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Evolving Crop-Livestock Farming Systems in the Humid Zone of West Africa: Potential and Research Needs[*]

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Cattle rearing in humid west Africa was nearly impossible in the past owing to the prevalence of trypanosomiasis, a disease caused by the tsetse fly. However, in recent times, with population pressure, jungle clearance, crop cultivation and tsetse control measures, the challenge has been reduced. Consequently there has been an influx of transhumant cattle rearers who used to visit the zone for dry season grazing and return to the safer sub-humid and semiarid zones in the wet season. An increasing number of them have begun to settle in the humid zone and are adopting crop-livestock mixed farming. There is also a tendency among some local crop farmers to adopt livestock in the farming systems. Consequently new farming systems are evolving in the zone. The potential of this evolving farming system and its implications for systems oriented research by national and international centres are examined.

Introduction

Livestock is an integral part of the economies of most sub-Saharan African countries. For the region as a whole, livestock constituted 8% of the total GDP and 25% of the agricultural GDP in 1988. If the values of intermediate products such as traction and manure are included, livestock's share of the agricultural GDP might amount to 35% (ILCA, 1987; Winrock, 1992).

The incidence, functions and relative importance of different types of livestock vary across countries and agroecological zones. The incidence of tsetse flies and trypanosomiasis has been the single most significant determinant of the distribution of

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livestock across ecological zones. The main focus of this paper is the humid zone, consisting of rain forests and derived savannas located mainly in central and west Africa. The humid zone has been generally considered as unsuitable for livestock production owing to high tsetse infestation levels (Stenning, 1959). However, recent events, both natural and manmade, have made situations in the zone more congenial for livestock production. An increasing number of transhumant cattle rearers from the northern sub-humid and semi-arid zones are settling in the humid zone and carrying out crop-livestock mixed farming. Local crop farmers are gradually including livestock in their farming system. Consequently, production, consumption, marketing and the live pattern of these farmers are contributing to the evolution of a new farming system in the zone.

The objectives of this paper are to assess the present status of livestock and livestock production systems in the zone, and the potential of the evolving crop-livestock farming system, in the light of local information and historical evidence from elsewhere in the world. A further objective is to enumerate research needs and priorities to facilitate the development of the evolving system.

Prevalence of livestock in the humid zone

Although the humid zone has generally been considered unsuitable for permanent livestock rearing, transhumant pastoralists from the semi-arid and sub-humid zones would visit the derived savannas during the dry season, when the tsetse challenge was relatively low, in search of feed and water. In fact, transhumant pastoralism made cattle production viable in the ecological stratification of west Africa. Where the tsetse challenge allowed and/ or where an acceptable degree of tolerance developed in the livestock, there has been a tendency among pastoralists to remain in the more humid areas. This process has, over a long period, led to a degree of adaptation, facilitating permanent exposure of livestock to light tsetse challenge (Ford, 1971; Fricke, 1979). There are also breeds of cattle, goats and sheep that have developed trypanotolerance through long periods of exposure to a high tsetse challenge. Such animals are kept by pastoralist in some regions with a high tsetse challenge and by crop farmers in the humid zone.

More recently, changing climatic patterns, land and bush clearance for agriculture due to population pressure, and specialized tsetse control programmes have contributed towards expanding the tsetse free areas. Up to 1978, over 300,000 km^2 was freed from tsetse flies in tropical Africa, of which over 200,000 km^2 was in Nigeria alone (Ford, 1971; Jahnke, 1982). Some parts of the derived savannas were directly covered by organized control programmes (Bourn, 1983; Putt et al., 1980), while other parts were indirectly affected by the spillover effects of the programmes in the adjoining sub-humid areas. As the boundary of the tsetse-free area moved southward into the savannas, the tsetse challenge in the adjoining humid areas became lighter. The degree of tsetse challenge continued to decline further owing to increased incidence and severity of bush fires and increased human settlement in cleared areas. Such areas attracted pastoralists for seasonal grazing, and subsequently for more permanent settlement (Bourn, 1983).

