

Livestock - Environment Interactions

ISSUES AND OPTIONS



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The Study was coordinated by the Food and Agriculture Organization of the United Nations, the United States Agency for International Development and the World Bank.

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European Commission Directorate-General for Development
Development Policy Sustainable Development and Natural Resources

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Livestock - Environment Interactions

ISSUES AND OPTIONS

THIS REPORT is intended to contribute to solving one of today's most crucial agricultural dilemmas: how to find a balance between a fast growing global demand for food and the need to sustain the natural resource base of land, water, air and biological diversity. It is a direct response to the concern for food security, as expressed at the World Food Summit, and to the concern expressed for the environment through several international conventions, such as the International Convention on Biological Diversity, the Montreal Protocol on the emission of greenhouse gases and the Convention to Combat Desertification. It is also cast in the light of changes in the global trade environment, following the Uruguay Round Agreement, which may bring about significant changes in the patterns of trade in livestock and livestock products.

Fully aware of these concerns, a group of multilateral and bilateral donors and other organizations undertook to identify ways to help the livestock sector to satisfy future demands while at the same time preserving the natural resource base. These are the Commission of the European Union, DANIDA of Denmark, the Food and Agriculture Organization of the United Nations, the Ministère de la Coopération of France, BMZ through GTZ in Germany, the Directorate General of International Cooperation of the Netherlands, the Overseas Development Administration of the United Kingdom, the Environmental Protection Agency and the Agency for International Development of the United States, and the World Bank.

Focussing on livestock production and processing, which often have been associated with negative environmental effects, this report identifies how to alleviate the negative and enhance the positive impact of livestock on the environment and thereby contribute to the sustainable use of the natural resource base. This summary report is directed at policy makers. In parallel, a fuller version will be published directed mainly at a technical audience in the domains of agricultural development, livestock production and the environment.

We sincerely hope that this document will contribute to finding practical solutions to these important global issues.

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Livestock, Environment & Human needs



THERE ARE massive pressures on animal production to satisfy the deeply rooted demand for high value animal protein. These pressures are resulting in a major transformation of the livestock sector, from one which is resource-driven (based on available waste and surplus products) to one that looks aggressively for new resources. The massive appetite of the growing urban populations for meat, milk and eggs often translates into environmental damage and disruption of traditional mixed farming. Where population pressure and poverty coincide, such as in pastoral areas poor management of livestock degrades resources still further. These pressures call for new policies, institutions and markets and require the development and adaptation of new technologies to make livestock environmentally more benign. The scope is enormous and so is the task.

LIVESTOCK IN A CHANGING WORLD

The association between humankind and animals dates back to prehistoric times but, although the environment may previously have been hostile it is only in recent times that it has become necessary to consider how to satisfy human needs for food without destroying the environment in which that food production must take place. The domestication of animals and their integration

with crop agriculture have provided the main avenue for agricultural intensification and this, in turn, has allowed for unprecedented economic and human population growth. Livestock production, mainly as a result of pressures in this process, has become an important factor in environmental degradation. Large land areas have become degraded through overgrazing and deforestation because of ranching. Biodiversity is affected by extensive as well as intensive livestock production. Water

Table 1.1 Animal production growth rates in percent for major livestock products from 1990 to 1995.

Commodity	Developing countries	Developed countries
Ruminant meat	4.3	-2.0
Pork	8.5	-1.2
Poultry	12.1	1.9
Milk	3.4	-1.9
Eggs	9.4	-1.5

Source: FAO - WAICENT, 1998.

availability in low-rainfall areas is affected by livestock. Where animal concentrations are high land and water may be polluted through waste from animal production and processing. Livestock are an important source of gaseous emission, contributing to global warming, which is projected to increase by 1.8^o Celsius worldwide over the next 35 years (Houghton, *et al.*, 1995). All these pressures on the environment are the result of a process of change in which the rising demand for livestock commodities is creating a new role not only for livestock but also for the environment. In essence, the conflict between livestock and the environment is a conflict between different human needs and expectations.

The world's livestock sector is growing at an unprecedented rate and this growth is only taking place in developing countries. Livestock are not only important as producers of meat, milk and eggs, which are part of the modern food chain and provide high value protein food, but other non-food functions, although of declining importance, still provide the rationale for keeping the majority of the world's livestock. For millions of smallholder farmers, animal draught power and nutrient recycling through manure compensate for lack of access to modern inputs such as tractors and fertilizer, and help to maintain the viability and environmental sustainability of production. Often, livestock constitute the main, if not the only, capital reserve of farming households, serving as a strategic reserve that reduces risk and adds stability to the overall farming system. As such, livestock can satisfy a large variety of human needs. Yet, in many places, livestock production is growing out of balance with the environment or denied access to traditional key resources and degradation is the result.

The driving force behind the surge in demand for livestock products is a combination of population growth, rising incomes and urbanization. The world's population is currently growing at 1.5 percent; the growth rate is 1.8 percent in the developing countries and stagnating at less than 0.1 growth in the developed countries. The real incomes of consumers in the

developing countries have doubled since the early '60s. With the exception of the '80s, per capita GDP has grown annually by over 3 percent per year. There is a strong positive relationship between level of income and consumption of animal protein. As people become more affluent consumption of meat, milk and eggs increases relative to the consumption of staple food. Diets become richer and more diverse, and the high-value protein that livestock products offer improves the nutrition for the vast majority of people in the world. Incomes have increased in most countries over the past five years, particularly in Asian countries. In the developed countries, however, increasing incomes are no longer associated with incremental consumption of animal protein as markets have become saturated. On the contrary, higher income often leads to a decrease in animal food consumption because of human health concerns particularly the incidence of heart and blood circulation diseases associated with excessive consumption of animal fats. We also observe a shift from red to white meat, and away from animal fat.

Urban populations differ from rural populations in having a higher consumption of animal products in their diets, further fueling demand (IFPRI, 1995). Currently, over 80 percent of the world's population growth occurs in cities of developing countries. Worldwide, urbanization has risen from 30 percent of the population to 45 percent in 1995 and is projected to reach 60 percent by 2025 (UNFPA, 1995). In the developed countries, urbanization rates have levelled at 80 percent while in the developing world urbanization still averages 37 percent with marked differences between the regions: 74 percent in Latin America but only 34 percent in Africa and Asia. In the past, many governments tried to slow down urbanization but it is now increasingly recognized as a rational pattern of development as economic activity at higher levels of development benefit from agglomeration.

Table 1.2 Gross Domestic Product per capita and annual percentage change in different world regions.

Region	GDP/kaput (US\$, 1994)	change % per year %	
		'80-'90	'90-'95
OECD-countries	21,393	2.1	0.9
East & South East Asia	947	6.1	9.2
South Asia	318	3.4	3.3
Central & South America	3,392	-0.1	1.4
West Asia & North Africa	2,309	-2.2	-0.5
Sub-Saharan Africa	482	1.1	-1.3
Eastern Europe and CIS	1,502	1.2	1.0

Source: Ingco *et al.*, 1996. UN, 1996. World Bank, 1996.



The rapidly increasing demand for livestock products pushes against a traditional resource base for livestock production that cannot expand at the same pace. Diversity is a main characteristic of traditional livestock production. A wide array of feed resources is being used, most of which have no or only limited alternative value. These include pastures in marginal lands, crop residues and, to a certain extent, agro-industrial by-products and waste from households. The scope for increasing the traditional feed resource base is limited. Firstly, across the world the most productive pasture lands are being turned into cropland as the demand for high-potential arable land continues to increase. Likewise, degraded cropland is fallowed and reconverts into poor pastures. As a result, the overall pasture area may not change much but the land productivity is likely to be lower. Technologies that increase pasture productivity have shown impressive results in Latin America but, globally, productivity growth is marginal. Secondly, the basic principles of crop research are to optimize the transformation of land resources, solar energy and inputs into high-value products, for example, into grains. Consequently, the availability of crop residues for animal feed does not increase with rising yields.

The desire for greater productivity from livestock is resulting in a change in the use of animal genetic resources. Traditional genotypes, which have developed through exploitation of harsh environments, cannot match the sector's demands for higher productivity. Now that the means exist to modify the bio-physical environment, even in the tropics, exotic genotypes are being introduced which provide a higher return on external inputs. Consequently, the use of indigenous breeds is diminishing.

As the world economy develops and many countries industrialize, people seek different uses of livestock. The association between man and livestock has undergone

many changes over time and will keep changing. For example, the empire of largest geographical expansion ever, was based on transport and communication by horses (the Tartars in the 14th century). Today, non-food functions are generally in decline and are replaced by cheaper and more convenient substitutes. The following trends may be depicted:

- ◉ The asset, petty cash and insurance functions that livestock provide is being replaced by financial institutions as even remote rural areas enter the monetary economy;
- ◀ With the notable exception of parts of sub-Saharan Africa and some areas in Asia animal draught is on the decline as more farmers mechanize;

Manure continues to be important for nutrient management in mixed farming but its role in overall nutrient supply is declining because of the competitive price and ease of management of inorganic fertilizer;

Although the demand for natural fibres is still high, and in some places even increasing, there are increasingly more synthetic substitutes for wool and leather.

The opportunities that arise from strong market demand conflict with the limited potential to expand the conventional resource base. This results in an extremely dynamic situation in terms of technology and resource utilisation. Technological progress has achieved over the past 30 years a doubling of productivity per animal in OECD countries. A major productivity gap remains in developing countries. Closing this productivity gaps could offer opportunities to relieve the strain on natural resources but it is clear that this cannot be obtained by

expanding the conventional resource base. Increasingly, the world livestock sector resorts to external inputs, notably high quality feed but also more productive breeds and better animal health and general husbandry inputs.

Grazing systems offer only limited potential for intensification and livestock production is becoming increasingly crop-based. Thus, the importance of roughages as a feed resource is decreasing at the expense of cereals and agro-industrial by-products. There is an important species shift towards monogastric animals, mainly poultry and pigs. While ruminant meat accounted for 54 percent of total meat production in the developing countries in 1970, this has gone down to 38 percent in 1990 and is projected to further decrease to 29 percent in 2010 (FAO, 1995). This species shift reflects the better conversion rates for concentrate feed by monogastric animals.

Livestock production is becoming separated from its land base, urbanized and is beginning to assume the features of industrial production. In recent years, industrial livestock production grew at twice the rate (4.3 percent) of that in mixed farming systems (2.2 percent) and more than six times the grazing system production growth (0.7 percent) (Seré and Steinfeld, 1996). This trend has accelerated in the past five years.

In agro-ecological terms livestock production is growing more rapidly in humid and sub-humid zones than in arid tropical zones and the highlands. The growing human population largely explains the expansion of livestock into the more humid zones because, when people move into an area, land is cleared thereby reducing the threat of animal diseases which would otherwise have precluded livestock production. It is in these zones, therefore, that pressure on the environment will build up most rapidly. The complexity of livestock-environment interactions makes generalizations difficult and has left a void in the development of comprehensive policies in this regard.

In some regions, such as the Americas, livestock ownership is severely skewed in favour of the wealthier groups in society. For example in southern Africa and Central America, political decision is often influenced by livestock owners. In the European Union and the USA, the livestock lobbies belong to the most powerful political action groups. Yet in many other regions, such as the Indian sub-continent and North Africa, livestock is especially owned by the poor. In sub-Saharan Africa, herders are politically marginalized.

Typically, livestock products have a high elasticity of demand but traditionally a low elasticity of supply, particularly in land-based smallholder production.

Because of this demand pattern it has been argued that livestock development tends to favour the higher-income sectors of society - an isolated view, yet one that has deterred potential donors - but does not adequately take account of benefits on the supply side. These factors have created a *policy void* which is further exacerbated by the general move, in developing and developed countries alike, to reduce the presence of governments and to liberalize markets and trade.

THE ENVIRONMENTAL CHALLENGES

The balance between human needs and natural resource requirements will depend, to a significant extent, on what we do with animal production. Over the last 35 years large land areas have become degraded. In many parts of the world, water resources have fallen to dangerously low levels or become unsafe to drink. Global temperatures have risen by about 0.5^o Celsius since the beginning of the industrial revolution of the nineteenth century. McNeely *et al.*, (1990) estimate that more than 3,000 plant species and more than 500 animal species are in immediate danger of extinction.

Focusing on the livestock-associated environmental problems, some hot spots stand out:

- *Land degradation of semi-arid lands* in Africa and India, caused by a complex set of factors involving man and his stock, crop encroachment in marginal areas and fuelwood collection. Land tenure, settlement and incentive policies have undermined traditional land use practices and contributed to degradation through overgrazing. (Map 1)
- Livestock follows deforestation where ranching pushes into the remaining *rainforest frontiers*. This is the case in Central and South America, and, to a very limited extent, in Central Africa and South-East Asia. Misguided policies, where the expedient use of ranching to obtain land titles and fiscal incentives, have encouraged extensive grazing and large-scale clearance of forest. Significant biodiversity losses are associated with such deforestation. (Map 2)
- In northwestern Europe, northeastern USA, and in densely populated areas of Asia, animal waste production exceeds the absorptive capacity of land and water. Continuous nutrient import results in over-saturation of nutrients with a series of negative implications on the environment, including biodiversity losses, groundwater contamination, eutrophication and

soil pollution. *Nutrient surplus* situations are a result of human population pressure and livestock density, access to markets, and feed and fertilizer incentive policies, aggravated by lack of regulatory response. (Map 3)

● In many *highland areas* of the tropics, high human population densities are traditionally sustained by complex mixed farming systems. Continuing human population pressures lead to decreasing farm sizes to a point where the system disintegrates. Livestock, often large ruminants, can no longer be maintained on the farm. The nutrient and farm power balance runs into a widening deficit and disinvestment occurs as natural resources degrade. This process has been called *involution of the mixed farming system* (Ruthenberg, 1980) and can be observed in the eastern and central highlands of Africa, Java and Nepal. Here, with the disappearance of the resource-enhancing role of livestock, the environmental balance is disrupted, often resulting in human conflict (Map 4).

● Mainly in the developing countries, *slaughterhouses* release large amounts of waste into the environment, polluting land and surface waters as well as posing a serious human health risk. Because of weak infrastructure, slaughterhouses often operate in urban settings where the discharge of blood, offal and other waste products is uncontrolled.

In these hot spots, livestock interacts mostly with the

Box 1.1 Scapegoats and missed opportunities.

PERHAPS IT is no coincidence that the scapegoat is an animal. Statements like: "Livestock have been criticised for damaging the environment in a number of ways" (FAO, 1995) and "Livestock have been charged with wholesale devastation of African rangelands and irreversible destruction of soils - desertification" (Winrock International Institute, 1992). It would appear as if livestock themselves go out and decide to destroy or not to destroy our environment; two centuries after the age of enlightenment we are still in need of a scapegoat, literally. Livestock do not move, produce or reproduce without our wanting it. They are completely dependent upon us and inseparable. Livestock do not degrade the environment - humans do. As a result of these misconceptions about livestock development, institutions and governments *continue to miss opportunities* which would permit the livestock sector to make its full contribution to human welfare and economic growth.

environment within the confines of a production system. In addition, livestock affect some global commons which are essential parts of our support system. Biodiversity is affected indirectly through concentrate feed requirements and the resulting intensification and expansion of crop agriculture. Related environmental effects may be disguised because livestock production and feed production are geographically separated and only linked through international trade. Furthermore, livestock and livestock waste emit important quantities of greenhouse gases such as methane and nitrous oxide, contributing to the phenomenon of global warming. Livestock can also have beneficial effects on the environment. Grazing livestock can improve species wealth and the integration of livestock into mixed farming systems can improve water infiltration and recharge of groundwater reserves. The biggest contribution of livestock to the environment, however, is to be seen in providing the main avenue for sustained intensification of mixed farming systems. This is bound to continue even when crop and livestock activities specialize into separate activities as they often do under developed market conditions. This resource-enhancement and resource-sparing effect continues to be underestimated because it is indirect and does not catch people's eyes. Without this environmental function, intensification of agriculture could not have taken place and current populations could not be sustained.

Increased attention to livestock-environment interactions is therefore of critical importance in sustaining the world's resource base. These interactions have been the subject of much conjecture, often lacking objectivity and over-simplifying complex relationships (Box 1.1). Such scarcity of informed decision-making has often exacerbated the negative effects. For example, the misperceptions regarding overgrazing in the arid areas led to measures which controlled stocking rates and movements, thereby causing more, rather than less, land degradation. A better understanding of the complementarity of domesticated and wild animals would have led to greater species wealth and improved well-being of local human populations.

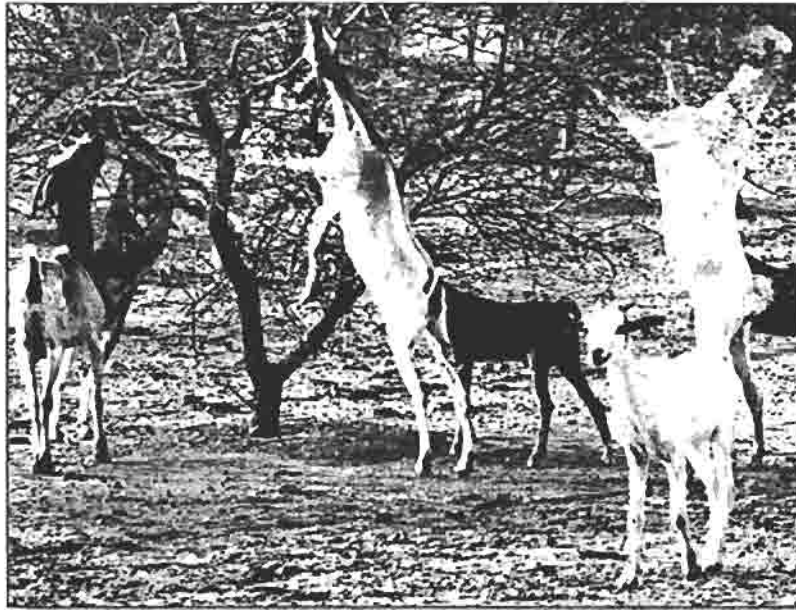
Finding the balance between increased food production and the preservation of the world's natural resources remains a major challenge. It is clear that food will have to be produced at less cost to the natural resource base than at present. Arguably, the environmental problems associated with livestock production would best be resolved by reducing consumption of their products, as many environmentalists suggest (see, for example, Goodland,

1996). We believe that chances for lowering the overall demand are close to nil and that the billions of poor people have a right to improve their diet. We acknowledge that consumption of meat and other livestock products is in some countries and social classes excessive, causing medical problems such as

cardiovascular diseases and high blood pressure. For the large majority of people, however, particularly in the developing countries, livestock products remain a desired food for nutritional value and taste. This, as well as the developing requirements of the majority of countries need to be respected.



