Chapter 10

Improved Use of Animals

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Improved Use of Animals

SUMMARY

Animals figure prominently in African economies, representing an estimated $10 billion in annual production of livestock products and services. An additional $3 billion is derived from fishing (40). Numbers of cattle and goats per person are considerably higher for Africa than the world average, although production per animal (as well as for sheep, poultry, and swine) is significantly lower (40).

African livestock serve a variety of important functions beyond producing meat and milk, although the latter typically is of primary importance (box 10-1). Also, animals are raised in a variety of ways:

- about three-quarters of Africa's livestock are raised on small farms where crops are the principal source of subsistence, and animals provide a major source of cash income;
- only 6 percent are reared on commercial ranches (table 10-1); and
- another 20 percent are herded in pastoralist systems where livestock provide the major source of both food and income.

The estimated 16 million African pastoralists have developed a number of specialized technical and social responses to deal with an inherently risky livelihood. Studies show that African pastoralist systems use scarce resources effectively. Although production per animal is low by normal world standards, African pastoral systems are generally more productive than ranching systems in Africa, Australia, or the United States when measured by other criteria, including food production per unit of land (2). Nonetheless, these systems are not self-sufficient in food production and depend to a significant degree on market links to buy food from farmers. Nomads, for example typically derive about one-half of their diet from milk, 16 percent from meat, and 34 percent from purchased cereals and other food (49).

Helping pastoralists presents unique challenges for development assistance because of pastoralists' mobility, their harsh and unpredictable environment, and their relative isolation from national economies (box 10-2). Any improvements in productivity are bound to be marginal. The primary potential of technologies to support pastoralist systems lies in the improved veterinary support and animal nutrition that are examined in chapter 11. This chapter focuses on the mixed crop and livestock systems that account for most African livestock production. The practices discussed—integrated crop/livestock systems using small ruminants and improvements in animal traction and aquaculture—can enhance the contributions that animals within farming systems make to resource-poor agriculturalists.

Major issues in African low-resource fisheries development are briefly outlined in box 10-3. OTA's analysis of fish production technology, however, is restricted to aquaculture development (this chapter) and technologies to reduce post-harvest losses of fish (ch. 11). Technologies for marine and inland fisheries development are not considered here. However, an analysis of various marine and inland fisheries technologies for developing countries is the subject of a recent report by the Board on Science and Technology for International Development (35).

Aquaculture—or fish farming—is not a common tradition in Africa, and represents only a fraction of Africa's total fish catch. Nonetheless, aquaculture holds particular promise for

Box lo-1.—Contribution of Livestock to Agricultural Development

Livestock, particularly in the farming systems context, provide many other benefits in addition to food. Food may not necessarily be the greatest concern for resource-poor farmers and herders. Development efforts in the past have usually been aimed at the improvement of livestock productivity for meat, however.

Animal Traction.—Livestock are a major supplier of draft power in the third world. Livestock provide an estimated 75 percent of traction power—ranging from a low of about 10 percent for Africa to as high as 99 percent for India. The use of animal traction will continue to be of importance to low-resource agriculturalists due to the high cost of fossil fuel and mechanical equipment and the ability of draft animals to use low-quality crop residues for their subsistence.

Food Reserve.—The food reserve or insurance against crop failure provided by livestock is important, particularly in those areas where climatic variation causes frequent fluctuations in crop production. During droughts, animals provide food, while during good years the herds are increased. A1though herds will fluctuate in size they provide security from climatic-induced crop failure. Usually enough of the herd will survive poor years so that the size can increase when climate improves.

Capital Accumulation.—Livestock serve as a bank which can be converted to cash as needed. The fund can be used for emergencies and medical expenses, school costs, taxes, and making investments in agricultural resources. Draft animals are often rented as a source of family income.

Value-Added.—Livestock convert low-value household and community-owned forage and family-supplied labor into high-value products. In extensive grazing systems, cattle, sheep, and goats graze on land which has no value for crop production. In intensive, confined systems (pen feeding) small ruminants are fed low-value crop residue and hand-collected forage harvested from land unsuitable for normal crop production. Children and women provide labor for these enterprises thus adding to family income and food supply.

Manure.—Most animal manure is valued as a source of fertilizer for crop production, and some types are used as building material and/or as a source of cooking fuel. As a source of fuel, manure reduces the pressure upon forest resources which are severely depleted in many parts of Africa. But its fertilizer benefits are lost when burned.

Social Equity.—Because land is not equitably distributed, development of crop agriculture has not benefited the landless. Ownership of small livestock may not require land ownership because of availability of public land or the development of backyard intensive projects. Animals provide opportunity for food and income for the landless. Because livestock products are purchased by urban people who have wealth, they will provide a channel for income to the poor.

Export Earnings.—Livestock products are a potential source of foreign exchange. Many African countries produce meat, hides, and fiber in excess of domestic needs and export provides important foreign exchange for the domestic economy.

SOURCES: Robert E. McDowell, *Ruminant Products: More Than Meat and Milk* (Morrilton, AR: Winrock International Livestock Research and Training Center, 1977); R.W, Rice, "Domestic Livestock in Arid Lands FSR/E," Department of Animal Science, University of Arizona, unpublished manuscript, n.d.

Table 10-1.—Livestock Distribution by Farming System in Sub-Saharan Africa

	Livestock units ($\times 10^6$)	Percent
Ranching	8	6
Pure pastoralism	29	20
Pure mixed farming	32	23
Agropastoral[a]	74	51

[a]Classification reflects the large number of animals that use communal lands for part of the year and farm land for the remainder.