The overall consequences are that the humid zone now has several times more cattle and small ruminants than, say, two decades ago, and an increasing number of these cattle are trypanosusceptible Zebus. At present there are 8.8 million cattle and 19.8 million small ruminants in the humid zone (Table 1). In the late 1970s an estimated 7.6 million trypanotolerant cattle and 26.7 million trypanotolerant sheep and goats were raised in the humid and sub-humid zones (Jahnke, 1982). So it can be reasonably assumed that a significant proportion of the cattle in the humid zone are trypanosusceptible Zebus.

Table 1. Some characteristics of agroclimatic zones in sub-Saharan Africa, 1989.

Main region	Humid Central + West	Sub-humid West + Central	Semi-arid West	Highlands East
Arable land and permanent crops (million ha)	19.8	16.1	38.5	18.8
Permanent pasture (million ha)	38.1	43.5	318.1	50.1
Tsetse-free area (%)	10.3	31.8	49.7	80.3
Agriculture, % of total GDP	29	33	31	38
Livestock, % of agricultural GDP	6	7	37	27
Value of net milk trade, million $	56	78	145	33
Value of net meat trade, million $	138	40	-71	-3
Ruminant livestock (million)				
Cattle	8.8	32.8	45.5	29.0
Goats	11.6	20.3	33.2	11.9
Sheep	8.2	14.2	23.1	21.4
Main animal feed	Natural vegetation	Grazing natural vegetation and residues	Grazing natural vegetation & residues	Harvested crop residues
Main source of soil fertility	Fallowing, fertilizer	Fallowing, fertilizer, manure	Manure, Fertilizer	Manure, fertilizer
Animal traction	Absent	Emerging	Present	Present

Source: McIntire et al., 1992

Such generalization can be substantiated on the basis of more specific information from particular areas. For example, the number of cattle in the humid zone of southwest Nigeria increased from 43,000 in 1950 to over 200,000 in the early 1980s (Table 2). Most of the additional cattle are Zebus. On the basis of aerial surveys, RIM (1988) estimated that over 100,000 cattle owned by transhumant Fulanis were seasonal migrants from the north into the derived savanna but a population of nearly 200,000 cattle were stationary in the zone. Cattle densities were higher near cropping areas, open woodlands and good sources of water. Between 4,000 and 6,000 semi-permanent rugas (groups of households) were located along the cattle-grazing routes. These are indications of a tendency towards sedentarization among some cattle owners.

Table 2 Estimated cattle population in southern Nigeria.

Reference year	Area	Cattle numbers by type		
		Zebu	Trypanotolerant	Total
1950	Western Region	-	-	43,300
1954	Western Region	-	-	70,000
1959	Western Region	-	-	65,000
	(Oyo Province)	-	-	(32,000)
1982	Derived savannah Southwest			
	West season	-	-	302,000
	Dry season	-	-	187,000
1984	Total South	240,000	67,000	307,000
	Southwest	161,000	38,000	199,000
	(Oyo State)	(115,000)	(25,000)	(140,000)
	Southeast	79,000	29,000	108,000
1989	North Anambra (SE)	53,000	14,000	67,000

Source: Shaw and Colville (1950), IMF (1954), RIM (1988), Akinwumi and Ikpi (1985).

Cattle movement into the derived savanna of southeast Nigeria is a relatively recent phenomenon compared with that in the southwest, yet estimates by Akinwumi and Ikpi (1985) and di Domenico (1989) suggest a rapidly increasing process of sedentarization. Such increases in cattle numbers can be explained by a significantly low incidence of trypanosomiasis and its vector tsetse flies. Field studies among sedentary cattle in five states of southwest Nigeria found an overall infection rate of 14.4% with variation from 2.7 to 28.2% between states (Ikede et al., 1987; Reynolds and Opasina, 1987). In a survey of 52 cattle farmers in southwest Nigeria in 1990, the incidence of trypanosomiasis was mentioned by only 6% of the respondents (Mohammed, 1990). In the southeast, Nwanta (1988) recorded similar incidence and infection rates among sedentary cattle. These studies concluded that trypanosomiasis was not a major problem for Zebu cattle production in the derived savanna zone, although protection against the disease was necessary. Moreover, with good husbandry and feeding, Zebu cattle acquired, through natural selection, some degree of trypanoloterance.