Where & how it happens



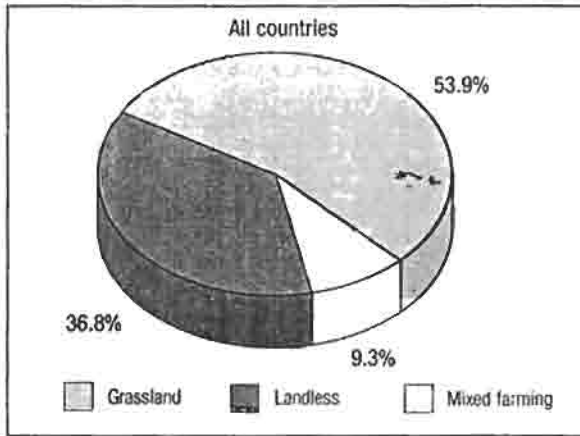
LIVESTOCK CAN damage land and vegetation in a number of different ways but there are also many examples of environmental balance and positive contributions. Livestock interact with land (which includes soil and vegetation), water, air, and plant and animal biodiversity. About 34 million km² or 26 percent of the world's land area is used for grazing livestock. In addition, 3 million km², or about 21 percent of the world's arable area is used for cereal production for livestock feed. Livestock produce approximately thirteen billion tons of waste. A large part of this is recycled but, where animal concentrations are high, waste poses an enormous environmental hazard. Livestock grazing can affect the water balance in certain areas. Water is needed for fodder and feed concentrate production, as drinking water for animals, and to drain surplus waste and chemicals. Livestock interact directly and indirectly with biodiversity; while often biodiversity is compromised there are also examples of mutual benefits. Livestock, and livestock wastes, cause gaseous emissions with important local and global impact on the environment.

“HOT SPOTS” OF LIVESTOCK-ENVIRONMENT INTERACTIONS

For a large part, livestock interact with the environment within the confines of a production system. These production systems are evolutionary responses to population pressure, resource endowment and marketing opportunities. Three main production systems are

distinguished (Seré and Steinfeld, 1996): grazing, mixed farming and industrial systems. *Grazing systems* are mainly based on native grassland, with no or only limited integration with crops. These systems rarely involve imported inputs and generally have a low calorific output per hectare (Jahnke, 1982). In *mixed farming systems*, livestock and crop activities are integrated. For agriculture as a whole, this has been the

Fig. 2.1 Total meat production from different production system.



main avenue for intensification. As by-products (crop-residues, manure) of one enterprise serve as inputs into the other, this system can be environmentally friendly. *Industrial production systems* are detached from immediate land in terms of feed supply and waste disposal. Where the demand for animal products increases rapidly, land-based systems fail to respond and lead to animal concentrations which are out of balance with the waste absorptive and feed supply capacity of the land.

Grazing and overgrazing

About 34 million km² or 26 percent of the world's land area is used for grazing livestock.

Grazing animals can improve soil cover by dispersing seeds with their hoofs and through manure, while controlling shrub growth, breaking up soil crusts and removing biomass which otherwise might provide fuel for bush fires. All these impacts stimulate grass tillering, improve seed germination and thus improve land and vegetation. On the other hand, heavy grazing causes soil compaction and contributes to erosion, and decreases soil fertility, organic matter content and water infiltration and storage.

The *arid rangelands* with a vegetation period of less than 90 days have generally been associated with widespread degradation. Several authors (Dregne *et al.*, 1992, WRI, 1992) argued that the majority of the world's rangelands are moderately or severely desertified. UNEP (ISRIC/UNEP, 1991), estimates that, since 1945, about 680 million hectares or 20 percent of the world's grazing lands show significant soil degradation.

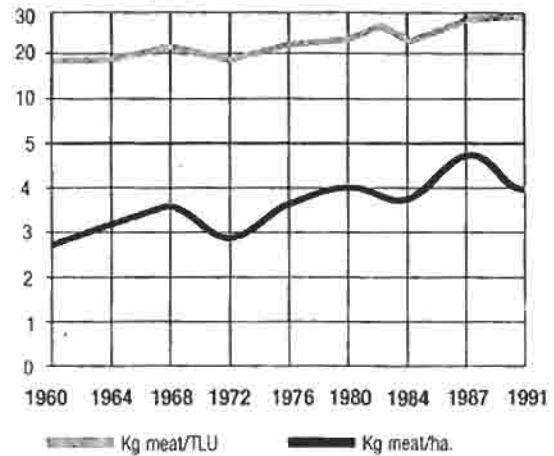
However, if irreversibility and declining productivity are taken as the main characteristics of degradation

(Nelson, 1990), then the actual situation of the world's arid grass and rangelands is better than generally reported. For example, in the Sahel, animal production per head and per hectare has improved, rather than declined over the last three decades (see Box 2.1). This has occurred in spite of a large increase in the number of livestock, and a decrease in the area of rangelands. This surprising increase in productivity confirms the findings of NASA (Tucker *et al.*, 1991), which show vegetation at the same northern limits as before the big droughts of the seventies and eighties. They point to a fluctuating pattern, or a "contracting and expanding Sahara" rather than a continuously expanding desert.

In the light of this evidence, the arid rangelands are

Box 2.1 Productivity trends in the Sahel.

AN ANALYSIS of livestock production in five Sahelian countries over a thirty year period, carried out as part of this study, shows a 93 percent increase in the meat produced per ha, and 47 percent increase in the meat produced per head. At the same time, there was a 22 percent increase in the animal population (from 14.5 to 17.6 million TLU¹) over the same period.



This productivity increase occurs in both cattle and small ruminants. Part of the increased productivity might result from the progressive move of the livestock population from the arid to the more humid areas, and the increased use of crop residues. However, a part from the sharp inter-annual variation, the long term trend points to a rather sustained productivity, and obvious stable resource base.

Source: Analysis carried out under this study, based on FAO-WAICENT data.

¹Burkina Faso, Chad, Mali, Niger, Senegal and Sudan

now seen as containing dynamic and highly resilient ecosystems, especially under traditional management of continuous adjustment to the highly variable rainfall (both in time and space). Arid vegetation is extremely resilient and most of the changes observed are the result of particularly dry spells and are therefore likely to be temporary. The decrease in woody and perennial species observed over the last decades in the Sahel (Boudet *et al.*, 1987) is likely to be the result of recent droughts. Restoring an area brings the original flora back again (Hiernaux, 1996), which indicates that the loss of these species is not irreversible. In effect, in an extensive review of grazing and production data of 236 sites worldwide, including many sites in the arid zone, it was shown that there was no difference in biomass production, species composition and root development in response to long term grazing in the field (Milchunas and Lauenroth, 1993). The continuous "dis-equilibrium"² conserves land, especially in the annual vegetation of the more arid areas, as the low pressure after a drought facilitates recuperation and, although with a time lag, overall grazing pressure is adjusted to the amount of feed available. Flexibility and mobility are therefore key requirements to achieve sustainable rangeland use in these areas.

Where this mobility is impaired and customary practice impeded by changing property rights, degradation often occurs. The nationalization of arid rangelands which was introduced by many governments in the post colonial period in Africa and Asia, undermined the intricate fabric of customary practice by replacing an ecologically well balanced system of communal land use with a "free for all" open access system. The deterioration of common property resources has been documented by Jodha (1992) for India. Here, the area under common property not only decreased by as much as 30 to 50 percent over 30 years but was also accompanied by significant degradation caused by the erosion of traditional institutions and informal obligation of common resource maintenance. Policies to "settle" the pastoralists, to promote ranches and regulate stocking rate, which were major principles of arid rangeland development of the 1960s and 1970s, reduced the critical mobility and flexibility in that system, and tied down stock to graze limited areas which might have received little rain. In the Middle East and Central Asia, state farms are being privatized and cut up, thereby impeding pastoralists' mobility.

The development of water points for human and livestock use often open up arid lands and cause land degradation. Around the water points, bare surfaces are caused by animal trampling. The degraded land typically accounts for 5 to 10 percent of the total area. Normally, soil fertility is quite high but normal vegetation patterns are impeded by the impact of hoofs, including soil compaction, and heavy grazing. Long term studies in Senegal and Sudan (Thomas and Middleton, 1994) did not find a significant expansion of the sacrifice areas of individual water points in these countries. More importantly, water development in the arid areas might upset entire ecosystems by changing the relationship between traditional wet and dry season grazing areas, and converting traditional dry season grazing into year-round grazing.

In the semi-arid zones, those with more than 90 days' growing seasons, land degradation through grazing livestock is much more serious than at the fringes of the desert, and this is where the main livestock-environment hot-spot is to be seen. Data from a transect in Mali showed that land degradation in the 600-800 mm rainfall areas was significantly greater than in the 350-450 mm rainfall area. In the higher rainfall area, the percentage of barren soil increased from zero to 10 percent over the period 1950-1990 whereas in the arid areas there was no significant change. A similar situation is reported in parts of North Africa and the Middle East (Sidahmed, 1996), although quantitative data are not available.

This degradation is linked to the growing population in these areas. Crop encroachment, fuelwood collection and overgrazing are the interlocking factors causing land degradation in the semi-arid zones. Crop encroachment

Box 2.2 How rational are pastoralists?

THE PERCEPTION that pastoralists maintain unproductive animals in their herds for "prestige" rather than economic reasons, is still widespread. This, in the eyes of many, is one of the main reasons for overstocking and land degradation. However, almost all studies on pastoral and agro-pastoral systems show that there are very few unproductive animals in traditional herds (ILCA, 1994). Animals are sold when they have their optimum market weight. Unproductive animals are sometimes found in "investment herds" owned by traders or civil servants who, in the absence of reliable and remunerative banking systems in sub-Saharan Africa, invest in livestock.

² The theoretical bases for range management under those conditions have recently been well described by Behnke, Scoones and Kerven (1993) and Scoones (1995).

not only exposes the soil directly to the erosive effects of winds and downpours, it progressively hampers the flexibility of animal movement because it obliterates passages between wet and dry season grazing areas. Fuel and fertilizer subsidies, especially in the Middle East and North Africa, often exacerbated the conversion of the higher potential sites within arid rangelands into marginal crop land. Drought emergency programmes, which handed out subsidized concentrate feed, probably also contributed to range degradation, allowing too many animals to be maintained on the range, and preventing an ecologically normal regeneration of the range vegetation after the drought. These feed subsidies have now become a structural phenomenon, especially in North Africa and the Middle East, leading to continuous growth of the livestock population which are no longer constrained by poor pasture productivity in these low rainfall regions.

While data on the effect of grazing on water infiltration are site specific, the picture emerges that light to moderate grazing can improve or maintain infiltration, whereas heavy grazing almost always reduces it. Long term observations on the Edwards Plateau in Texas have shown that both heavy grazing and no grazing caused lower infiltration and higher erosion rates than moderately grazed pastures (GMS, 1996).

Complementarities can be observed between wildlife and livestock. There is increasing evidence that the combination of wildlife and livestock can result in greater biodiversity and a higher income for pastoralists and ranchers. Usually, livestock-wildlife combinations do not require significant reductions in livestock stocking rates. For example, a reduction of only 20 percent of the cattle stocking rate is estimated to be required to create the "niche" for most wildlife species to prosper (Western, personal communication). Others estimate (Byrne *et al.*, 1996) a larger dietary overlap, and thus the need for a greater reduction, but all agree that there is substantial complementarity. There is also fairly general agreement that wildlife ranching on the basis of meat alone is not financially viable. Game meat is now attractive because it occupies a "niche market".

Environmental degradation in semi-arid zones also occurs as *water pollution* by agrochemicals used for the control of livestock disease "vectors" such as ticks (carriers of many diseases, such as Anaplasmosis and East Coast Fever), tsetse flies (carriers of the African Sleeping Sickness in man and animals) and weeds. Ticks have been controlled traditionally by cattle dips or sprays using organo-chlorines. Fauna has been damaged both by inappropriate dosing (which has led to increased resistance of ticks) as well as by inappropriate drainage

(which has led to used dip being discharged to open water). Herbicides and other pesticides have frequently been used in the industrialized world although the amount used on range and grasslands is minimal. For example, only one percent of the rangelands in Texas is treated with herbicides (GMS, 1996).

For the *temperate climates*, the main concern is the impact of grazing on biodiversity in stream riparian areas, which account for about 5 percent of the total grazing area in these zones. Such stream sides typically receive 20-30 percent more grazing animals (GMS, 1996), and cattle in particular can thus influence the water quality (increased nitrates and phosphates), as well as plant and animal biodiversity of land and aquatic systems (GMS, 1996). In such riparian areas sheep have been shown to have a smaller impact on plant communities and stream pollution. These areas require special attention, site specific mitigative actions and the use of appropriate livestock species.

Livestock and deforestation

Tropical rainforests cover about 720 million ha. and contain approximately 50 percent of the world's biodiversity. Since 1950, more than 200 million hectare of tropical rainforests were lost, with various contributing factors, including ranching and crop cultivation and forest exploitation. Ranching-induced deforestation is one of the main causes of loss of some unique plant and animal species in the tropical rainforests of the Americas, one of the world's richest sources of biodiversity. These rainforests are estimated to contain 50 percent of the world's plant and animal species (World Commission on Environment and Development, 1987). Since 1950, the area in Central America under pasture has increased from 3.5 million to 9.5 million hectares, and cattle populations have more than doubled from 4.2 million to 9.6 million head over the same period (Kaimowitz, 1995). On the other hand, in Asia and Africa deforestation is mainly the result of crop expansion.

Table 2.1 Annual deforestation 1980-1990 (million ha and percent) in different regions of the world.

Region	Annual change in area (m.ha)	Annual rate of change (%)	Remaining forest area (1990) (m.ha)
Latin America	1.9	0.4	454
Africa	0.5	0.5	86
Asia	2.2	1.1	177

Source: FAO, 1994.

Table 2.2 Some estimates of the main causes of deforestation (percent of total deforestation).

Region	Crops	Livestock	Forest exploitation
South America	25	44 (70 in Brazil)	10
Asia	50 - 60	Negligible (Philippines & Indonesia to some extent)	20
Africa	70	Negligible	20

Source: Breinig, 1991.

In the humid tropics, forest and savanna clearing to establish pastures for ranching causes soil nutrients to leach out rapidly. Weeds displace grasses, and artificial pastures can only be sustained for a period of up to ten years. More than 50 percent of the pasture areas in the Amazon area has now been abandoned in a degraded state. Natural regeneration of forests is quite difficult, especially in large areas. Under good management and using modern technology, however, the establishment of pasture and the introduction of cattle can be the "second best" in maintaining soil fertility. For example, CIAT (1994) developed a sustainable land management system, using grass and nitrogen-fixing legumes.

Land speculation, titling procedures and governments providing financial incentives have been the main reasons for ranch-induced deforestation (Kaimowitz, 1995). *Land speculation* is heavily influenced by road construction, because land prices are closely correlated to the distance to an all-weather road. In many countries, *land titling* procedures still require that the land is under agricultural use before a title can be given. Such procedures, of course, encourage deforestation. *Incentive policies*, in the late '60s and '70s which provided subsidized interest rates with lenient reimbursement conditions and beef export subsidies, have played an important role in ranch expansion. They have been phased out, and this has stopped investment in large ranches by absentee owners. This is reflected in the decline in the deforested area. In Central America in the 1980s, rainforest disappeared at an annual rate of 430,000 hectares per year. This had declined to 320,000 hectares over the period 1990-1994, although this should be seen in the perspective of only about 19 million hectares remaining in 1990. Current ranch-induced deforestation is mainly caused by smallholders, who have no other means to sustain themselves, and who have to "slash and burn" new areas because the current system of pasture establishment and management is not sustainable.

Crop-livestock interactions: intensification and involution

The integration of crop and livestock still represents the main avenue for intensification of food production. Mixed farming provides farmers with an opportunity to diversify risk from single crop or livestock production, to use labour more efficiently, to have a source of cash and to add value to low value or surplus feed. To varying extents, mixed farming systems allow the use of waste products of one enterprise (crop by-products, manure) as inputs to the other enterprise (as feed or fertilizer). Mixed farming is, in principle, beneficial for land quality in terms of maintaining soil fertility. In addition, the use of rotations between various crops and forage legumes replenishes soil nutrients and reduces soil erosion. (Thomas and Barton, 1995)

Adding manure to the soil increases the nutrient retention capacity (or *cation exchange capacity*), improves the physical condition by increasing the water-holding capacity and improves soil structure stability. This is a crucial contribution because, in many systems, it is the only avenue available to farmers for improving soil organic matter. It is also substantial in economic terms. Approximately 20 million tons or 22 percent of total nitrogen fertilization of 94 million tons (FAO, 1997) and 11 million tons or 38 percent of phosphate is of animal origin, representing about US\$ 1.5 billion worth of commercial fertilizer. Not only does animal manure replenish soil fertility but it helps to maintain or create a better climate for soil micro-flora and fauna. It is also the best way of using crop residues.

However, mixing crops and livestock neither generates new nutrients (with the exception of nitrogen fixation by leguminous plants) nor reduces nutrient surpluses. But livestock, even in situations of low technological levels allow for 1) the *spatial and temporal allocation* of nutrients from areas of lower returns from cropping to those with higher returns; 2) the *acceleration* of nutrient turnover in the production cycle; and 3) the *reduction of nutrient losses* within the cycle compared to agricultural production without livestock.

Thus, the key issue is the nutrient balance. Most mixed farming systems of the developing world have a *negative nutrient balance*. Deficits are partially covered by a flow of nutrients from (often communal) grazing areas to cropland. As population pressure changes the crop/grazing land ratio, and if other sources are not available, fertility gaps widen. This is typically the case of many mixed farming systems in the tropics. Reported deficits ranged from about 15 kg N/ha/year in Mali, to more than 100 kg N/ha/year in the highlands of Ethiopia

(de Wit *et al.*, 1996). The result is that crop yields continue to decline. This can lead to increased competition for land and grazing resources which, in turn, can lead to privatization of crop residues, or of the rangelands. Resource degradation, property and population pressure carry a high risk of conflict as the recent events in Rwanda have proven.