SOURCE: P.J. Brumby and J.C.M. Trail, "Animal Breeding and Productivity Studies in Africa," *ILCA Bulletin*, No. 23, January 1986, pp. 23-27.

increasing food security among many African resource-poor farmers. Promoting aquaculture, however, is a long-term undertaking requiring a prolonged period of technical support. Contributions and adoption are likely to be slow and incremental. Current efforts should be directed toward promoting extensive aquaculture systems, allowing systems to evolve into more intensive polyculture systems as expertise and availability of

Box 10-2.—Pastoralism in Africa

An estimated 6.8 million people in West Africa, south of the Sahara, and 9.3 million people in eastern and southern Africa depend on pastoral herding as their principal livelihood (30). Three general categories of pastoralist production are (9,49]:

- Nomadism: Pastoral systems almost entirely dependent on livestock and that do not involve a permanent place of residence or practice of regular cultivation.
- Transhumant Pastoralism: Pastoralist maintains a permanent residence for several years near which a few crops are typically cultivated. Animals are usually herded by adult male members of the household, sometimes migrating over hundreds of kilometers, in order to obtain adequate forage and water.
- Sedentary Pastoralism: A form of mixed farming where Permanent residence is established and crop-s are grown, but livestock production is the dominant enterprise.

These three forms of pastoralist production have been described as "three different ways of life (that) are specific human answers to the painful choice between high-quality forage and drinking water" (2). This characterization stresses the importance of water and soil nutrients in determining" the form of livestock production in the arid and semi-arid Africa where pastoralism prevails. Water is the limiting factor in the driest region (i. e., below 300 mm rainfall). In these low rainfall areas, the growing season may only last 1 month but the vegetation produced is nutrient rich. Nomads and transhumant pastoralists try to take full advantage. Availability of soil nutrients quickly replaces water as the limiting factor in wetter regions. The increased quantity of available forage in the wetter regions cannot compensate for poor nutritional quality of forage due to inadequate availability y of nitrogen (as well as reduced digestibility and phosphorus content) (2).

Researchers have also identified a wide array of adaptive strategies employed by pastoralists to ensure reliable and adequate production throughout the year in their unpredictable and unproductive environment (7,8). Briefly, these include:

- Movement: Movement is an obvious but essential aspect of pastoralist production that enables herders to take optimal advantage of patchy, fluctuating, and low-density resources. Pastoralists also tend to divide herds into smaller groups to further optimize use of scarce resources.
- Use of Resource Reservoirs: Pastoralists depend on pockets of higher biotic productivity (e.g., highlands, swamps, or rivers), as forage and water availability in the broader range become scarce—either seasonally or because of poor rainfall. Social mechanisms commonly evolve to help control use of these resources. Because of their greater agronomic potential, these areas also tend to be the focal points of farmer encroachment or other agricultural development schemes that can undermine this critical resource for pastoralists.
- Species Composition and Herd Structure: Multi-species herd composition provides effective use of available browse as well as providing pastoralists with consistent supply of food due to differing periodicities of growth and reproduction, and differing lactation patterns. Mix of different species is also a function of plant productivity and rainfall (e. g., higher proportion of cattle in more favorable areas or years). Herd size is typically maximized to the limits of available labor, while composition of household labor (i.e., age and sex) may also define herd structure.
- Social Systems and Interactions: These include the various ritual, political, juridical, and economic relationships that have developed to enhance efficiency in the use of resources and to provide insurance against disaster. Examples include various forms of resource sharing and redistribution.

Disturbing trends in land use and livestock ownership have emerged in Africa that raise serious concerns for efforts to promote food security among Africa's herders. Taken together they suggest a growing vulnerability to drought and famine among increasing numbers of poor pastoralists that depend primarily on their livestock for food and income.

First, pastoralists are among the biggest losers in Africa's growing competition for agricultural land, Poor farmers continue to expand into new areas due to population growth or displacement after giving up land to commercial production. Many have moved onto grazing land traditionally used by pastoralists. This, in turn, has forced pastoralists onto still poorer land. In addition to reducing productivity and increasing vulnerability of production *to* drought, this trend has resulted in *a* shift from what was largely a complementary relationship between farmers and herders to one of increasing conflict over resources (13,18,28).

Second, a marked trend toward increased economic differentiation is occurring in pastoralist communities. Specifically, ownership of herds is being heavily concentrated among a few wealthy stock owners and increasing numbers of pastoralists are becoming paid laborers to herd for these, often absentee, owners. Although this trend raises specific equity concerns, it also raises concern over sustainability in emerging systems (18,49).

> The intensity and specifics of absentee herd ownership vary but its occurrence has important implications for local ecology, since this group of "part-time" pastoralists usually operates outside the indigenous management system, and is likely to be less concerned than local herders with long-term conservation and grazing control (28).

Technical or institutional success stories in assisting Africa's pastoralists are rare. Not surprisingly, a high degree of frustration has emerged over the little progress that has been made in improving pastoralist production despite considerable investment. The fallout seems to be a retrenchment of development assistance effort in support of pastoralists. The argument made is that development funding is better spent where chances of success are more likely. In neglecting the development needs of this group, however, human impoverishment and land degradation are likely to accelerate. This dilemma has led to serious reevaluation among livestock and pastoralist development experts of where and how things have gone wrong, but questions of how best to proceed remain unresolved (12,45).