Recent reconnaissance surveys by ILCA in the Accra Plains and central Ghana, the maritime and plateau zones in Togo, the coastal belt in the Republic of Benin, and the northwest province of Cameroun have indicated a continuing process of sedentarization, whereby nomadic pastoralists become sedentary pastoralists, then agropastoralists by adopting crop cultivation. Evidence of increasing investment in cattle by crop farmers, traders and retired civil servants was also observed.

Cattle production systems

Although general descriptions of different cattle production systems are available, information on the proportion of cattle reared under different systems is scarce. It is reported that over 80% of cattle in west Africa are reared under some form of crop-livestock system (World Bank, 1987). Such systems include sole livestock farming practiced in proximity to and in functional association with sole crop farming through exchanges of inputs and products, and crop-livestock mixed farming under the same management with various degrees of mixes (Jahnke, 1982). The incidence of more integrated crop-livestock farming is higher in the drier zone than in the humid zone. For example, about 40% of the cattle and small ruminants in the semi-arid (Sahelian) zone are owned by crop farmers and most of the Zebu cattle are owned by sedentary and semi-sedentary pastoralists.

Crop-cattle farming in this zone is a recently evolving phenomenon. Limited amounts of available information point to some characteristics of this evolving system. Firstly, crop-cattle farming is emerging from two directions. The dominant line is that of the nomadic Fulani pastoralist becoming a sedentary pastoralist and eventually an agropastoralist. A minor but perceptible line is that of the crop farmer becoming a mixed farmer by purchasing cattle and first giving them to Fulani herdsmen for management, or hiring Fulani herdsmen for management, then taking up management themselves after gaining experience. For example, in a sample of 66 cattle farmers in southwest Nigeria, 53 (80%) were Fulani and 13 (20%) were indigenous Yoruba. Eight out of the 13 Yoruba cattle owners managed cattle by themselves and five others hired Fulani herdsmen for management, or gave cattle to Fulani farmers on a caretaking (share cropping) basis (Jabbar *et al.*, 1992). In another sample of 52 Fulani agropastoralists, 30 (28%) managed their own cattle, and 22 (42%) managed their own as well as those given to them for caretaking by 64 Yoruba people. There were about three owners per caretaker. Nineteen percent of the total cattle managed by the sample farms were owned by the absentee Yorubas. Among 64 Yoruba cattle owners, 30% were crop farmers, 15% were livestock traders/ butchers and 55% had trading or government service as their occupation in addition to farming (Mohammed, 1990).

Secondly, cattle farmers settle in the supply hinterland of small and large cities, i.e. in the peri-urban areas, so that they can gain access to a regular market for their products, mainly dairy products. Investment by crop farmers in cattle for fattening is also a sign of commercialization. Dairy consumption studies in southern Nigeria showed a good market potential. Average daily *per caput* consumption among the indigenous population was 45g liquid milk equivalent (LME), which was comparable to west African averages, and consumption was generally higher in the urban areas. Where consumers had access to local products from peri-urban producers, up to 80% of the households consumed such products, and 45% of consumption came from local sources (Jabbar and di Domenico, 1992).

Thirdly, herd size has a tendency to decline with increasing period of settlement. On the basis of aerial surveys, RIM (1988) found an average grazing unit (a proxy for herd size)

of 50 in the region. Mohammed (1990) found an average herd size of 27 among sample agropastoralists. Jabbar et al. (1992) found averge herd sizes of 65 and 38 for Fulani and Yoruba owners, respectively. The Fulani sample included both agropastoralists and sedentary pastoralists. Generally, herd sizes were larger among recent settlers (sedentary pastoralists), but with longer duration of settlement and with cattle rearers' involvement in crop production, the herds became less mobile between seasons and herd sizes decreased. Increased competition for labour between cropping and herding might be contributing to reduced mobility and herd size. Akinwumi and Ikpi (1985) observed smaller herd sizes in the southwest than in the southeast, which could be explained by the fact that farmers in the southeast were more recent settlers than those in the southwest.