However, positive trends, intensifying and diversifying production also occur. A key factor facilitating such positive trends is access to markets as illustrated by the Machakos case study in Kenya. (see Box 2.3). This development path has the biggest potential in Latin America and sub-Saharan Africa, where, in most areas, land is not a limiting factor and integrated crop-livestock systems have the immense potential to contribute to the required productivity growth. However, in the intensive production systems of the tropical highlands, soil erosion problems become critical but, here also, livestock can play a positive role. For example, in Ethiopia losses from poorly managed sloping terraces under crops and degraded rangelands amount to between 20 and 100 MT/ha/year, whereas well managed pastureland loses between 0-7 MT/ha/year and well managed forest land loses between 0-10 MT/ha/year (Bojo and Cassells, 1995).

Animal draught is still a main component of many smallholder farms in developing countries, substituting for human labour and drudgery. An estimated 250 million working animals provide the draught power to approximately 28 percent of the world's arable land,

**Box 2.3 Positive effects of intensification:
The Machakos case.**

HUMAN PRESSURE and intensification can also work positively. English *et al.*, (1992) showed, that in the semi-arid Machakos district in Kenya the natural resource base improved despite a 500 percent population growth over the last 60 years, an increase of cropland from 35 percent of the higher potential area in 1948 to 81 percent in 1992, and an increase of the livestock population per farm from 5.4 Animal Units in 1940 to 16.2 in 1980. Dynamic market development made farming profitable, and off-farm employment generated enough capital for investments in soil and water conservation. Horticulture and smallholder dairy production are the main activities generating the cash for resource conservation. The famine predicted in the 1930's for the Machakos district never occurred.

equivalent to 52 percent of total cropping land in developing countries. In southeastern and east Asia, animal draught is decreasing in importance as rapid mechanization takes place. By contrast, many areas in Africa are developing into mixed farming with draught animals playing a key role in providing tillage for crop area expansion and yield increases. As a renewable form of energy, animal draught substitutes for fossil energy and the use of other natural resources.

For the mixed farming systems, livestock provides the economic justification for maintaining a mosaic of land use patterns. Agroforestry inputs such as rows of fodder trees and grass bands are widely known in terms of controlling wind and water erosion and therefore conserving biodiversity. An often overlooked component of this biodiversity is soil micro-flora and fauna. Arthropods, with 90 percent of all species, dominate biodiversity (Pimentel 1991) and are found throughout forested and agricultural areas. In a New York alfalfa "ecosystem" Pimentel reported 600 species of above ground arthropods. Mixed farming systems and the use of manure, which bring about an increase in the organic matter of the soil, enhance soil micro-flora and fauna.

Past policies have often limited the synergistic effect of crops and livestock in nutrient deficient situations. Imposing high import duties to protect domestic cereal production pushed cropping into marginal areas and upset the equilibrium between crops and livestock. Poor land tenure security, especially in the rainfed mixed farming systems of the developing world, has provided a disincentive for investment in long-term soil fertility improvements, such as the use of inorganic fertilizers and the use of green manure and leguminous fodder crops in the crop rotation.

In many places of the world, subsistence farms with crops, livestock and household closely interlinked ("closed circuit" farms) have developed and continue to be a predominant feature. With human population pressure increasing further, the need for intensification brings livestock more and more into cropping areas and integrates them in nutrient and energy cycles. Almost throughout the world the family-based and diversified mixed farming system has come under pressure either from novel technologies and market forces or from resource degradation and poverty. Two major features emerge: One scenario leads to specialization where market forces and technological requirements force mixed farming systems to grow in unit size and to specialize. With specialization, there are fewer opportunities for on-farm crop-livestock integration. The resultant environmental problems which result will



be dealt with in the following chapter. Another significant trend is what has been described as "involution", or collapse of the mixed farming system. In virtually all tropical highland areas the relatively high human population densities are traditionally sustained by rather complex, mixed farming systems. Population pressures may decrease farm sizes to a point where associated land pressures are no longer compensated by commensurate land productivity increases resulting in the disintegration of the system. Livestock, often large ruminants, can no longer be maintained on the farm. This results in a greater deficit of nutrients and energy, and leads to natural resource degradation and loss of investment. There is mounting evidence that human population pressures, poverty and resource degradation, aggravated by lack of access to markets and employment opportunities, are cause-and-effect factors of the involution. (Himalayan hills, African highlands, Andean countries, Java).

This involution of previously well-integrated mixed farming is to be seen as another livestock environment "hot spot". Here, it is not the interaction between livestock and natural resource that creates a degradation problem but rather the socio-economic context that lead to a diminishing interaction which eventually ceases altogether.

Livestock and nutrient surplus

Excess soil nutrients, which are a result of net nutrient imports, exist in large areas of northwestern Europe (the Netherlands, Germany, and Brittany in France), in the eastern and midwestern USA and Japan. These areas are generally located near ports (in order to benefit from low transport prices), and near large urban areas (to benefit from low transport costs of milk and meat). In OECD countries, nutrient excess situations are increasingly regulated, alleviating some of the environmental hazard, particularly in extreme situations such as the Netherlands. By contrast, in most developing countries, in particular pig and poultry production in Asia, lack of regulations and weak infrastructures allowed a surge of peri-urban production. Industrial livestock production emerges where the demand for animal products increases too rapidly for land-based systems to respond. This creates a vacuum which draws livestock into land-detached industrial systems. Because of weak infrastructure and therefore, high transport costs, these systems are usually found close to urban centres. Industrial production which is based exclusively on external inputs, bears enormous pollution problems and associated human health risks. Animal concentrations are out of balance with the waste absorptive and feed supply capacity of the land and, because of pollution and health hazards, most industrial production is moved out of city boundaries as soon as infrastructure permits.

In areas of high animal concentrations, excess nitrogen and phosphorus leaches or runs-off into groundwater, damaging aquatic and wetland ecosystems. Tests in Pennsylvania have shown that about 40 percent of the tested soil samples from dairy-crop farms exhibited excessive phosphorus and potassium levels. Soils are saturated, and surplus nutrients are leached into surface water and pollute the environment (Bacon *et al.*, Narrod

et al., 1994). A similar scene is set in Brittany, France, where in the 1980s, one in eight counties had soils with nitrate levels of more than 40 mg/litre. Now all eight counties report similar nitrate levels (Brandjes et al., 1995), which can cause extensive damage to the region's aquatic systems. More generally, such nutrient surpluses may affect particularly valuable ecosystems such as those adapted to poor soil conditions, by allowing encroachment by flora and fauna which are adapted to fertile soils, therefore reducing overall biodiversity.

Industrial and specialized livestock production systems emit large quantities of waste, resulting in excessive loading of manure on the limited land areas within reasonable distances of the producers. Globally, pig and poultry industries produce 6.9 million tons of nitrogen per year, which is equivalent to 7 percent of the total inorganic nitrogen fertilizer production in the world. According to Bos and de Wit (1996), 44, 50 and 20 percent of the nitrogen excreted by pigs, broilers and laying hens respectively is lost before being applied to the land.

The return of nutrients to land-based systems via manure frequently causes problems due to high water content and high transport cost. While it is difficult to generalize, transport beyond 15 kilometres is often uneconomical. In addition, mineral fertilizers, frequently a cheaper and more readily available source of nutrients, reduce demand for nutrients from manure even further, turning the latter into "waste". Surveys in Brittany have shown that, while the manure nitrogen would suffice, farmers bought an additional 80-100 kg of nitrogen per hectare per year in inorganic fertilizer. At farm level, the type of management defines the environmental burden of this waste. At the regional level, the nutrient surpluses result from feed imports. With low levels of feed imports, such as prevailing in Denmark, almost all manure can be used on the farm. With large feed imports, such as in the Netherlands, regional imbalances emerge and transport costs become a critical issue.

These nutrient surplus situations yield also excessive amounts of heavy metals, which are contained in feed as growth stimulants (copper and zinc mainly), or simple pollutants (cadmium). If the addition to the soil of heavy metals exceeds crop uptake, this may affect soil flora and fauna, ultimately posing human and animal health risks (Bos and de Wit, 1996). Regulations to reduce the heavy metal content of animal feed are now in place in most OECD member countries.

Direct drainage of manure in to surface water and leaching from saturated soils is a feature associated with industrial systems. In areas with high livestock concentrations, such as the Netherlands and Brittany in

France, but also in East Asia, the spreading of manure on land can lead to nitrogen leaching into water. Nitrates contaminate surface water, leading to high algae growth, eutrophication and damage to the aquatic and wetland ecosystems. Phosphates, although less mobile than nitrates, can cause similar problems.

In the past, industrial systems have greatly benefited from policy distortions which, in many cases, have given these systems a competitive edge over land-based systems. In the EU, high domestic prices for beef and milk and low import tariffs for cereal substitutes, such as cassava meal, have encouraged intensive production systems and the creation of nutrient surplus situations. In the former centrally planned economies, beef feedlots were based on heavily subsidized feed grain and on subsidized fuel and transport. In many developing countries there are not only direct subsidies on feed but also on energy. With energy being a major direct and indirect cost item in industrial production systems, economy-wide policies often tend to favour them over their land-based counterparts.

Waste from processing

Like waste from animal production, the processing of animal products results in environmental damage when it is concentrated and unregulated. This is the case in urban and peri-urban environments, particularly in developing countries. *Slaughtering* requires large amounts of hot water and steam for sterilization and cleaning. Therefore, the main polluting component is waste water. (Verheijen et al., 1996). The concentration of organic compounds in waste water leads to oxygen demand, usually expressed as *biological oxygen demand* (BOD). Waste water contains fat, oil, protein, carbohydrates and other biodegradable compounds. Degradation of these organic substances requires oxygen. In addition, waste water usually contains insoluble organic and inorganic particles called *suspended solids*. In most developing countries, *tannery effluent* is seweraged, discharged into inland surface waters or irrigated on the land (Verheijen et al., 1996). High concentrations of salt and hydrogen sulphide present in tannery wastewater greatly affect the water quality. Suspended matter such as lime, hair, fleshings, etc. make the surface water turbid and settle to the bottom, thereby affecting fish. Chromium tannin is toxic to fish and other aquatic life. When mineral tannery waste water is applied on the land, the soil productivity is adversely affected and some part of the land may become completely infertile. Due to infiltration, groundwaters are also adversely affected. Discharge of untreated tannery effluent into sewers

causes deposition of calcium carbonate and blocks sewers. Discharge from dairies is often an issue in the developed world where the bulk of milk is factory-processed. In developing countries, home or village processing or consumption of processed milk is much more common. In Africa, it is estimated that 80-90 percent of milk is home processed or consumed raw whereas for Latin America, this share averages about 50 percent (FAO, 1990). Waste water production is the major environmental concern, mainly resulting from cleaning operations.

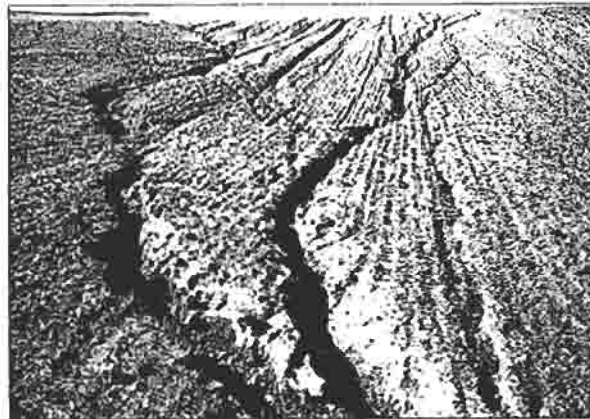
Waste water, mostly in large quantities, is one of the greatest environmental problems. The biodegradable organic compounds, suspended solids, nutrients and toxic compounds (particularly chromium and tannins from tanneries), result from a reduction of dissolved oxygen, into a deterioration or destruction of aquatic ecosystems. It also damages the quality of drinking water. Huge variations have been found, due to large differences in scale, in housekeeping and management practices of each factory or plant. The quantity of water used during processing is of major importance with high water use related to high emission values. In principle, the production of waste water does not necessarily lead to environmental problems if animal product processing is smallscale and not concentrated in a given area (Verheijen *et al.*, 1996).

GLOBAL OVERLAYS

In addition to the livestock-environment "hot spots", there are a number of effects which go beyond those related to the different, and usually site-specific, livestock production systems. These *global overlays* may occur as a result of trade, as in the case of the environmental effects of feed production, or because the atmosphere is affected, as in the case of gaseous emissions, or because a common resource of the whole sector is concerned, as in the case of animal genetic resources.

Concentrate feed production

3 million km², or about 21 percent of the world's arable area is used for the production of livestock feed, mostly concentrates (Hendy *et al.*, 1995). For 30 years livestock production and productivity have been increased by feeding ever greater amounts of high quality feed. Pigs and poultry, the main users of concentrate feed, require diets with a high concentration of energy and protein; such high density feeds are also used in dairy production and beef feedlots. Because concentrate feed is tradable, decisions on feed production and use are often unconnected. In other words, decisions are made separately by different individuals at different places and



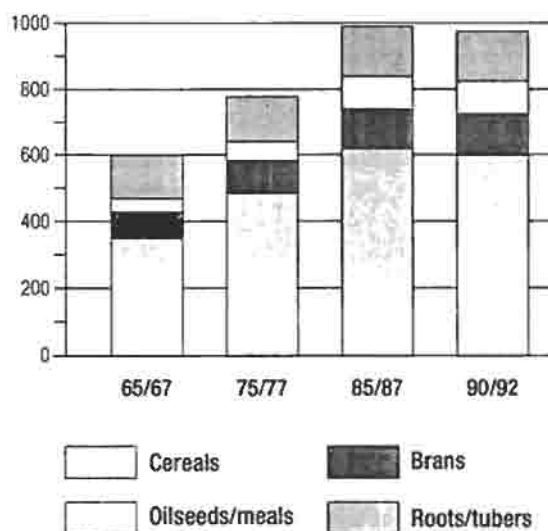
times. In effect, trading these concentrates means trading the environmental impact. Worldwide, trading feed grain and other feedstuffs involves a massive transfer of nutrients, depleting the production resources, and fertilizing, and often polluting, the location of final use.

The production of concentrate feeds has an impact upon the natural resource base at various stages of crop production, trade and processing of feeds. Production affects land use through deforestation and change of habitats, and it has an impact upon biodiversity and aesthetic aspects of the landscape. In addition, there are direct effects of cropping on soils, water and air, and indirect effects as a result of the production and supply of inputs to agriculture such as machinery, fuels, fertilizers and pesticides.

Cereals are the major component of livestock concentrate feed. Thirty-two percent of the world's cereal production is consumed by livestock. Yet this cereal is produced on only 20 percent of the total cereal cropland. The total of all cereals, oilseeds and roots and tubers used for livestock feeding is 744 million tons. An additional 252 million tons (about 24 percent) of all concentrates are processing by-products (brans and oilcakes) for which there is little alternative use.

Averages based on 1990 to 1992 data indicate that global cereal production was 1854 million tons, of which 600 million tons were used for livestock feed. Maize is the most important feed grain accounting for 55 percent of total feed grain used, followed by barley and wheat.

Fig. 2.2 Global total utilization of concentrate feed resources ('000 MT per year).



Source: Hendy et al., 1995.

Soybean is the most important oilmeal, because it supplies more than half the requirements for these high-protein feeds.

The environmental impacts of crop production are site-specific, depending on a whole range of natural and socio-economic conditions and technologies. Therefore generalizations are not possible. However, some specific characteristics of feed concentrate production on the natural resource base are:

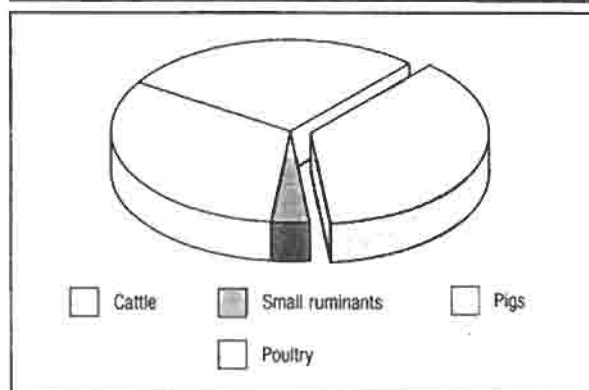
- feed is generally produced in more intensive systems in agro-ecological zones of high potential rather than the more erosion-prone marginal areas. In the high potential areas, feed can be produced at low cost, whereas the costs associated with the risks of producing crops under marginal conditions are usually prohibitive. The latter is reflected in the low grain to meat price ratios that prevail in, for example, the Sahel countries;

- feed use most commonly represents the lowest opportunity cost. Typically, feed concentrates are real surpluses, and the feed use acts as a buffer in the overall use pattern.

By the mid-1980s concentrate feed accounted for about a quarter of all feeds for livestock; and this proportion was growing at about 0.2 percentage points annually. Concentrates comprise about 40 percent of all feeds in the developed countries and 12 percent in the developing world. Roughly, cereals constitute about 60 percent of total concentrate feed, with most of the remainder provided by brans and oilcakes. Industrial pig and poultry systems are the largest single users accounting each for almost one-third of the total.

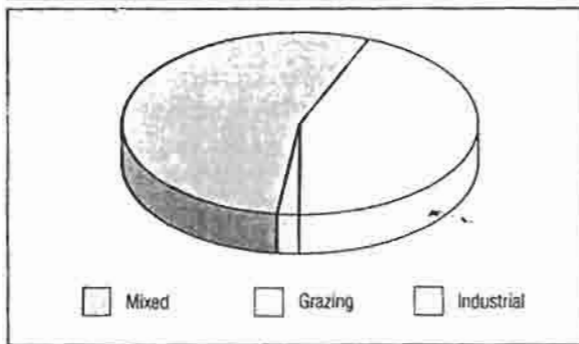
Growing demand for concentrate feed leads to area expansion and intensification, and thus potentially

Figure 2.3 Feed concentrate use by species



Source: Hendy et al., 1995.

