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Energy and the Evolution of Farming Systems: The Potential of Mixed Farming in the Moist Savannah of Sub-Saharan Africa[1]

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Abstract

The moist savannah zone in sub-Saharan Africa is regarded as a high potential area for crop and livestock production. Currently, human labour is the principal source of power for crop production and the level of commercial energy use is very low. Agropastoralism and pastoralism are the principal methods of livestock production. Crop-livestock mixed farming, in which manure and animal power are important energy sources in the production process, is only now emerging. The integration of crops and livestock and the implications for agricultural energy sources are related to population pressure and labour intensity, the intensification of crop production with and without livestock, the role of traction in general and in specific niches, the contribution of livestock to the development process in terms of food or other inputs, and the role of public policy and intervention in development.

Energy and farming systems

Background and objectives

Production is essentially a process whereby one form of energy is transformed into another. Humans and animals are chemical converters of food energy into mechanical energy or work. Man's power capacity is very limited so a system based only on human muscle power cannot be very productive. The history of human civilization is largely a story of man's progress in harnessing energy from various sources and converting it into useful forms. The only source of energy for primitive people was the food they ate and its principal use was for hunting and gathering food. Compared with them, people in the most advanced societies now use over one thousand times more energy par caput, mainly in the form of electricity, gas and petroleum, and only a tiny share (3-5%) of this is used in agriculture for food and feed production (Stout et al., 1979).

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The sources and the quantities of energy used in agriculture have evolved as production systems developed. Because of uneven development around the globe, different production systems and associated sources and levels of energy use are observed. For example, shifting cultivation and pastoralism, two of the oldest agricultural practices developed, are still widely practiced in a large part of Africa, where human muscle power is the primary source of energy in agriculture (Table 1), and the use of commercial energy is lowest among the developing regions, as are crop yields (Table 2). In West Africa, only about 7.5 kg of chemical fertilizer is currently applied per hectare of arable land and cereal yield is about 900 kg per hectare compared to over 3000 kg in the developed countries (Fischer et al., 1992).

Table 1. Share of different sources of power in agriculture in selected developing regions.

Region	Share of power source (%)		
	Human	Animal	Mechanical
Africa	81	16	3
Far East	64	34	2
Near East	63	25	12
Latin America	56	25	19

Source: FAO, 1981; Ahmed and Kinsey, 1984.

Table 2. Annual commercial energy use and cereal yield in selected regions

Regions	Energy/ha (10^9J)	Energy/worker 10^9J)	Output/ha (kg)	Output/worker (kg)
Developed countries	24.8	107.8	3100	10508
Developing countries	2.2	2.2	1255	877
Africa	0.8	0.8	839	538
Far East	1.7	1.4	1328	781
Near East	3.8	4.4	1335	1386
Latin America	4.2	8.6	1440	1856
World	7.9	9.9	1821	1671

Source: Stout et al., 1979.

In order to meet the food, fibre and fuel needs of the growing population of sub-Saharan Africa, a higher level of agricultural and industrial production will be required which in turn will require harnessing many times more energy than the muscular capabilities of man. The principal objective of this paper is to establish the relationship between energy and the evolution of farming systems, to assess how the increased agricultural energy needed in the moist savannah region may be generated and particularly to assess the potential for development of mixed farming and its role in meeting future energy needs.

Land use and energy needs in the moist savannah

The moist savannah agroecological zone roughly corresponds to the subhumid zone. So the two terms will be used interchangeably in this paper. It has 1000-1500 mm of annual rainfall and a growing period of 180-280 days. It covers 22% of the land area and accommodates 27% of the human and 20% of the livestock population of sub-Saharan Africa (Table 3). Overall population density in the zone is somewhat similar to those in the semi-arid and humid zones. However, rural population density in the zone is about 27 people/ km^2 compared to about 14 in the other two zones. This is because most of the major cities are located either in the humid or in the semiarid zones, so a higher proportion of the population of these zones is urban. Livestock density in the zone is lower because in the past the high incidence of trypanosomiasis made sedentary cattle production difficult, although this constraint is rapidly disappearing and more cattle are now being reared.

Table 3. Distribution of land and human and livestock populations in sub-Saharan Africa (SSA) by agroecological zone.

