Agriculture and Livestock Integration in the context of the developing world with emphasis on sub-Saharan Africa

(DRAFT)

Kwaku Agyemang (PhD)
International Trypanotolerance Centre
P.M.B. 14
Banjul

An invited Key Presentation at the Global Forum for Agricultural Research (GFAR) 2003 Conference, Meridien President Hotel, Dakar, Senegal
May 22-24, 2003

1. Introduction

1.1 Definitions and concepts

In the context of this paper, which attempts to provide a current state of understanding of integration of agriculture and livestock, and how synergies between them can be better exploited for the welfare of humankind (food security, livelihoods, employment, etc) and for the improvement of the environment, the term "agriculture" must be decoupled from "livestock" as a resource and "animal husbandry" as practices and management processes employed in the utilization and conservation of the resource. In order to capture the full breadth of the linkages between livestock and agriculture, the latter should be defined to include the "tilling of land" for the purpose of raising traditional food crops, horticultural and tree products. Since crops, horticulture and trees generally take their below-ground sources of live from the soil, a discussion on the integration (interactions) between agriculture and livestock essentially revolves around the interphasing of soils (land), crops, horticultural, tree resources and livestock, their products and management, processes and practices. Livestock, in turn is defined broadly to include domesticated or semi domesticated species currently being used for food, work, as fibre and as assets. These livestock populations include ruminant species (cattle, sheep, goats, buffaloes, etc), monogastrics (poultry, pigs, etc), non-conventional micro stock (grasscutters, rabbits, etc). Fish is excluded from the definition of livestock in this presentation. The pattern of changes in the population of humans and of the livestock species from 1960s to the 1990s are in Table 1.

1.2 Poverty and agriculture/livestock enterprises

A casual survey of the literature on the development processes in third world countries would seem to indicate that poverty reduction or alleviation as a development goal is assuming greater importance, as poverty broadly defined, impinges on food insecurity, hunger, malnutrition, ill-health, and illiteracy, all of which are usually included as undesirable social menace to be eliminated or reduced in the development process. To emphasise the multidimensional nature of poverty, the International Livestock Research Institute (ILRI) recently adopted the definition "Poverty is the pronounced deprivation in human well-being encompassing not only material deprivation but also poor health, literacy and nutrition, vulnerability to shocks and changes, and having little or no control over key decisions" (ILRI, 2002).

By implication, a large section of the human populations in the developing world are poor because they lack assets, are unemployed, are of poor health and may also lack networks sometimes necessary to survive in the society.

If a simple indicator of poverty used by the World Bank, that is, the number of people living on less than US$2 per day is applied, an estimated 2.8 billion of the world 6 billion people (47%) are considered poor. Approximately 1.3 billion (22%) people live on less US$1 per day (World

Bank, 2001: Perry *et al.,* 2002) and are considered to live under abject poverty. The crucial role and the potential of the Agriculture and Livestock sectors in combating poverty in developing countries become more glaring when it is considered that by 2025 when the world human population would have reached 8 billion, approximately 97% of the population will be living in developing countries, where agriculture (including livestock) forms the backbone of the economies.

Africa's population in 2025 is estimated at 1.3 billion people. It is currently estimated that Agriculture provides 60% of all employment in Africa. The rural areas of Africa contain 70 to 80% of the total population, and therefore Africans depend even more heavily on the Agricultural sector. It is further estimated that 70% of Africa's extreme poor and undernourished are also found in rural areas. From these statistics, it can thus be argued that to significantly reduce poverty in developing countries, especially those in sub-Saharan Africa, with large rural populations, improvement in agricultural and livestock production is not an option but an imperative. If further analysis can establish that important synergies and complementarities between agriculture and livestock enterprises exist or potentially exist in the African farming context, then the nexus of improved agriculture and livestock integration-poverty reduction would have been established. The corollary will be that poor agriculture and livestock integration would tend to increase poverty among the people engaged in agriculture and livestock production.

