

Chapter 1

Managing natural resources for sustainable livestock-based agriculture

The aim of this chapter is to provide guidance to researchers as to the topics which should, or should NOT, be researched, if there is to be a firm commitment to promoting the sustainable use of natural renewable resources. For further discussions on some of these issues the readers are referred to the books by Preston and Murgueitio (1992) and Ørskov (1993).

The issues discussed in this chapter provide a conceptual basis for the sustainable use of renewable natural resources in livestock-based farming systems for the tropics. The interpretation of this strategy in the form of practical farming systems has profound implications both for the type of feed resources that will be on offer, the species of livestock most suitable for their utilization, the most appropriate way to evaluate them and the manner in which such feeds should be incorporated into the diet of the animal. These themes are the basis of research into the better use of tropical feed resources for livestock and will be dealt with in detail in the remaining chapters.

THE ROLE OF LIVESTOCK IN RURAL DEVELOPMENT

Livestock production (i.e., all aspects of production systems, their products and by-products) in tropical countries of the less-developed world, has been and must continue to be one of the most important economic and social activities of human culture. In these regions of the world, hundreds of millions of people depend directly or indirectly on livestock-based activities, the analysis of which is complex and multi-sectorial.

Many technical and economic endeavours, at national and international levels, have attempted to increase animal production and animal productivity in the tropics but results in general have been meagre. Of the many explanations of this phenomenon, perhaps the most pertinent is the lack of understanding of the ecological, socio-economic and cultural limitations inherent in these countries which constrain severely the application of conventional development models.

Paradoxically, there are also incredible opportunities for sustainable development, thanks to the enormous cultural and biological riches of the tropics, the rational exploitation of which could support sustainable production in the medium and long term, but which have not been considered seriously in previous attempts to develop the livestock sector in these regions.

The role of livestock in developing countries is quite complex and extends beyond their traditional uses to supply meat and milk as is invariably the case in the industrialized countries (Sansoucy, 1994). They are certainly multi-purpose. They are valued for one or several (sometimes all) of the following traits: capital, credit, traction, milk, meat, hides, fuel and fertilizer. Thus, for families without land, livestock are primarily a means of increasing the family income. For the crop farmer especially in Asia, but increasingly in Africa and Latin America, the large livestock - cattle and buffaloes - are primarily sources of traction and power. In many societies the dung is used for fuel and to a lesser extent as fertilizer. For the transhumant grazier, livestock may be most valuable as a capital resource and a source of credit. Production systems must take into account these varied roles, and must be adapted to specific local situations.

If, as expected, fossil fuel prices increase in the long term at rates exceeding average inflation in the industrialized countries, then one increasing role will be the use of livestock as sources of power in agriculture. This is already the case for many countries in Asia with low GNP and low international purchasing power (e.g., Bangladesh and Vietnam).

The other issue, which perhaps relates more specifically to Latin America and parts of Africa, is that the principal livestock production system is extensive grazing by large ruminants, the establishment of which has mostly been through the destruction of the natural ecosystems

of the tropical rain and cloud forests. These systems have consolidated the position of the medium to large landowner/cattle rancher and, by so doing, minimized opportunities for the small-scale farmer.

Despite the privileged role accorded to extensive cattle ranching - witness the supporting research and development efforts over more than three decades by both international and national institutions - these production systems have become increasingly less profitable, due to increased prices of animals, feeds and other inputs, as well as increasing land prices due to competition with other end use patterns. The result has been their conversion into secondary activities kept in place by support (subsidies) from industry and commerce.

Livestock are enormously important to the economies of the less-developed countries as a whole. According to Brumby (1987), when the value of livestock in providing rural transportation, draught power for cultivation, manure for crop production and their ability to utilize non-arable land and the agricultural residues are added to the direct economic value of animal products, livestock accounts for about half the total agricultural production. Livestock also play a critical role in maintaining a cash flow for poor farmers who grow their crops essentially to provide food for their own household. Milk, meat and hides will always be sought after by those segments of society that have the necessary purchasing power to acquire these products. To the farmer-producer these products represent opportunities for generating income.