Zone	% of SSA total			Density/km^2	
	Land	Population	Livestock	Population	Livestock
Arid	36	11	30	7	5.5
Semi-arid	18	25	27	31	10.4
Subhumid	22	27	20	28	6.3
Humid	19	21	6	26	2.3
Highlands	5	16	17	80	26.8
All zones	100	100	100	23	7.1
SSA total	21.6 Mha	498 million	153.8 mil TLUs		

Source. Adapted from Winrock, 1992. TLU, Tropical Livestock Unit.

On a regional basis, moist savannah covers 16% of the land area in both West and East Africa, 29% in central Africa and 38% in southern Africa. Full information on the current land use pattern in the zone is not available, but and FAO study has shown that among the regions of sub-Saharan Africa where subhumid environments exist, all the suitable and moderately suitable cropland in West Africa has been used up but suitable unused land still exists in East and southern Africa (Table 4). In West Africa, increased population pressure has resulted in shorter fallow periods and annual cropping in some places, with expansion of crop production into forest and grassland in others (FAO, 1986).

The FAO study also assessed the future requirements for cropland, grazing land and forest land to meet the food, fuel and feed needs of the projected human and livestock populations. The assessment was made on the assumption that all potentially cultivable land would be used for 15 major food crops or grassland under different input levels and circumstances. Two levels of input were distinguished. Low input cultivation is defined as a system with a traditional mixture of crops, no fertilizer, no chemical control of pests or weeds, not conservation measures, hand tools and human labour, little or no use of crop residues for feed, and no planted forage. Intermediate input level cultivation is defined as a system with half of the optimum mixture of traditional and improved cultivars, some (30-50 kg/ha) chemical fertilizers, some chemicals for pest control, some conservation measures, manual labour and animal traction, and some crop residues being used as animal feed.

Table 4. Current and projected land use in selected regions of sub-Saharan Africa

Land supply and use	Humid and subhumid West Africa	Subhumid and mountain East Africa	Subhumid and semiarid southern Africa
Total land area (10^6 ha)	206.6	251.0	559.2
Subhumid area (%)	62	38	60
Humid area (%)	35	14	3
Semiarid area (%)	3	48	37
Potentially cultivable (10^6 ha)			
Very suitable or suitable	49.1	49.1	141.9
Marginally suitable	49.7	28.1	87.9
Total	98.8	77.2	229.8
Present use (10^6 ha)			
Cropland or fallow	55.4	29.0	32.7
Forest	49.4	47.4	212.4
Shrub, bush fallow and grassland	101.8	82.7	160.4
Projected land need for year 2010 at low input (10^6 ha)			
Cropland	69.6	37.3	46.3
Forest	22.0	43.0	198.0
Grassland	98.6	248.2	445.0
Total	190.2	328.5	689.3

Source: FAO, 1986.

The results indicated that at the low input level, the land area available in East and southern Africa would be insufficient to meet the needs of the projected population in the year 2010 (Table 4). In West Africa, nearly all the available arable land would be used up and cropland would expand, causing substantial further reduction of forest and grassland. At the intermediate input level, the land requirement for the projected population in the year 2000 could be met in all three regions, but six or seven countries would still fail to meet the needs of their projected population from domestic production.

Thus, not only will the low input option fail to meet the land requirement, but in the absence of conservation practices and investment in land improvement, expansion of crop production into marginal areas will make soil and grassland degradation even more severe. Even at the intermediate input level, marginal land will have to be used. A significant proportion of the available land in all three regions is under physical and/ or chemical constraints (Table 5). A recent survey has shown that only 25% of arable land in the West African moist savannah has good fertility (Manyong et al., 1994). Therefore, the use of marginal land for crop production will require a substantial amount of energy in the form of labour and other inputs. Crop cultivars responsive to water and soil chemical stress conditions are not yet available, so energy efficiency in the marginal areas is expected to be low.

Table 5. Proportion of land with physical and chemical constraints in selected regions in sub-Saharan Africa.

Constraints	Humid and subhumid West Africa	Subhumid and mountain East Africa	Subhumid and semiarid southern Africa
Physical constraints (% land)			
Steep slope	7.4	21.8	8.8
Sandy texture	27.8	7.6	48.5
Other problems	30.5	20.8	9.1
Chemical constraints (% land)			
Low nutrient retention	54.2	24.2	69.3
Aluminium toxicity	32.5	18.1	30.2
Phosphorus fixation hazard	18.4	13.6	17.7
Low potassium supply	41.8	24.2	30.7

Source: FAO, 1986.

