9

Livestock and the environment

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Smallholder mixed farming in Meru District, Kenya

Most farmers in Giaki, Meru Central District, Kenya, have a few indigenous cattle, goats, sheep, pigs and/or chickens. Formerly rangeland, the area has been settled for almost 50 years and is now intensively cultivated. Little natural vegetation remains and the once plentiful wildlife has disappeared, as have tsetse flies.

During the wet season, when crops are growing, animals are tethered around homesteads or kept in enclosures, and family members cut-and-carry forage from fallow fields and roadsides to feed their stock. When available, crop residues are also collected and fed. During the dry season, animals are allowed to forage freely.

Manure is collected from livestock pens and applied to fields to improve fertility and increase yields. The practice has become more common as farm size has declined with the sub-division of inherited land. Cattle manure is most abundant and widely used, but goat and sheep manure is considered to be more effective as a fertiliser, and comes in a pellet form that is easier to apply.

Small-scale livestock production in Giaki contributes to soil fertility in other indirect ways. Cut-and-carry feeding of animals tethered around fruit trees, including mangoes, avocadoes and oranges, results in an accumulation of litter, which benefits tree and fruit growth. Farmers have learnt that plant litter decomposition is enhanced by the urine of tethered animals, and excess quantities of waste feed and litter are scattered on fields as mulch.

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There is no piped water in Giaki, so everyone depends on local rivers, streams, springs or wells for their supply. Animals share many of the same sources. As temporary streams and pools dry up during the dry season, animals concentrate around permanent water sources, where surroundings are eroded and water is contaminated by urine and faeces. Pollution is particularly severe towards the end of the dry season, when water sources become stagnant.

Cameo 2 Livestock rearing in the highlands of Lesotho

Lesotho is a land-locked, mountainous country with a temperate climate and relatively high rainfall, which provides Johannesburg and Gauteng with much of their water through the Lesotho Highlands Water Project. Most of the highlands above 2,000 m are unsuitable for cultivation and are used for grazing by sheep, goats, cattle, donkeys and horses, in descending abundance. Livestock are kept mainly by smallholders.

Merino sheep and Angora goats are raised for wool and mohair, slaughter and ceremonial purposes. Cattle are raised for milk, meat, fuel (dung) and draught power, as well as for investment and socio-cultural reasons, such as bohali (bride-wealth) and other ceremonies. Donkeys and horses are widely used as pack animals and for personal transport. A system of livestock borrowing and lending, known as mafisa, in which the holder has rights to wool, mohair, milk and draught power, whilst the owner retains title to the animal and any progeny, is widely practised (Marake et al., 1998).

Lesotho's extensive rangelands are used under two management regimes: maboella that governs the use of village common lands in the lowlands and foothills; and a `cattle-post' regime for the control of highland grazing. Maboella was instituted in the mid-1800s by Lesotho's first Paramount Chief to protect communal lands at particular times during the year. Maboella rules were enforced at village and local levels by the Paramount Chief's designates, who were compensated for their efforts. The cattle-post regime was established in the 1920s and evolved as a seasonal transhumance of lowland livestock to mountain cattle-posts for the summer months so as to co-ordinate the activities of increasing numbers of livestock grazing mountain pastures and protect those pastures from over-exploitation. As with maboella, the cattle-post regime was enforced by the Paramount and Principal Chiefs, who granted permission to individual livestock owners to use specific cattle-posts (Swallow and Bromley, 1998).

Land degradation, overstocking and grazing control have been major concerns of Government and development planners for decades, resulting in various laws and regulations which have resulted in considerable controversy and in calls for the reform of Lesotho's land tenure system (Phororo and Letuka, 1993). Community-based land use planning and identification of specific uses for specific areas are essential for the future sustainable use of natural resources, whilst local and national authorities also have vital roles to play in co-ordinating activities and ensuring that wider environmental concerns are addressed.