Some potential does exist for enhancing pastoralist livelihoods and improving their food security, but exploiting it may require a different approach and different expectations than have been applied to date, A growing consensus is emerging that development goals should shift more toward enhancing the subsistence base of pastoralist production sytems, rather than focusing on increasing meat production for commercial markets. Increased attention should be directed at smaller scale interventions and incremental improvements, rather than large-scale interventions. Also, failure to improve significantly on traditional production systems should be seen as testament to their effectiveness and suggests that building off existing systems—rather than replacing them—and tapping the knowledge base of pastoralists themselves is a rational approach to finding solutions (11).

Too often development efforts have focused on introducing a specific technology without assessing its broader impact on the larger production system or its desirability from the perspective of the pastoralists themselves. Greater appreciation now exists of the critical role of social and institutional devices that enable the direct participation of pastoralists in the definition, design, and management of projects (13,27). The emergence and support of local groups such as pastoralist associations is seen as a response to the needs for pastoralists to gain a greater voice in regional planning and political decisions affecting them. They also provide institutional mechanisms to assist herders in stemming the tide of expansion of sedentary farmers onto critical dry-season grazing areas. Such issues also relate directly to the need to address changing patterns of land tenure and communal resource use (46).

needed inputs and markets grow. Immediate gains in enhancing Africa's fisheries sector are possible through various technologies that cut down on post-harvest losses and spoilage (ch. 11).

Animal production can serve as an important catalyst to agricultural development among resource-poor farmers (31). Selling animals and their products commonly is the most important source of cash income for resource-poor farmers. This income can in turn be used to purchase inputs (e.g., fertilizer and improved seeds) to enhance crop production. National production statistics provide evidence of this positive association between livestock and crop

Box 10-3.—Fisheries Development in Sub-Saharan Africa

Fish, on average, provide about 12 percent of animal-derived protein in the African diet, three times as high as in Latin America and four times as high as in the Near East. Sub-Saharan Africa's approximately 2.7 million metric ton fish catch in 1984 was derived in almost equal parts from marine and inland fisheries (43), Africa's marine fisheries production declined between 1976 and 1984, while inland fishery production has increased about 8 percent during the same period. While large-scale marine fisheries have increased in importance in a few African countries, traditional small-scale (or artisanal) fishing still accounts for 85 to 95 percent of Africa's total fish catch (9,35,43).

Further development of Africa's predominantly small-scale fisheries faces many of the same problems as efforts to enhance low-resource farming and herding. Factors intrinsic to fishing operations, including low productivity and consequent low incomes, make investments in improvements difficult. Productivity is also hampered by the fishers' poor access to markets, transportation, and credit. A recent study of technologies for low-resource fisheries suggests that the most effective technologies are generally those that: 1) are adaptable to solving specific local problems, 2) mitigate against ecological or social disruptions, and 3) are economically feasible and desired by the community they are intended to serve. The study also concludes that projects promoting new mechanical or fabrication technologies should include a training component, service support, and emphasize locally available components and spare parts (35).

Productivity of traditional fisheries is being undermined by deteriorating natural resources. Overfishing and disruption (e.g., pollution) of spawning or feeding areas, commonly due to impacts of large-scale commercial operations, are major causes of this deterioration. Deforestation in coastal areas has also made certain woods that are preferred for boat construction increasingly scarce (35),

Just as low-resource farmers and herders have been largely neglected by national and international agricultural research, so too have the low-resource fishers been neglected. For example, studies show that although some 70 percent of the marine catch off West Africa is taken by small-scale fishers, this group receives no more than 20 percent of government fisheries funding. Considerable benefits are identified in supporting these small-scale fisheries, including creating employment, effective use of local investment, and production of high-quality products using little energy and causing little pollution (42). Evaluation of the economics of large- v. small-scale fishing in Africa is scant (9). One such comparative study for Sierra Leone, however, concluded that small-scale operations were more profitable and could produce fish at a lower cost per ton than large-scale firms (26).

The Fishery Committee for the Eastern Central Atlantic, a regional fishery organization set up by the U,N. Food and Agriculture Organization, has suggested numerous mechanisms to promote and protect African small-scale fisheries. Designating in-shore areas specifically for use by low-resource fishers, as has been done in Cameroon, Mauritania, and Senegal, is one mechanism. Developing credit for fishers to purchase canoes, nets, and motors is another. Interventions must be preceded by assessments of possible negative impacts on communities, however (42).

The neglected role of women should be integral to such investigation (24). Though they seldom go out in the boats, women play a critical role in shore-based fishing (e.g., 95 percent of the work-force in Ghana and Togo)—with principal responsibility for processing, transportation, and marketing. Further, women commonly are major owners and investors in boats and gear, the principal source of wealth among low-resource fishers (9,42).

production on small farms: generally speaking, those African countries with the greatest increase in stock numbers also experinced the highest cereal production increases (5).

Diversified production systems that include 1ivestock (or fish] and crops also offer increased security of production. For example, producing millet as the staple grain in the northern Sahel is only possible because of the added food security provided by livestock rearing since millet crops often fail (49). Combining several types of livestock—for instance, cattle, goats,

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OPPORTUNDTIES FOR IMPROVED USE OF ANIMALS

Mixed Crop/Livestock Systems Using Small Ruminants

Small ruminants—sheep and goats—are a valuable asset for resource-poor farmers. They are generally well suited to small mixed farms because of the low capital investment per head, contributions to nutrition and family income (in small but timely amounts), and minimal competition for land and labor (47). Research on their actual contributions is scarce, however. Increasing attention now is turning to the complementary roles small ruminants can play in integrated crop/livestock systems, particularly in medium to high rainfall areas.