Fischer et al. (1992) expanded the FAO analysis of population supporting capacity for the 13 countries in West Africa by incorporating three additional food crops, meat and milk, six forage legumes for soil improvement and forage supply, and ten different systems of cattle and small ruminant production (pastoral and sedentary management using feeds from sown and natural pastures, crop residues and by-products), using commodity-specific national demand targets or the attainment of self-sufficiency, including meat and milk, in the year 2000 and 2025 by using intermediate input levels in crop production and by raising livestock supplemented with planted forage legumes. The optimum land allocation would comprise 136 million hectares of food crops, 65 million hectares of forage legumes, and about 270 million hectares of pastures. Forage legumes cold also be cultivated on half of the crop fallow land of over 50 million hectares. The model results showed that forage legumes had the potential to contribute up to 30% of the feed needs of a potential livestock population of about 140 million. Soil conservation measures would be important additional contributions.

The actual quantities of labour and inputs required for achieving the optimum production strategy were not quantified. Although pastoral and sedentary cattle and small ruminant production systems have been distinguished in the model, it is not clear from the optimum production plan how much land and how many animals will be reared under sedentary or mixed farming systems. However, the intermediate input level assumption implies the need for over five million tones of chemical fertilizers and substantial amount of forage legumes and animal traction. Whether these are achievable will depend on how the overall production system evolves in the subregion. The study under reference did not elaborate on this issue.

Energy, technical change and evolution of production systems

In the classical economic theories of growth and technical change, energy was not mentioned as a discrete factor of production. It is only since the oil price crisis of the mid-1970s that serious attention has been given to energy as a factor alongside labour and capital.

Technical change and transition to more intensive production methods have followed different paths in different parts of the globe. The theory of induced innovation is one of the most recent attempts to explain the causes of such variation. According to this theory, the nature of technical change in a given society has been induced by the endowment of resources, particularly land and labour, reflected in their relative prices and their relation to product prices (Hayami and Ruttan, 1985). In North America, Australia and western Europe, where land was inexpensive compared to labour, engine-powered mechanization replaced animal traction to increase output per worker. Later when both land and labour became expensive, more sophisticated and large-scale mechanization and biochemical inputs were used to increase both land and labour productivities.

In south and east Asia, where land was scarce relative to labour, a strategy of labour-intensive agriculture was adopted over a long period until biochemical technologies were available, in order to support an increased population on limited land. Large quantities of labour were used for land improvement, land leveling, drainage and water control measures, all of which contributed to increased land and labour productivities. Once biochemical technologies became available, land productivity increased significantly but labour intensity and labour productivity also increased because more labour per unit of land was being used for improved irrigation, land and crop management. Small-scale mechanization was adopted at a later stage when urbanization and industrialization started pushing wages up.

Although the theory of induced innovation explains variation in the nature of technical change in terms of the relative prices of land and labour, a closer look at history would show that prices of commercial energy have played a significant role in the choice of both mechanical and biological technologies (Jabbar, 1982). The period of major capital investment in agriculture and industry coincided with a sharp decline in the prices of energy relative to other productive factors (Carter and Youde, 1974; Lockeretz, 1977). Relative prices of coal, oil and electricity compared with wages have shown consistently declining trends over a long period (Figure 1). In other words, the quantities of these items that can be bought with an hour's wage have been steadily increasing.

The amount of commercial energy required annually to operate farm machinery is about twice the requirement for its manufacture; the energy required to operate irrigation equipment is about five times that required for its manufacture (Stout et al., 1979). Petroleum is the main ingredient for the manufacture and distribution of pesticides. Natural gas is the main ingredient for nitrogenous fertilizer, which is by far the most important chemical fertilizer in terms of both the amount of plant nutrient applied to world agriculture and the energy requirements for its production and distribution. The price of natural gas is so low that much of it is wasted. For example, the OPEC countries annually flared about 60% of their natural gas production in the mid-1970s. The quantities flared annually would have been sufficient to produce about five times the annual nitrogen fertilizer requirement of developing countries for that period (FAO, 1974). In the late 1960s, one dollar's worth of petroleum was equivalent in energy terms to 3800 hours of human labour (FAO, 1976) or "two human energy slaves working for about a year" (Leach, 1975). This explains why agriculture in the advanced countries became highly energy-intensive after the Second Word Was. The initial success of the green revolution in Asia also had a lot to do with the availability of cheap energy.