Fourthly, with longer duration of settlement, the proportion of farms with mixed Zebu/trypanotolerant cattle herds increased (de Jode, 1989; Jabbar *et al.*, 1992; Mohammed, 1990). This was partly a risk management strategy, given the fact that some degree of trypanosomiasis challenge still existed and veterinary services in the area were not easily accessible. However, trypanotolerant breeds were chosen for other reasons as well. In a sample of 50 livestock keeping households in southwest Nigeria, 25 had some N'Ddama cattle. When asked about the advantages of N'Dama, 70% of respondents cited greater disease resistance, 30% cited versatile grazing habit and production of better quality meat and milk, 19% cited higher fertility rate and 16% cited the ability to maintain a more constant weight through the dry season (de Jode, 1989). These perceived advantages corroborated actual findings. De Jode (1989) found an overall calf mortality of 29.5% of which 36.5% were White Fulani, 24.2% Fulani x N'Dama Crosses and 2.25% pure N'Dama. Both de Jode (1989) and Mohammed (1990) found higher reproductive rates in trypanotolerant breeds (Muturu, Keteku, N'Dama and N'Dama x Fulani Crosses). Overall, these rates were favourably comparable to those found among Zebu cattle in the sub-humid zone of Nigeria (Egbunike, 1984; Nuru and Dennis, 1976; Oyedipe et al., 1982; Pullin, 1979) and in the humid tropics in general (Mukasa-Mugerwa, 1989).

Fifthly, progression from no cropping to singe or multiple but sole cropping to mixed cropping with increased duration of settlement was observed (Jabbar et al., 1992). Mohammed (1990) found an average farm size of 3.33 ha, increasing with longer period of settlement. Land use intensity was 67%, i.e. for 2 ha under crop, 1 ha was under fallow. This land use intensity is more than twice that of local Yoruba crop farmers; the higher intensity is possible owing to intensive manuring by the Fulani farmers. Although these animals generally graze away from the homestead during the day, night kraaling helps to collect adequate manure for crop fields which are generally located around the homestead.

Mohammad (1990) found that 24% of the crop area was devoted to cassava, yam, maize, sorghum and other sole crops and 76% to various mixes of these crops (Table 3). Taking sole and mixed crops together, 93% of the crop area grew different cereals, while 77% grew roots and tubers. The share of cereals in a local Yoruba farmer's land allocation would be much less.

Table 3 Farm size and cropping pattern of agropastoralists, southwest Nigeria.

Average farm size (ha)	3.33
% under fallow	33
% crop area devoted to	
Sole crops	24.05
Cassava	2.70
Yam	4.32
Maize	7.30
Sorghum	2.43
Others	7.30
Mixed crops	
Maize – Cassava	75.95
Maize – Sorghum	48.11
Yam – Sorghum	3.24
Other mixes	22.16
	2.44
All roots and tubers	
	77.29
All cereals and grains	92.97

Source: Mohammed, 1990

Sixthly, in spite of good grazing opportunities, increased use of crop residues as animal feed was observed. Jabbar el al., (1992) found that 23% of the sample farmers used crop residues as feed, and most of them grazed residues in local crop farmers' fields. Mohammed (1990) found that 96% of the farmers grazed maize residues in local crop farmers' fields, 17% used sorghum residues mostly from their own source, 27% used cassava leaves mainly from their own sources and 100% used tree browse from the range. In another survey, de Jode (1989) found that residues of wet season maize were not always used owing to the availability of better quality grass and the possibility of damage to second season crops, but second season residues were more widely used because available grass was then of lower quality and quantity. Mohammed (1990) mentions mixed cropping as a deterrent to using residues as feed. However, with more land pressure, farmers may move towards more sole cropping in order to use residues as feed, because most residue users said that, even under present conditions, crop residues were important to them as a source of feed.

Finally, as the period of settlement increased, changes in diet and sources of income were observed. Among the agro-pastoralists in Mohammed's (1990) sample, 50% produced adequate crops for home consumption, about 20% produced some surplus and about 30% had a deficit. On the other hand, about 20% of their daily milk output was consumed and 80% was processed into wara (soft cheese) for sale to local farmers, or to traders who in turn sold it in the nearby towns. Propensity to sell tended to increase with longer period of settlement. Farmers reported increased cash needs as the main reason for higher

propensity to sell milk (Gherzi, 1991; Mohammed, 1990). Total offtake rate (% of total cattle sold) was 8% while effective offtake rate (% of weaned calf crop sold) was 25%. These rates were higher than those generally found in the drier zones.