Rearing of small ruminants in mixed production systems often is a minor enterprise relative to crop production. For example, African women primarily engaged in food preparation and processing may complement these activities by rearing small numbers of animals using household wastes as feed supplements. Production efficiency could be improved, however, by taking greater advantage of possible complementary interactions between small ruminant and crop production (17).

- Small livestock are able to convert low-value crop residues to high-value animal products (e.g., milk and milk products, meat, hides, etc.).
- Animal manure provides an effective means to convert forage to fertilizer, particularly for small home garden plots.
- Rotations or intercropping of food crops with forage crops (especially leguminous species) enable farmers to produce high-quality animal feed, as well as increase soil fertility and control crop disease.

ILCA has been testing ways to enhance efficiency in low-resource farming systems by increasing crop/livestock integration in existing farm enterprises (see box 10-4). Two general approaches have emerged. One is an integrated alley farming approach based on work conducted at the International Institute of Tropical Agriculture in Nigeria, which links crops and livestock through the use of leguminous browse trees (ch. 8). The second is referred to as an Intensive Feed Garden Approach and is directed toward regions where land is scarce and animal confinement is appropriate or necessary (36).

Both systems are based on the premise that small ruminant production must occur within the context of existing agricultural systems. Researchers thus have stressed the need to keep demands for cash, time, and management to a minimum, as well as focusing attention on those areas where land scarcity makes increased management more acceptable.

Although research on both systems is incomplete, preliminary results are promising. As Africa becomes increasingly populated and livestock grazing is restricted in some areas, livestock production will have available more labor but less land. Efforts like the two ILCA models will become increasingly attractive to and necessary for resource-poor farmers, especially as greater confinement of animals increases the need for “cut-and-carry” fodder operations.

On-farm investigations of alley farms in Nigeria show greater flexibility in how farmers use the system than had been anticipated by researchers (36). This suggests that alley farming is adaptable to meet a variety of objectives under low-resource conditions and that trade-offs in inputs are possible, enabling farmers to adjust systems to meet their particular needs or limitations. The Nigerian government has now initiated its own program to promote alley farming.

The intensive feed gardens have not been thoroughly evaluated. However, some investigations have shown that when the fodder crops are rotated to food crops after 2-year intervals, the enhanced soil nitrogen and organic matter can boost sorghum yields up to 300 percent [32). The system could offer a sustainable rotation that would be highly beneficial to low-resource farmers (32)—particularly under conditions where alley farming may not be possible, where

Box IO-4.—TWO New Farming Systems Using Small Ruminants

Alley Farming in Humid Nigeria

Throughout much of the humid zone of West Africa, small ruminants are kept in free-roaming village flocks with low management inputs and relatively low productivity. ILCA's Humid Zone programme has developed for this region an improved sheep and goat production system that is closely integrated with crop production.

The new system employs the fast-growing leguminous trees *Leucaena leucocephala* and *Gliricida sepium* as animal feed and as a means of maintaining soil fertility. The system uses alley cropping techniques in which crops are grown in 4-m wide alleys between rows of *Leucaena* or *Gliricidia*. During cropping years, 75 percent of the tree foliage is applied to the soil as mulch, while the rest is fed to small ruminants. The cropping system is periodically fallowed for 2 to 3 years, and during this period the natural vegetation, as well as the tree foliage, is eaten by small ruminants.

The Humid Zone Programme is evaluating 16 alley farms in different villages. All farmers include *Leucaena* and *Gliricidia* trees that have been established from seed. At least 40 accessions of *Gliricidia* were collected from Costa Rica during 1983, some of which are now producing fresh weight yields 160 percent higher than the local types.

Nigeria's Federal Livestock Department is starting a pilot development project in which 60 participating farmers will practice alley farming on their own land. The farmers will also adopt an improved animal health package recommended by ILCA, which includes vaccination and dipping to prevent common diseases.

Fodder Banks in the Subhumid Zone

Livestock producers in the West African subhumid zone have great difficulty feeding their animals during the long dry season. Fodder is scarce and of poor quality, and cattle commonly lose 15 percent of their body weight before the rains return. Milk yields and reproductive performance fall and mortality rises.

Supplementary feedstuffs are scarce and expensive, but home-grown legume forages are likely to offer a solution. However, livestock owners have little access to land, few implements for cultivation and little money to spare for fertilizer.

ILCA's Subhumid Zone Programme has addressed these problems by introducing "fodder banks" of forage legumes which are cultivated and partially fertilized by the animals themselves. Large numbers of animals are crowded onto the 2- to 4-ha fodder bank areas at the start of the rains. They graze the remaining vegetation, their hooves break up the soil surface and their dung and urine provide fertilizer to help in the establishment of the forage legumes. The fodder bank is then sown with successfully tested varieties of *Stylosarzthes (e.g.,* lucerne and style) and 150 kg/ha of phosphate fertilizer. By the end of the rainy season such fodder banks yield 4 to 6 tons of dry matter per hectare, with a crude protein content of at least 13 percent.

The fodder banks are made available to animals periodically during the dry season, giving high-quality feed and boosting production at a time of the year when the animals are accustomed to only a small amount of low-quality grazing.

The ILCA package has been enthusiastically received by local herders and by Nigeria's Federal Livestock Department. Now 23 fodder banks exist in ILCA's case study areas, some of which have been started by the pastoralists themselves after seeing the success of banks grown by ILCA's team.