A green revolution of the type and scale of the Asian one has not taken place in sub-Saharan Africa, and so the current level of commercial energy use is very low. High energy prices since the mid-1970s must have contributed to some extent to this low use. However, the need for increased productivity to support a rapidly growing population implies that among other things the use of commercial energy, particularly chemical fertilizers, has to be increased. If prices of commercial energy and fertilizers remain high, the importance of organic fertilizer (animal manure, nitrogen-fixing trees and forage legumes) will increase which may induce crop-livestock integration. Such an option will also increase labour intensity in agriculture both for animal and crop production (see below).

The theory of induced innovation principally used 'choice of technique analysis' to explain the process of transition from mixed farming to specialization in the advanced countries, and intensification within the framework of long-established mixed farming in Asia (Gass and Biggs, 1993). Little has been said about the circumstances and forces that led to the evolution of mixed farming in Asia, Europe and North America at different times and in different forms. An adequate understanding of the historical and institutional dimensions of the process of technology development, application and diffusion would provide important pointers towards possible developments in sub-Saharan Africa, particularly in the moist savannah zone where the evolution of mixed farming is at a rudimentary stage and its possible path of intensification is as yet unclear. Of particular importance is the role of research and policy in fostering the intensification and development of mixed farming.

Potential for mixed farming in the moist savannah

Some authors have postulated that population pressure will induce agricultural intensification in sub-Saharan Africa (Boserup, 1965, 1981; Ruthenberg, 1980) while some others have emphasized the intensification of crop production as well as the development of mixed farming (Pingali et l., 1987; McIntire et al., 1992). Still others have mentioned market access, the presence of cash crops, the dominance of cereals in the cropping pattern and relative prices as additional factors fostering crop-livestock interaction and integration in specific situations (de Wilde, 1967; McIntire et al., 1992; Smith et al., 1993). The subhumid zone and the higher rainfall part of the semiarid zone in West Africa has been identified as the best potential area for crop-livestock farming

(FAO, 1986; Winrock, 1992). Although population pressure has resulted in reduced fallow, annual cropping and degradation of land in some areas of the subhumid zone (Jahnke, 1982). Although population pressure has resulted in reduced fallow, annual cropping and degradation of land in some areas of the subhumid zone (Jahnke, 1982), there are still large areas in the zone with a sparsely settled population. Rural population density is lower than in the semiarid zone and livestock density is also low, but both densities are increasing rapidly because crop production is less risky in the more humid areas and pastures are potentially more productive, due to the higher and less variable rainfall they receive. Pastoralists from the drier north are moving into the zone, settling and adopting crop-livestock farming. Some sedentary crop farmers are also adopting cattle cultivation. Some migration into the zone from the densely populated humid zone is also visible (Jabbar, 1993). Such migration and multiplication of the local population is expected to create pressure on the available land resources.

Some of the suggested indicators of crop-livestock integration and the related causes or driving forces are sporadically observed throughout the subhumid zone. However, the possible evolutionary path and the time frame for the development of mixed farming is still unclear from the existing literature. In Ruthenberg's (1980) classification of seven types of production systems and their implied evolution from less to more intensive cultivation, there is no integral role for livestock, implying that intensification in crop production may proceed without (significant) integration with livestock. On the other hand, Pingali et al. (1987) and McIntire et al. (1992) have characterized the role of livestock in intensification as an evolutionary process. They postulate that population growth increases the area of cropland, shortens fallow periods and decreases the area of pasture land, making external inputs necessary to maintain soil fertility. Where livestock are available, farmers paddock animals on cropland or otherwise collect and use manure and graze crop residues. As population pressure increases further, more intensive technology including heavier applications of manure and fertilizer are required to increase production. A shift from paddocking to collection, processing and incorporation of manure takes place. Herders increasingly use crop residues, get settled and engage in crop production. At the next stage, the grazing of natural pasture falls, crop residues are harvested and preserved for feeding, and manure is more intensively used. Finally, human labour is replaced by animal traction and mechanization which become economic due to the higher intensity of land use. As a further step, farmers may grow legumes and forages to improve soil fertility, crop yield and livestock productivity.

From the foregoing, several questions arise about the path of intensification and its implications for sources of energy in agriculture.

1. Will increased population pressure increase labour intensity in agriculture?
2. Can intensification in crop production proceed without significant interaction or integration with livestock?
3. Will traction become important? If so, where and when?
4. Can food rather than the input contributions of livestock become a driving force for integration?