Potential for development

In a major assessment of animal agriculture in sub-Saharan Africa, rapid intensification of agriculture and development of crop-livestock farming has been predicted on the basis of projected high population growth, high rate of urbanization and consequent changes in food production, marketing and consumption patterns. The sub-humid zone and the higher rainfall area of the semi-arid zone of west Africa have been identified as high potential areas for crop-livestock farming. Arid and humid zones have been identified as second priority areas (Winrock, 1992).

Several authors have postulated population pressure as the prime mover for agricultural intensification and development of crop-livestock farming (Boserup, 1965; McIntire *et al.,* 1992; Pingali *et al.,* 1987; Ruthenberg, 1980). Market access, presence of cash crops, dominance of cereals in the cropping pattern, and relative prices have been mentioned as additional factors fostering crop-livestock interaction in specific situations (de Wilde *et al.,* 1967; McIntire *et al.,* 1992). If these criteria are used to judge the potential for crop-livestock development in the humid zone, there are good reasons to be optimistic. Firstly, the humid zone is generally sparsely settled, but in parts of west Africa and around major cities the densities are high and comparable to those in the drier zones. Most major cities are located in this zone and they are expected to grow rapidly with migration from within and outside the zone. Population pressure in other zones may also push migration into rural areas in the humid zone. Secondly, two major dimensions of market access are population size and communications to link producers and consumers. The humid zone is better endowed than the other zones in this respect because of the presence of big cities well connected with rural areas. Several times more animal (and some crop) products are consumed in this zone than are producd (Table 1), and the size of the market will expand rapidly, as indicated earlier. Thirdly, although cereals may not immediately become dominant in the cropping systems, their importance in the zone is steadily increasing. With commercialization of agriculture, and with increased income of consumers, the importance of cereals will increase further, and there will be a move towards producing cereals as sole crops. A related phenomenon is the possible decline of plantation crops such as cocoa.

These robust arguments may sound like mere assertions in view of the rather rudimentary level of crop-livestock farming in the zone at present. However, if the elements of this rudimentary development are superimposed on a wider view of the history of agricultural development around the world, the assertions may appear realistic and plausible.

Two thousand years ago, few or no crops were grown in Western Europe; there were no domesticated grazing animals and hardly any crop production in the entire American hemisphere, in Australia and New Zealand, or in the tropical forests of Africa and Asia. Crop growing was concentrated in tropical and semitropical river valleys such as Egypt's

Nile, Mesopotamia's Tigris-Euphrates, India's Indus-Ganges, South-East Aisa's Irrawady-Mekong and China's Yangtze-Yellow river. Part of Japan, Java and Mezzo-America are also ancient crop growing locations. Outside this environmental belt, crop growing in the Mediterranean littoral (Greece and southern Italy) was a remarkable exception. While Asian crop growers were a few centuries old in using animal energy for crop production in the Graeco-Roman crop growing empire was expanding on the basis of slave-based production methods. It appears that the relationship of man to crops and livestock has changed very little in Asia to this day, while the collapse of the Graeco-Roman empire in the fifth century after extending into pastoral northwestern Europe paved the way for a course leading to the world today, where crop and livestock production in the developed countries are highly specialized and mechanized (Crotty, 1980).

The history of human civilization is marked with Man's changing relationship with plants and animals. Methods of crop and livestock exploitation have evolved through the ages, in varied and complex ways, to suit specific environments and to meet varying needs of societies. Institutions and customs governing the exploitation of these resources have also evolved to serve specific needs of society. For example, the eating of beef was banned, making it a religious taboo, by the Hindus in India when saving draft animals became crucial for expanding crop production to less fertile areas. Beef eating is still taboo in India and an impediment to development. Centuries later, the Christian church in Europe prohibited meat eating during Lent for economic considerations, i.e. to dissuade peasants from slaughtering and eating their oxen during springtime when they were most needed for draft power. At an opportune moment this partial ban was lifted in Europe, but in Ethiopia meat is still prohibited during Lent fasting, and this remains an impediment to development.