1.2.1 Objectives

The objectives of this paper are to provide and analyse information on the current status of agriculture and livestock integration in developing countries, with particular reference to Sub-Saharan Africa, ascertain trends in the evolution of such systems with the aim of identifying factors that could contribute to their improvement to enhance food security and livelihoods. Emphasis is placed on the developing world in view high proportion of the global mixed farming systems found in the developing world. Sub-Saharan Africa is given an additional focus in view of the continent's status as a continent of smallholder producers and also characterized by environments that are said to be very sensitive to shocks.

However, in order to gauge the extent to which poverty, food insecurity, malnutrition and unemployment can be reduced through improvement in the agriculture and livestock sub-sectors, a deeper analysis of the contribution of these sectors to the economies of developing countries would be required.

2. Contribution of Agriculture to economic development

2.1 Agriculture

Agriculture is widely recognized as an engine for economic growth in developing countries, in general and in Africa in particular. The economic importance of Agriculture in developing countries is depicted in Table 2. In these African economies large proportions of the food consumed are produced locally. Additionally, an estimated US$14 billion worth of agricultural products were exported to the world market in 2000. The contribution of agriculture to the Gross National Products (GNP) of African countries remain very high. Similarly, agriculture contributes 30-50% of GDP in most countries. As referred to earlier, the sector employs 60% of the labour force. In spite of these huge contributions of the agriculture sector, the performance of the sector in the past 30 to 50 years can only be described as abysmal. Agricultural productivity per capita has declined in several regions of sub-Saharan Africa (SSA). For example, in West Africa, the per capita productivity experienced a decline from the 1950s to the 1980s (World Bank, 1984). With the exception of few crops, the decline has persisted into the 1990s. The low per capita production has contributed to the increase in the number of chronically undernourished people on the continent. In 1999, 194 million of the 200 million chronically undernourished on the Africa continent were in sub-Saharan Africa, representing 34% of the entire population of the sub-region (NEPAD, 2002).

The dismal picture depicted could have been worse were it not for the progressive rise in food imports into the continent. In last decade, an estimated US$18.7 billion per year worth of food was imported into Africa, and represented about 15% of all imports into the continent (NEPAD, 2002). More and more of the revenues from African exports are being used to import food to feed human populations growing at a rate of 2.8 – 3.0% per annum. It is estimated that domestic growth rate in food production must be at least 3 to 3.5% annually to bridge the gap between demand and supply.

Where increases in food production in SSA have occurred they have been attained from expansion of cultivated lands. There is however some evidence that suitable uplands, where expansion in food production has traditionally occurred, are becoming scarce in some parts of the region (Thenkabail and Nolte, 1995; Windmeijer *et al.,* 1994). Globally, it is projected that available cultivatable land per capita in developing world would have decreased from 0.3 in 1988 to 0.11 ha by 2025. All of the land on the African continent classified as very suitable for cultivation is already cultivated (FAO, 1986). Although urban farming is becoming significant in some countries in Africa, a proportionately large amount of both urban and rural demand for food will have to be met largely from rural supply from a fixed or even diminishing land base, therefore, an overall intensification of agriculture is almost inevitable (Boserup, 1981; Pingali *et al.,* 1987; Smith *et al.,* 1997). It has been suggested, and generally being accepted by policy makers, that perhaps the most sustainable means of increasing land productivity is the intensification of agriculture through greater integration of crop and livestock production or mixed crop-livestock farming (McIntire *et al.,* 1992; Winrock, 1992).

2.2 The role of, and contribution of livestock to agricultural and rural economy in SSA

Approximately 70% of the worlds ruminant populations are located in developing countries, where they play multiple roles. It is estimated that livestock contribute to the livelihoods of more than two-thirds of the world's rural poor and to a significant minority of the peri-urban poor (ILRI, 2002). The relative importance of livestock products in the developing regions of the world is captured in Table3. In Table 4 are the contributions to total value of livestock in developing world by agro-ecological zones.