5. What can policy and government intervention do to accelerate the process of intensification and integration?

Labour intensity

Currently about 70% of the population of sub-Saharan Africa is rural. This proportion is projected to decrease to 56% in 2010 and 44% in 2025. However, the actual rural population is projected to increase from 354 million in 1990 to 593 million in 2025, an increase of 68% (Winrock, 1992). As the subhumid zone is currently thinly populated, the rate of growth of the rural population is expected to be higher here due to migration and new settlement.

In pre-green revolution Asia, the principal response to population pressure on a given land mass was to increase labour intensity. The low opportunity cost of labour meant that its use could be extended until the marginal productivity of labour was very low or near zero. Sanders et al. (1995) reported a similar response in semiarid areas with a high population density and low opportunity cost of labour, where off-season labour is used in various land improvement and water control measures to maintain and increase the productivity of degraded land.

Most of the good land in the West African subhumid zone has been used up, so the impact of an increased rural population may be to increase labour intensity in at least three ways:

- decreasing the fallow period and increasing annual cropping, thereby increasing labour intensity per unit of land. Increased land use intensity will reduce soil fertility, so more effort will be required to improve land and crop management and maintain yields;
- extending crop production to less and less suitable areas of land, which will also require a high labour input per unit of land and per unit of output;
- among other factors, by forcing pastoralists to settle in increasing numbers and adopt crop-cattle farming, thus increasing labour intensity compared to pastoral herding.

Both land and labour use intensity may increase further if improved technologies become available and market conditions permit their extensive use. However the density of population in the subhumid zone is not expected to be as high as in Asia, sot the extent of labour intensity may not reach the level of pre-green revolution Asia.

Intensification without livestock

Before mixed farming evolved in Asia and western Europe, the more intensive crop-growers pushed the less intensive pastoralists on to more marginal pasture land. A time came when neither group could sustain productivity without the other. The need for manure and animal power by crop growers and the need for crop residues as animal feed by pastoratlists became driving forces for crop-livestock interaction and subsequent integration. In those days, improved crop cultivars, chemical fertilizers and engine power were not available as substitutes for land, manure and power as they are available now.

In the ecological stratification of West Africa, transhumant pastoralism made cattle production viable through interseasonal movements to take advantage of varying vegetation and water sources. Pastoralism is still the dominant cattle production system in the region. Crop-livestock interaction and integration are evolving, this process being slightly more advanced in the drier regions because of the greater possibility of settled or sedentarized crop-cattle production in a more disease-free environment. However, the unidirectional linear evolutionary process of crop- livestock interaction postulated by Pingali et al. (1987) and McIntire et al. (1992) may not always hold in West Africa, particularly in the subhumid zone.

There are indications from field studies that the initial interaction between nomadic herders and settled crop growers through paddocking (manuring) and crop residue grazing may be terminated if chemical fertilizer is cheap and easily available. The chances of this happening are greater if improved crop varieties and market access are also available, and due to intensive cropping on good land, herders are pushed away from cropping areas to avoid crop damage and potential conflicts. Intensification in crop production in the fertile land areas may then advance without cattle, and particularly without manure. Such crop farmers may adopt cattle in small numbers, generally as a form of investment, giving them to the herders for management or hiring herders to manage them before eventually taking up management themselves (Jabbar, 1993; Jabbar et al., 1995). At some stage and in some circumstances these crop farmers may used animals for traction (see below), and traction and the sale value of fattened animals (cash income) may be the primary motive for adoption of cattle. Manure may be considered as a secondary benefit for intensive crop/ vegetable production near the home-stead, the distant crop fields being treated with chemical fertilizers.

This scenario is unlikely to hold for areas less suitable for crop production, where most new settlements are likely to take place and where herders are expected to interface with crop growers. In the absence of improved biochemical technologies for degraded land, interaction through manure and crop residue exchanges remains a viable option. Traction may also be useful in reclaiming degraded grassland for crop production (not so for opening bush fallow or forest) but since sedentary crop-cattle production is likely to emerge slowly in the less suitable areas, the use of animals for traction may not occur in the beginning.

Animal traction

Mechanization in the advanced countries has gone through a process of transition from hand tools to animal-drawn equipment and engine power, with improvement within each of these categories, while in parts of Asia the process stagnated for a long time after the initial transition from hand tools to animal power (Table 6). The necessary technical condition for each mechanization process, whether transition to a new power source or improvement within a power source, was that the new process increased agricultural production by enabling tasks to be performed more easily or in a more timely way. The sufficient condition was that adoption of the new process should be profitable. In most cases, power-intensive operations such as tillage and threshing were mechanized before control-intensive operations such as weeding and planting (Binswanger, 1982).