Figure 2.4 Feed concentrate use by system



Source: Hendy et al., 1995.

exerts a wide range of pressures on the environment. Increases in the areas of land used for crop production occur at the expense of other forms of land use, mainly pastures and forests, potentially placing greater pressures on these land resources, with subsequent threats to habitats and biodiversity. However, the extent of this change needs to be put in the context of overall land use. Land with potential for cropping, including marginal areas, represents some 40 percent of total land surface in developing countries but by the year 2010 less than one-third of this land will be cultivated (FAO, 1995). Thus,

while changes in land use may be very significant in some countries and locations, they will be reduced at an overall level. The notable exception is the loss of forests where cropland development accounts for up to 60 percent (World Bank, 1992) of the annual deforestation rate of 0.8 percent (FAO, 1994).

The current expansion of cropland is globally very small, 0.1 percent annually, which compares with growth in crop production of 1.9 percent annually. (FAO, 1995). This suggests that the bulk of the increased demand for crops is met by cropland intensification rather than expansion. FAO (1995) estimates that out of the potential cropland of 2,573 million hectares in developing countries only 757 million hectares or little less than 30 percent, is currently in use. The bulk of the currently uncropped land is in the humid and subhumid zones, mostly in Africa and Latin America. It also includes substantial forest areas.

All cultivation results in soil loss and invariably depletes soil nutrients and organic matter. Excessive soil losses result in land degradation and abandonment which currently amount to 6-7 million hectares per year or 0.5 percent of the global cultivated area (El Swaify, 1991). The main causes of these losses are soil erosion

Box 2.4 The feed-food controversy.

THE FACT that one-third of the world's grain harvest ends up in the digestive tracts of livestock where the conversion of vegetable protein into animal protein is converted incurring losses of 60 to 90 percent, is disturbing large parts of the public. Often, it is perceived to be irrational and unethical.

Among the 996 million tons of concentrates used in 1994 (FAO, 1996), all cereals, roots and tubers, and pulses and some feedstuffs of animal origin (milk powder) can be classified as edible. Edible feedstuffs provide 7.4 million tons of protein to livestock.

In the same year and by contrast, livestock produced 199 million tons of meat, 532 of milk and 45 million tons of eggs, altogether yielding 53 million tons of protein. Leaving aside the differences in nutritional value, the world's livestock sector consumes more protein than it produces. The input/output ratio is 1.41 and continues to grow because livestock production increasingly relies on grains which is only partially offset by gains in efficiency of feed conversion. However, such input-output considerations overlook two important aspects: firstly, ruminants have the capacity to produce protein without being fed protein because of rumen flora activity. This allows for large ruminant

populations to produce without being fed high quality feed. Secondly, the quality of different proteins needs to be considered. Proteins of animal origin have a much higher digestibility and nutritive value than most vegetable proteins.

However, the question of feed-food competition is somewhat ill-posed. Rather than looking at what potential food goes to livestock one should look at the resource requirements. An example: a highly intensive dairy production system may rely on alfalfa fodder produced under irrigation and with heavy use of external inputs including fossil fuel, fertilizer and pesticides. Alfalfa is not edible but the land on which it is grown, and other resources could be used for food production. Apparently the food feed debate has to do with the value that food has beyond its commodity price - a less tangible religious and cultural dimension.

A recent FAO study (1996) shows that the increasing use of feed grains appears not to have had an adverse effect on the provision of cereals for human consumption. In times of food shortages such as in 1974/75, it is in feed use that adjustments are made and food consumption of cereals remained largely unaffected.

and salinization in irrigated areas. Soil erosion causes progressive loss of yields on most soils, requiring expensive correction and supplementation of nutrient. Off-farm impacts of erosion are siltation, reduced water holding and contamination of water supplies.

Nutrients and organic matter may be supplied by crop residues, composts, animal manure and crop rotations with legumes, but these sources must be supplemented with increasing use of inorganic fertilizer in order to maintain soil fertility. Increased use of inorganic fertilizer carries the risk of nutrient losses to the environment, particularly of nitrates and phosphates leached to groundwater or in run-off to surface water.

Increased crop production entails a decline in biodiversity. The major threat to biodiversity is habitat loss and alteration due to land-use change (World Resources Institute, 1994). Additional impacts are due to effects of crop production practices, such as pesticide use and some tillage practices, on non-target organisms.

Energy expenditure for producing feed concentrates vary widely but can be substantial. In crop agriculture energy consumption is comprised of direct consumption of energy on farms for field crop operations, threshing, transport, irrigation and others and indirect consumption required to produce inputs such as machinery, fertilizers and pesticides. Energy consumption is generally higher per hectare of cropland in developed than in developing countries as input levels are higher to substitute fertilizers for land and mechanisation for human labour. Typically, energy expenditure ranges between three and six GJ per ton of grain. (Compare Stout 1990, Bonny 1993, Pimentel, 1991).

Crops differ in the degree of depletion of soil moisture and water resources, in their relative demands on soil nutrients and in their typical need for applications of pesticides. In general, cereal crops, and in particular maize, have the potential to cause greater environmental damage than other crops. This is due to heavy fertilizer and pesticide use, high water demand and poor ground cover in the early stages of plant development. On the contrary, potential impacts are generally lowest for legume crops, such as soybeans and pulses. Environmental risks due to nitrate and phosphate losses are greatest from maize and wheat while risks of soil nutrient depletion are greatest in cassava and sweet potato.

Gaseous emissions of livestock and waste

Livestock and livestock waste produce gases. Some are local, such as ammonia whereas others, such as carbon dioxide (CO₂), methane (CH₄), ozone (O₃), nitrous oxide (N₂O) and other trace gases (together forming greenhouse gases) affect the world's atmosphere, by contributing to "global warming" or global climate change. Livestock's contribution to that effect can be estimated at between 5 and 10 percent. Within this range, there are considerable problems in assigning emissions to single causes.

Carbon dioxide

There are three main sources of livestock-related carbon dioxide emissions. Firstly, all domesticated animals emit carbon dioxide as part of basic metabolic function or respiration, estimated at a total of 2.8 billion MT annually. Secondly, carbon dioxide emissions result from biomass burning, part of which can be attributed to land clearing and bush fires for pasture and enhancing pasture growth. Thirdly, carbon dioxide is released in relation to livestock-related consumption of fossil fuel for heating, manufacturing of machinery and production of feed, etc.

Carbon dioxide is the least aggressive of the greenhouse gases but is emitted in large quantities. Annually, savanna and deforestation fires pump approximately 1.6 billion tons into the atmosphere, between 20 and 25 percent of the total anthropogenic CO₂ emission of 7.1 billion tons (Houghton *et al.*, 1995). However, unlike the emission from fossil fuels, the same grasslands and forests recapture part of these emissions. In effect, some of savanna improvement technologies show that improved savannas accumulate 50 tons (or the annual emission of about 15 cars) more per hectare than the traditional unimproved savannas (Fisher *et al.*, 1995).

Leaving aside respiration of domesticated animals, livestock can be associated with about 15 to 20 percent of total carbon dioxide emissions. When the carbon sequestration capacity of natural and improved grassland is considered, the contribution to the net increase in carbon dioxide concentrations in the atmosphere is probably much smaller. There are however, notable differences between the systems. Grazing systems, with little fossil fuel inputs and often considerable sequestration are likely to have a positive carbon balance whereas this balance is likely to turn negative as intensity and commercial inputs increase, such as in industrial systems.



Methane

This gas is much more aggressive (24 times) in causing global climate change than carbon dioxide. It is the product of animal production and manure management, rice cultivation, production and distribution of oil and gas (pipelines), coal mining and landfills. Livestock and manure management contribute about 16 percent of total annual production of 550 million tons (Bolle *et al.*, 1986, see graph). It is produced as a by-product of the feed digestion of mainly ruminants and, on average, about 6 percent of the feed energy is lost in methane (U.S. Environmental Protection Agency, 1995). Methane emission is the direct result of the capacity of ruminants to digest large amounts of fibrous grasses and other feeds which cannot be used for human consumption. Pigs and poultry cannot digest these fibrous feeds and therefore emissions from these animals are relatively low. Methane emissions per unit of product is highest when feed quality and level of production is low, conditions which prevail in the arid and humid tropics and sub-tropics. This offers the opportunity for a *win-win* situation: improved feeding leading to more efficient and profitable production and to reducing methane emissions.

Twenty percent of methane emanating from animal production comes from manure stored under anaerobic conditions (USEPA, 1995). Here the picture is reversed: high levels of methane emissions from manure management are usually associated with high levels of productivity and intensity, as well as from large production units.

Despite growing livestock populations, global methane emissions from livestock remain static. The reasons for this stagnation are twofold. Firstly, increases in productivity lowers emission levels per animal and per unit of product. Advances in feed resources and nutrition, and breed development are significant

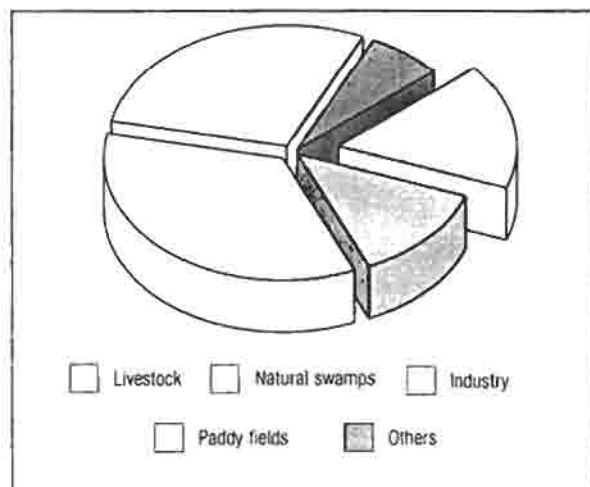
contributing factors. Secondly, monogastric production is growing at a much faster pace than ruminant production. About 80 percent of the total growth of the livestock sector is attributed to pigs and poultry which emit comparatively small amounts of methane.

Any reduction in methane production, however, is likely to result in increased emission of other gases, notably carbon-dioxide and nitrous oxide, as fossil fuels and fertilizer will be required in the intensification process.

Nitrous oxide

This is the most aggressive greenhouse gas (320 times CO_2) contributing to global warming. It is produced in animal manure which contributes about 0.4 million tons N per year, or 7 percent of the total global anthropogenic emissions (Bouwman *et al.*, 1995). Indirectly, livestock are associated with N_2O emissions from grasslands and, through their concentrate feed requirements, to emissions from arable land and N-fertilizer use.

Figure 2.5 Sources of methane emission.



Source: Bolle *et al.*, 1986.

Currently, the main policy constraint is the lack of appropriate incentives for the many existing technologies to reduce greenhouse emissions. The adoption of biogas technologies which convert methane from manure into energy is often hampered by the price of fossil fuels. In addition, there is still a lack of information on how to value the benefits accruing from reducing the losses in the global commons and on which mechanisms to use for distributing these benefits.

Domestic animal diversity

Increased intensification and industrialization of livestock production requires increasingly uniform genotypes and has caused the extinction of some, and the genetic erosion of other, local livestock breeds. There are currently about 600 breeds at risk of extinction, representing about 20 percent of the total global livestock breeds (Hammond and Leitch, 1995). In addition, it is projected that by the year 2015 the U.S. Holstein population will only have an effective population size of 66 animals, i.e. animals which are unrelated. Pig breeds in China, dairy cattle breeds in India, some of the non-cattle bovine species (yak, gaur, mithun, banteng) and buffalo resources are especially at risk. Development policies favouring exotic breeds (subsidized imports and multiplication of exotic genetic material) and technologies (subsidized machinery, replacing traditional draught breeds) have been primary causes for the erosion of traditional breeds.

Population pressure and income growth create competition for resources in special ecological "niches", which is the main reason for loss of species wealth (Cunningham, 1995). There is a significant statistical relationship between human population density and conversion of habitat into agricultural land. In most cases, however, it is not an over-exploitation of the endangered species but a change in the habitat which undercuts their capacity to survive. The transfer of excessive nutrient to a nutrient poor ecosystem is an example. This is compounded by unfamiliarity with technologies promoting symbiosis of agricultural intensification and biodiversity conservation.

A number of issues in the preservation of biodiversity need to be resolved. While conservation of biodiversity can provide some benefits to farmers, there are a number of benefits, such as the conservation of domestic genetic resources or the preservation of medicinal plants, which will benefit primarily other groups of the global population both now and in the future. This lack of an appropriate valuation of domestic and wild plant and

animal genetic resources leads to under-investment. Even where there is no deliberate attempt to distort markets, valuable habitats are converted into agricultural production, including livestock, because other costs, such as loss of biodiversity have not been accounted for.

UNDERLYING CAUSES

A growing imbalance between livestock and the environment has little to do with livestock *per se*, but with the changing expectations that people carry for both livestock and the environment.

Strong *human population growth* is fueling demand for livestock products while at the same time limiting the traditional resources for livestock production. Increase in *per capita income and urbanization* is raising the demand for livestock products and changing the geographical distribution of production, essentially breaking its balance with the land. This is further aggravated by *social inequality* allowing for different motivations for degradation, the greed of the rich and the desperation of the poor. Different levels of income, between and within countries, lead to different valuation of environmental resources and willingness to pay for their conservation.

Ignorance about ecosystems and their links with livestock leads to wrong decisions, particularly at the policy level. *Lack of know-how* in understanding the importance of ecosystem dynamics, such as those of the arid lands, has led to wrong interventions. The result of this incomplete understanding can only be corrected by a re-invigorated research, training and extension effort. *Lack of information* on the consumer side also plays a role in explaining why certain modes of production continue and more stable systems are placed at an economic disadvantage in the developed countries.

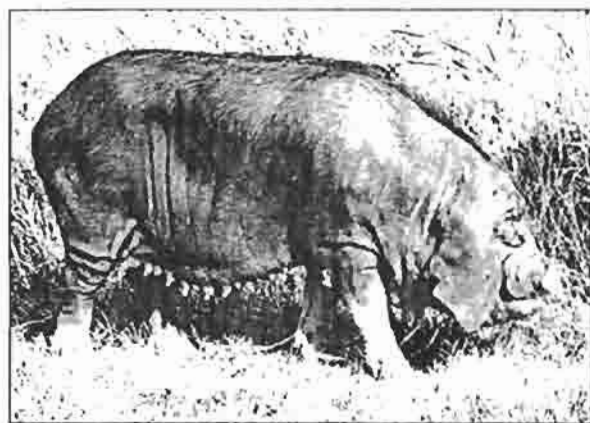
Institutional weaknesses result in ill-defined and un-enforced property rights, which deny access to essential resources in many extensive grazing systems. Poorly defined and enforced regulations fail to protect environmental resources, such as forest areas, surface waters or cropland, and poorly developed instruments to value and allocate costs and benefits of environmental goods pose practical difficulties to designing feedback mechanisms for environmental degradation.

Lack of infrastructure reduces the incentives to develop land-based livestock production and encourages the establishment of industrial systems and the concentration of large amounts of waste. Infrastructure development, on the other hand, has paved the way for reckless exploitation and destruction of valuable

ecosystems in humid forest areas, with livestock being used as a means of claiming land titles. However, in all other areas, infrastructure development and marketing infrastructure are powerful instruments to mitigate environmental impact, clearly shown in the case of Machakos (Box 2.3).

Price policies and incentives affect productivity by influencing decisions about input use, technology adoption and investments in research and development. Policies have misguided livestock development through

the pricing of inputs and products and have induced wasteful use of natural resources. Subsidized concentrate feed and free artificial insemination services are some prominent examples. Economy-wide and sector price policies often pursue social or economic objectives outside the sector and usually fail to address the environmental dimension altogether. The challenge is to design policies that direct technologies and resource use towards environmental objectives while meeting the social and economic targets.





What can be done?



POLICIES NEED to be designed to correct negative environmental effects of livestock production which are not reflected in product and input prices. These policies should address the underlying causes of environmental degradation and must be flexible, site-specific and well targeted.

Instruments to enhance positive and mitigate negative environmental effects include pricing, regulations and institutional development. The collective purpose of these instruments is to establish the use of feedback mechanisms that ensure that the use of livestock is consistent with overall social objectives.

Within an enabling policy framework, a wide range of available technologies can be employed while others still need to be developed. Their purpose is not simply to reduce the environmental damage by reducing the polluting load, but also to enhance and save natural resources, through the use of livestock, and to turn waste into useful products.

PRINCIPLES AND OBJECTIVES

The previous section analyzed the major environmental contributions and losses attributable to livestock, and the fundamental pressures that drive various systems into dis-equilibrium with the environment. The symptoms are manifold and so are the causes. However, a common thread links them: those who reap the benefits from over-exploitation or from degradation do not pay the full

costs, and those who preserve natural resources or who pay the costs of conservation gain few of the benefits. Economists refer to such a phenomenon as a *market failure*. Thus, the principle to redress this imbalance is to devise instruments which ensure that these environmental effects or externalities are "*internalized*", i.e. that the conserver gets a fair share of the benefits and that the degrader and exploiter pay the full costs.

Problems associated with implementing this principle

are not easily overcome. It begins with the need to quantify environmental damage because, as we have seen, interactions are complex and actors not easily identified. It continues with the need to translate these effects into monetary terms. Policies must then be designed to redress the externalities. This results in a redistribution of income. Whatever the levels of adjustment countries adopt, none will be cost-free. Such measures meet opposition of vested interests, and powerful lobbies will seek to avoid full accountability.

In addition, countries are constrained by economic capacity to respond to environmental externalities. The major determinant of this capacity is income (Runge, 1995). Compared to higher income countries, lower income countries cannot be expected to respond with the same intensity to environmental externalities through regulation, taxation or subsidization, a difference which carries potential for trade conflicts. In higher income countries, high concentration of animals can be reduced if governments are prepared to subsidize extensification, or to tax or regulate nitrate use, water or the scale of operations. By contrast, in lower income settings, such interventions are often beyond the government's capacity to implement. Obviously, willingness and ability to pay for environmental goods depend primarily on income. In lower income countries, food production tends to take precedence over environmental concerns. Preoccupied with day-to-day survival, the poor have limited scope to make long term investments in natural resources. Very often, they also rely on fragile, open access resources such as extensive rangelands.