In Asia livestock contribute 10% of the total value of all agriculture and forestry products (Devendra, 1995). In sub-Saharan Africa there are an estimated 196, 152, 182, 14 million cattle, sheep and goats and camels, respectively in 1998 (Agyemang, 2000). These animal genetic resources (AGRs) not only provide food to their owners, they impact on the rural and urban economies as a whole. As with food imports slow domestic growth in livestock products in regions of the developing world has lead to increased imports and reduced exports. Williams *et al.,* (1995) quotes figures on regional net meat imports in WANA, Asia and SSA in the early 1990s as 950,000, 282,000 and 148,000 tonnes per year. Similarly, all the regions recorded net import of dry milk. In the late 1990s import of dairy products into SSA averaged 2,200,000 metric tonnes.

On the average livestock production contribution to the agricultural Gross Domestic Product (GDP) is about 25% when only the main products (milk, meat, hides and skins) are considered. If manure and animal traction provided by livestock towards crop production are valued, the contribution to agricultural GDP increases to about 35% (Winrock, 1992). The corresponding figures for developing regions of South-East Asia, South Africa and North Africa (WANA), South America and Central America are 15, 23, 27, 37 and 43%, respectively (Williams *et al.,* 1995). In SSA and elsewhere in the developing world, the contribution of livestock to household and livelihoods is closely linked with the income generation function of livestock.

2.2.1 Household income generating function of livestock

Incomes from sales of livestock products, meat, milk, manure, hides and skin are often a large proportion of the household total income in developing countries. Some studies have reported incomes derived from livestock constituting 34-87% of total farm income (Gryseels, 1988; Omiti, 1985; Lebbie, 1996). In Mali in West Africa, approximately 78% of the total farm cash incomes from crop-livestock farms came from livestock sales (Debrah and Sissoko, 1990). Overall, 50% or greater of the cash income earned by farmers engaged in mixed crop-livestock production in tropical Africa is obtained from livestock products. These incomes support the purchase of food, farm inputs (fertilizer, pesticides and seeds), animals for restocking and other households requirements (Brumby, 1986; Jabbar, 1995). The sale of small stock such as sheep and goats by women in times of financial crises and grain shortages particularly contribute to food security in many societies in Africa where women tend to own the majority of the sheep and goats. Furthermore livestock production is a major source of employment and national wealth.

2.2.2 Livestock production as a source of employment and national wealth

It is said that understanding the labor market is as important for addressing the food security problems of the rural and urban poor in developing countries as understanding the food market (Braun, 1997). Furthermore, the linkage between poverty and unemployment is well known, and several Employment Acts or Plans have been formulated by governments around the world to target poverty. The agriculture sector constitutes the largest avenue for employment in most developing countries. In Africa, an estimated 50-80% of the work force is engaged in agriculture. At the household level, livestock production (the range of activities from feeding of animals, grazing, milking, marketing of live animals) usually occupy several members of households, who otherwise may not be gainfully employed. In India, it was estimated that each 6 to 10 kg per day of additional milk produced, added one man-day for animal feeding and care. It has been estimated that in smallholder dairy systems in Kenya and parastatal dairy farms in Zimbabwe, the processing of 25 kg of milk adds one-man day (Sansoucy, *et al.*, 1995; Lebbie, 1996). The incomes from sale of products when computed on annual basis and expressed on per capita household member, are usually competitive with those employed in civil service (Agyemang *et al.*, 1989). Processing of livestock products such as milk, typically offers additional employment to women and girl children. Intensive case studies in central Nigeria showed that women processed a range of products from raw milk and enhanced their shelf life and at the same time increased the economic value of milk. Sale of these products on selected market days and at targeted markets yielded higher margins and returns to these women than would have been the case if milk was sold in the immediate neighborhoods (Waters-Bayer, 1988).