ECONOMIC GROWTH AND RENEWABLE NATURAL RESOURCES

It is becoming a matter of increasing concern (Daly, 1993) that the present rate of economic growth is already outstripping the capacity of the earth's ecosystems: (i) to produce the required resources; and (ii) to absorb the pollution caused by present levels of economic activities. The impact of the expected doubling of the human population by the mid-term of the next century, most of which will take place in developing countries, coupled with the aspirations of the present and future under-privileged majority, poses a threat that can in no way be described or predicted.

It is quite clear that future scenarios of resource utilization must be predicated on:

- Optimizing the capacity of the earth's ecosystems to produce biomass, as the only renewable source of energy, chemicals and food, without compromising the biological diversity on which the survival of all ecosystems depends.
- Minimizing waste through recycling, which reduces the need for raw materials and helps to protect the environment.

For livestock to play a symbiotic role in such a scenario, it will be necessary to give priority to species that combine efficiency of conversion and productivity, produce low emissions of methane (a major "greenhouse" gas), and have the capacity to use by-products and residues from other primary industries.

Pigs and scavenging poultry undoubtedly are the preferred animal species in this scenario, but there will be an increasing role for the small, as opposed to large, ruminants and for the small non-ruminant herbivores (Cardozo, 1994). High reproductive rate is what gives the competitive edge to these species. Aquatic systems with multiple production of fish, ducks, geese, water plants and other animal and plant species will also find an increasingly important niche in the new livestock development model. The large herbivores will have a primary role as sources of power and fertilizer for agriculture, which they will achieve by recycling the residues from the crops they help to produce. Increasingly they will be expected to combine these activities with milk production and reproduction. The use of castrated males for work is a luxury which future pressures on resources will make increasingly less attractive. As with the plant kingdom, the need for biodiversity *per se* will justify the domestic use of the widest possible range of livestock species.

Among the largely unexplored possibilities of the diverse animal species present in tropical ecosystems, the natural wildlife - mammals, birds, reptiles, fish and crustaceans - can also make a contribution to sustainable livestock production systems, especially because of their adaptation to the ecologically fragile zones and their contribution to biodiversity (Cardozo, 1994).

SUSTAINABLE USE OF NATURAL RENEWABLE RESOURCES

The World Commission on Environment and Development (Brundtland Report, 1987) defined sustainability as "ensuring that development meets the needs of the present without compromising the ability of future generations to meet their own needs". To this can be added the need to respond to the pressures increasingly coming to bear in both industrialized and developing countries to safeguard natural resources (see Brown *et al.*, 1991). In livestock-based agriculture, production systems must take into account these issues. In practical terms this means measuring the "sustainability" of the system according to its effects on:

- the economy,
- the environment,
- the need for energy (especially from fossil reserves),
- animal welfare, and
- food quality and security.

Economic constraints

The prerequisite of any livestock system is that it should be profitable to the producer. In all industrialized countries, the costs of livestock production have escalated mainly because of the increase in the cost of labour caused by rising expectations (standard of living) and competition from other industries. The situation is exacerbated in those countries where farm size is small and therefore unit costs of mechanization are high. Faced with such situations, governments have resorted to subsidizing agriculture through guaranteed support prices and other forms of financial assistance. The total cost of this support amounts to a staggering 75% of the total value of agricultural production in Japan, 40-50% in the European Economic Community and up to 25% in the USA.

Producers are supported in industrialized countries through subsidies and protected markets. These supports have two important consequences: (i) they increase the price of food to the domestic consumer; and (ii) they reduce the economic growth of many developing countries unable to export primary and secondary commodities against the barriers of tariffs and quotas.

Such policies in the long term are not sustainable. They are inefficient in resource utilization since they direct expensive resources

(often produced with cheap fossil fuel) into products which could be produced elsewhere with fewer resources. The production of wheat and milk in some oil-rich countries, which is only made feasible with massive inputs derived from fossil fuel (in fertilizers, irrigation and machinery) is an example of this misguided policy.