It is now more widely accepted that capital has more than one dimension and that, in the face of rising and changing pressures of demand for food and agricultural products, it is impossible to maintain the natural resource base unchanged. Furthermore there are trade-offs between the different forms of natural and man-made, or owned, capital. In addition to the natural resource capital of land, water and biological diversity, there are forms of human capital resources (indigenous knowledge, education and better health), and man-made capital resources such as infrastructure. There is also a social capital which may reflect the status of the poor as decision makers and architects of their own futures, or as curators of natural resources. For the total wealth of a nation, policies need to be designed that correct for market failures indicated by environmental damage or benefits. Such policies change the availability of production factors by making them more or less expensive. Consequently, and following the concept of the *induced innovation* (Hayami and Ruttan, 1985), different technologies are employed or developed that

optimize the use of the new set of scarcities. Before designing policies, the intrinsic scarcity of key inputs such as land, labour, capital, water, feed or energy needs to be analyzed. It must then be determined how environmental externalities and government policies may cause certain inputs to be undervalued as, for example, water and feed in many Middle Eastern countries and energy in industrializing countries such as Brazil and India. Such distortions have given rise to a different set of technologies, often environmentally degrading, than those which would have been adopted had inputs been available at the market price. The task is to develop a comprehensive perspective on environmental protection and development, and an integrated approach to decision-making.

The challenge is to achieve the social and economic objectives that are often the primary motivation of public sector interventions without directing resources into unsustainable use.

POLICY DESIGN

Sectoral and economy-wide policies affect livestock's relationship with the environment. Often, these effects are unintended because they were designed to address social and economic rather than environmental objectives (Munasinghe and Cruz, 1995). This effect is compounded by the complexity of livestock's interaction with the environment and the overall economy. However a few general principles can be established (Young, 1996):

- Mechanisms that address the underlying causes of environmental degradation are likely to be more effective than those that address the symptoms. When an underlying cause can be removed the incentive for managers to cause the problem disappears and little monitoring or enforcement is required.
- Instruments, mechanisms and policies need to be coordinated in order to maximize effectiveness and they must be adjusted over time according to circumstances. The heterogeneity in land-based livestock systems which operate in very different production environments, and the varying responsiveness of people to each instrument according to factors like relative wealth, age, family needs and status, necessitates a suite of instruments that will complement and enhance each other.

● Policies and programmes that have perverse or unintended effects on the environment should be replaced by those more precisely targeted to the prime policy objective. Thus, for example, tariff barriers to protect farmers' income and farming structure inside the European Union should be replaced with direct payment schemes that would avoid, for example, nitrate pollution of groundwater in the Netherlands or soil erosion in Thailand from where much cassava feed is imported. Wherever possible, mechanisms designed to achieve social or economic objectives should be decoupled from the processes that determine market prices.

The choice of policy instruments should take careful account of local institutions, infrastructure and levels of income. Where institutions are weak, and where the polluter is difficult to identify (non-point source pollution) regulations are difficult to enforce and more reliance has to be placed on market instruments. Regulations work best where the polluter or degrader can be unmistakably identified (point-source pollution) and where government has the financial resources to establish the infrastructure and where there are reliable institutions to enforce environmental regulations.

There is ample evidence that economy-wide policies, including fiscal and monetary policies or structural adjustment programmes, have strong positive as well as negative impacts on the natural resource base. These complicated interactions are not well understood and generalizations are difficult to make. However, where market failures occur, or policy distortions and poverty cause environmental damage, broad policy reforms that promote efficiency or reduce poverty can generally be regarded as beneficial to the environment.

The objective is not necessarily to modify the original broader policies which have conventional economic or social goals because this would be an unrealistic proposition, particularly for developing countries. Rather, complementary measures with specific or localized foci should be designed that help mitigate negative effects or enhance positive effects of the original policies on the environment (Munasinghe, 1994). The challenge is to design policies that correspond to the intended social and economic objectives but still comply with environmental sustainability. The current trend in the EU to direct income support rather than price support is one move in that direction.

Institutions

Institutions are required to develop environmental policies and laws and to assist line agencies to incorporate environmental concerns into economic development planning and budgeting. There must also be institutional capability to monitor compliance and enforce environmental regulations. Institutions are essential in managing access to common property resources, such as grazing land or tropical rainforests, or to ensure security of tenure. The presence and performance of other institutions have a more indirect effect on the environment, such as those offering financial services, but are still very important in their impact on the environment.

For most traditional grazing systems under pressure by changing property rights, institutions need to be improved by decentralizing decision making. Local empowerment is required in all situations, but especially where governmental institutions are weak. The need to transfer authority and responsibility for resource management to the lowest level at which it can be exercised effectively is increasingly recognized. Often, consultation and direct participation of the community in decision-making enables local knowledge to be harnessed and for responsibility for identifying problems and finding solutions to be taken at local level. Institutions need to establish stewardship for environmental resources and to regulate access. This, in particular, refers to extensive systems where a large part of the environmental damage can be traced to a regulatory vacuum left by eroding traditional institutions.

Community-based wildlife management is becoming generally accepted as an essential component of sustainable wildlife management, and for managing livestock-wildlife interactions, in particular. There has been considerable progress in decentralizing wildlife management, especially in East Africa, and in sharing the benefits from wildlife with the involved population (Otichillo, 1996). Key issues still involve the strength and cohesion of the traditional social fabric. One example is the difference between the successful community management around the Maasai Mara park, and the less successful experience in Amboseli where traditional authority is much weaker (Kiss, 1992). An equitable distribution of revenues from wildlife among the local population is also difficult to achieve.

Property-right instruments have the potential to grant resource users a tangible interest in the environmental consequences of their actions (Young, 1996). Property-rights need to be enforced by governments and, in a subsidiary fashion by traditional institutions. Lack of security of tenure has often been identified as a prime cause of

land degradation. In the Brazilian Amazon, for example, security of tenure has been conditional upon land clearance with the result that significant areas of rainforest have been cleared solely as a means to obtain access to wealth. Land tenure arrangements are a key factor in facilitating long term investment into sustainable resource use, for both grazing and mixed systems. Farmers will only accept or initiate such activities if they can expect to harvest the revenue on such investments.

Similarly, in many parts of Africa, effective common property regimes have broken down because governments have seen fit to allocate key grazing areas to people who wish to crop them. Pastoral systems have an overriding need for mobility over large areas and to maintain access to the key resources of dry season or mountain summer pastures. This need calls for the strengthening of traditional communal grazing rights, combined with enforcement and conflict resolution mechanisms, and decentralized decision making, both in public (government) and customary law. Empowering pastoral people will be the main challenge in future pastoral development. The development of local, regional and national herder organizations has been a major thrust of most donors in West and North Africa over the last decade. While there has been considerable progress in establishing viable organizations for the provision of services such as animal health and education, these organizations have been less successful in range management (Shanmugaratnam *et al.*, 1992). The exception may be the Middle Atlas programme in Morocco funded by the World Bank where the principle of subsidiarity was applied. Lessons to be drawn from these experiences are the need to: (i) work, wherever and as early as possible, within the traditional social organization, (ii) assume a gradual transfer to pastoral groups, starting with services and progressively moving towards more demanding tasks, such as range management, and (iii) tailor the organization to the goals envisaged.

Government institutions must establish and enforce a regulatory framework for land protection or waste control, such as for industrial production systems or animal product processing units. To strengthen pollution control and enforcement mechanisms in the developing world will be an important future task. Depending on the scale of the problem, enforcement costs can be considerable.

The establishment of financial institutions may alleviate pressure on the environment where significant numbers of animals are kept primarily for investment purposes, such as by absentee herd owners in Africa or Latin America. Positive interest rates on safe deposits provide better investment alternatives if the primary purpose for keeping livestock is not production.

Incentive policies

Incentive policies rely on market forces. The more a production system is exposed to the market the more susceptible it will be to price changes. In particular, intensive production depends on inputs that contain a high component of natural resources often not reflected in their market price. These should be priced higher by *abolishing subsidies* or, in some situations, *taxation*. Examples include feed concentrates, fossil fuel, inorganic fertilizer, livestock products, land, mechanization and genetic material. This, in addition to a quantitative effect of reduced consumption, will induce a more efficient use of natural resources, with both environmental and economic gains. It will also favour a more even spatial distribution and promote land-based systems. Correspondingly, *subsidies or tax relief* can be provided where natural resources are saved or used wisely, such as through the use of renewable energy (methane) or protecting biodiversity. Essentially, the recommendation is for full cost recovery of the provision of all goods and services used by livestock producers, and also, those sectors that compete with the livestock sector for resources and markets.

To a varying extent, livestock producers in *grazing systems* need to market their produce and are thus susceptible to market stimuli. By introducing incentive policies, the system can be directed towards more sustainable resource use. For example, grazing pressure may be reduced by increasing the cost of rangeland grazing because the incentive will be to sell animals earlier than they would have been sold had it been possible to keep them for longer at little extra cost. *Incentive policies* which reduce grazing pressures are:

- *Full cost recovery*, especially for water and animal health services would provide an incentive for rapid destocking of pastoral areas when feed resources are in decline, and would encourage more efficient use. Water has been, in many places, a free good supplied publicly. Full cost recovery, including construction costs, would reduce the number of large boreholes, and therefore reduce local degradation around these water points.

- *Levying grazing fees* for communal areas could be another step to reduce grazing pressure, and has been frequently proposed. The introduction of such fees requires institutional capabilities as well as the political will to tackle the issue of fairness, with owners of larger herds paying more on a per head basis (Narjisse, 1996). Because of these problems, very little long-term experience of such fee structures exists. The use of fees is

a critical issue; ideally they should go back to pastoralists for resource management.

- Appropriate *benefit sharing* systems may also be devised for the protection of biodiversity. Their importance for community-based combined livestock-wildlife management has been mentioned. At the national or regional level, a number of instruments have been developed over the last years, including debt for nature swaps or international tradable development rights. In the European Alps (Austria, Switzerland), farmers receive income support for landscape maintenance. At a global level, benefit sharing systems may be devised for the production of global commons. Brown *et al.*, (1993) estimate the damage from a doubling of atmospheric carbon dioxide in terms of global warming at 1 percent of Gross World Product. Carbon dioxide sequestration would thus be equivalent to US\$ 10 per ton of CO₂ trapped. This would mean that the improvement of South American savannas could be valued at US\$ 500 per hectare. The key issue is how to fund and distribute such payments (de Haan *et al.*, 1997)

Box 3.1 How to reduce grazing pressure?

INTENSIFICATION: Many development projects have been based on the assumption that intensification would reduce grazing pressure. Social forestry projects in India, for example, promoted stall feeding with improved crossbred cows, but there is no evidence that this decreased the number of traditional animals in the forest. Similarly, stratification of production in, for example, North Africa and the Middle East, has not yet shown clearly a reduction in grazing pressure in the feeder lamb production area. It appears that intensified production alone does not reduce grazing pressure if access to common grazing resources remains unchanged.

MEAT PRICE INCREASE: In the same context, price increases seem to give a positive supply response in some of the trade-oriented production systems (West Africa), but yield a negative supply response in the subsistence, often milk-oriented systems (East Africa, for example). This points to the importance that flow products (draught, milk) have in relation to stock products such as meat (Steinfeld, 1988). The higher the importance of flow products the less sensitive the system will be to price variations. Thorough knowledge of the production systems is thus required before promoting intensification or stratification.

- *Taxation for pasture and crop land* in rainforest areas to discourage conversion of forest to crop and pasture land is conceptually attractive. However, with poor, or even non-existing land registry services this will be very difficult to enforce in many rainforest areas.

If the full environmental benefits of *mixed farming* systems are to be achieved, feed, fertilizer and mechanization subsidies should be removed. Cheap feed favours the development of industrial production at the expense of home-grown feed whereas cheap mineral fertilizer and fuel place inputs from internal sources, such as manure and animal traction at a disadvantage. Removing or lowering subsidies on such items will promote a closer integration of crop and livestock systems in many parts of the world because it will increase competitiveness of on-farm products and services, such as animal draught, manure, crop by-products and farm-grown feed. Lower subsidies may also reduce nutrient imports into surplus areas. Taxation of these inputs may be considered where their production and use have proven harmful to the environment.

For nutrient surplus reduction in mixed farming and industrial systems in surplus areas there are a variety of incentives or penalties. These include:

- removal of subsidies on, or taxation of, imported concentrate feed to reduce the significant nutrient transfer. This will increase the cost of feed concentrate intensive production and favour land-based systems over industrial systems. In a more indirect way, taxes on fossil fuel may have a similar effect by raising the cost of feed. Removing subsidies on concentrate feed and on inputs used for its production such as fertilizer, fuel and machinery encourages efficient resource use. The same holds true for the taxation of inorganic fertilizer, which would not only encourage its more efficient use but also promote the use of animal manure in mixed farming areas.

- incentives to achieve a more balanced distribution of crop and livestock activities: these include, *taxes on manure surpluses or phosphate loads or systems of tradable manure quotas* to limit the number of animals (Brandjes *et al.*, 1995). Marketable permits and pollution trading is based on the establishment of payment per unit of pollution or the use of pollution reduction credits.

- levies on waste discharge; In the United States, there are examples of water treatment utilities paying farmers to adopt low polluting management practices because this option is more cost-effective for them than

Box 3.2 The effects of internalizing environmental costs on production costs and income.

NO SYSTEMATIC evaluation exists and data are scarce. Costs are very site-specific and rarely are full environmental costs actually covered. However, in some countries, regulations for intensive production systems are so strict that practically all environmental costs, at least for waste, are absorbed by the producer. For example:

- In Malaysia, for cultural reasons swine production is kept out of sight and no pig manure can be applied to land. In certain prescribed areas, industrial pig producers have to reduce BOD to less than 50 mg/l (95 percent reduction), through screening and aerobic treatment. For a 500 animal pig unit, investment costs are around 10,000 Ringgit Malaysia (RM) and operating costs are 24 RM per production place (Hassan, 1996). This turns into an incremental production cost of 0.23 RM (approx. 9 US cents) per kilogram of liveweight produced, equivalent to a cost increase of around 6 percent.

- In Singapore, in 1986, the large-scale Ponggol Pigwaste plant turned wastewater into recycled water (7 mg/l BOD₅), essentially absorbing all waste-related environmental effects. Total average annual costs were calculated at US\$ 14.39 (Taiganides, 1992) per porker marketed or between 8 and 9 percent of total production costs.

upgrading their water treatment plant (USEPA, 1996).

- removal of import restrictions on materials (such as phosphate enzymes, and amino-acids) and equipment that improve feed efficiency. This could lead to lower waste loads through better feed conversion.

- subsidies for investment or running costs to improve the adoption of emission control technologies. An example is subsidies for constructing manure storage facilities, practised in many EU countries. In the USA, cost-sharing and state revolving funds have been established for manure storage sheds and dead poultry composters. Another example is the adoption of methane recovering techniques from manure which is largely determined by the price and availability of other forms of energy. Some OECD member countries have started favouring the use of regenerative energy *vis-à-vis* fossil sources and have created price incentives accordingly.

- Australian beef feedlot regulations are the strictest in the world and contribute to construction costs of new feed lots being much higher than in the United States (Miyamoto, 1991). Most feed lotting is in the vicinity of grain producing areas. The regulatory frameworks differ between the states and costs of compliance with environmental regulations have been given at A\$ 27 per head for feedlots in Queensland and A\$ 41 for New South Wales (Ridley et al., 1994) or approximately 4 and 6 percent respectively of total production costs. Investment costs related to compliance with environmental regulations are 6 percent of total investment costs.

While it appears that overall impact on production costs, even in extreme cases, do not exceed 10 percent incremental costs, investment requirements and effect on income can be prohibitive if such measures are applied unilaterally. Furthermore, unit costs for establishing and operating waste treatment facilities decrease with increasing size, so small producers are disadvantaged. However, the latter often face less severe regulations, such as dairies in the USA, or are exempted altogether.

Regulations

Regulations can also be used to promote more sustainable resource use by prescribing *quantitative limits* (of emissions or animal numbers or input use), *technical methods* and *access to resources*. A further regulatory instrument is *zonation*, to promote a more even spatial distribution of animal production. Deregulation through freer movement of germplasm internationally, while respecting intellectual property rights, may help foster biodiversity conservation.

For grazing systems in the humid and sub-humid zones, the establishment of *protected areas* for the preservation of biodiversity is often the only appropriate measure. With growing population pressure, this becomes increasingly difficult. Government agencies in the developing world are often too weak to enforce such restrictions. While effective protection of large areas may be difficult to implement under the prevailing situation of understaffed,

under-paid and poorly motivated government staff, the areas most valuable in biodiversity can be set aside. Mechanisms to provide revenue sharing from the rainforest, which should be based on the participatory principle need to be explored with a view to improving the incentives for forest conservation.

For intensive mixed farming systems and industrial systems, the control approach focuses on regulating manure management. It prescribes a number of technical solutions, including storage and application techniques, seasonal bans of manure application and maximum amounts of manure application or livestock units on farm. In addition, restrictions for sensitive areas are imposed. Some of these regulations are difficult to control and enforce, such as maximum amounts of manure applied per unit area, while others are more easily controlled like storage capacity and number of livestock per farm. An overview is given in Table 3.1. Enforcement of regulations within reasonable social cost remains a major challenge and limits the validity of this approach, particularly in countries with weak institutions. It is implied that compliance with regulations has differential impact on cost structure and thus affects regional distribution.

Regulations often aim to establish rational patterns of land use through zoning laws and should take into consideration, among other factors, the environmental value and susceptibility of an area. Zoning is an important

current and future instrument for both animal manure and product processing, not only for environmental objectives but also for reasons of human health concerns and reduction of nuisance. Two different approaches can be taken: intensive production units can be distributed over a wide geographical area to bring the production of waste products in line with the absorptive capacities of the land, and production can be concentrated to benefit from economies of scale in waste treatments. The first approach has successfully moved industrial production units away from urban centres in OECD member countries. Good infrastructure is an important prerequisite for successful zonation as perishable animal products have to be transported over larger distances. Zonation has to consider the marketing and processing infrastructure and be accompanied with supporting policies to facilitate respective investments. The creation of confined *industrial parks* as an alternative to a geographic spread with, sometimes, shared facilities for waste collection and treatment, offers opportunities to burden industrial production systems with the environmental costs while still maintaining advantages of market access and economies of scale. To a varying extent, zonation may also be obtained through incentives. The strict regulations on manure production and emissions are expected to be further strengthened in the OECD countries and to become increasingly important in the mid-income level countries of Latin America and East Asia.