In sub-Saharan Africa, there is a long history of using animal traction in the East African highlands, particularly in Ethiopia. Traction has been introduced in parts of semiarid West and southern Africa as part of a package involving cash crops (cotton, groundnut) and /or improved technology (hybrid maize, millet) both of which provided opportunities for higher profitability. Autonomous adoption of traction as part of a crop-livestock integrative process is rather limited. In the subhumid zone animal traction is only emerging.

Several studies have shown that the transition from hand tools to animal traction is profitable only at high levels of capacity utilization of the animals and / or at high levels of farming intensity, neither of which is commonly found in the semiarid zone except in limited areas of cash crop and improved tehnology-based farming (Pingali et al., 1987; Jaeger and Matlon, 1990; Ehui and Polson, 1993). The other reason for slow adoption in the semiarid zone is that because most soils in the semiarid areas are light and prone to erosion, intensive tillage is not required, and therefore timeliness and labour shortage may not be major constraints for most small-scale farmers (Ehui and Polson, 1993; Sanders et al., 1995).

Table 6. Evolution of main sources of power for energy-intensive farm operations.

Date	West Europe	North America	Japan	South Asia	Sub-Saharan Africa
300 BC	Human labour			Human labour, oxen	Human labour
400 AD	Oxen				
1400	Horses	Human labour	Human labour, horses		
1800		Horses			
1930	Machinery	Machinery			
1950			Machinery		

In the subhumid zone, rainfall is higher and spread over a longer period than in the semiarid zone, so timeliness may not be a problem for upland cultivation by small-scale family farms. But timeliness is important for commercially oriented medium-scale farming, for which there appears to be substantial scope. Also, timeliness may be important where only inland valleys (lowlands) or both uplands and lowlands are cultivated. Te heavy clay soils in most lowlands make land preparation by human labour time-consuming and difficult. Lowlands are potentially productive resources in the moist savannah which have not been properly exploited. Proper utilization of uplands and lowlands with improved technologies will require easy and timely land preparation which could provide a role for traction. The potential use of traction for reclaiming degraded grassland for crop production has been mentioned earlier. These are indications that there may be room for traction use well before high intensity cultivation or mature mixed farming conditions are reached. If the opportunities for animal traction use are not taken, power tillers may fill the vacuum. Because it operates on a smaller scale than tractors, the chances of power tillers being a success are greater, though this technology has not been adequately tested in sub-Saharan Africa.

The contribution of livestock to integration

Among the main contributions of livestock are food (beef and milk) and inputs to crop production (draught power and manure). As pastoralism and specialized crop farming evolve into mixed farming, the input of livestock becomes more important. This is evident from the differences between mixed farming societies in Asia and predominantly pastoralist societies in sub-Saharan Africa (Table 7). In fact, the agricultural inputs provided by livestock have often been the driving force for crop-livestock integration, rather than the meat and milk they produce, as few urban consumers have historically depended on rural dwellers for food, and cash generation through the sale of meat has not been important. In present day sub-Saharan Africa however, particularly in West Africa, the food contribution of livestock has a great potential for fostering the process of development by increasing the food supply for the domestic population, saving foreign exchange, generating farm income, and promoting the intensification of agriculture.

Table 7. Main contribution of large ruminants in selected regions

Region/country	Relative importance of contribution within each region			
	Draught	Manure	Milk	Beef
India	****	**	**	
Bangladesh, Indonesia	****	***	**	*
East Asia	**	*	***	
South/Central America	**	*	***	****
Sudan			****	***
Ethiopia	***		***	****
Dry West Africa	*	**	****	***
Wet West Africa			**	***

Currently about 50% of milk and dairy products and 5% of meat consumption in West and central Africa are imported, compared to 12 and 5% for the whole of sub-Saharan Africa. The failure of the subsistence-oriented domestic production sector to keep pace with growing demand due to population growth, urban growth and income growth has resulted in increased imports at the expense of valuable foreign exchange. Importation meant that valuable resources were diverted from investment in domestic production into current consumption.