For the world economy to grow at an optimum and more equitable rate, it is essential that there is free trade in basic commodities. The objective of GATT (General Agreement on Trade and Tariffs) is precisely to promote the concept of "comparative advantage", whereby commodities are produced in the areas/countries which use least resources for that purpose. Unfortunately, the free movement of capital means that the principal beneficiaries from the exploitation of "comparative advantage" are likely to be the large multi-national companies. An even more worrying issue is that comparative advantage can also mean advantage gained by not paying the environmental cost of a given production activity.

Another world trend likely to have considerable economic impact is the future cutback in the availability of cereal grains for livestock feed. Two factors will contribute to this trend. On the one hand, the rising human population in low income countries will increase the demand for cereal grain which usually is the cheapest staple either to produce locally or to import from world markets. On the other, state subsidies and protection, although still at high levels in the industrialized countries, will gradually be reduced as a result of the GATT agreement. Grain prices will rise as a consequence. Increasing cost of agro-chemicals and fossil fuel, and environmental pressures, will lead to cutbacks in the use of these inputs which in turn will lead to lower crop yields and increased costs of production.

For the poor small scale farmer in a less-developed country where subsidies on the scale presently employed by the industrialized countries are out of the question, the priorities are food security and to maintain their life style (e.g., as with pastoralists and indigenous peoples). The essential steps to achieve this are to produce first for family consumption, using an integrated production system involving crops, forestry and livestock, and which ensures self-reliance by making maximum use of renewable natural resources with minimal dependence on inputs from outside.

This is a more economical and ecological way of improving their standard of living, as compared with the developed country models which have used fossil fuel to achieve this end.

ENVIRONMENTAL ISSUES

The productivity and efficiency of livestock production per animal unit in the least-developed countries is considerably less than in the more-developed world. But 'productivity' and 'efficiency' are references that relate specifically to temperate agricultural practices. In the tropics, livestock activities are different - how does one measure the efficiency of survival, or as a credit institution? These and other productive traits are achieved with minimum inputs of fossil fuel. The biomass availability and the potential to produce more biomass in those countries which are in the tropics is many times higher than in the major industrialized countries which are exclusively situated in temperate zones. But we have only just begun to recognize the potential of tropical feed resources, let alone devise ways of exploiting them in a way which will be sustainable.

Another factor likely to become increasingly important in the future is the potential for tropical soil-based ecosystems, derived from decaying biomass, to foster atmospheric nitrogen fixation (Patriquin and Moncado, 1992), sequester carbon (Hall *et al.*, 1991) and oxidize methane (Keller *et al.*, 1990; Mosier *et al.*, 1991). Threats to the environment come from:

- atmospheric contamination (global warming),
- deforestation,
- accelerated erosion,
- soil and water pollution,
- loss of biodiversity, and
- excessive human aspirations and lack of awareness of the finite nature of renewable resources.

Global warming

Livestock production is intimately linked with build-up of atmospheric carbon dioxide and methane since: (i) emissions of carbon dioxide are caused mostly by burning fossil fuel and tropical deforestation; (ii) some 20% of methane emissions arise from digestive fermentation in the gut of herbivores, the methane itself contributing to some 15% of total greenhouse gases.

Forests and high biomass producing crops are important sinks for carbon dioxide (one hectare of sugar cane is a permanent sink on average for some 80 tonnes of this greenhouse gas). Decaying biomass in contact with soil appears to be an important ecosystem where anaerobic micro-organisms oxidize methane (Keller *et al.*, 1990; Mosier *et al.*, 1991). Use of animal traction reduces the burning of fossil fuel; and permanent (as opposed to slash and burn practices, which provide for natural regeneration of the forest) tropical deforestation is mostly caused by activities leading to establishment of pastures for extensive ruminant livestock production.

Alternative methods of livestock production using high biomass-producing crops, fed mainly to monogastric animals and small herbivores, in partial or total confinement, will lead to increases in the size and number of sinks for both carbon dioxide and methane.