Table 3.1 A cross section of manure management regulations.

Country	N - Emissions	P - Emissions									
European Union	Maximum stocking rate: 2.0 cows, equivalent to 170 kg N per year in manure Nitrate level in drinking water: MAC [†] 50 mg NO ₃ /l	P ₂ O ₅ in drinking water: 5,000 microgram/l.									
Netherlands	Same water standards as EU. Reduction of NH ₃ emission by 50-75 percent, through low ammonia emission techniques: injection, bans on autumn and winter applications, and covered manure storage. Cost sharing for manure drying and transport to manure deficient regions.	Max. amount of P ₂ O ₅ (kg/ha) in animal manure allowed to be added to the soil to decline as follows: <table border="1" style="margin-left: 20px;"> <thead> <tr> <th></th> <th>1990</th> <th>2000</th> </tr> </thead> <tbody> <tr> <td>Grassland</td> <td>250</td> <td>90</td> </tr> <tr> <td>Maize</td> <td>350</td> <td>65</td> </tr> </tbody> </table> with levies for every kg of phosphate produced per hectare of farm-owned land in excess of a tax-free amount of 55 kg P per ha. The tax of US \$ 0.40 per kg of P ₂ O ₅ is doubled for production over 87 kg per ha.		1990	2000	Grassland	250	90	Maize	350	65
	1990	2000									
Grassland	250	90									
Maize	350	65									
Germany	Varies according to the State. Maximum fertilizer rate at 240 kg N per ha, and in some states maximum stocking rates of 3.5-4.5 cows (or manure equivalent) per ha. Manure application (winter) and storage restrictions. Mineral record keeping required.	Unlike Netherlands, most attention is on nitrogen									
USA	Varies according to the State. Manure management plans required for all farms (with federal and state sharing cost in implementation) and permits required for concentrated animal feeding operations (CAFO's). Bans on the direct discharge on surface water.										

[†] Maximum Allowable Concentration

To control the environmental damage caused by excessive application of animal waste, Indonesia, the USA and a number of European countries require farmers to have *nutrient management plans* that follow best management practices. These usually include timing and methods of application, animal waste collection and storage (Narrood *et al.*, 1994). *Guidelines on manure storage and application*, which direct method, timing, crops and amounts, are in place in practically all countries with high animal densities.

In the case of processing, regulations which have been introduced to reduce the emission load are often not adequately enforced. The use of chromium in tanneries, the use of CFCs in chilling processes or BOD output in wastewater and waste treatment techniques are frequently prescribed.

Similarly, for environmentally-sensitive feed crop production, the adoption of technologies is increasingly dependent on environmental regulations to conserve soil and water resources, and to minimize the use and impact of, inorganic fertilizers and pesticides. Many developed countries, but increasingly also developing countries, now have regulations controlling land use and agronomic practices, including protection of habitat reserves, forests and wetlands, protection of landscape features, restriction of cultivable areas of damage, control of use of pesticides and other inputs, enforcement of soil conservation measures, limitation of soil nutrient effluents in water courses, control of crop residue disposal methods and others. Furthermore, proper land use planning is an important instrument in containing land degradation. Ideally, feed production should take place in areas of high cropping potential and low susceptibility to erosion and other forms of land degradation. Areas could be categorized according to these two criteria and restrictions on their use imposed, as in, for example, the land targeting successfully practised in Minnesota (Larson *et al.*, 1988). A strong institutional base is needed for its successful implementation, but this is more likely to be available in the developed and advancing developing countries where most of the feed grains are produced.

Infrastructure development

Public sector investment in infrastructure is warranted for protecting and enhancing public goods. But the effects have not always been beneficial to the environment:

Infrastructure development is essential for achieving a better regional balance between livestock and land. Investments in roads, markets, slaughterhouses and cold storage can support rapid destocking for grazing systems in times of drought. Infrastructure is also indispensable for all policies that aim to reduce animal densities or processing activities in critical areas. Policies to relocate animal production away from the cities can only succeed if transport costs are not prohibitive, and infrastructure is the main component in determining transport costs. At the same time, infrastructure provides market access which is an important prerequisite for most incentive policies.

In contrast, road construction is the single most important factor in deforestation. Discouraging road construction would probably be the most powerful deterrent to ranch and farm establishment. Such a policy could, however, be politically sensitive because proper targeting is difficult and the preservation effect of desisting from infrastructure development has to be weighed against the development needs of the population.

Information, training and extension

Knowledge transfer, in many instances, has to be seen as the key factor to keeping a balance between livestock and the environment. While changing scarcities stimulate a search for new technologies this process can be accelerated by the targeted transmission of technical knowledge at all levels. For example, a traditional technique of straw treatment for cattle feeding, helps not only to convert crop waste products into beef but also reduces methane emissions. This technique, known since the forties was recently successfully introduced in China and was adopted by seven million farmers within six years (Li-Biagen, 1996). Policy-makers need to keep pace with changing scarcities of production factors, and anticipate them in their technology policies, and they must also take into account the impact of environmental effects and policies on these scarcities. This requires a strong institutional base for technology generation and transfer.

Research, extension and consumer information services are important in the livestock-environment domain. Research, as seen in chapter 2, is essential in

order to make an objective valuation of the interactions between livestock and the environment. In addition, alternative technology is badly needed in the grazing systems even though no ecologically and socially viable alternatives to the traditional pastoral systems of the arid zones have yet been identified. While the current efficiency of those traditional systems makes this a formidable task, the strongly growing population pressure in these areas makes it imperative as well.

A considerable array of technologies is available to address environmental issues in mixed farming and industrial systems. The policy and regulatory framework to induce these technologies needs to be established, while research could make a more concerted effort to adapt technologies to changing scarcities and demand. Livestock extension services in the developing world have traditionally focused on animal health services at the expense of production issues and there has been an almost complete neglect of the environmental aspects of livestock production. Improvement will not be easy. The grassroots and front-line extension services in many countries are composed of rather poorly trained and sometimes poorly motivated staff. The introduction of environmentally more benign practices often requires complex social and institutional changes, which these front-line extensionists are poorly equipped to handle. However, some positive results are being achieved, especially when group approaches are followed. Examples are the social forestry projects in India and, in sub-Saharan Africa, in the natural resource management projects now being funded by many government and non-government organizations and by external agencies.

In the industrial countries, the extension service has been forced by the complex systems of regulations on livestock-environment interactions to play an important role in informing farmers about friendlier technologies and related incentives. In effect, a large part of the work of the publicly funded extension service focuses on these issues.

Finally, consumers must be given more objective information on the environmental effects of certain products and production systems. For example, there is a widespread perception that the industrial system is detrimental to the environment. However, as we have seen, this system may indirectly save biodiversity and land in the more fragile ecosystems. Consumers must also be educated about the need for internalizing environmental costs. Better public information services will be required to convey these messages.

TECHNOLOGIES

Technological change occurs as a response to changes in availability of inputs and in demand. Over the past decades the livestock sector has responded mainly by increasing efficiency and by the major structural shifts outlined earlier. There is little doubt that the sector will adopt and develop environmentally friendly technologies where policy makers provide a corresponding and consistent set of signals. On the whole, technologies which can address the environmental problems of livestock production are already available or are in sight.

Technologies which can work to the benefit of the environment, can be conveniently grouped into four different sets:

1. Technologies that *simply reduce the environmental damage* by alleviating the direct pressure on natural resources or by reducing the pollution load through modifying the chemical or physical characteristics of work products;
2. Technologies that *enhance natural resources*, i.e. that make them more productive or richer;
3. Technologies that *save natural resources*, that allow us to get more revenue from the same resource or to get the same from less;
4. Technologies that *turn waste into products* by closing cycles.

While admittedly there is some overlap among those categories, it brings clarity in what is meant by "*beneficial to the environment*" and it takes the focus away from the direct physical interaction between livestock and the environment, by introducing a more comprehensive picture of resource management.

Reduction of environmental damage

In the arid and semi-arid grazing areas, careful water development can help to prevent environmental damage. Any water development needs to be considered for its potential effect on distribution of seasonal grazing and settlement patterns. Investment in market technology may also reduce environmental pressure by encouraging greater off-take. In addition, new and more benign methods are now available to control diseases. Vaccines are available for tick-borne diseases spread by a number of sub-species, although not yet for East Coast

Fever. Long duration tick sprays, which can be applied on individual animals (pour-on) now exist, and these have a negligible environmental effect. A number of environmentally benign control methods, which use extremely low concentrations of easily degradable insecticides, now exist for tsetse control, although the overall effect of tsetse clearance on the natural resource base remains in dispute.

Environmental damage control is of great importance for intensive systems. The environmental impact can be significantly reduced by focusing on emissions from manure by, for example, improving collection and storage techniques. The main focus should be on reducing nitrogen losses, most of which are in the form of ammonia from manure. Most losses can be avoided by manure collection and covered storage facilities. Minimal amounts of ammonia are emitted when manure is collected under solid floors, and 80 to 90 percent reductions can be achieved by covering storage tanks (Voorburg, 1994). A further reduction of odour and ammonia loads can be achieved through natural or forced ventilation systems or through bio-filters or bio-washers that absorb odours and ammonia from polluted air. This is done by oxidizing ammonia into NO_2 and NO_3 . Up to half of the ammonia can be eliminated through such air washing systems which are, however, costly in investment and operation. (Chiumenti *et al.*, 1994).

Nutrient losses during and after application of manure on soils can be significantly reduced by injection or application of manure into the subsoil (Brandjes *et al.*, 1996). Better timing of application in response to crop requirements avoids further losses and enhances the nutritive value of manure. Nitrification inhibitors can be added to slurry to reduce leaching from the soil under wet conditions.

In tanneries, dairies and slaughterhouses, anaerobic systems can purify waste water and reduce by half the Biological Oxygen Demand (BOD), while more sophisticated anaerobic systems reach 90 percent BOD-purification (Verheijen *et al.*, 1996). Waste water treatment usually first separates solids from the liquid, followed by biological treatment under anaerobic conditions (lagoons). Nutrients such as phosphorus, are then removed by chemical or physical processes such as adsorption, stripping or coagulation. The same process serves to remove the remaining BOD as well as pathogens. In a few developed countries environmental problems have already led to the establishment of high quality standards for discharge water. To meet these standards, a combination of anaerobic and aerobic methods is required, often coupled with nutrient

removal systems. In slaughterhouses, the environmental impact can often be greatly reduced by employing a simple technology such as dry rendering of offal which reduces the amount of waste water produced. With reductions in water use the waste load decreases and wastes should be collected as solids wherever possible. Blood and paunch, and other solids, contribute enormously to the waste water load and should be prevented from being washed away by systematic collection.

Resource-enhancing technologies

For grazing systems in arid zones, "deferred grazing", which has been a traditional practice in many Middle Eastern countries, may regenerate the vegetation. For the semi-arid areas, overseeding or planting of adapted fodder, and the introduction of a multi-species grazing pattern, will often encourage better use of the vegetation and may have positive effects on plant and animal biodiversity. Such technologies may be part of overall "management" approaches, such as *Holistic Resource Management*, which consider the most appropriate tools for any particular site. Such management approaches should explicitly acknowledge the high efficiency of the current pastoralist systems and their pattern of disequilibrium (Behnke *et al.*, 1993). For the humid tropics, perennial grasses and legumes have now been developed that maintain soil fertility better than any other crop. Biodiversity may also be enhanced through careful management of wildlife-livestock interactions in pastoral systems as well as through prevention of bush encroachment.

Livestock, mainly through their input function within a mixed crop-livestock system, enhance the main natural resource - land. Animal manure and traction make the land more productive than would be the case in their absence. Thus, all technologies that reduce nutrient losses from manure, and improve the efficiency of their application, enhance land productivity. This may be done, for example, by promoting stall feeding which doubles the effective availability of nitrogen and phosphorus. Fodder shrubs and trees may be introduced to reduce soil erosion and improve soil fertility. Several mixed farming systems have been developed using fodder shrubs and trees. An example are agroforestry systems with three strata, including grass, fodder shrubs, and tree crops such as oil and coconut palms or cashew nuts as successfully introduced in Indonesia.

Raising the productivity of already cultivated land through crop-livestock interaction reduces the overall

land requirement to meet the demand for food and thereby protects other land from being brought into cultivation. In this indirect way, crop-livestock interactions foster biodiversity. It remains one of the most important avenues for intensification of agriculture and is certainly the most environmentally friendly. It is also creating important positive externalities which are usually not accounted for and are, in fact, very often restricted by overall policies working to their detriment.

Resource saving technologies

The livestock sector possesses and continues actively to develop, technologies that increase the efficiency of natural resource use. In particular, these technologies target feed conversion because feed is a major cost item, typically accounting for 60 to 70 percent of the production costs. Better feed conversion saves land used for its production while reducing the animals' waste load. But technologies also provide solutions to saving and sparing other natural resources such as water and biodiversity.

There is a wide array of technologies that improve feed conversion. The most important ones are:

- Introduction of multi-phase feeding whereby feed composition is much better suited to the needs of animal classes. By better adjusting the nutrient supply to the needs of animals, less waste is produced and therefore less nitrogen and phosphates appear in waste and in the environment;
- Improving the accuracy of determining nitrogen and phosphate requirements, followed by a better balancing of feeds with these essential nutrients. In this respect, important gains have been obtained in a better balancing of pig and poultry rations in essential amino acids, the building blocks of feed proteins. For example, a combination of better feed balancing, improved digestibility and inclusion of synthetic amino acids allows for a substantial reduction of the protein content in feed, and hence a reduction of nitrogen and phosphorus excretion by 20 to 40 percent (Van der Zijpp, 1991). Other options include the use of hormones for growth or milk production (bovine somatotropine or BST) or other stimulants (clenbuterol), frequently used in the USA but banned in Europe for public health considerations.
- Increasing diet digestibility has seen spectacular improvements with the addition of an enzyme (called

Box 3.3 Reducing methane emissions from digestive fermentation through strategic supplementation in South Asian countries.

UREA AND other supplemental nutrients are mixed with molasses to make it palatable to livestock. In addition, molasses provides the energy needed in order to realize the improved microbial growth that can result from enhanced ammonia levels. These Multi-Nutrient Blocks (MNB) have been used in many countries including India, Pakistan, Indonesia and Bangladesh, Habib *et al.*, (1991), Hendratno *et al.* (1991), Leng (1991) and Saadullah (1991). Typical results have been: milk yield increases of 20 to 30 percent; growth rate increase of 80 to 200 percent and increased reproductive efficiency. Based on these results, methane emissions per unit product went down by up to 40 percent. Bowman *et al.*, (1992), estimated that strategic supplementation of dairy animals will reduce methane emissions by 25 percent while increasing milk production by 35 percent.

The efficiency of digestion in the rumen requires a diet that contains essential nutrients for the fermentative micro-organisms. Lack of these nutrients lower animal productivity and raise methane emissions per unit of product. For animals on low quality feed, the primary limitation to efficient digestion is the concentration of ammonia in the rumen. Supplying ammonia can therefore greatly enhance digestive efficiency and utilisation of available feed energy. Ammonia can be supplied by urea, chicken manure or soluble protein that degrades in the rumen. Urea is broken down in the rumen to form ammonia, and adding urea to the diet has been the most effective method of boosting rumen ammonia levels

phytase) which catalyses the digestion of phosphates contained in feed. The same enzyme might also increase the availability of zinc in feed thereby reducing the need for feed additives. This optimum nutrient ratio and composition management reduces the risk of loading the environment with these elements.

- Promoting feeding systems which reduce intake and stop buffet-style *ad libitum* feeding, popular in the eighties. Poultry, in particular, require feed of high energy and protein concentration for optimal production. This has led to research to develop specific feed mixtures with higher protein content and the most

appropriate amino-acid composition for poultry feed requirements.

- In mixed farming systems of lower intensities, strategic supplementation for specific classes of animals, such as lactating cows or growing animals, can greatly improve the efficiency of limited amounts of available feed. A basic technological approach to mitigate environmental damage is to improve feed production and quality, thereby reducing pressure on grazing areas and improving internal nutrient transfers.
- In addition to feed and nutrition, other technologies can improve feed conversion efficiency. These include enhanced genetic potential, better health and environmental conditions, and improved general livestock management.
- Increasing efficiencies in feed conversion for the livestock sector as a whole can be obtained through a shift to monogastrics as better feed converters, and to poultry and fish in particular. This trend is likely to continue, and will be particularly strong in the developing countries.

Bearing in mind that most expansion and productivity growth in the livestock sector will have to be based on concentrate feed, the main environmental challenge is to limit the land required for growing feed. This can only be done by productivity increases in both crop and livestock production. In that sense, biodiversity is best preserved by intensifying livestock production (aiming at better feed conversion) while also intensifying crop production (aiming at higher yields). Both will reduce the land requirement for given volumes of final product and will alleviate pressures on habitats and biodiversity as well as limit requirements for land and water resources.

Increasing efficiencies also explain why, despite growing livestock populations, the global trend for methane emissions from livestock is to remain steady. The reasons for this stagnation are lower emission levels per animal and per unit of product, and the fact that monogastric production is growing at a much faster pace than ruminant production.

Box 3.4 Alternatives to cereal feeding.

COUNTRIES IN the humid and sub-humid tropics are cereal deficit countries. Livestock production, in particular monogastric production is thus faced with high prices for feed concentrates. This has spurred the development of sugarcane-based feeding systems (Preston and Leng, 1994) in a number of tropical countries (Colombia, Cuba, Vietnam, Philippines). Sugarcane is one of the highest yielders of biomass per unit time and area. Its juice can be used for monogastrics while the tops can be used in ruminant nutrition. As a perennial crop, sugarcane production has very low rates of erosion and can be produced with low external input. In the past, the association of sugar cane and livestock production has been problematic since sugarcane was traditionally produced on large plantations, geographically separated from livestock production. Recent developments on the diversified use of sugarcane may lead to more village-based intensive monogastric production systems in the humid tropics.