It is generally recognized that the currently dominant pastoral and agropastoral production systems are efficient in the given context but that their productivity is low, as is their offtake rate for milk and meat. Large herds may not be fully milked if the product cannot be sold in the rural local market. Instead calves may be fed with it in order to reduce mortality and increase herd size. Cattle are sold to meet cash needs. The response of supply to demand is generally low or even negative, as cash needs may be met by fewer sales when prices rise. With such a system, the needs of the vast urban market for animal products cannot be served. Higher productivity and higher offtake are required which may come from an integrated crop-livestock (dairy) system. Unlike crops which generate cash at specific harvest times, dairy has the potential for generating regular cash income, so the marketed surplus of milk as well as beef will increase (typically 20-40% of the income of a dairy enterprise will come from the sale of male calves and culled cows). An enhanced regular cash income from dairy, with manure and traction as secondary benefits, may be a stronger driving force for the integration of crops and livestock than manure and traction alone.

The regular cash-generating potential of the dairy enterprise may enable a higher level of investment in both crop and livestock enterprises in the form of seeds, fertilizers, pesticides, drugs and feeds, thus enhancing production and income. Increased crop income may also be invested in animal production (Brumby, 1986). There is evidence to suggest that livestock provides a dominant part of the cash income and gross margin of crop-livestock farmers (ILCA, 1987; Gryseels, 1988; Debrah and Sissoko, 1990) and that the gross margins of crop-dairy farmers are higher than those of crop farmers (Gittinger et al., 1990; Okoruwa, 1994). Dairy-based mixed farming also provides more productive employment than crop farming.

The system described above, being dependent on access to regular markets, is most likely to develop in the periurban areas, that is, in the supply hinterlands of urban areas. Such a phenomenon can already be observed in the subhumid zone (Waters-Bayer, 1988; Agyemang and Dogoo, 1992; Jabbar, 1993; Jabbar et al., 1995). Pastoralists are trying to settle in areas that are accessible to markets for milk and dairy products. Crop farmers and retired civil servants who have invested in cattle are also located in the peri-urban areas.

Policy and intervention

Appropriate policies and interventions may help accelerate the autonomous process of farming systems evolution, but inappropriate policies and interventions may distort and stifle the process of development. An example may be given with respect to traction and mechanization.

In the 1960s, differences in technological achievement in crop production between more and less developed countries were sometimes attributed to differences in the amount of power applied, and theories of ‘farm power ladder’ and ‘minimum power levels’ were advocated for agricultural development (see for example, Giles, 1967a, 1967b; USGP, 1967; Weil, 1970). Such arbitrary comparisons provided the basis for the initiation of many tractor mechanization projects in sub-Saharan Africa (also in Asia) by national governments, with or without support from the aid agencies. In some cases, the tractorization programme was part of a policy to develop large scale commercial agriculture under parastatal or private sector management while ignoring the small scale family farm sector (Ahmed and Kinsey, 1984). Most of these projects were later found to be technically inefficient and socially unprofitable (but privately profitable in some cases due to heavy subsidies) and they eventually failed. The theoretical possibility of transition from hand tools to engine-powered mechanization in the family farm sector turned out to be unrealistic. Nigeria is a classic example of this experimentation.

Animal traction was first introduced with cash crops in the semiarid part of Nigeria in 1928 by the colonial government. Subsequently training schemes for animals and ploughmen were also introduced. As a result, the number of farms using animal traction increased to 1820 in 1940, 3052 in 1950, 15 452 in 1955, and about 34 000 in 1963 (Calvin Antonza and Lawrence Stifel, personal communication). The adoption of traction spread into some parts of the subhumid zone as well (Blench, 1988, quoted in McIntire et al., 1992). However, in the late 1960s, with the arrival of the oil boom, tractorization rather than animal traction was emphasized. Federal government expenditure on the tractorization programme incrased from N11 million during the first five year plan period (1970-74) to N54 million during the second plan (1975-79) and N240 million during the third plan (1980-85). Two tractor assembly plants and a national centre for agricultural mechanization were established in 1980 with a target of releasing 5000 tractors per year. During 1975-83, 22 000 mostly imported tractors were sold at subsidized prices to parastatal agencies such as the River Basin Development Authorities, and to large-scale private companies. In the meantime, the draught animal training centres closed down and traction adoption slowed down heavily, although a low level of farmer-to-farmer diffusion continued.

The oil boom was accompanied by a policy of indirect taxation of agriculture through an overvalued exchange rate which also encouraged imports and discouraged domestic agriculture. By the mid-1980s, the oil boom had collapsed and policy changes slowly started to take place, but over two decades of improper intervention and distortion had stifled the natural process of development and evolution of production systems.