2.2.3 The Livestock – Poverty nexus

Notwithstanding the demonstrated positive roles that livestock play in income generation and employment, in a recent in-depth study on global poverty and its associations with agricultural systems, it was observed that among 2.4 billion people living in four study-targeted regions (West Africa, East-Central-Southern Africa (ECSA), South Asia and South-East Asia), 38% were considered poor and that nearly 50% of the rural poor were found in livestock-keeping households (Figure 1). In SSA, 40% of the 150 million poor livestock keepers were found in West Africa with the remaining 60% located in East, Central and South Africa (Figure 2). The study also showed that the great majority of poor associated with livestock are found in mixed-crop livestock systems. In West Africa, 77% of the poor in livestock production systems are associated with the mixed rain-fed arid/semi arid and humid/sub-humid systems. In the Eastern-Central and Southern Africa region, the corresponding figure was 42%, while 25% are associated with the mixed rain-fed temperate/tropical highlands (Perry *et al.,* 2002). Proportionately smaller populations of the poor are associated with non-mixed, livestock only systems and mixed irrigated systems. Nevertheless, since in some cases livestock are the only material asset that the poor (including the landless) can accumulate, they represent a major pathway for the poor to get out of poverty, irrespective of the system of production. In addition, the livestock poor, in general, usually better off than poor crop farmers (ITC, 2002) can reduce their level of poverty through the improvement of the productivity of their livestock and their production systems as well as more active participation in existing and emerging livestock-related markets (ILRI, 2002). Thus, from the analysis of the livestock sub-sector and its contributions there are strong connections among viable livestock enterprises and poverty reduction. As the ability to work is a pre-requisite to income generation in the developing world, good health and ability to get out of poverty are linked.

2.2.4 Livestock as a source of sustenance to man

Livestock is a source of sustenance and good health to man, in providing not only food security but also nutritional security. To achieve a true food security, food should not only be available to individuals of a household, the food should be adequate and biologically balanced such that the nutrients therein, when absorbed upon digestion, would meet the maintenance and physiological requirements of the individuals. A balanced diet is one with adequate levels of energy, essential amino acids and needed micro-nutrients. Essential amino-acids are those that can not be synthesized by the body and which must be provided from ingested foods, and in ready-to-use forms. Proteins that provide a large proportion of these essential amino acids are rated as high biological value. Proteins from plant sources typically have low levels of these essential amino acids, especially lysine, tryptophan, methionine and threonine (Abassa, 1995). In several plants, at least one of these essential amino acids may be missing or present in inadequate quantities. Thus, plant-based diets must often be supplemented with these amino acids to make the diets balanced. Animal source proteins, on the other hand, are rich in these essential amino acids. Meat, milk and eggs are the major sources of animal proteins. They are used globally but the quantities available and the frequency of use vary widely around the world.

In Sub-Saharan Africa, an overwhelming majority of the human population lives on cereal and root-based diets with large carbohydrate content and low protein content. While the energy requirement may be met from roots and tuber diets, the lack of proteins results in imbalance, and such imbalance has led to diseases, such as *kwashiorkor* in children. Retarded growth and development are often associated protein-energy malnutrition. The proportion of underweight (low weight for age) children in Sub-Saharan Africa as a whole, averaged 31%, but reached nearly 50% in some countries (UNICEF, 1992). Some studies have also shown that for some regions in Africa the average proportion of children with stunted growth (low height for age) was as high as 43%, while the mean proportion of growth-wasted children (low weight for height) was nearly 11% (Abassa, 1995). Morbidity and death are common outcomes of malnutrition. It is argued that some animal source proteins will greatly improve the energy-protein balance of starch-based diets characteristics of poor developing nations. The consumption of even a small amount of animal products corrects amino acid deficiencies in cereal based diets, permitting more of the total protein to be utilized (Winrock, 1992).

One of the often over-looked advantages of food of animal origin is the presence in animal products of non-protein materials, such as minerals, vitamins and accessory factors that are not found in many plant materials. Micro-nutrients have been linked with the development of motor-skills in children, implying that children whose diets lack these nutrients may not do as well in school compared with those whose diets are rich in these micro-nutrients. Some studies have shown that where intakes of animal products are low, increases in meat (in particular), milk and eggs in the diets of toddlers and school children have resulted in marked improvements in growth, cognitive development, and health, due in part to the higher availability of essential amino acids, minerals and vitamins in food of animal, compared to plant, origin (CAST, 1999).