Photo 9.1 Lesotho cattle with reflectors. Use of reflective neck and/or girth bands is a recent innovation to aid night movements and reduce road accidents. Note the encroachment of cultivation on former rangeland and erosion gullies in foreground and on distant hillside

Introduction

This chapter outlines the main interactions between livestock and the environment, and identifies interventions and strategies to enhance the positive effects and/or mitigate negative impacts of livestock production, focusing on smallholder animal husbandry. Resource-poor livestock farmers are at the forefront of livestock interactions with the environment, as highlighted in the cameos above.

The cameos also illustrate the variety of roles and complexity of livestock interactions with the environment, and the need for careful consideration of specific local circumstances and concerns in the prioritisation and implementation of interventions.

Interactions between livestock and the environment

Livestock interactions with the environment have been the subject of much discussion and heated debate over the past decade, and have spawned numerous studies and a substantial literature, encompassing:

- destruction of the Amazonian forest to produce beef for the hamburger society (Nations and Komer, 1987)
- livestock as sources of greenhouse gases (IPCC, 1995)
- advocacy for a more harmonious balance between livestock and the environment (de Haan *et al.*, 1997; Steinfeld *et al.*, 1997; Nell, 1998)
- the environmental risks and recuperative effects of animal agriculture in the developing world
- the unwarranted blanket condemnation of livestock production (Nicholson *et al*., 2001; Blake and Nicholson, 2004).

A major component of the International Livestock Research Institute's (ILRI) programme is directed at people, livestock and the environment. The World Bank, the European Union and many bilateral donors have sponsored the Livestock, Environment And Development (LEAD) initiative and a compilation of 130 publications on CD-ROM concerning livestock, environment and development interactions (FAO, 2003).

The natural environment can be conceptualised as a complex and dynamic entity, composed of a variety of interlinked ecological systems and cycles that are buffered against disturbance by their relative size and feedback loops, and are reasonably stable over time, within certain limits of tolerance. Livestock interact with and impact on their environment through various activities, inputs, outputs, and management practices. Direct interactions include respiration, drinking, feeding, gaseous emissions from digestion, excretion and movement. More general interactions and indirect impacts relate to animal husbandry, land management and mode of production. The relative importance of these interactions and impacts depends on their magnitude, extent and duration, and specific local circumstances, as well as the standpoint and perception of the observer. The main interactions between livestock and the environment are outlined below, together with a summary assessment of key monitoring indicators.

Atmosphere

Agriculture, including livestock production, is a major source of greenhouse gases and other atmospheric emissions, which contribute to climate change, acid rain and the eutrophication (nutrient enrichment) of water bodies, as summarised in Table 9.1. Crude global estimates, such as in Table 9.1, are subject to considerable uncertainty but provide an indication of relative importance.

Carbon dioxide

Land use changes, including the clearing and burning of forests, woodlands and grasslands for cultivation and the grazing of livestock, account for 15 per cent of total anthropogenic releases of carbon dioxide, the balance coming largely from burning fossil fuels and industrial processes. Livestock also contribute to carbon dioxide emissions through their basic metabolism and respiration (Bruinsma, 2003).

Methane

Livestock account for 30 per cent of all anthropogenic emissions of methane. Although methane is less persistent in the atmosphere, it has 20-25 times the global warming potential of carbon dioxide Livestock emissions of methane come from enteric fermentation of ingested plant material and releases from animal excreta. Other important anthropogenic sources include rice paddy fields, biomass burning, landfills, coalmines and the exploitation of oil and gas fields (Moss, 1993; Bruinsma, 2003).

The amount of methane produced by livestock depends on their size/age, digestive system and the quantity and quality of feed intake. Ruminants (buffalo, cattle, camels, goats and sheep) emit the greatest quantities of methane: 25-118 kg per head per annum for cattle, and 5-8 kg per head per annum for small ruminants (IPCC, 1995). Pseudo-ruminants (horses, donkeys and mules) and mono-gastrics (pigs and poultry) produce less methane, because their digestion is not so dependent on enteric fermentation.