Deforestation

Extensive cattle grazing is the principal production system employed by the colonizers of rain forests and has been, and still is, encouraged by most state agencies for rural development and agrarian reform, even though scientific research has demonstrated clearly the failure of this system in most tropical ecosystems (IGAG, 1988). Livestock production parameters in extensive grazing systems in tropical developing countries are notoriously poor. The average fertility rate rarely exceeds 50% and is often less; average stocking rates are less than one mature cattle unit per hectare; slaughter age for 450 kg live weight steers is more than 40 months; mortality rates frequently reach high figures in many regions due to contrasting food supply situations caused by long droughts and dry periods (Salazar and Torres, 1981).

The recent evaluation of a dairying project in Costa Rica provides further confirmation of the unsustainability of tropical pasture-based livestock systems (Holman *et al.*, 1992). Rain forest (4,000 mm rainfall annually) was cut down and burned in 1979-84 to establish *Brachiaria* pastures for family farm resettlement. In 1992, it was revealed that incomes had deteriorated (to less than the minimum wage), soil fertility had decreased, weeds had taken over from the *Brachiaria* and concentrate usage had increased. The authors concluded that tropical pasture milk production was not sustainable and that research was

needed to facilitate transition to other systems of land use.

When cattle grazing systems are the main activity of poor farmers, with insufficient capital and minimal access to credit, returns are usually inadequate to support the basic needs of the family. The consequence is that the land is sold usually to the rich landholders who, through economies of scale, can continue with the extensive grazing systems; the poor farmer turns once again to the forest, and so the destructive process continues. This cycle has been repeated through successive generations during the present century, the situation becoming increasingly severe since the areas cleared of vegetation are highly prone to erosive tendencies, especially the soils in the Andean and Amazonian regions (Murgueitio, 1990).

The peasant farmer sector in Colombia (1-15 ha per farm) accounts for 70% of the rural population, supplies half the national food budget, yet occupies only 15% of the national territory (Minhacienda, 1984). In contrast, extensive grazing systems occupy more than half of the agricultural area of Colombia, are owned by less than 5% of the rural population and still produce very little (annual consumption of cattle meat *per capita* in Colombia is only 20kg; CIAT, 1978).

The contrast with Asian livestock production systems is interesting. In Vietnam, for example, erosion is not a serious problem and even the areas desiccated by defoliants during the war are regenerating vegetative cover. The reason for the environmentally-friendly role of livestock in Vietnam is that there is no recognized pasture-based beef industry. The role of cattle and of buffaloes is to supply the power needed by agriculture. They are therefore kept in the cropping areas and are fed almost exclusively on fibrous crop residues and by grazing on fallow and common lands (Preston, T.R., unpublished observations).

Erosion

Africa's grazing systems are characterized by agro-pastoralism and transhumance. Such systems were apparently sustainable in times of low population density, with little pressure on the natural resource base and with opportunities to move from degraded lands to new territories or to adapt the pastoralist practice (e.g., to herd camels and goats instead of cattle); but they have been destabilized by "development" practices, which have removed former "density-dependent" constraints (e.g.,

through veterinary care, reduction in tribal raiding), or added new constraints (e.g., reduction of range land area due to encroachment of crops and settlement of pastoralists; and increasing herd sizes) (see Ellis and Swift, 1988).

The impact of this destabilization was clearly seen in the Dodoma region of Tanzania (Christiansson *et al.*, 1987). Explosive growth of the population resulted in increasing areas of rangeland being diverted to cropping. At the same time, the livestock herds of the pastoralists were also increasing. The outcome was uncontrolled over-grazing of the non-cultivable areas, leading to severe land degradation, threatening total ecological collapse of the region. The seriousness of the situation resulted in the initiation of a far reaching and, in some respects, unique programme - The HADO Project (Hifadhi Ardhi Dodoma - Dodoma Region Soil Conservation Project).

The HADO project was started in 1973 and was initially concerned with arresting the accelerating land degradation occurring in parts of Dodoma Region through physical soil conservation measures. However, it quickly became apparent that the terraces, bunds, cut-off drains, etc. that had been constructed were not having the desired effect due to their destruction by grazing animals, and also due to uncontrolled water run-off from higher slopes denuded by over-grazing. As a result, a decision was taken in 1979 to close the most severely affected area of over 1,200 km² - the so called Kondoa Eroded Area - to all livestock, which involved the eviction of over 85,000 cattle, goats, sheep and donkeys.