In southern Nigeria, human beings used to be sacrificed to satisfy the gods. More recently, cattle, particularly Muturu cattle, have been accepted as a substitute for human sacrifice. As a result cattle, previously considered more like a god, has now become a commercial good (Akinwumi and Ikpi, 1985). Although Muturu cattle are still frequently described as a ceremonial animal with a limited prospect for commercial exploitation, it should be recognized that its acceptance as a substitute for human sacrifice was a giant step towards commercial exploitation of cattle. The remaining taboos are bound to disappear in time.

As well as adapting animals and plants to his needs, Man also adapted himself to the plants he grew and the animals he domesticated. Pastoralist Man acquired the characteristic of adult lactose tolerance. Interbreeding with pastoralist societies diffused this characteristic among other populations. Notable exceptions are east Asians and people in the high tsetse infested areas in Africa, who, having remained beyond the reach of the pastoralists in the past, retained the normal characteristic of adult lactose intolerance. But with tsetse control and decline in the tsetse challenge, cattle movement into the humid zone has become possible. For example, the cattle population in the Central African Republic increased from 700,000 to 2 million in 15 years following tsetse control (World Bank, 1987). A consequence of this is that people hitherto unaccustomed

to dairy products have developed tastes for some dairy products, though not necessarily for fresh liquid milk. Throughout the coastal belt of west Africa nomadic and sedentary pastoralists produce soft cheese and yoghurt (named variously in different places, such as wara in southwest Nigeria and northern Benin) for indigenous populations. Through experience they found that these people did not like fresh milk because they possibly could not digest it, but cheese and yoghurt were readily acceptable. Areas classified in the 1940s as non cattle-raising are now inhabited by cattle; areas classified as non-milk-producing are now producing and consuming milk (Stenning, 1959). Trypanotolerant Muturu are not milked by local farmers in southern Nigeria, but Fulani owners or rearers of such cattle milk them (Ferguson, 1967; Grandin, 1980; Mohammed, 1990). More recently, with aid, relief and commercial import of dairy products, hitherto non-consuming populations are consuming as much dairy produce as one would find in conventional milk-producing areas (Jabbar and di Domenico, 1992).

After the demise of the Graeco-Roman Empire, oxen instead of slaves were used for crop production in Europe. In the middle ages, oxen were replaced by horses, a more powerful animal. Slavery was reintroduced in North America by European colonizers more than a 1,000 years after its demise in Europe. Defeated European pastoralists were turned into slaves by Roman crop growers. Defeated African pastoralists and crop growers were turned into slaves by colonial crop growers in North America, where slaves were later replaced by horses. Asian crop growers still depend for power on cattle, buffalo and mules which they started using probably 3,000 years ago. In Europe, north America and Australia, crops and livestock competed for land, so transition from horse to engine power released land for extra crop/livestock production. In Asia, men competed with each other for land, and the competition has increased over time. In much of Africa, a predominantly pastoral system is evolving into a mixed farming system. The late arrival of cattle in the humid zone does not necessarily mean that crop-livestock farming development in the zone should follow exactly the same historical pattern as happened elsewhere. Indeed, there is no natural sequence or uniform evolutionary process of technical and system change that one can follow as a blueprint or rule. However, historically, crop farmers were more intensive, and stationary land users pushed pastoralists into marginal lands. But a time came when neither could push the other further without affecting each other's survival, so conflict ensued, and this was resolved through adopting mixed farming. Crop farmers needed manure and traction to cultivate less fertile and difficult soil, pastoralists needed better feed for animals and themselves. Mixed farming increased the productivity of both crops and livestock, and enhanced the capacity of the land to support Man. The humid zone is currently going through this phase of social/system change.