Livestock manure consists mainly of organic matter, which decomposes under anaerobic conditions to produce methane. The amount of methane produced depends on the quantity of manure and the proportion that decomposes anaerobically. When stored or treated in liquid form, as in the slurry lagoons, ponds, tanks or pits common to more intensive systems, anaerobic decomposition is favoured, and greater quantities of methane are produced. When manure is managed as solid in heaps or stacks, or when deposited on pastures and rangelands, it tends to decompose aerobically and little or no methane is produced (IPCC, 1995).

Table 9.1 Agriculture's estimated contribution to global greenhouse gas and other emissions

Gas	*Carbon dioxide*	*Methane*	*Nitrous oxide*	*Nitric oxides*	*Ammonia*
Main effects	Climate change	Climate change	Climate change	Acidification	Acidification & eutrophication
Agricultural source (% contribution to total global emissions)	Land use change, especially deforestation	Ruminants (15)	Livestock (incl. manure on farmland) (17)	Biomass burning (13)	Livestock (incl. manure on farmland (44)
		Rice production (11)	Mineral fertilizers (8)	Manure and mineral fertilizers (2)	Mineral fertilizers (17)
		Biomass burning (7)	Biomass burning (3)		Biomass burning (11)
Agricultural emissions as % of total anthropogenic sources	15	49	66	27	93
Expected changes in agricultural emissions to 2030	Stable or declining	From rice: stable or declining From livestock: rising by 60%	35-60% increase		From livestock: rising by 60%

Source: Bruinsma (2003).

As livestock populations increase and are managed more intensively, as projected for most regions, the quantities of methane and manure produced are projected to rise by up to 60 per cent by 2030 (Bruinsma, 2003).

Nitrous oxide

Nitrous oxide is the most potent greenhouse gas, some 320 times more powerful than carbon dioxide. Agricultural emissions account for most of the anthropogenic sources of nitrous oxide and come primarily from microbial nitrification and denitrification in soil, and biomass burning. Increasing application of nitrogen to the soil, from whatever source including animal manure, produces more nitrous oxide (Bruinsma, 2003).

Nitric oxides

Just over a quarter of all anthropogenic sources of nitric oxides are agricultural, emanating from biomass burning and microbial nitrification and denitrification of animal manure and organic fertilisers.

Ammonia

Agriculture accounts for nearly all anthropogenic emissions of ammonia, with livestock production, including the application of manure to farmland, accounting for nearly half of the global emission. Ammonia emissions are potentially even more acidifying than sulphur and nitrogen oxides, and releases from intensive livestock systems contribute to both local and long distance deposition of nitrogen, with damage to trees and the acidification and eutrophication of aquatic systems (Table 9.1).

Odours

Livestock may also emit unpleasant odours, especially from the accumulation of wastes from intensive production units, which may be a nuisance and cause offence in populated areas. The most prominent gas is hydrogen sulphide, which is very toxic at high concentrations.

Vegetation

As herbivores, ruminant and pseudo-ruminant livestock are dependent entirely on vegetation for their nutrition. Monogastric livestock, although technically omnivorous, are often fed cereal-based diets and/or vegetable wastes, and are thus also largely dependent on plants for their survival. However, the interactions of livestock and impacts of livestock production on vegetation extend far beyond the consumption of plant material, to the shaping of agricultural landscapes around the world. Some 34 million square kilometres of land (26 per cent of the total) are used for grazing livestock and an additional 3 million square kilometres (21 per cent of all arable land) are used for producing cereals for livestock feed (Steinfeld *et al.*, 1997).

Cattle ranching has been accused of contributing to the deforestation of Central and South America through the clearance and conversion of land to pasture (Nations and Komer, 1987; Kaimowitz, 1995), and pastoralists have been blamed for the degradation and desertification of rangelands through `overstocking' and reduction in vegetation (Hardin, 1968; Sinclair and Fryxell, 1985). There are many detailed discussions and rebuttals of these complex and controversial issues (Homewood and Rodgers, 1991; Behnke et al., 1993; Brockington and Homewood, 1996; Nicholson *et al*., 2001; Blake and Nicholson, 2004).