SOURCE: International Livestock Center for Africa (ILCA), ***ILCA Annual Report 1983: Improving Livestock and Crop-Livestock Systems in Africa,*** Addis Ababa, Ethiopia, 1983.

land is particularly scarce, or where the numbers of landless Africans are increasing.

In a similar vein, research begun in 1979 on dual-purpose (milk and meat) goat production systems in Kenya show promising results in developing low-cost, low-risk technologies able to accommodate the land, labor, and capital constraints faced by resource-poor farmers (48). In this work, the major factor limiting improved production was found to be the poor quality and scarcity of feed, especially during the dry season. To compensate, the researchers introduced an indigenous legume, *Sesbania sesban*, which provided supplemental protein for goat diets, improved soil fertility and provided fuelwood and a living fence. Introducing sweet potatoes into the system and using its vines as supplementary feed was also found to be effective.

Despite these promising results, a number of problems need to be addressed, Paramount is the need to incorporate veterinary care into such programs (ch. 11). Peste de Petit Ruminant (PPR), a respiratory disease, poses a particularly severe threat because it is widespread in Africa and can wipe out an entire flock or herd quickly. Preliminary results show that innoculating small ruminants each year with tissue cultured rinderpest inoculation can control PPR under village conditions (36), but the problem remains whether resource-poor farmers are willing to invest in vaccination. Unpublished cost-benefit data suggest attractive returns (36), but other social, technical, and institutional factors must also be considered, not the least of which is the effectiveness of extension services in reaching low-resource farmers.

Animal Traction

Animal traction refers to the use of animals, primarily cattle, for farming activities like land preparation; sowing, weeding, and harvesting crops; and transportation. Substituting animal for human power can reduce human labor while increasing the farmer's ability to cultivate more land per day, and with less drudgery. Savings in labor, however, are offset to varying degrees by the work needed to maintain the animals.

Some 10 to 20 percent of Africa's farmers use animals for traction, but the practice is steadily spreading. The area cultivated by animal traction is estimated at about 15 million ha, or 15 percent of total cultivated land, This average figure masks major variations at a regional level; the proportion cultivated by animal traction varies from no more than 2 percent in central and West Africa to 42 percent in eastern Africa. It reaches a high of 90 to 100 percent in Ethiopia and Botswana (41),

Even on farms where animals are used for plowing, manual labor is often relied on for other farming activities. For example, only 5 percent of farmers who plow with animals use them to pull mechanical weeders (41). Overall, animal traction makes only a small contribution to the overall power requirements of African agriculture, which is still about 90 percent dependent on human labor. Several West and Central African countries are nearly 100 percent dependent on human labor.

Although animal traction can be used for deep plowing, which sometimes can lead to increases in crop yields, few farmers use the technology to improve tillage. Rather, animals are mainly used to expand the area cultivated and improve labor efficiency, and these factors lead to increases in overall production rather than yield increases per hectare (38),

It has been argued convincingly that the acceptance and viability of animal traction, as well as use of tractors, is a function of the type of fallow practiced by farmers (38). The ability to benefit from animal traction is hampered by the presence of tree roots and stumps in regions where tree fallow prevails. This suggests that animal traction or tractors become more viable under progressively more intensive bush-fallow and grass-fallow systems (38). Studies of the relationship between fallow type and shifts from hand cultivation to animal traction provide the following general observations (38):

- The transition to the plow would not be cost effective in forest and bush fallow systems due to the high overhead costs required for removing stumps and for animal maintenance.
- A distinct point exists in the evolution of agricultural systems where plow use becomes economically feasible.
- This point is conditional on soil types and soil fertility: the transition would occur sooner for hard-to-work soils (clays) and for soils which require high labor inputs for maintaining soil fertility.

The high costs involved in buying animals and equipment can deter resource-poor farmers from adopting animal traction. Oxen and equipment may cost one to three times a farmer's annual income, depending on the amount of equipment included (20,38).

Although animal traction can be used to double or triple rates of return by using mechanization to free up labor, it can be as long as 5 years before these rates are reached (21). Also, the economic return from animal traction seems to decrease if too much equipment is introduced at once or if it is too complex (20). For example, in some cases earnings per worker and even per hectare on the highly mechanized enterprises (ones using a seed drill, hoe lifter, and cart) can be lower than on farms using only a seed drill).

Where draft animals are already in use, inadequate or untimely access to draft animals can result in a failure to plant at the optimal time and, thus, significantly reduce yield (37). Making more efficient use of draft animals can make important contributions to improving yields. Improving animal health offers one important avenue to increased efficiency (ch. 11). Improvements in, and diversification of, animal traction equipment offer others.

ILCA has modified the traditional Ethiopian maresha plow so that it can be pulled by one ox instead of two in one attempt to address the problem of insufficient draft power. This simple change could have significant impact in a country where only one-third of the farmers own two oxen. Using the new plow, a single well-nourished ox can plow 60 to 70 percent of the area normally covered by two oxen, and the farmers can make the inexpensive plow modifications themselves (19). Initially enthusiasm was high based on result from tests at the research headquarters. However, subsequent on-farm studies identified a number of problems that have dampened expectations and reinforced awareness of the need to promote increased farmer participation in technology development (29).

Increased attention is now being directed to other modifications of the maresha that, based on on-farm trials, offer great promise (23). One modification is the development of a terracing plow that could make important contributions to efforts to reduce soil loss, increase water conservation, and provide stable crop yields.