A review of the Kondoa area, 10 years after the decision to de-stock (Preston, T.R., 1989, unpublished data), showed that the regeneration of the vegetation, and the arrest of ecological degradation generally in these areas had been dramatic. Honouring the promise to the farmers that some form of livestock keeping would be allowed when the land had recovered, in 1990, the government, with help from SAREC and SIDA, introduced a zero grazing scheme for milk production with improved crossbred and local cattle. Results have surpassed expectations (Ogle *et al.*, 1993), with milk yields of up to 10 litres daily being achieved on locally available feed resources, and with major participation of women in the feeding and management of the cows and the use and sale of the milk.

Soil and water pollution

The problem of soil and water pollution has arisen due to excessive use of chemical fertilizers and insecticides in "green revolution" agriculture. Loss of soil organic matter, which increases the need for fertilizer inputs, through monoculture of exploitive crops such as cotton and cassava has been a contributory factor.

A related issue is the effect that excessive chemical fertilizer application and burning of crop residues has had on natural ecosystems. There is increasing evidence that high levels of nitrogen fertilization decreases fixation of atmospheric nitrogen in the rhizosphere of, for example, sugar cane (Patriquin, 1982); and that it increases emissions of nitrous oxides and decreases oxidation of methane (Mosier *et al.*, 1991). By contrast, leaving post-harvest cane trash on the soil as a mulch, instead of burning it, increases sugar cane yields (Mendoza, 1988; Phan Gia Tan, 1994) and soil fertility (Phan Gia Tan, 1994).

The integration of livestock with crops provides both nutrients for the plants and organic matter as an energy source for soil micro-organisms to aid soil fertility. On a specialized crop farm there may be little incentive for planting break crops of legume forages. But if livestock are present then such forages can be turned into income by feeding them to animals. Planting of multi-purpose nitrogen-fixing trees in association with cash crops, as in "alley farming" systems, is also more attractive to the farmer if some of the foliage can be used to give added value to livestock (Attah Krah, 1991).

Loss of biodiversity

Genetic selection for livestock of ever-increasing productive potential has inevitably lead to decreased biodiversity at the animal level. Intensive feeding systems for monogastric animals, almost exclusively tied to use of cereal grains and soya bean meal, have encouraged replacement of indigenous ecosystems and local strains of cereals with 'more productive' hybrids. Emphasis on specialized grazing systems in the tropical savannahs has created vast expanses of pasture monocultures of *Brachiaria* spp. In both cases plant biodiversity has been reduced.

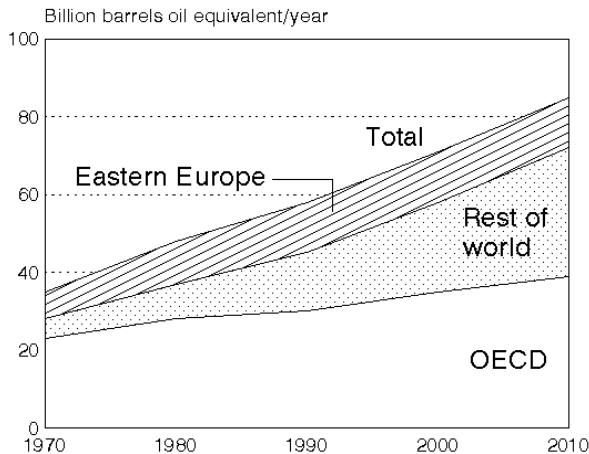
The positive side of increasing affluence is the opportunity to choose more on quality and less on price. In Colombia, eggs from scavenging 'local' poultry were preferred and brought higher prices than those from

'battery' birds (Solarte *et al.*, 1994a). Meat from an indigenous pig breed had a better taste than that from imported 'improved' breeds and was preferred by local inhabitants in Guadeloupe (Depres *et al.*, 1994). The meat from non-ruminant herbivores living in natural ecosystems is considered to be a delicacy (and therefore worthy of a higher price) in many tropical countries.