Animal husbandry in mixed-farming systems has a strong influence on vegetation and land-use patterns, through individual and/or collective choices of:

- what areas should be set aside for livestock use as fallow, or rough grazing
- where cereal and forage crops are grown
- the use of live fencing for field boundaries and stock routes.

Livestock also have important roles in arable agriculture through manuring, ploughing, seeding, weeding and consuming crop residues, whilst in cut-and-carry and more intensive systems, vegetation is collected, or crops are grown, to be fed to animals kept in confinement. In East Africa, nutrient hot spots from seasonal kraaling of pastoral livestock can remain visible for decades and facilitate tree regeneration (Reid and Ellis, 1995).

Soil

The physical impacts of livestock on soil include:

- breaking and penetrating surface crusts
- compaction
- creation of denuded pathways along which rainwater run-off may flow

- disturbance through digging and rooting
- consumption of mineral and salt deposits and
- tillage for crop production.

All forms of soil disturbance have the potential to cause erosion, but may also facilitate rainfall infiltration, organic matter incorporation and seed germination, depending on circumstances and management.

Livestock influence soil chemistry through the supply of nitrogen, minerals and organic matter. Livestock excreta contain a high proportion (60-90 per cent) of the nitrogen, minerals (phosphorus, potassium, magnesium etc.) and heavy metals obtained from their feed (de Haan et al., 1997). Only for high-yielding dairy cows, do the excreta contain less than 80 per cent of nutrients consumed. In low-intensity systems, 85-100 per cent of these nutrients are excreted (Sundstøl et al., 1995). Accumulations of solid and liquid manure from feedlots, piggeries and poultry houses are a potential source of various environmental pollutants. Whilst the judicious application of animal excreta on fields and recycling of plant nutrients are beneficial to soil composition and fertility, the indiscriminate disposal of excessive quantities on arable land can result in accumulations of nutrients and heavy metals that threaten soil fertility. Some diseases and pathogens harmful to human and animal health may be spread in a similar manner (Menzi, 2001).

Water

For their survival livestock depend on regular supplies of water which may be obtained from a variety of naturally occurring springs, streams, rivers and lakes, or man-made sources. Problems arise from the concentration of animals and the contamination of water sources by dung, urine and run-off, especially where those sources are shared by other users. Whilst drinking, or crossing streams and rivers, livestock may also reduce water quality by disturbing sediments and increasing downstream turbidity.

Run-off from heavily-manured fields and discharges from intensive production units, abattoirs and processing plants into streams and rivers can have severe impacts on aquatic systems, in particular eutrophication of water bodies and consequential algal blooms; composition of fish populations; ecological balance; and water quality (de Haan et al., 1997). Nitrates may also leach out to contaminate ground water and threaten drinking water supplies.

Monitoring indicators

From the foregoing, livestock clearly have a multitude of interactions with, and potential impacts on, the environment. Whether or not these interactions are considered to be beneficial or harmful depends on the specifics of local circumstances, and the observer's point of view. With continuing human population growth and agricultural expansion, and the predicted further intensification of livestock production in years to come (Delgado *et al*., 1999), ever-widening land-use changes and impacts on the environment are inevitable. Key indicators for monitoring the environmental interactions of different farming systems and processing plants are summarised in Tables 9.2, 9.3 and 9.4.

Table 9.3 Monitoring indicators for industrial livestock production systems

Input-related	*Production-related*	*Output-related*
Land use changes and land requirements for feed production	Conversion efficiencies for nitrogen and phosphorus by animal species	Manure discharge nutrient balances
Percentage of grain in concentrates and diet	Farm nitrogen and phosphorus balance	Fertilizing value of manure
Rangeland requirements for young stock	Ammonia emissions	Methane emissions
Livestock breeds used	Methane emissions	Quantity of live-weight slaughtered
Inputs to feed production (fuel, fertilizer)	Fossil energy consumption	Quantity of raw milk produced
Animal welfare index	Weight of raw hides processed	
Chemical use	Manure storage	

Source: Derived from de Haan *et al.* (1997).