Another modification is the development of a broadbed and furrow maker that could promote better use of the nearly 100 million hectares of Sub-Saharan Africa's vertisols. Vertisols are clay-rich soils that have a very high water-holding capacity and thus, when wet, tend to get waterlogged and sticky. When dry, they become hard and cracked. To grow anything besides a few waterlog-tolerant crops, elevated beds need to be built to increase water drainage and evaporation. Making such broadbeds in these difficult to work soils is traditionally done by hand, and requires labor inputs of about 60 hours/ha. The maresha broadbed maker, costing about $25 for modification, can cover the same area in about 16 hours using a pair of oxen. Although power requirements are about so percent higher than for the traditional maresha, power needs are considered well within that which can be provided by a pair of local zebu oxen (23). Improvements in total labor productivity are estimated to be at least 40 percent, while measured yield gains of bread wheat and teff were found to be about 80 percent and 25 percent higher, respectively.

Increased use and modification of animal traction technology in crop production, including plowing, planting, and weeding, show significant promise for increasing labor productivity. Weeding—the second most important labor bottleneck after plowing—can be done six to seven times faster using animal traction compared to hand weeding (22). Increased attention could also be directed to other underdeveloped uses of animal traction. ILCA for example has developed an ox-drawn scoop that can be used to dig and remove silt from ponds to store water for the dry season, or to develop aquiculture (19). Animal traction as a pumping technique in small-scale irrigation schemes may also deserve greater attention as does animal-driven transport.

Expansion and diversification of animal traction technology in promising regions will require access to equipment and will increase demand for repair services and spare parts (38). Large factories in several countries, for example, Senegal, Mali, and Ivory Coast, have been set up to manufacture animal traction and transport equipment. These tend to be parastatal operations and their production capacity is generally much higher than existing demand. As such, these operations tend to be subsidized and are given access to preferential credit terms (44). Increased use of animal traction may make such operations cost-effective in the future, However, increased attention should be directed toward supporting small private, locally based, enterprises. Significant benefits exist in supporting the training of blacksmiths in equipment production, maintenance, and repair where these artisans are widely dispersed and integrated into villages, and where they provide services directly to local farmers (10,38),

Photo credit: U.S. Agency for International Development

Mastering the use of animal traction can take as long as 5 years for farmers unfamiliar with it. Here a Senagalese farmer practices plowing during the dry season.

Aquacuhre'

Aquiculture refers to practices by which fish and other aquatic organisms are cultivated, much like any other agricultural product, rather than caught from rivers, lakes, or oceans. Land, water, and climate combinations in many places in Africa have potential for supporting aquiculture. Appropriate technologies have been demonstrated that are profitable and within the management capability of low-resource farmers (15). By regulating stocking and improving pond design, small pond systems can be the basis of modest managed fisheries.

Ponds built for aquiculture can be designed to play a role in a larger soil and water conservation program. Ponds help slow the erosional force of runoff water and can reduce downstream flooding. The water stored in ponds can be used during the dry season for watering stock, irrigation, drinking, washing, recreation, and to support wildlife. Therefore, fish production facilities can be combined with many other uses.

The management used in aquiculture can be extensive—using random stocking of available fish species into existing ponds—or intensive—using exotic species raised on processed feed in ponds built with mechanization. Extensive and semi-intensive approaches currently hold the most promise for resource-poor farmers (6, 14,15). Many unsuccessful efforts to establish aquiculture in Africa bypassed extensive management and attempted to introduce intensive systems (15). Extensive systems, however, are better suited to and more likely to be adopted by low-resource farmers becomes of their lower capital input and lower financial risk (34).

Farm systems could be studied to design aquiculture systems that are compatible with farmer labor and financial constraints. As farmer familiarity and competence in managing aquiculture increases, efforts can be directed to emulate the more productive but more complex "polycultures" such as those of China. As with intercropping or mixed-species herding, polyculture ponds increase yields because the mix of species more efficiently uses available resources than can any one species *(14).*

One of the simplest ways to enhance fish production in ponds is by the use of fertilizers. Chemical fertilizers or organic material can be used to stimulate natural fish food production. Fish may also be fed directly, but products that provide a nutritionally complete diet are usually expensive and in short supply in less developed countries. The same is often true of chemical fertilizers. Nevertheless, some locally available farm byproducts such as animal manure, cereal brans, and crop residues sometimes can be used to supplement natural foods in ponds to enhance fish production. Efforts to increase aquiculture production should include identification of these local feed/fertilizer resources and the design of production systems that take advantage of this local availability.

Integrating fish, livestock, and garden production into a singIe system—a practice common in the Orient—may be applicable in select cases in Africa. Local application may take various forms. A typical situation might be for a farmer to have a few small fishponds, with water enriched with runoff from a small poultry or stock pen. The enriched water from the pond, besides producing fish, would also be used to irrigate and fertilize a vegetable garden. Garden wastes would then be fed back to the stock or be put into the ponds. The diversity of such an integrated system reduces the risks associated with any single part of the system and also provides a variety of products for household use or local markets. Small operation can usually be built and maintained with family labor and can be programmed to keep within existing demands for time and food, or cash crop production. Such. systems require relatively little capital and remain in the control of the producing family.