The search for alternatives to cereal grains and protein-rich oilseed and animal by-product meals (Sansoucy, 1994) is already leading to the identification and promotion of a wide range of indigenous (to the tropics) crop and water plants, trees and shrubs. Biodiversity will be enhanced by these practices which should be encouraged (e.g., by more research).

Human aspirations and the resource base

Figure 1.1. The demand for energy (mostly as fossil fuel) will increase most rapidly in the least-developed countries as they aspire to the living 'standards' of the industrial countries (Source: The Economist, June 18 1994).



The economic strength and the standard of living of the industrial countries is directly linked with their consumption of fossil fuel (Figure 1.1). The aspiration of the less-developed countries is to follow a similar

route. But reserves of fossil fuel are finite and have a lifetime measured in decades, not centuries. Hydro and nuclear power pose serious threats to biodiversity and to contamination with hazardous wastes, with fewer opportunities for employment.

The only sustainable solution is to promote life styles, and goods (of which energy is a priority), which are derived from activities associated with the development and management of natural biologically-based resources. For the researcher in a tropical country, responding to this challenge should be a privilege and source of satisfaction, long since absent from the agenda of their colleagues in industrialized countries for whom agriculture is of declining importance.

RENEWABLE AND NON-RENEWABLE (FOSSIL) ENERGY

The close link between livestock policies and fossil fuel use has been mentioned. Three examples put this in perspective. On the 30,000 ha sugar estate in the Dominican Republic (La Romana), some 18,000 oxen haul the sugar cane from the fields to pickup points on a railway system leading to the sugar mill. This system is highly sustainable since the energy for the oxen is derived from the carbohydrates in the cane tops; nitrogen and minerals in the tops are returned to the soil in their excreta, since the animals eat and rest in the recently harvested areas.

By contrast, in Cuba, some 80% of the sugar cane is harvested mechanically by diesel-driven combines and loaded onto trucks which transport the stalks and attached trash to cleaning centres. Here, electrical power is used to blow off the trash and the stalks are elevated onto rail wagons or trucks for continued transport to the factory. This system is not sustainable. At the time of writing this manual, the problem of de-mechanization of Cuba's agriculture was the subject of keen debate.

The example of Vietnam has already been mentioned, where agricultural power is supplied almost exclusively by buffaloes and oxen, and bicycles are the major means of personal transport. Vietnam's rating in terms of GNP may be one of the lowest in the world but, if it were assessed in terms of sustainable agriculture, it would be among the leaders. By contrast, in most tropical countries in Latin America, oxen have been replaced by tractors and forests are burned to develop pastures for beef cattle. These policies are highly unsustainable.

A specific problem of less-developed countries is the provision of

domestic fuel for the more than 2,000 million families that use firewood from woods and forests for this purpose. In Colombia, it is estimated that 29% (240,000 ha) of the annual rate of deforestation (800,000 ha) is caused by domestic fuel wood consumption, half of which is in rural households, a third in poor urban communities, the remainder divided between charcoal production (9%) and rural handcrafts (11%). The amount consumed varies from region to region, but it is calculated that a rural family of 8 persons uses 18 cubic metres (about 3.6 tonnes) of firewood annually solely for cooking. If this is purchased then it may cost (in Colombia in 1990) up to US\$70.00/tonne. When cut from the forest, it is estimated that 50 work days are expended annually for this purpose, with a value of US\$147.00 (Solarte, L., personal communication). The situation in much of Africa and in parts of Asia is similar.

Several solutions have been proposed which involve livestock. They are complementary and depend on natural and economic resources available and on cultural acceptance of the technology on offer:

- biogas digesters,
- establishing energy plantations, and
- use of crops that fractionate easily into "feed" and "fuel" components.

Biogas technology was first developed in India and China. The mixture of methane and carbon dioxide (biogas), produced by the anaerobic fermentation of livestock and human excreta, has found major uses in cooking. Biodigesters are intimately linked with livestock production, as they depend for substrate on the excreta of animals. Thus, use of this technology strengthens the arguments for partial or full confinement of animals, and thereby forms part of the strategy against uncontrolled grazing. The major constraint to the popularization of biodigesters has been cost and availability of suitable materials for their construction. The recent development of low-cost (less than US\$50/family unit) biodigesters using standard polyethylene tubular film (Preston and Botero, 1988) has had a major impact in Vietnam (Bui Xuan An *et al.*, 1994) and Cambodia (Than Soeur, 1994) where the even lower costs (less than US\$30.00/family unit) put the technology within reach of the majority of families.