Table 9.4 Monitoring indicators for processing plants

Direct indicators	*Indirect indicators*
Amount of solid waste	Proportion of industrial and traditional processing
Total Biological Oxygen Demand (BOD) of wastewater	Proportion of by-product utilization
(NB not percentage of effluent, as this would provide incentives just to increase water use)	
Carbon dioxide, carbon monoxide and nitrous oxide emissions	

Source: Derived from de Haan *et al*. (1997).

Table 9.2 Monitoring indicators for grazing and mixed-farming systems

Category	*Natural resource base*	*Livestock*	*Socio-economic*
		Grazing systems	
Soil/land	Erosion: universal soil loss equation	Arid: herd mobility	Arid: human carrying capacity of the land
	Presence and use of legumes	Sub-humid and humid: stocking rates and productivity trends	Land tenure and recent trends in fencing and encroachment of cultivation in key areas
	Manure collection and application practices		Vulnerability to drought (reliance on food aid)
Vegetation	Proportion of ground cover	Forage demand	Infrastructure
	Proportion of land cultivated	Diet preferences	Cohesion of user groups
	Plant species composition	Animal productivity and species composition	Diversity of land use
	Rate of firewood extraction		
	Presence and use of leguminous plants		
	Utilisation of crop residues, tame pastures and native rangelands		
	Rate of deforestation		
Water	Quality: turbidity, oxygen, nitrogen, phosphorus, pesticides content etc.	Use requirements	
	Number of boreholes		
	Number of new surface watering points		
Air	Greenhouse gas balance	Greenhouse gas balance	

Table 9.2 Contd.

Category	*Natural resource base*	*Livestock*	*Socio-economic*
		Mixed-farming systems	
Soil	Erosion: universal soil loss equation	Access to animal traction	Rate of integration and degree of reliance on outside inputs
	Nutrient levels: nitrogen, phosphorus, copper, zinc	Manure storage and utilization Quantity of concentrates brought into system	Community cohesion in watershed and regional landscape
	Organic matter: cation exchange capacity Farm and regional nutrient balances Presence and use of legumes		
Vegetation	Proportion of ground cover Proportion of land cultivated Plant species composition Presence and use of legumes	Forage demand Diet preferences	Farm income
Water	Surface water quality: turbidity; oxygen, nitrogen, phosphorus, pesticides content etc. Ground water quality, nitrogen, phosphorus content	Use requirements	
Air	Manure application techniques	Quality of animal diets Number of animals	

Source: Derived from de Haan *et al.* (1997).

Nutrient cycles, flows and accumulations

Nutrients are a collection of chemical compounds, minerals and elements essential to the survival of living organisms. Plants obtain these nutrients from their surroundings, and animals obtain theirs from what they eat. The passage, or flow, of a nutrient through the environment, via various plants and animals and alternative pathways, is a nutrient cycle. Nutrient cycles are a sub-set of a broader class of global biogeochemical cycles, including water, carbon, oxygen, nitrogen and mineral cycles.

Agriculture has a significant influence on several biogeochemical cycles, especially those relating to nitrogen, phosphorus and potassium (the three primary ingredients of manufactured fertiliser) and sulphur (Bruinsma, 2003). Livestock have an important role in the recycling of nutrients, both by defecation and urination whilst grazing, and farmers' application of manure to fields as organic fertiliser. Environmental problems may arise, however, from excessive applications, and from the uncontrolled disposal and discharge of accumulated animal wastes from `industrial' livestock production units (de Haan et al., 1997; Steinfeld et al., 1997). In such circumstance, where animals are kept at high density in piggeries, poultry farms and feedlots, they are dependent entirely on cereal-based diets containing supplementary nitrogen, potassium, phosphorus and various heavy metals, including copper and zinc.