[1]The material on fisheries is based primarily on John Grover and Stephen Malvestuto's contractor report (app. A) and an unpublished description of the U.S. Peace Corps' fisheries work by Harry Rea and John Zarafonetis, June 29, 1987, Washington, DC.

planners, however, must also evaluate and mitigate any potential adverse health impacts that may arise from aquiculture operations—both on the stock produced and on people. Disease or parasite outbreaks are commonly the most severe constraints to aquiculture development in a region (l). For example, greater attention could be directed to evaluating the threats of increased influenza pandemics that may arise from the spread of aquiculture operations, particularly systems that closely integrate fish, waterfowl, and swine production (39). Threats of introducing or exacerbating schistosomiasis is another important concern. Agrochemical use in farming operation should also be evaluated to avoid problems of introducing toxins (e.g., pesticides) that commonly accumulate in aquatic food organisms. Aquiculture operations can also generate their own pollution problems, such as nutrient build-up, for which mitigation plans may be needed (l).

Experience with promoting integrated aquiculture systems in Africa is small, although initial results of the Peace Corps' work in a few areas, such as Tanzania, for example, seem promising (14). Reviews of aquiculture development elsewhere suggest that it is best approached in stages. Integration of fish production with other forms of animal husbandry may follow but may be too complicated during start-up (14).

The Peace Corps, initially with support from Oxfam and later from AID and the Zaire government, have been involved in aquiculture in Zaire since 1973. OTA asked the Peace Corps to outline briefly what factors are most important for successful aquiculture development, based on their experience (box IO-5). These lessons seem to provide useful guidelines for supporting aquaculture development in other parts of Africa as well,

Box 10-5.—EIements of Successful Aquiculture Development in **Zaire**

The Peace Corp's Fish Culture Expansion Project in Zaire began in 1978, building off earlier work and feasibility studies dating to 1973, The earlier experience demonstrated the technical and eco*nomic* feasibility of small-scale *Tilapia* culture in family-operated fishponds. This work provided an understanding of local conditions, including the biology of fish production in the area and the culture and institutional framework around which the project was to be oriented. The following points have been identified as the most important elements of successful aquiculture development based on at least 10 years of experience with the project.

- *Farmer interest in and familiarity with fish culture.* In the project area, people have harvested river fish for centuries. They liked *Tilapia* and were interested in the project. Although colonial introduction of aquiculture was unsuccessful, many people were familiar at least with what fishponds were. Therefore, Peace Corps Volunteers (PCVs) did not have to introduce a completely foreign technique.
- *Tilapia culture is ideal as a first form of intensive animal husbandry. Tilapia* are extremely hardy fish, they rarely die from disease or mismanagement, and they reproduce in a wide range of conditions. Farmers left their village for weeks at a time, in certain cases, and returned to find not only that their fish had survived, but also had spawned. Little capital investment is necessary. Fingerlings are inexpensive, ponds can be dug by hand when labor is not needed for tending other crops, and inputs are available locally (feed, organic fertilizer, and fingerlings for restocking).
- *Excellent technical and logistical support.* A technically qualified Associate Peace Corps Director has been responsible for the project nearly continuously since 1974. Most PCVs have participated in pre-service technical training and are involved in all planning processes. This technical training not only has provided PCVs with the needed technical and extension skills but also instilled in the locals high levels of confidence, enthusiasm, motivation, and, perhaps most importantly, a sense of direction.
- *PCVs set high standards for project ponds.* High work quality standards are expected from participants in the demonstration ponds. This often means withdrawing support from those farmers who are unwilling or unable to meet adequate standards and commitments. The re-

maining farmers each build several high-quality ponds that serve as models for other interested farmers. Failure to set standards for pond operations has been a major shortcoming of several other technical support programs.

- *Focus on management.* Even though the mechanics of fish culture are simple and the risks considerably lower than with other forms of animal husbandry, the concepts can be difficult to understand. Concepts such as stocking, feeding, growth, and production rates—let alone pH and oxygen cycling—are unfamiliar to farmers that have never raised animals. Proper management is the reason that some farmers produce two to three times more fish than their neighbors.
- *Development of local infrastructure.* The Zaire fish culture project demonstrates that this type of agricultural development is possible even with minimal national government support. The program's focus has always been on the individual farmer. Fingerlings are produced and distributed locally, experienced farmers advise new farmers on site selection, pond construction and management, and farmers meet regularly to discuss problems. Numerous seminars, meetings, and field trips are held before there is ever talk of forming a group. Farmers get to know each other and come to rely on each other for advice and assistance. The result is the development of a local private infrastructure capable of taking over PCV responsibilities.
- *Long-term commitment.* A 10-to 20-year commitment maybe necessary for introducing aquacult&e into a region, although shorter support periods may be possible for particular sites. The Peace Corps recognized the need for a long-term view when introducing the technology into a village, and plans to be actively involved from 4 to 8 years depending on the village. PCV input is designed to last long enough for farmers to see positive results, but then it is phased out as local management skills are developed.

SOURCE: Harry Rea and John Zaraphonetis, unpublished cast study, U.S. Peace Corps, Washington, DC, June 19, 1987.

POTENTIAL

Improvements in existing low-resource farming systems for much of Africa will be predicated on access to increased income so there is cash available to invest in inputs to enhance productivity, such as improved seeds, fertilizer, and labor. Livestock, particularly small ruminants and poultry, provide the most important source of income for subsistence farmers. The improved diets that result from introducing animals into farming systems further enhances the production potential. So, too, do livestock systems that help modulate labor demand—i.e., those that can employ labor during periods of underemployment but do not place heavy demands on labor during seasonal labor bottlenecks.