Waste technologies

Historically, the *raison d'être* for keeping livestock was its use of resources for which there was no alternative use. Waste land was turned into high value food. The characteristic of using resources of no or low opportunity cost also explains why efficiency per animal was not, and in many low input systems is still not, a major concern.

The conversion of organic waste into livestock products, although associated with livestock waste, reduces at the same time the environmental hazards associated with crop and agro-industrial waste. Also, food wastes are consumed by livestock and increasingly so, as urban agglomeration and changing eating habits offer a window of opportunity for the collection of food waste from catering units to be recycled as feed. Large amounts of straw, otherwise burned on the fields or slowly decomposing with little nutritional benefit to the crops, may be turned into quality feed, for example through urea treatment of feeds (Li Biagen, 1996).

The cycles of matter can also be closed by using livestock waste as feed, energy or fertilizer. The latter has already been discussed above. Recycling manure by feeding it to other animals, as well as fish (Muller, 1980), is practised only on a limited scale largely because of a widespread reluctance to use manure as feed. This originates mainly from fear of health risks but is also due

to the low nutritive value of manure with the exception of that of poultry. Poultry manure is incorporated in to the diets of livestock in intensive systems and, particularly in Asia, manure is fed to fish and pigs (China). Poultry manure has reasonable quality when used as ruminant feed.

In intensive production systems, where large amounts of collectable manure are available, the low quality of manure as feed or high processing costs make its use as feed uncompetitive with commercial feed stuffs. In less intensive production systems where use of low quality feeds is common, high collection costs and opportunity costs (manure as fertilizer or fuel) prohibit the use of manure as feed. A recent overview of the possibilities is given by Sánchez (1995).

Technology also exists to make use of the energy content of manure. Biogas plants of all sizes and different levels of sophistication not only recover the energy contained in manure but also eliminate most of the animal and human health problems associated with contamination of waste by micro-organisms. Other methods of controlling the waste load are the purifying and drying of manure.

Promising approaches exist to reduce emissions from manure lagoons by recovering methane and using it for energy. Large confined animal operations allow for such techniques to be profitable. This methane can be used for on-farm energy to generate electricity and the slurry effluent can be used as animal feed, as aquaculture supplements, or as crop fertilizer. In addition, managed anaerobic decomposition reduces the environmental and human health problems often associated with manure management. The controlled bacterial decomposition of the volatile solids in manure reduces the potential for contamination from run-off, significantly reduces pathogen levels, removes most noxious odours and retains the organic nitrogen content of the manure.

Box 3.5 Biogas in China

IN CHINA, more than 5.3 million rural biogas systems are in place, producing 1.25 million m³ annually. Biogas is used for household heating and cooking, poultry hatching, tea roasting, grain and fruit storage. The slurry is used for fertilizer, fish farming and for feeding pigs which show good results in the semi-intensive production systems (Henglian, 1995).

Methane can be recovered in covered lagoons where manure solids are washed out of the livestock housing facilities with large quantities of water, and the resulting slurry flows into an anaerobic primary lagoon. However, such anaerobic conditions result in significant methane emissions, particularly in warm climates. Placing an impermeable floating cover over the lagoon and applying negative pressure recovers the methane which can be used as fuel or to generate electricity. Alternatively, digesters can be used. Large scale digesters are engineered vessels into which a mixture of manure and water is placed and retained for about 20 days. The digester is heated to about 60°C, after which the gas is drawn off and used for energy. Large dairy and pig farms with high energy requirements find these systems to be cost effective. Small scale digesters do not include heating and are appropriate for warm climates only.

Large scale manure processing is possible where intensive production is concentrated in certain zones, but it is often not economically viable. The efficient use of manure for feed and energy production entails high capital costs which often cannot be borne by individual farmers. Most processing waste can be turned into food, feed, fertilizer or energy. Slaughterhouse wastes can be composted and used as fertilizer. Anaerobic treatment



Box 3.6 Regulations induce search for innovative solutions: the case of Tyson Food Inc.

IN THE state of Arkansas, USA, Tyson Foods Inc. was sued by more than 100 Green Forest residents who contended that their water supply had been fouled by a lack of adequate sewage treatment from chicken processing plants in 1980. Tyson was ordered to pay for property damage, for the overloading of the city's water treatment system and for violating the Clean Water Act. Furthermore, the use of burial pits for dead bird disposal by growers was banned. This resulted in Tyson Foods investing into research and development to remedy the problem. Tyson Foods developed a recovery technology that allowed them to recycle proteins, fat and carbohydrates recovered in their water treatment process into nutrients for animal feed. This enabled the company to recycle not only various solids (primarily proteins, carbohydrates, and fats) from its water treatment plants in Arkansas, Oklahoma, and Missouri but also the inedible animal parts from its poultry treatment and pre-treatment centres, attached to its processing plants. Further, it also enabled the recycling of the dead birds from the farms. In order to facilitate the use of this technique, Tyson Foods distributed some 2000 custom freezers to their growers to aid them in the disposal of the dead birds, which were collected and transported to the rendering plant. Thus the refinement of the rendering process resulted in a win-win solution, i.e. an improvement of the environment and a profitable solution for Tyson. The ability to recycle by-products is becoming more of a concern as consumers are demanding more processed meat. Pet food companies, among others, purchase the processed protein meal and other products for use as high-quality ingredients in various animal rations. Furthermore the feathers can also be hydrolysed into a feather meal that can be used as another high protein feed ingredient most often used in cattle rations.

Source: Narrad, 1994.

results in a slurry that can be used as animal feed, the liquid part can be used as irrigation water, fish or algae production. Bones can be crushed, ground and prepared into bonemeal as feed.

In summary, improving the impact of livestock on the resource base is not constrained by the lack of technology, but more by the lack of an appropriate enabling environment, to allow these technologies to be adopted. The next chapter will provide the beginning of an action plan to promote such.

STRATEGIES FOR LIVESTOCK PRODUCTION SYSTEMS

Putting the environment into the forefront does not mean that only environmental objectives count. On the contrary, only if and when sound and economic objectives are met can environmental goals be effectively tackled.

Grazing systems will remain a source of extensively produced animal products. To some extent, these systems can intensify production by incorporating new technologies, especially in the higher potential areas (subhumid and highland areas). Often this can be facilitated by stronger organizations, local empowerment and regulation of access to resources. Where there is potential for mixed farming, policies need to *facilitate the transition* of grazing systems into mixed farming systems in the semi-arid and subhumid tropics through integrating crops and livestock (manure management, animal draught, residue feeding and fodder crops, etc.).

They can also intensify by diversifying and opening up other uses for these grazing systems. In grazing systems, livestock's role, in addition to providing a livelihood to pastoral people and market production, should be to *protect the natural resource base*, in particular land, water and biodiversity.

Mixed farming systems will see continued intensification and important growth. Smallholder and family mixed farming will remain predominant for some time to come, with livestock based on crop by-products and surplus. Important productivity gains can be achieved by further enhancing nutrient and energy flows between the two components. Livestock's role, in addition to production, is to *enhance and substitute natural resources*. The environmental and economic stability of this system, makes it the prime focus for continuing technology transfer and development. Where involution of the mixed farming system occurs (see p.11), in areas of extreme population pressure, resource degradation and poverty, this must be fought through accelerated technology uptake, (feed resources,

animal traction, development of small ruminants, etc.). Under more favourable agro-ecological and market conditions, new forms of industrial production will have to be established. These industrial systems will have to be based upon the resource endowments of a region, if nutrient balances are to be maintained and the environment's ability to absorb waste respected. We are therefore projecting *industrial systems integrated into a wider land use concept*, particularly for pig and poultry production. This trend is already under way in some developed countries. This would blend resource saving technologies with the absorptive capacities of the surrounding land. New organizational arrangements will have to be found to allow specialized units to capitalize on economies of scale. The strategy is thus to *transform mixed farming systems into specialized and commercial enterprises in rural areas* through infrastructure and institutional development, animal production and health technologies, and processing) where land pressure is on the increase and where the market allows.

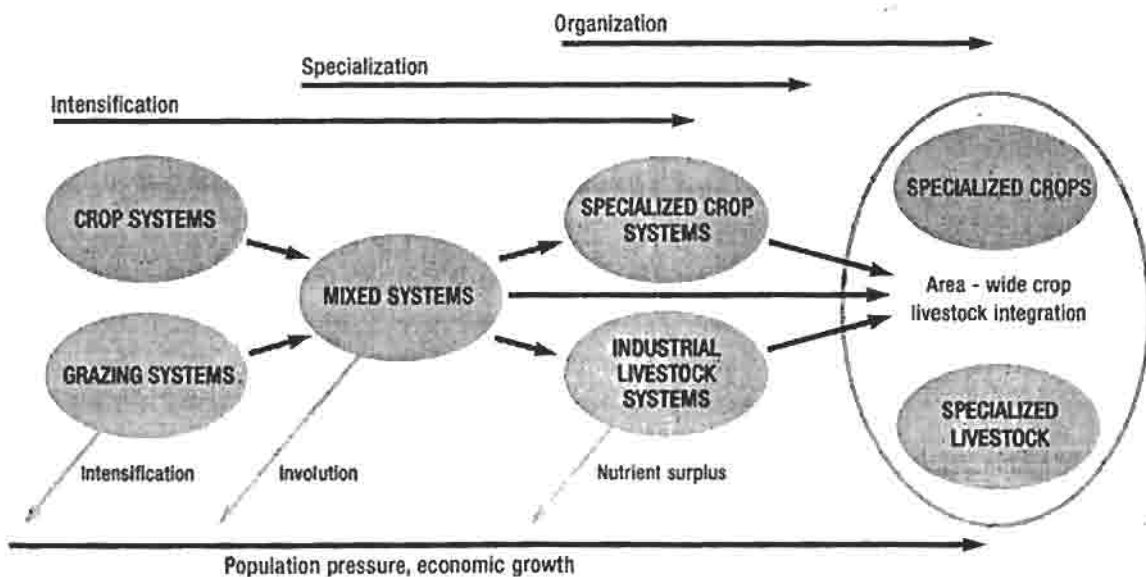
Industrial systems in areas of high animal densities will face the challenge of coping with higher production costs as a result of more stringent regulations and pollution levies. This will remove, in some cases, the competitive edge that industrial production has over land-based production. Potentially, this would also raise prices for livestock products and reduce demand. Higher prices would provide incentives for the land-based systems to intensify. Scales of industrial production would grow further because of economies of scale for waste treatment. This system's purpose is mainly to be

seen in satisfying the soaring demand in many parts of the developing world over and above the supply capacity of land-based production and at maximum resource use efficiency.

With increasing resource scarcities, livestock producers must continue to search for technologies that increase resource use efficiency if the rapidly increasing demand is to be met without putting additional strains on natural resources. The challenge is to obtain higher efficiency without concentrating animal production in a given area. Limiting livestock numbers while still maintaining market mechanisms through, for example, tradable emission quota, seems to be an appropriate choice. Ideally, the advanced *resource-saving technologies and the absorptive capacities* of extended rural areas should be married. Thus, the motto for most of the developed world and the more densely populated parts of the developing world is: *intensify, but do not concentrate animal production*. Such an approach would promote the spread of processing into these areas thus bolstering economic development.

In a schematic way we can thus identify pathways for livestock production systems. Intensification, specialization and organization are the processes that characterize the different phases. As a result of the interaction between livestock production systems and natural resources, coupled with other factors such as market access, there are development opportunities as well as threats to sustainability. They are sketched in the chart which follows and lead to the identification of areas for strategic intervention.

Figure 3.1 Livestock systems development pathways.



To minimize environmental damage, governments should, in very general terms, intervene as suggested by the chart on the previous page. Strategic interventions need to focus on:

- the phases of transition from one state to another, where entirely new sets of technology are introduced: to intensify where the agro-ecological and market potential allows;
- the fundamental pressures of poverty, population growth and weak institutions.

It is evident that questions relating to livestock and the environment cannot be solved in environmental terms only. A comprehensive perspective is needed to ensure an enabling policy framework in which effective technologies can be introduced. Technology remains the key component because future development, including that of the livestock sector, will depend upon technology to substitute for natural resources. This trend to *knowledge-intensive systems* is widely observed: smart technologies, supported by astute policies, can help to meet future demands while maintaining the integrity of the natural resource base. Better information on which to base decision-making is therefore urgently required.



Looking ahead: Elements of future strategies



THE CHALLENGE for policy makers and environmental and livestock specialists is to fully capture the contribution of livestock in development that will satisfy current and future human needs while maintaining the natural resource base. There is no resource-compromising aspect of animal protein production that cannot be resolved. The technologies exist but their successful adoption is often constrained by the difficulty in creating the right political and economic conditions in which environmentally friendly livestock production can take place. These difficulties stem from different interest spheres and complex links between livestock, the economy and society. Decision-makers in national governments, NGOs, at farming and community levels and in international and donor organizations, are the actors who must put the policy and technology elements to work within the context of consistent strategies. With government support and willingness to act, there are sufficient mechanisms to keep adverse effects of livestock production within tolerable limits and to enhance the net contribution to human welfare.

THE NEED FOR INFORMED DECISION-MAKING

There is ample evidence that current decision-making regarding the role of livestock in sustainable agriculture

is hampered by a lack of information and awareness of the type, extent and causes of livestock's current negative and positive impacts on the environment and of what may be expected of any change of policy or action. The complexity of livestock's interaction with

other sectors imposes a formidable task at any level of decision-making. Better information on which to base decision-making is therefore urgently required. Production systems and ecosystems need to be documented, with emphasis on current hot spots, future environmental hazards, and potential positive contributions. For that, there is a need to:

- take stock of resource endowments (“intrinsic scarcities of production factors”), technologies and policies; monitor resource use, through geo-referencing and assess environmental impact of technologies and policy changes.
- increase awareness among decision-makers, producers and consumers of the environmental effects of different modes of production; educate consumers about the health risks associated with excessive consumption of animal products, particularly in the rich countries;
- increase analytical skills at farming level, schools and universities, government and non-governmental institutions for environmental impact assessment and related policy analyses; further develop economic evaluation techniques for environmental goods at farming, project and national levels.

THE NEED FOR CONSISTENT POLICIES

Any sustainable livestock development strategy has to fully recognize the set of objectives which govern behaviour. For many farmers, the first priority is household food security and family welfare. Less tangible future sustainability of resource use is often traded off against immediate food needs. At a policy level, social and economic objectives may be in conflict with environmental objectives or have different time scales.

With multiple objectives in play a balance must be found between different production systems in different agro-ecological zones or regions, and technological options that govern resource use. The environment warrants government attention as a public good in addition to others, such as public health, equality and economic growth. Policy choices must be consistent with each other and be brought into the wider context of sustainable development. For example, subsidies on feed grains may help to supply inexpensive livestock products to urban centres and develop a “modern” livestock industry but, as has been seen, they often misdirect technology and resource use. It is therefore

important to screen all relevant policies against internal consistency and their contribution to overall policy objectives. Once the objectives have been set, it is necessary to assess how current policies and operational measures support or act against these objectives.

In the above analysis we have identified policies that make neither economic nor environmental sense (what may be called a *lose-lose* situation). These are poorly informed, formulated or simply misguided policies, or the result of the domination of certain interest groups. With growing trade liberalization and reduced public expenditure these are being corrected in many cases. Examples are land titling through ranching in South America or the beef and milk tariff policies of the Common Agricultural Policy in the EU after the initial post-war justification become irrelevant. Here, political will must exist to accept possible negative public reaction from the beneficiaries of those policies. This political will is particularly important in countries with strong livestock interest groups.

Other policies make economic sense mainly in the short term, but have negative environmental effects (what may be called a *win-lose* scenario) in the long term. An example is road construction in tropical forest areas where land requirements and development needs may be in direct conflict with conservation objectives. Here, it is necessary to formulate local and specific complementary measures (i.e. protected areas, institutional development) to minimize the trade-off. As has been shown, the majority of negative livestock impacts on the environment fall into this category.

A third set of policies are those that make both economic and environmental sense, but often do not pay off in the short term. These *win-win* situations are, for example, the reduction of methane emissions through increased animal productivity, livestock-wildlife integration and the use of slaughter waste for alternative feed or energy sources. However, problems occur because benefits that accrue to the global common goods are only slightly or not tangible for the originator of these benefits. A completely new set of mechanisms with novel financing approaches needs to be designed for the protection of these global commons.

In summary, there is a need to:

- set realistic objectives - environmental, economic, social - and decide on the balance between these objectives where trade-offs exist; identify critical conflict areas between broad social or economic objectives and environmental goals; identify policies that bear the potential for trade conflicts and try to negotiate bilateral arrangements;

- develop the analytical skills to screen and monitor policies for their desired and undesired effects;
- correct policies which are misleading resource use or which have perverse effects; target policies carefully and as directly as possible avoiding sweeping arrangements for cost-effectiveness and;
- develop support schemes to finance accelerated adoption of win-win solutions such as benefit sharing through national and international arrangements, such as GEF.

THE NEED FOR INSTITUTIONAL DEVELOPMENT

With the livestock sector under pressure from surging demand and competition for resources, there is an increasing need for a legal basis with well-defined and enforceable rules and institutions for resource utilization. In fact, a major underlying cause for important externalities is the insufficiently defined access to resources, like open access grazing land for pastoral systems or the use of surface water for the uncontrolled discharge of waste of industrial production systems or processing units. To a certain extent this restricts private behaviour, sometimes resulting in pressure against which the political will has to resist. Institutional development requires:

Preparation of a regulatory framework:

- to establish clear access rights to land. Clear rights of access to land is a necessary although rarely sufficient condition to provide the economic and social incentives to motivate people to protect and improve resources, particularly where traditional regimes of resource management come under pressure such as in pastoral systems and tropical rainforests;
- for land use and regional planning, to establish protected areas for fragile eco-systems, with due attention to local capacity to enforce the protection, and to establish zoning for industrial production systems, to bring the animal densities in line with the absorptive capacity of land and water through quota systems;
- to prescribe regulations for waste control, use of noxious substances, management practices and labeling.

Empowerment of formal and informal institutions where the regulatory framework is available but insufficiently respected or enforced, by providing mandates and support. For pastoral systems in particular, the principle of subsidiarity (Swift, 1995) needs to be applied by transferring responsibility for resource management to the lowest possible level, local groups.