Relatively small proportions of these supplementary nutrients are absorbed, with most passing through the gut to be excreted with other animal wastes. Net imports of animal nutrients lead to local accumulations and excess soil nutrients, with adverse effects on soil fertility, increased run-off, eutrophication of aquatic systems and contamination of ground water and drinking water supplies. Hot-spots of nutrient surplus are found in North-Western Europe, Eastern and Mid-Western regions of the USA, Eastern China, Japan, Korea, Malaysia, Thailand and parts of Java and Sumatra in Indonesia (de Haan et al., 1997; Steinfeld et al., 1997), and are a potential problem for intensifying peri-urban livestock production in general.

With the anticipated further intensification of livestock production to feed increasingly urbanised populations in years to come (Delgado et al., 1999), the eutrophication of terrestrial and aquatic systems is likely to become more widespread around the world, unless preventative measures are taken. Such interventions might include zoning land use and agricultural practices, regulating the distribution of intensive livestock production units, taxing excess nutrients, reducing nitrogen and phosphate excretions by improved feed formulation and utilisation, and minimising emissions from manure storage and spreading.

Interventions to enhance positive effects and/or mitigate negative impacts

Given the range of environmental impacts outlined above and the limited degree of control over many traditional livestock production systems (Chapter 3), there are no panaceas, or `quick-fixes', that will solve all problems; but there are various measures that can be taken to enhance positive effects and mitigate negative impacts. In the first instance, there is a general need at all levels, from central government to farmer, and from university to primary school, to promote greater awareness of livestock related environmental issues and the options available for dealing with them.

In reviewing the range of interactions and impacts that livestock may have in a specific location, a useful distinction can be made between:

- intensive (high input/high output) production systems, including dairying, feedlots, piggeries and poultry farms
- extensive (low input/low output) production systems, including pastoralism and ranching and
- intermediate mixed-farming systems.

Whether or not such interactions will result in serious adverse impacts on the environment depends on their magnitude and extent, specific local circumstances and individual perspective. It is worth noting, however, that with increasing production per animal, livestock emissions and excretions decline per unit of product.

Clearly, much depends on specific circumstances and technical capacity, and it is always essential to build on indigenous knowledge and experience of local conditions, but the following smallholder and community-based measures should be considered:

- Application of manure to fields to recycle nutrients, improve fertility and increase organic matter content
- Use of crop residues by livestock to improve nutrition and reduce biomass burning
- Use of animal traction for tillage and carting to increase efficiency and reduce engine emissions

- Use of urea-molasses blocks by ruminants to enhance microbial fermentation, increase digestive efficiency and reduce methane production (see Chapter 11 on feeds and feeding)

- Protection of water sources and segregation of use to reduce contamination and ensure access and adequate to supplies to all users

- Anaerobic digesters to produce biogas (methane and carbon dioxide) as an energy source, rather than release into atmosphere, for when burnt, the methane in biogas produces a mixture of carbon dioxide and water vapour, which are less powerful warming agents than methane

- Measures to maintain vegetative ground cover and use of live fencing and planting of forage tree legumes (Gutteridge and Shelton, 1998) and various plant species, such as Vetiver grass (Anon, 1993), to reduce erosion

- Construction of drainage ditches and biologically active settling ponds to recycle nutrients and minimise downstream contamination and

- Use of leguminous crops, both to increase nitrogen fixation and as forage crops.

At policy setting, strategic planning and regional levels, priority should be given to promoting:

- Mixed farming systems and the closer integration of arable and livestock production

- Zero-, or reduced-grazing, cut-and-carry systems in areas of high human-population density, with safeguards for animal welfare

- Community-based, catchment-oriented land use and environmental management planning and

- Monitoring key environmental indicators, especially water quality and discharges from livestock markets, intensive production units and processing plants, including: dairies, feedlots, piggeries, poultry houses, abattoirs and tanneries.

Given current global environmental trends, particular attention needs to be given to the zoning, monitoring and control of livestock production activities in urban and peri-urban areas.

In general evolutionary terms, even after 10,000 years of development, the future course of arable and livestock production is by no means certain, but it would seem reasonable to assume that agricultural production systems are most likely to be sustainable, if their adverse environmental impacts are minimised.