Similar examples abound throughout sub-Saharan Africa. As a result of the introduction of structural adjustment programmes in some countries in recent years, or some components of it such as currency devaluation, the environment for agricultural development and the possibilities for rapid crop-livestock interaction are reappearing. For example, in the face of rising prices of fertilizers after currency devaluation in the Francophone countries, farmers have responded by applying more manure and by making compost in a systematic manner, and a market for manure is also developing (Sanders et al., 1995). This is certainly a short-term survival strategy, because without chemical fertilizers higher productivity cannot be expected. However, this temporary backward movement may put the natural process of development back on track. Government policies need to be supportive or complementary to this process.

Conclusions

The moist savannah zone is an area of high potential for agricultural development. Crops, animals and forests are important components of the ecosystem. Any strategy for agricultural development in the zone should take into account the current and possible future changes in the relationships among the three components.

In the past, nomadic pastoralism dominated in the zone because of the risk of trypanosomiasis but with the decrease in this risk, sedentary cattle production and crop-livestock mixed farming is evolving. Human labour is the main source of power for crop production and the level of commercial energy use is very low. In Asia and Europe, mixed farming developed at a time when improved technologies (hybrid seeds, chemical fertilizers and machine power) were not available and external influences through government policy and markets were small, if they existed at all. In sub-Saharan Africa, the availability of some improved technologies and associated government policies and interventions are likely to influence the path, form and time frame of the evolution of mixed farming. Researchers and policy makers need to learn from experiences elsewhere and identify appropriate niches for technology development and intervention to facilitate the autonomous process of evolution.

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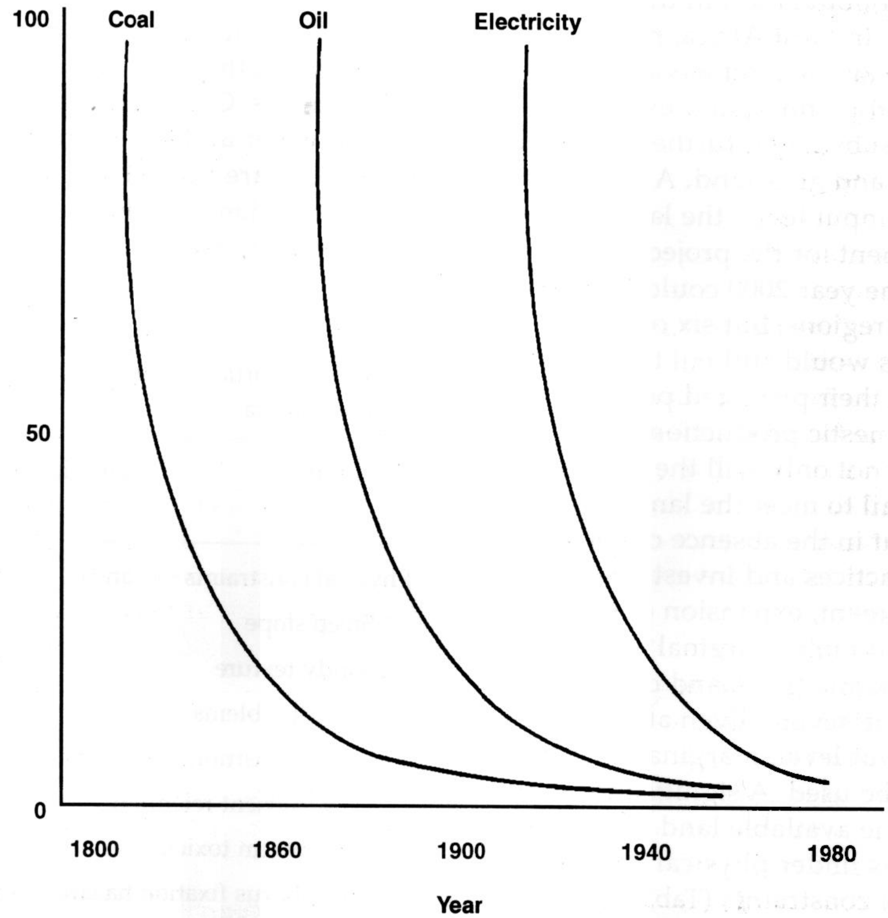

Figure 1 Indices of the prices of coal, oil and electricity relative to wages, 1880–1980 (adapted from Simon, 1981).