation, including as a result of a 15 year drought. The importance of creating alternatives was mentioned as the next step for the future, which would address the land issues in the region which tend to be more complex than as addressed in the policies. The tribe is still an important unit of interaction with the government and the roles of Bedouin society is recognized by the government. It is therefore important to define the tribes’ rights and roles in a better way.

Research and education to increase awareness of environmental roles of animal genetic resources

Many responses identified the need for research activities to better understand the environmental roles of traditional livestock breeds. Different aspects of the management of local breeds should be addressed. Many respondents mentioned that the current state of knowledge on the ecosystem services provided by livestock species and breeds in grassland ecosystems is limited to habitat provisioning and the effects of overgrazing (disservice). The available research almost exclusively addresses animals’ roles at species level. Breed effects are rarely integrated in the studies on environmental roles of grazing and are more difficult to measure. However, communicating information on the importance of traditional breeds for the provision of ecosystem services is important for increasing awareness of the decision-makers, livestock keepers, land managers and the public.

A response from Kenya, for example, mentioned that there has not been much research performed on Zebu cattle's role in the provision of various ecosystem services. Several other questionnaires mentioned the need for better communication of the breed values and roles; not only to the decision-makers, but to the livestock keepers as well, to support the herding communities in better protecting their interests and rights.

In European countries, conservation, characterization and diffusion of traditional breeds seem to be addressed by research more than in other regions. In Spain, for example, La Garcipollera Research Station managed by the Center of food science and technology (Centro de Investigación y Tecnología Agroalimentaria) in Aragon focusses on the study of mountain agriculture and livestock production systems. Many questionnaires from European countries report the existence of some research activities on traditional breeds, including to a limited extent on the ecosystem services these provide. Although financial support mechanisms for endangered livestock breeds through measures under the Common Agricultural Policy were also mentioned in these responses, the respondents noted the lack of communication on their ecosystem services values.

Increasing awareness at the level of farming units is another important area of promoting the roles of animal genetic resources. In Finland, for instance, an organic farm was involved in a regional project "Polku mansikkapaikalle" (network of farms with valuable biotopes), which aimed to promote the management of traditional biotopes. Farmers as well as visitors were educated by this project about the values of the area and its traditional farming systems.

Annex 3: Estimated shares of global livestock populations attributable to breed classes in different regions, land cover classes or production systems, and climatic areas

	Locally adapted					Locally adapted, exotic and crossbreds					Total				
	Cattle	Goats	Pigs	Sheep	Chicken	Cattle	Goats	Pigs	Sheep	Chicken	Cattle	Goats	Pigs	Sheep	Chicken
By region															
Africa	13.23	24.86	1.83	21.77	5.10	5.99	8.89	1.15	5.77	3.19	19.22	33.75	2.98	27.54	8.29
Asia	7.83	15.64	12.54	18.42	11.74	29.45	44.89	51.36	28.61	47.36	37.27	60.53	63.90	47.03	59.10
Europe	1.10	0.41	2.11	2.23	0.79	5.11	0.92	13.80	6.38	5.25	6.22	1.32	15.91	8.61	6.04
North/Central America	3.38	0.79	1.61	0.77	5.27	7.64	0.85	8.80	0.82	9.81	11.01	1.64	10.41	1.59	15.08
Oceania	1.21	0.21	0.30	3.15	0.15	1.31	0.20	0.21	5.81	0.38	2.52	0.41	0.51	8.97	0.53
South America	11.54	1.91	2.37	4.32	4.38	12.22	0.43	3.93	1.94	6.58	23.76	2.34	6.29	6.26	10.97
By land cover class / production system															
artificial/urban						0.22	0.23	0.73	0.31	0.67	0.22	0.23	0.73	0.31	0.67
grazing															
grass	6.76	6.78	1.46	7.53	1.71	3.18	3.43	2.47	9.50	1.85	9.94	10.21	3.94	17.03	3.55
herb	0.57	0.24	0.08	0.33	0.58	0.08	0.01	0.08	0.19	0.09	0.66	0.25	0.16	0.52	0.67
shrub	5.74	6.45	1.82	8.24	3.68						5.74	6.45	1.82	8.24	3.68
sparse	4.00	12.33	1.02	18.24	5.56						4.00	12.33	1.02	18.24	5.56
tree	16.20	8.38	15.21	8.13	14.03						16.20	8.38	15.21	8.13	14.03
mixed irrigated	0.00	0.00	0.00	0.00	0.00	15.47	22.21	26.76	11.04	25.14	15.47	22.21	26.76	11.04	25.14
mixed rainfed	5.01	9.64	1.15	8.20	1.88	41.33	26.48	48.02	25.75	41.50	46.34	36.13	49.18	33.95	43.38
water	0.00	0.00	0.00	0.00	0.00	1.44	3.81	1.18	2.55	3.32	1.44	3.81	1.18	2.55	3.32
By climate															
Hyper-arid	0.18	0.77	1.04	0.91	0.48	0.06	0.13	0.02	0.09	0.08	0.23	0.90	1.06	1.00	0.55
Arid/semi-arid	18.22	33.63	3.60	36.43	12.13	16.89	18.42	4.39	17.52	8.91	35.10	52.06	7.99	53.95	21.04
humid	14.32	4.23	9.90	3.77	9.52	24.68	15.33	28.54	5.69	30.39	39.00	19.56	38.44	9.47	39.92
temperate	5.56	5.19	6.21	9.56	5.30	18.44	18.25	44.39	23.17	29.20	24.01	23.44	50.60	32.73	34.49
any						1.66	4.04	1.91	2.86	4.00	1.66	4.04	1.91	2.86	4.00
Total	**38.28**	**43.82**	**20.75**	**50.66**	**27.43**	**61.72**	**56.18**	**79.25**	**49.34**	**72.57**	**100**	**100**	**100**	**100**	**100**