Results from field research in Africa tend to support the correlation between balanced diets (including animal proteins) and well being of children. In Ethiopia, households which adopted an agricultural technology package that included crossbred cows that produced a lot of milk, had less stunted-growth children than those households that did not adopt the technology. Furthermore, children in non-adopting households were also more prone to sickness and slightly lighter in weight than those households that adopted the technology (Gryseel, 1988; Shapiro, 1994; Abassa, 1995). In northern Nigeria, 74-85% of households who added dairy cows to their farming enterprises reported some improvement in the overall health of their children (Agyemang *et al.*, 1999).

The data presented in the preceding paragraphs support the view that the inclusion of livestock enterprises in the overall rural development programs in rural and peri-urban settings of developing countries can bring added benefits to the short and long term well being of individuals in communities.

3. Agriculture-Livestock Integration in the Context of Natural Resources Management.

The summary of the discussions in Section 2 of this paper is that in many developing countries there are on-going and evolving agriculture and livestock systems which separately or in some form of associations are contributing to food security, employment and economic development. Indicators on crop yields, land productivity, livestock performance, export – import ratios, attest to the need for improvement in the two sectors. Integrated natural resource management (INRM) approaches are being advocated as possible options to arrest the situation, and in some cases reverse the observed negative trends. In this context, the management of agriculture, utilizing the natural resources of soil and water to support plant growth, when linked with livestock, can be likened to integrated natural resource management for production and for environmental sustainability. As with other INRM, the outcomes from the ensuing Integrated Agricultural-Livestock Systems should be more durable, and in some cases, superior to the either Agriculture or Livestock systems as single entities.

Agricultural-Livestock Integrated Systems (ALIS) can be viewed as part of the many agricultural systems supporting the economies of both developed and developing regions of the world. Like all systems, ALIS have their own components, linked by resource flows and managemental influences as illustrated in Figure 3 below (STA, 1998).

3.1 The building blocks of ALIS

3.1.1 Plants: For the most described of the mixed systems, crop-livestock systems, the "crop" component is taken to include both cash and food crops providing green forage and residues to the organic resource pool that provide feed nutrients to livestock. In this model, range and forest are considered external and contribute to the organic resources. Soil is embedded in the land component and provides nutrients and water to the crops.

Livestock in turn provides products, namely, meat and milk, for home consumption and for sales while manure/compost and draught power contribute to the land component.

As specialization in enterprises occur, and for example, agro-forestry becomes a main-stream activity whereby trees provide fodder for livestock, nitrogen to crops in alley farming systems and fuel wood for home and for sale to generate cash that supports "food production", trees themselves become an integral part of the system as is the case of Malaysia (Devendra, 1995), interact with food crops and livestock directly and are no longer seen as external inputs as depicted in Figure 3.

Similarly, as horticultural production becomes an important enterprise in urban and peri-urban systems, the linkages with livestock, when produced in same environments, become stronger as organic manure from livestock become critical inputs for the continuously cultivated plots and residues from horticultural plants become "non-convential feeds" (Akinbamijo et al., 2002). In these scenarios horticultural plants become main stream component of the system.

As specialization in enterprises occur, as described for agro-forestry and horticultural production, and some production shifts from rural areas to urban and peri-urban settings, certain elements of the components assume greater complexity in their management in order to sustain effective integration. For the land component in Figure 3, the soil and water sub-components need special consideration. For livestock, issues of appropriate species, suitable genetic composition, bio-diversity and adaptive characteristics become pertinent.

3.1.2 Soil:

The soil sub-component is the main support of the crop, tree or horticultural sub-systems. The initial physical and chemical components of the soil, their rate of change, depending on how much chemical fertilizer, manure, crop residues are returned to the soil, and the composition of plants grown (leguminous vs. non-leguminous) determines the sustainability of the integration. For short fallow or continuous cropping systems, as is the practice in most mixed agriculture-livestock systems, soil fertility is the most important constraint to sustaining yields. Kang (1993) for example, reported that soil pH, organic carbon and exchangeable calcium and magnesium levels declined markedly under continuous cropping. In plots where inorganic fertilizer was applied, soil pH declined faster than unfertilized plots. Similar results were reported by Adepetu *et al* (1979) and Kang and Balasubramanian (1990). Thus, in addition to soil degradation occurring in much of SSA due to activities of increasingly human population (removal of cover, inappropriate farming practices, etc), poorly managed integrated crop, tree, horticultural-livestock systems could lead to rapid soil nutrient depletion.