Frequent conflicts between crop farmers and pastoralists in the present day humid zone are replications of events from long past elsewhere. This conflict, and other external forces such as frequent droughts in the drier areas, and increasing restriction on movement across political boundaries, are likely to hasten the process of pastoral settlement, and development of crop-livestock farming. The settlement history of agro-pastoralists in southwest Nigeria indicates a continuous process of settlement, but there are clear peaks immediately after the 1972-73 and 1984-86 droughts in the Sahel. Herd

buildup and low offtake are major hindrances to livestock productivity in Africa. The evidence that herd size declines and offtake increases with settlement and mixed farming are indications that mixed farming is the proper avenue for a natural solution to these twin problems.

Figure 1 shows a possible technology – growth path for the humid zone. Currently (Stage I), crop farmers and transhumant pastoralists dominate. Most of them use traditional technology. Therefore, both crop and livestock productivities are low. Opportunities for increased productivity are also low. However, crop-livestock mixed farming is evolving and will become dominant in Stage II. Productivity will increase in this stage both because of crop-livestock interactions and because of the application of more productive technologies (varieties of crops and breeds of animals, better quality inputs) and better management practices. In Stage III, more specialized crop and livestock production will ensue with the application of highly productive commercial inputs resulting in higher productivity of resources.

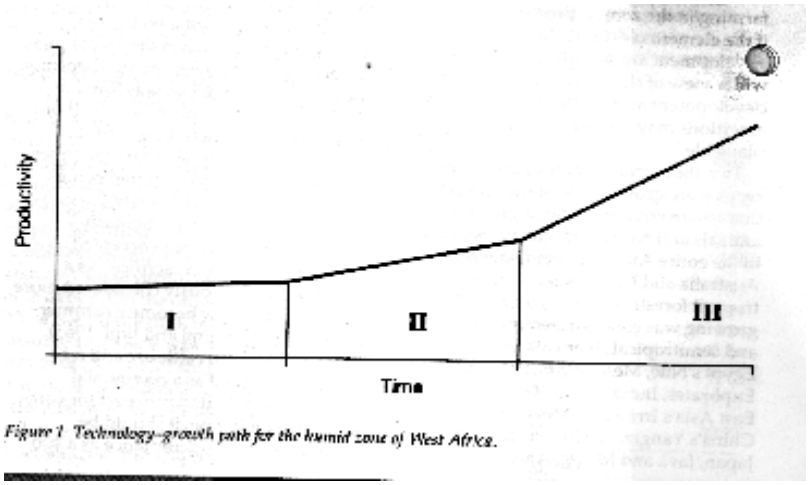

Figure 1 Technology–growth path for the humid zone of West Africa.

In Stage I, subsistence food production is a primary goal, for both crop and livestock producers. Cash income generation and interacting input supply are less important. In Stage II, family food production still remains a major goal but income generation and integration of the whole farm system through input interaction for raising overall productivity are also important goals. Production and consumption choices are more subject to the market, and to prices. In Stage III, income generation is the dominant goal, so production activities are primarily subject to markets and prices.

This technology-growth path may resemble the history of agricultural development elsewhere, but the time frame and the sources of growth are bound to be different. How quickly the evolving crop-livestock mixed farming may reach maturity will depend on a host of social, economic, political and biophysical factors, but the process can certainly be hastened through appropriate research and technology generation.

Research needs and priorities

Alongside tsetse control programmes, research initiatives were taken in several west African countries to evaluate the feasibility of cattle production in the humid zone,

particularly in the derived savannas. Notable among these are Fashola Stock Farm, Mokwa Station and the University of Ibadan in southwest Nigeria, Research and Animal Husbandry Centre, Avetonou in Togo, Bouake in Cote d'Ivoire, Bamenda in northwest Cameroun, and several other university and research farms in the region. There were two main characteristics of these initiatives: (1) At some places, the adaptability of pure breds from temperate climates and of their crosses with locals were assessed for dairy production. Local breeds were sometimes used as controls. At other places, trypanotolerant breeds were used as the basic material, mainly for beef production, with traction as a secondary objective. (2) Intensive pasture and purchased concentrates were used as principal feeding strategies for both dairy and beef production.

The main experiences that have emerged from these research initiatives are: (1) the high mortality, intensive management requirement and costs of pure temperate breeds and their crosses render them largely unsuitable for dairy production in the humid zone environment, in spite of their overall higher productivity compared to local breeds, (2) beef production on intensive pasture is marginally profitable and risky because of the excessive cost of pasture development. Provision of uniform feed throughout the year is a major problem causing dry season weight loss and affecting profitability (Doppler, 1980; Ruthenberg, 1974).