Cereal crops are easily separated into grain and straw. The latter is burned for fuel on open fires (with low efficiency) in many developing

countries. But increasingly in industrialized countries, especially those with strong legislation against uncontrolled burning, it is used as fuel in boilers designed for this purpose. In Denmark whole villages are heated in the winter using this technology. In tropical countries, there are even greater opportunities for applying this principle. Production of sugar from sugar cane is one of the few agro-industrial activities which is self-sufficient in energy (and can even be an exporter of energy). In Vietnam, the growing of enough sugarcane to feed four pigs (with the juice) produced fibrous residues (the pressed stalk) sufficient to cover half the fuel needs of a family of six (Nguyen Thi Oanh, 1994). The concept of the multi-purpose biomass refinery, in which the juice is the basis of animal feed or chemicals and the fibre is converted to synthesis gas to power gas turbines for electricity generation (Preston and Echaveria, 1991), promises to be a more viable - economically, sociologically and ecologically - than the single-purpose production of alcohol as in the Brazilian model. Multi-purpose trees can also be fractionated easily into feed (the leaves) and fuel (the branches and trunks) and can thus be part of the same "integrated" model.

Energy plantations are important for the arid and semi-arid regions as they are complementary to pastoral-forestry schemes. Many species that can be used also fix atmospheric nitrogen and produce edible foliage and/or fruits. They include: *Acacia*, *Prosopis*, *Leucaena*, *Gliricidia*, *Guazuma*, *Inga*, *Albizia*, *Cassia*, *Pithecellobium* and *Alnus* spp. They may be sources of food, feed, fuel, timber and protection against erosion and desertification. These systems can also be the basis of biomass refineries as described above.

Thus the promotion of sustainable systems of agricultural production, in which livestock play a fundamental role, can also contribute to the solution of the domestic energy crisis. The use of multipurpose crop plants and trees, and the recycling of livestock excreta, provide not only much needed domestic fuel, but also control erosion, reduce contamination and act as sources of fertilizer.

ETHOLOGICAL ISSUES

Animal behavior studies were originally conceived as a means of exploiting livestock more efficiently through greater understanding of their habits and activities in different environments. The approach today is quite different. Behavior studies are done so as to develop less exploitive methods of animal production. The aim is to reduce stress to the animal and the attendant so that the quality of life of both is improved (Fox, 1988).

By contrast, the deliberate promotion of contentment through natural means can be reflected in higher productivity. The calf, lamb or kid that is suckled by its mother will grow faster, be healthier and have a better feed efficiency than if it receives its milk from a bucket. The dam will also respond to the more natural environment of having her offspring present at milking, and having it suck the residual milk from the udder. Milk yield will be higher and udder diseases less than if calves are weaned permanently soon after birth (Preston, 1983; Preston and Vaccaro, 1989). Calves suckled naturally do not have the urge to suck the navels of their neighbours and thus can be managed in groups instead of being confined to individual pens. Sows fed fibrous feeds during gestation are less prone to develop anti-social behavior (e.g., biting of tails and ears) than when high nutrient density feeds are given. They can then be managed in (more social) groups rather than in separate individual stalls.

Stressful systems of livestock management, such as raising animals in cages and stalls, are already being legislated against in many countries in Europe. Practices such as debeaking of birds housed in cages, amputation of the tails of pigs and castration, reduce productivity and invite cannibalism.

Embryo transplants have been heralded as a means of increasing beef cow profitability by inducing multiple births and thus raising prolificacy (King, 1989). However, this technology can result in a high degree of stress in both the cow and her attendant. The long term effects are likely to be reduced lifetime fertility. Stimulation of cow milk yield by injecting recombinant growth hormone appears to reduce longevity and to increase stress (Kneen, B., 1994; personal communication) through accelerated

partitioning of nutrients from body tissues into milk. The welfare of these cows is certainly decreased and cannot be considered to be sustainable.