Establishment of a legal authority for the implementation of environmental policies, preferably including an independent non-line agency with a mandate to monitor the use and protection of resources;

Use of participatory approaches in strategy formulation, planning and programme implementation.

THE NEED TO GET PRICES RIGHT

Ideally, commodity prices should include all direct and indirect environmental costs in order to give market signals that embody the proper valuation of environmental goods. Prices should encourage efficient resource use and guide technologies to anticipated future scarcities. They should promote waste recycling and resource enhancing technologies. Astute pricing is a powerful tool and the instrument of choice where institutions are weak and where the financial or social costs of control become unreasonable. There may need to be differential prices between agricultural or livestock sectors and the rest of the economy. As a general rule a "level playing field" should be provided. Prices of different environmental and agricultural goods should be corrected for market failures where environmental costs and benefits are not adequately internalised. For example:

- eliminate subsidies for inputs such as water, concentrate feed, fossil fuel, fertilizer and reduce or abolish price support for livestock products and directly support farmers' incomes if that is socially or economically desirable;
- introduce cost recovery for communal water and grazing, and public services such as artificial insemination or clinical treatments provided to the producers (Umali *et al.*, 1992);
- introduce levies or taxes for waste disposal;
- create price incentives for methane use and alleviate investment costs (preferred credit) for waste control and

conversion facilities with proper targeting and fixed time scale;

- remove tax advantages for different sizes and types of enterprises where this is not warranted by public food or environmental concerns; and
- introduce equitable benefit sharing mechanisms for social and environmental goods.

THE NEED FOR TECHNOLOGICAL CHANGE

Leveling the playing field, and appropriate price signals may induce a different set of technologies. This new set will respond, to a higher degree, to true scarcities as they incorporate the value of environmental goods. This process needs to be facilitated and accelerated.

● Firstly, there is the need to *facilitate technology adoption*, essentially by training, education and extension and by incorporating environmental aspects into extension messages and curricula; by providing credit where high investment costs constitute an impediment, for example, methane digesters or waste treatment facilities; correcting policies which are misleading resource use or which have perverse effects; and financially supporting accelerated adoption of *win-win* solutions such as benefit sharing arrangements.

● Secondly, there is a continued need to *generate technologies* if the adapted technological solution for more sustainable livestock production is not available. It is important to design technologies that anticipate future resource constraints based on current intrinsic scarcities. To achieve this there is a need to invest in basic and adaptive research and to create and sustain the institutional capacity to undertake the work.

Technological change is the key to solving the problems of sustainable agriculture as technology determines resource use. This study demonstrates that currently available technologies can already significantly increase efficiencies, enhance resources in use and recycle waste at various stages of the production process. The study also demonstrates that knowledge needs to progressively substitute for physical inputs, and that the scope for increasing knowledge about livestock production while simultaneously reducing the use of natural resources per unit of product is enormous.

THE NEED TO SELECTIVELY DEVELOP INFRASTRUCTURE

This study has shown the importance of infrastructure, in particular to establish a better balance between livestock and land resources. Infrastructure development is often a prerequisite for technology uptake and resource access. Infrastructure development is a two edged sword in that it not only alleviates pressure on natural resources but also makes them accessible to sometimes uncontrolled exploitation as, for example, in the case of the tropical rainforests. It is therefore necessary to:

- construct, or facilitate the construction of slaughterhouses and dairies, and cold chain facilities in the vicinity of producing areas to avoid waste accumulation in sensitive and urban areas; The better the infrastructure the better the opportunities for geographic spread for intensive systems and for flexibility of adjustment to variable biomass growth in extensive pastoral systems;
- facilitate the establishment of markets, transport and communication while taking account of the trade-offs between increased road and transport infrastructure and biodiversity conservation.

THE NEED TO CHANGE PERSPECTIVE

All of the above changes will be brought about only if industry, policy makers and environmental groups:

- remove the emotional conjecture, lack of objectivity and over-simplification from the debate on livestock-environment relationships;
- acknowledge the need to correct unsustainable livestock production systems and act accordingly. In the developing world, where environmental pressure will grow most strongly over the next decades, policy makers must heed the strong warning signs and learn from the errors of the industrialized world;
- accept the ample evidence that the contribution of livestock to sustainable development can be greatly enhanced, provided the appropriate enabling environment is created, and act accordingly;
- take full account in future policy and planning of the dramatic changes transforming the global livestock sector. The shift towards grain crops for feed use may

turn animal production into the single most important agricultural activity on the planet. Selecting the right land and water resources, efficient generation of feed, transporting feed to farm animals, the conversion of feed into animal protein, the marketing of products as well as the adoption of healthy consumer habits by, particularly, wealthier individuals, plus the potential synergism between efficient resource use and economy-wide development: all of these factors need to become integral parts of the livestock-environment equation.

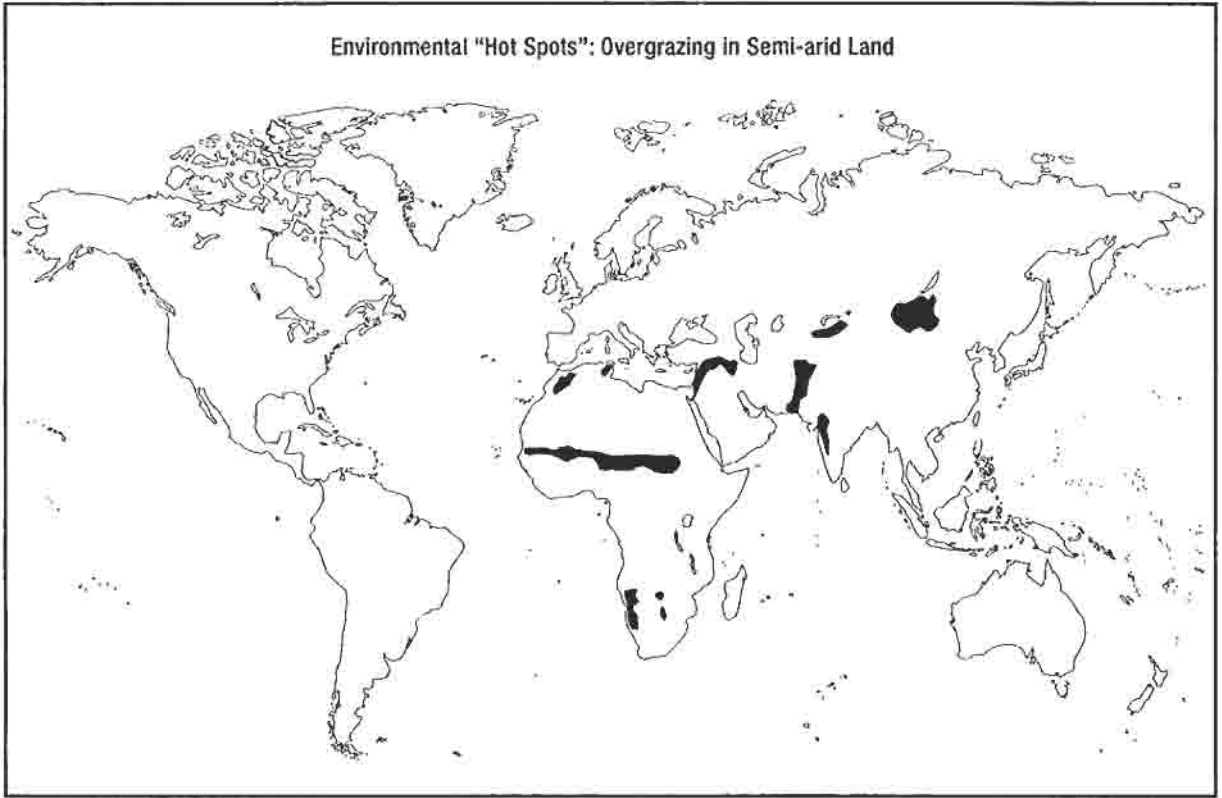
CONCLUSIONS

Improved management of the world's natural resources is essential if they are to continue to provide the basis for life support and human well-being. Only with improved management can the dual objectives of sustainable agricultural production be fulfilled - to feed the world's growing population while sustaining its natural resource base. Livestock production is the largest land user and is about to turn into the most important agricultural activity in terms of economic output. Left to uncontrolled growth, not only will the environment suffer but human welfare is also likely to be compromised. However, this is unlikely to happen. The opportunities not only to mitigate environmental damage but to tap the immense development potential that livestock offer are large: awareness, political will and readiness to act are growing among all those involved and ensure that the problems are no longer denied but effectively tackled.

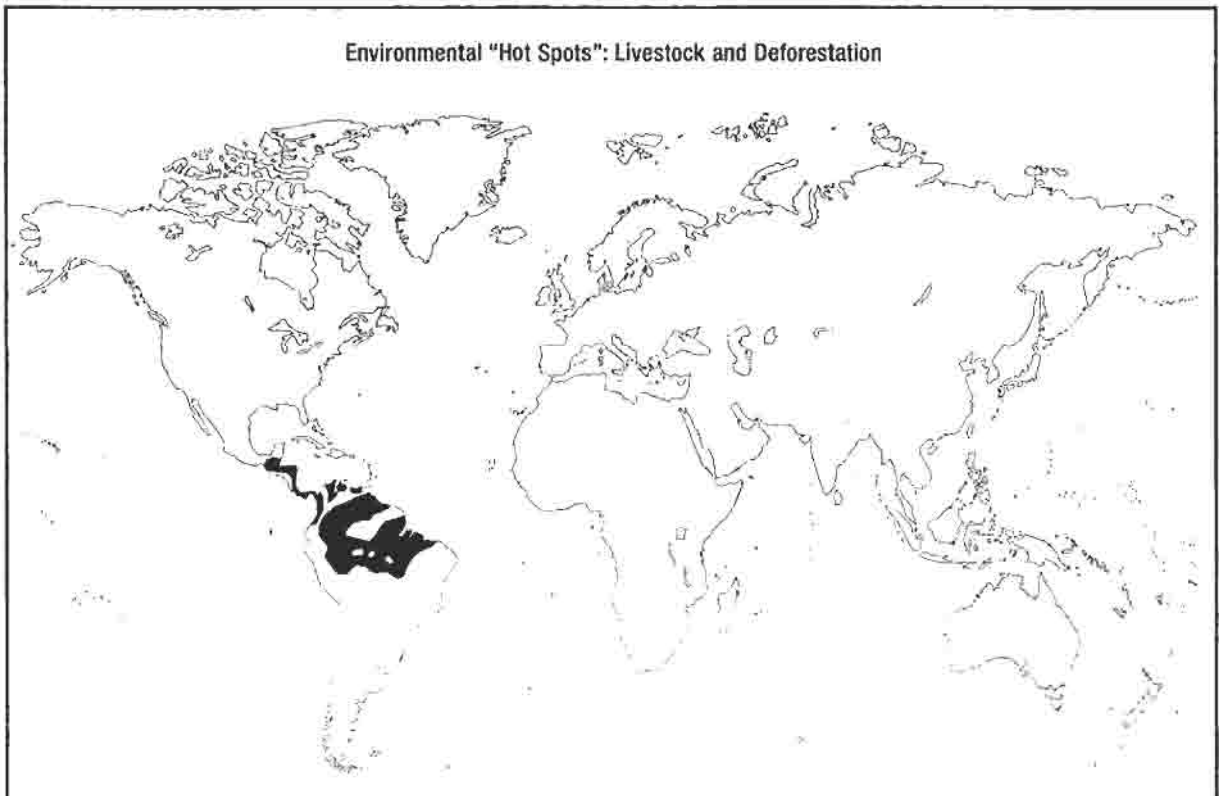


MAPS

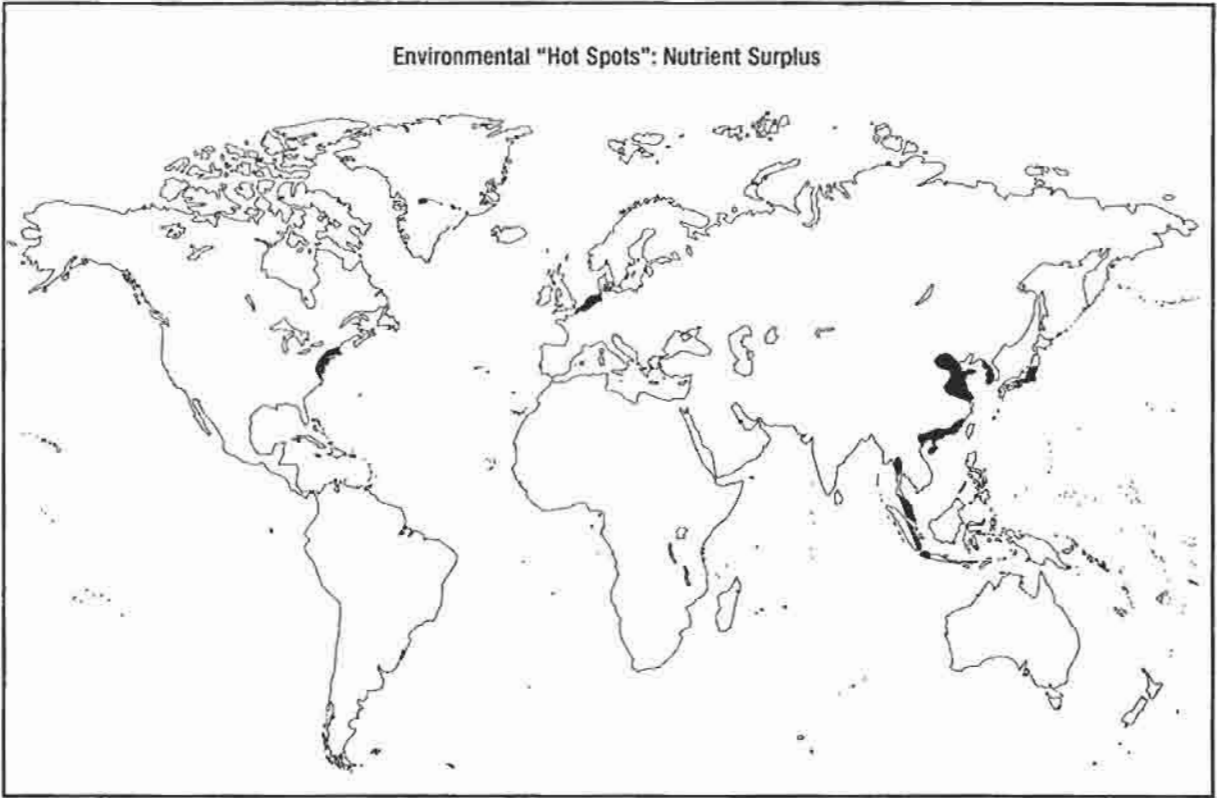
Environmental "Hot Spots": Overgrazing in Semi-arid Land



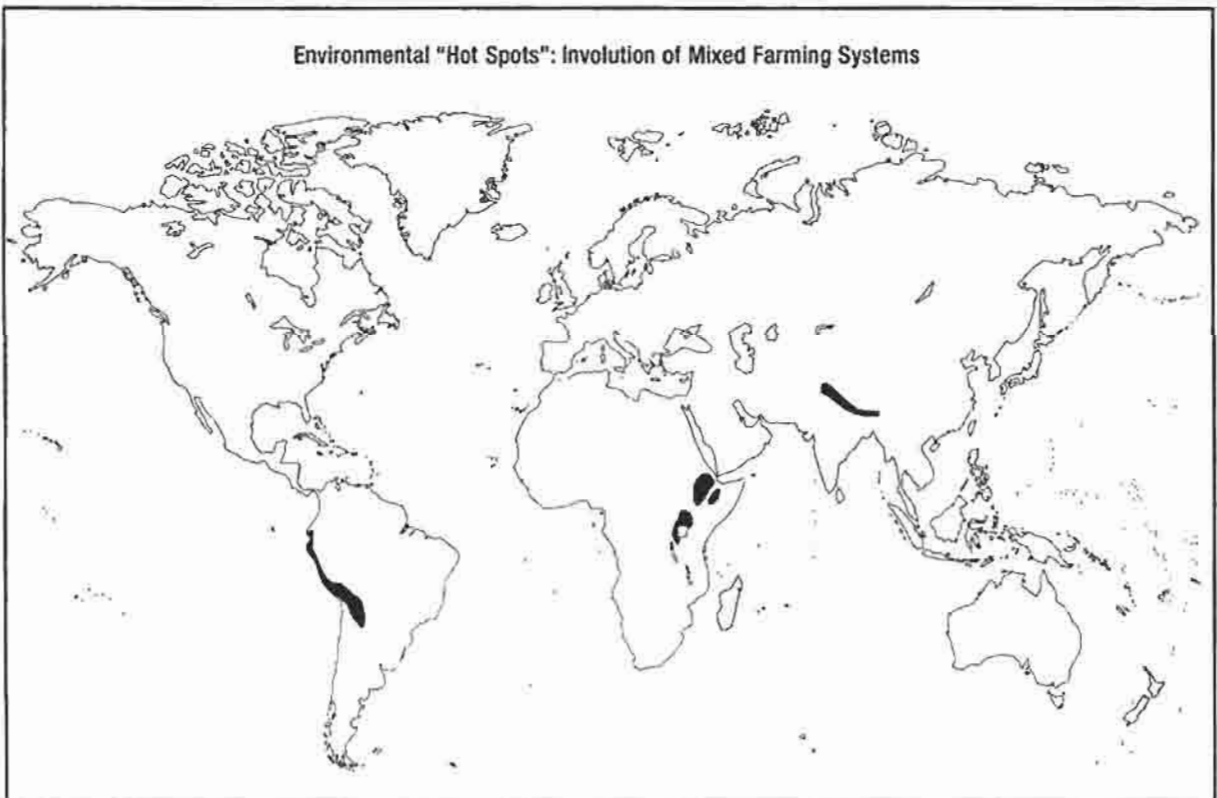
Environmental "Hot Spots": Livestock and Deforestation



Environmental "Hot Spots": Nutrient Surplus



Environmental "Hot Spots": Involvement of Mixed Farming Systems



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and Development via GTZ (Deutsche Gesellschaft für
Technische Zusammenarbeit)
Netherlands: Directorate General of International Cooperation
United Kingdom: Overseas Development Administration
United States: Environmental Protection Agency and the
Agency for International Development