Strategies to sustain/improve farm animal genetic diversity

Chapter 12 considers breeding strategies to achieve sustainable improvement in livestock productivity. It is considered relevant to address the question of genetic diversity here in the context of `livestock and the environment'.

More than 40 species of mammals and birds have been domesticated, and some 5,000 livestock breeds are recognised, 20 per cent of which are endangered because their populations have declined rapidly in recent years, or their breeding stocks are low (Scherf, 2000). This loss of genetic diversity limits the options for improved production and sustainable agriculture, and reduces the gene pool available for new breeds. The need to conserve livestock diversity and the means by which this might be achieved have been reviewed by Blench (2001).

The maintenance of farm animal genetic diversity is of crucial importance to food production, food security and the sustainability of farming systems. Indigenous livestock breeds are important because, through many generations of natural selection and selective breeding, they are adapted to local conditions and farming systems, and are more likely than exotic breeds to tolerate seasonal variations in climate and forage supply, and resist local diseases and parasites. Despite the superficial attractions of modern, `high-tech' methods, traditional farming systems still account for most of the food produced in the developing world. Just as some local crop varieties are resistant to drought, or tolerant of poor soils, indigenous livestock breeds and landraces provide an invaluable reservoir of genetic variation and breeding potential for adaptation to changing climatic and farming conditions.

Conservation strategies include:

- the in situ maintenance of breeding populations in their regions of origin
- the ex-situ maintenance of breeding populations away from their ancestral homes and
- the `cryo-conservation' of genetic material, such as semen, embryos, DNA, cells or ova, by freezing (FAO, 1998).

The choice of conservation strategy obviously depends on the breed and specific local circumstances, but wherever possible in situ conservation is the preferred option, through the promotion of livestock breed associations and stud books to maintain and enhance breed characteristics (see Chapter 12).

Strategies to accommodate global warming

Global warming refers to the progressive increase in mean surface temperatures over the past century. Despite general agreement amongst scientists that global warming is a reality (IPCC, 2001), great uncertainty remains about its consequences in different parts of the world. Predictions from climate models are subject to considerable doubt and different climate models, based on different assumptions, produce different results (Hadley Centre, 2004). Nevertheless, some general predictions can be made about the consequences of global warming. Sea levels will continue to rise, with increased risk of flooding in estuarine and other low-lying coastal areas. Climatic conditions are also likely to become more variable, with more frequent extreme events. Some regions will become wetter, others will become drier. The poorest and weakest members of society and the least-developed regions and countries of the world will be most vulnerable to adverse impacts because of their limited assets, weak infrastructure, and restricted access and ability to invest in technological solutions.

A wide variety of impacts on global agriculture and food security has been predicted for the 21st century (UNEP and UNFCCC, 2002; Bruinsma, 2003), but these remain largely speculative because of the uncertainties inherent in their derivation. One of the few predictions about the future that can be made with virtual certainty, however, is that farming systems and agricultural environments will be subject to increasing pressure to produce more food to feed an ever-increasing number of people. Whilst specific changes at precise locations are impossible to predict with accuracy, they are likely to be progressive and cumulative, which means that communities and societies should have some time to adapt to them as they occur.

Given the highly variable and uncertain impacts of global warming on agriculture and renewable natural resources, six sets of activity are considered to be of critical importance to the establishment of effective strategies to meet the challenges of environmental change at national and local levels:

- Assess what changes may occur and identify representative areas for retrospective and future monitoring

- Conduct periodic, standardised surveys of agricultural resources, including characterisation of livestock breed attributes, population size and distribution
- Review agricultural and economic significance of potential and actual change, and act accordingly
- Maintain flexibility in agricultural development scenarios at national level
- Ensure diversity of choice in livelihood, farming and livestock production options at local level and
- Increase awareness on livestock-environment interactions at all levels from producer to policy makers.

The long-term consequences of global warming on farmers and farming systems depend very much on their response to change and ability to take advantage of potential benefits and mitigate adverse impacts. Sustainable agriculture can be promoted and food security can be enhanced through the adoption of coherent policies and the implementation of appropriate strategies at national, local and farmer levels.