The direct economic cost of stressful systems of management will ultimately be reflected in the market place with premiums for products from contented and well cared-for animals and penalties for products of animals that are ill-treated.

The transformation of both extensive cattle ranching and the highly intensive methods practiced in monogastric animal production, into more integrated systems in which the livestock play a catalytic and complementary role rather than being the primary goal, will bring with it related advantages in terms of animal welfare.

WHOLESOME (NATURAL) FOODS

In an increasing number of supermarkets and stores in the industrialized countries, premiums are paid for food produced in "environmentally-friendly" farming systems. Crops that are grown according to "organic" farming principles are in this category; as are animal products (e.g., meat and milk) derived from such cropping systems.

The ban on imports to EU countries of beef from cattle treated with synthetic hormones shows how this concern for more natural food translates into economic criteria.

INAPPROPRIATE MODELS DERIVED FROM INDUSTRIALIZED COUNTRIES

The issue here is that, in contrast to crop production, livestock systems in tropical developing countries have been highly influenced by practices developed in the industrialized countries, most of which are in temperate climatic zones. For example, most "modern" methods of pig, poultry and dairy production in tropical countries are almost exact copies of those practiced in industrialized countries, using the same germ plasm and feed resources. The term 'assembled' is often used to describe the products derived from such systems to emphasize their dependency on imported inputs.

Such practices have been justified by the need to respond to the aspirations inherent in a 'better standard of living' through increased

consumption of food of animal origin. In fact, they exacerbate the basic problems since they result in:

- Minimum employment opportunities.
- An increase in the foreign exchange deficit, due to high imports (some countries import 100% of their feeds for industrial-scale pig and poultry production).
- More pollution, as usually the animal population in such units is high and there are no associated crops for recycling the excreta.
- Impoverishment of the small scale farm family, which cannot compete in the purchase of the required inputs and may not have the skills for the more sophisticated management that is required.

Countries such as Nigeria and Venezuela, which built up sophisticated intensive animal industries in times of high oil revenues, found that these were not sustainable when oil prices fell and agricultural subsidies had to be reduced.

INDICATORS OF SUSTAINABILITY

Indicators of sustainability are derived from measurements which describe the effect of the system on the sustainability of the resource. While this topic is presently the subject of much discussion, the following parameters are proposed as criteria on which the sustainability of resource utilization can be measured. The items (not in order of priority) include:

- Total biomass yield.
- Soil organic matter content.
- Soil pH.
- Soil content of P, N, K, and Ca.
- Degree of diversity of animal genetic resources and their use at the level of small scale users.
- Water quality.
- Production and use of renewable energy.
- Use of fossil energy.

- Energy balances.
- Diversity in fauna and flora at plant and soil level.
- Greenhouse gas emissions and sinks (carbon and methane).
- Employment generation.
- Involvement of women and children.
- Food security.
- Maintenance of lifestyle of households in rural areas.
- The catalytic role of livestock in the integration of crops, livestock and forestry.
- Protection against erosion and desertification.

Using the above criteria it has been the experience in several tropical countries that the production and use of feed resources derived from sugar cane (small scale - not industrial), African oil palm, sugar palm, forage trees and shrubs, and most water plants, can be sustained. The use of cereal crop residues (but not always the production) is also a sustainable feeding system as the primary product will always be produced for human consumption. By contrast, cultivation of cassava, cotton and "introduced" tropical pasture species is unsustainable due to negative effects on soil fertility and, in the case of tropical pastures, due to negative effects on socio-economic indicators (e.g., employment, and persistence of households in rural area).

CONCLUSIONS

The issues discussed in this chapter provide a conceptual basis for the sustainable use of renewable natural resources in livestock-based farming systems for the tropics. The interpretation of this strategy in the form of practical farming systems has profound implications both for the type of feed resources that will be on offer, the species of livestock most suitable for their utilization, the most appropriate way to evaluate them and the manner in which such feeds should be incorporated into the diet of the animal.