Promoting improved integration of crop and livestock production holds strong promise for Africa. For the region as a whole, an extra animal in the cattle population on a mixed farm correlates with an additional one-quarter hectare of crop land, a 200 kg incremental grain output per year, as well as an additional 30 kg of meat and 38 kg of milk (3,4). Research also shows that integrating animals into a small farm increases returns over cropping alone. For example, maize grown solely for human consumption recovers 39 percent of the crop's energy and 20 percent of the protein. When the materials left from food preparation are fed to an animal, nearly 50 percent of the crop's energy and 30 percent of the protein is used. Small ruminants offer particular advantages and opportunities within low-resource agricultural systems and deserve increased attention (49).

Research on improved integrated crop/livestock management systems is new but shows great promise and seems well adapted to meeting the particular needs and constraints of resource-poor farmers. Development of other technologies, such as new or adapted implements to make more effective use of animals, promises to provide improvements in production efficiency. Animal traction enables farmers to cultivate more land and reduce drudgery, and helps improve nutrition for the farm family, Animal disease, particularly trypanosomiasis, severely limits animal use in much of Africa. Disease control, particularly through expanded use of trypanotolerant breeds and improved management systems (ch. 11), offer hope for future wider application of mixed crop/livestock technologies,

Also important for the resource-poor farmer is the increased food security that can be achieved through diversification of food and income sources made possible by mixed crop/ livestock production. Aquiculture, for example, potentially could be a part of farming systems throughout the humid lowlands, tropical highlands, and wherever else water is available to supply small, year-round ponds,

PROBLEMS AND APPROACHES

Currently, about 75 percent of African livestock are raised on small, primarily subsistence, farms where animal nutrition is the most limiting factor in increasing animal productivity. It is likely that this will remain the norm for some time to come (31). Improving efficiencies by better integrating crops and livestock to facilitate small-scale mixed production is thus a logical focus for the immediate future.

Despite the predominant importance of livestock in arid and semi-arid regions, efforts to develop technology for pastoralist systems largely have been unsuccessful, with the possible exception of veterinary interventions. A reassessment of goals and strategies is needed so lessons learned from mistakes are better used in planning future activities. Further, soliciting knowledge and participation of herders themselves is now seen as an essential component of successful interventions (13,45,49). AID and others have expressed an emerging agreement that the prime emphasis in the livestock sector at this time should be to support the subsistence base of pastoral herding rather than to stress commercial meat production (45). Increased attention needs to be directed toward resolving the resource conflicts between pastoralists and sedentary agriculturalists. The problems that emerge where farmers move into grazing areas that pastoralists require for dry season browse are particularly acute.

The potential of livestock development in wetter regions is more promising. Livestock remain underexploited in subhumid regions, particularly for animal traction and integrated crop/livestock systems. Cattle production in the humid zone will continue to be restricted by trypanosomiasis, but small ruminant production using leguminous trees to complement other feed sources seem promising although, here too, there are disease problems to combat.

More broadly speaking, the need exists to better account for the interaction between crops, trees, livestock, and wildlife—as well as the social and cultural values that emerge at the interface of human and natural systems. Perhaps the single most important objective should be to recognize and take advantage of complementary areas and mitigate against areas of conflict. One example is the potential links leguminous trees and shrubs can play in simultaneously providing access to high protein forage for livestock, improving soil fertility for crops, and reducing pressures on the surrounding environment by providing fuelwood, stabilizing soils, and enabling more intensive production.

Conversely, an accounting is also needed of possible deleterious interactions. For example, plants that may be best for nitrogen fixation may produce forage that is toxic for animals (33). Plant breeders' efforts to increase grain yield may affect the needs of African farmers who use crop residues as a source of livestock feed. Farmers in Mali, for instance, rejected an improved variety of cowpea because the improved crop yield also significantly reduced the amount of residue for fodder (49). In a similar case, new bird-resistant varieties of sorghum contained increased tannin, which reduced the utility of plant protein. Plant breeders must consider these potential trade-offs and look at "whole plant" uses in order to respond to the needs of low-resource farmers (31).

Animal traction, although not prevalent in Africa compared to other developing regions, is steadily increasing in importance. Fostering increased use of animal traction has a significant role to play in the future of African agriculture. It is necessary, however, to consider environmental and sociological factors before promoting animal traction in an area. Structure of the soil, relative content of clay to sand, and erodibility are obvious considerations. Sociological factors more difficult to measure are also important, however. For instance, consider the analysis below of the problems encountered trying to promote animal traction in the Dukolomba region of Mali (25):

> When elders of Dukolomba, upon being confronted with the ox-drawn plow by the French, told the laboring youth of the village that the "cow hoe, " as it is called, would wear out their soil too quickly, they are, as we have seen, not lying. But it wasn't the soil that they were trying to economize on. As the decision makers, but not the laborers, in the family firm, these elders felt that with the labor-saving device of the plow they would lose control over the youths, who feeling less needed by the family, would drift away, either to the Ivory Coast or into their own separate firm. Thus in purchasing a plow, the elder would lose not only its price but also control over labor which he could use to advantage throughout the year. The youths were to be shamed into staying at home by the spectre of famine which would result from their being absent during the moundmaking and the weeding season. Both elders and youths concur on this explanation of Dukolomba's early avoidance of the plow.

Although research and technology development in support of integrated crop/livestock systems is scant, that which does occur is more common in the international research centers than in African national research centers (31), This is a serious omission from national research programs given the prevalence of mixed farming systems in Africa and the potential gains from improved crop/livestock integration,

CHAPTER 10 REFERENCES

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