Options available to promote sustainable agriculture, include:

- characterisation and conservation of existing genetic resources
- selective breeding programmes to enhance local crop varieties and livestock breeds
- improved water-management and irrigation systems
- modification of planting schedules and tillage practices
- closer integration and intensification of arable and livestock production through mixed farming and
- promotion of more effective, participatory land-use planning and watershed management.

National and local strategies to accommodate and adapt to global warming must obviously be developed to meet specific national and local circumstances. Key principles for such strategies should be to promote adaptability and sustainability by maintaining collective diversity of livelihoods and livestock resources, i.e. by not putting `all your eggs in one basket'.

Access to water and wetlands is already a source of conflict between arable and livestock farmers in many regions, not just in arid and semi-arid zones, and is likely to become an increasingly contentious issue in decades to come. Increasing urban populations demanding an ever-increasing standard of living leading to increased urban:rural competition for water will also be a contentious issue in the future. Local communities and natural resource user groups, including arable farmers, settled livestock producers and transhumant pastoralists, must be encouraged to participate actively in the preparation, implementation and monitoring of adaptive, natural resources/land-use management plans, to ensure equitable access to, and sustainable use of, water and wetland resources. Implementation of such plans will be fraught with difficulties and conflicting demands, but these must be resolved by stakeholders themselves, through negotiations, compromises and trade-offs, if sustainable use is to be achieved.

Conclusions

- Livestock and livestock production have a wide range of interactions with, and impacts on, the environment, which can have both adverse and beneficial consequences.
- Individuals, communities, governments and international bodies need to be aware of both the positive and negative impacts of animal husbandry and livestock production, so that appropriate measures can be taken to maximise benefits and minimise, or mitigate, adverse consequences.
- Hasty decisions, blanket judgements and all-purpose, `quick-fix' solutions, based on inadequate information and limited understanding of local conditions, are unlikely to be sustainable in the long term.
- Each situation should be examined and evaluated separately in relation to its own specific environmental and socio-economic circumstances.

Further reading

FAO/ILRI. 1999. Farmers, their animals and the environment. CD-ROM. Food and Agriculture Organisation of the United Nations (FAO), Rome, Italy, and International Livestock Research Institute (ILRI), Nairobi, Kenya. http://www.virtualcentre.org/en/enl/vol1n2/read.htm

FAO. 2003. Livestock, Environment and Development (LEAD) Digital Library. CD-ROM. Livestock, Environment and Development (LEAD) Initiative, Animal Production and Health Division, Food and Agriculture Organisation of the United Nations (FAO), Rome, Italy.

Hall, S.J.G. and Clutton-Brock, J. 1989. Two hundred years of British farm livestock. British Museum. London, UK.

Mason, I.L. 1996. A world dictionary of livestock breeds, types and varieties. CABI Publishing, Wallingford, UK.

Scherf, B.D. (ed.). 2000. World watch list for domestic animal diversity. Food and Agriculture Organisation of the United Nations (FAO), Rome, Italy.

Websites

Animal Production and Health Division of the United Nations Food and Agriculture Organisation (FAO AGA):
http://www.fao.org/ag/againfo/home/en/home.html

Domestic Animal Diversity Information System (DAD-IS):
http://dad.fao.org/en/Home.htm

Ecological Society of America (ESA) Issues in Ecology:
http://www.esa.org/sbi/sbi_issues/

Intergovernmental Panel on Climate Change (IPCC):
http://www.ipcc.ch/

International Livestock Research Institute (ILRI)
http://www.ilri.cgiar.org/

Livestock and the Environment/Livestock-Environment Interactions:
http://www.fao.org/ag/aga/LSPA/LXEHTML/Default.htm

Livestock, Environment And Development (LEAD) Initiative:
http://www.virtualcentre.org/en/frame.htm

United Kingdom Meteorological Office, Hadley Centre Climate Change Projections:
http://www.met-office.gov.uk/research/hadleycentre/models/modeldata.html

United Nations Framework Convention on Climate Change (UNFCCC):
http://unfccc.int/

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