The breeds, feed and management strategies used in these research initiatives were intended for large scale specialized commercial producers. Small-scale crop-livestock farmers were not the target for such research. For example, grass-legume mixtures were studied for maintaining soil fertility, but the role of legumes in crop/pasture rotation has not been addressed. Without crops, crop residues were also absent from these systems (Ahlgren and Adegbola, 1959; FAO, 1966).

Since the crop-livestock farming system is evolving and will presumably become the dominant system in the derived savanna and sub-humid zones, research and development strategies should be aimed at "supporting, accelerating and helping to direct the natural forces of intensification of agriculture and the evolution and maturation of mixed crop-livestock farming systems that will make agriculture more productive and sustainable, while at the same time improving the social and economic conditions of people" (Winrock, 1992). It is envisaged that such a strategy should adopt a resource management approach, using land as the most critical resource. The main objective of research will be to modify existing resource management practices and/or to design new ones. Major research issues are, among others:

Determination of optimal livestock densities for crop livestock system sustainability and resource conservation under varying crop/pasture rotation systems.

In the humid zone, soils are low in organic matter content, fragile and easily degraded when the vegetative cover is lost. These problems have been aggravated by agricultural intensification due to exponential growth of the human population and the need for more agricultural land. Tsetse control or eradication programmes have further exacerbated these problems in two ways. Tsetse control through insecticide application has destroyed

many non-target insects and animals, thus creating ecological imbabalance. Areas freed from tsetse attracted increased human settlement and livestock, and this led to land use intensification, bush burning and damage to vegetation (de Vos, 1975; Ormerod, 1976). Whether tsetse control programmes should have been pursued in more fragile areas is a debatable question, but without increased human settlement and cultivation tsetse cleared areas would be taken over by the flies again, and the progress of eradication would be lost. So intensive land use may be considered a necessary adjunct for the consolidation of tsetse eradication (Eicher and Baker, 1982; Putt *et al.,* 1980). However, the optimum level of intensification under varying conditions has yet to be determined.

Determination of the environmental impact of animal as against the impact of other sources such as climatic change, cultivation intensity and bush burning.

There is no evidence that rain forest is cleared to expand livestock production *per se*, but forest is regularly cleared to expand crop production. Then cattle may move in, particularly trypanotolerant breeds in the beginning. Unless constrained by external forces, this process is likely to expand. Therefore, it is essential to develop controlled, integrated land use systems for sustainable crop and livestock development. In the absence of such systems, tsetse control and crop-cattle production in the more fragile areas should be positively discouraged. At the same time, the impact of animals on the environment needs to be separated from impacts from other sources, so that any adverse impact of animals may be controlled.

Role and potential of animal manure in system sustainability and productivity.

Currently little manure is used in the humid zone, but the potential of animal manure as a resource needs examination.

Role of legumes (forage, crop and tree) in soil fertility, weed management, crop productivity and feed supply.

Current emphasis of research is on soil fertility and weed management. If the feed dimension is added, the issues will become complex. Combined with manure, they will be even more complex, but they have a high pay-off potential.

Efficient use of crop residues in the system, and residue quality and quantity as criteria in crop breeding.

Feed value is not currently used by crop breeders in screening crop varieties. This can be added with small marginal cost.

Potential use of animals for traction

Traction use of animals is rapidly evolving in the sub-humid zone, and its potential in the humid zone needs examination.

Dry season feeding is a major problem, and research on strategies for production, conservation and utilization of feeds to solve it is a priority. Low milk production potential is a problem for adoption of intensive management. Breeding for milk production and disease resistance is necessary to solve this problem. It is assumed that the system will be dairy oriented because of its regular cash generating potential, although beef will be an important component of the system. Research will be needed to develop appropriate milk processing and preservation options for small and medium scale producers. In the past, unfavourable policy environments kept the dairy sector undeveloped in west Africa. Development of dairy based crop-livestock systems will depend on the existence of proper policy environments. So research on various policy issues will be needed.

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