3.1.3 Water:

Water is inextricably linked with nutrient uptake by plants, and is therefore needed in all systems, whether rain-fed or irrigated. Livestock also require and use water. In low rainfall areas, the performance of both crops and livestock may be negatively affected due to inadequate water. In extensive mixed crop-livestock systems, the quality of water is not an issue of concern. On the other hand, in intensive production systems, such as those found in urban areas, health risks associated with water arise in at least two ways. First, high use of agro-chemicals on crops potentially can contaminate ground water which may subsequently render it un-suitable for plants, livestock and humans. Second, household/industrial waste water currently being used widely in peri-urban and urban farming systems in developing countries, especially those around cities in SSA, contaminate ground water used subsequently by crops or directly contaminate produce with microbial, parasitic and chemical materials. Thus, water, especially wholesome water, could be an object of severe competition in some mixed farming systems, and in some cases could become a major source of health risk to consumers (Smith, 2002).

3.1.4 Livestock:

Livestock themselves can be considered as natural resources whose management and use, like other resources (e.g. soil, water, etc), can influence the performance of agriculture-livestock systems under consideration. Whereas most of the ruminant species can "fit" into the extensive, low input mixed systems, in intensive systems, especially peri-urban/urban systems, only high producing animals (improved genotypes) are generally considered appropriate and profitable. Mixed farming systems in areas of high animal disease risk are likely to be profitable only if the livestock breeds have special adaptive features, such as disease resistance. In exceptionally high disease risk areas, mixed farming may not occur in the absence of resistant livestock. Under certain socio-economic conditions only small stock (e.g. sheep and goats) or micro stock (rabbits, grass cutters, etc) may be suitable in a given agriculture-livestock system.

3.2 The Inter-phasing of the components -- Reciprocal benefits.

At the component level the situation of interest is where soils, crops and livestock interact and are managed under one unit (Figure 4). At the output level, the relationship is cyclical. Crop-residues are consumed by animals including work animals which produce manure to support crop growth. Animal draught power also supports crop yields.

Soil fertility maintenance is the most important constraint to sustaining crop yields under short fallow or continuous cropping systems as now practiced in much of developing world, including Africa. Manure from livestock represents a very considerable resource in ecozones where livestock are used in mixed production systems. In some of these areas inorganic or chemical fertilizers are beyond the reach of most farmers, even when the costs of fertilizers are subsidized by governments. These resource-poor farmers have come to recognize manure as contributor to maintenance of soil fertility and to meeting energy needs. Therefore, much effort is made to collect and store this resource, where practicable, or they develop management schemes that allow animals to deposit feces and urine *in-situ* to manure plots.

In one study in Kaduna State in Central Nigeria, the cattle, sheep and goats populations produced approximately 30,000, 2,500 and 5,000 tons of nitrogen in manure annually. It is projected that by the year 2025, production of nitrogen from manure by resident cattle, sheep and goats in Kaduna State would have reached 80,000, 10,000 and 35,000 per year, respectively (Smith *et al.*, 1997). These levels of nitrogen production to support food production are a major relief in sub-Saharan Africa where, because of cost and unavailability, chemical fertilizer use is only about 11 kg/ha of harvested land compared with a world average of 96 kg/ha (FAO, 1997; Westlund, 1995). In so far as nitrogen in manure and the beneficial effects of manure on soil pH, organic matter and available phosphorus contribute to increased crop yields, the presence of this resource assures food security.

Agronomic trials with manure have shown significant increases in yields. For example, McIntire *et al.* (1992) estimated increases in grain yield ranging from 15 to 86 kg per ton of manure applied to cropland (CAST, 1999), while Powell (1986), reported a response of 180 kg maize grain per ton of manure applied to plots in sub humid zone of Nigeria. In areas where costs of fossil energy are very high, manure is used as an energy source (burning of dry dung or generation of biogas from manure), and hence not only bringing in cash incomes to owners of livestock, but also helping in transforming food to forms that are consumable and acceptable to humans

Some domesticated animal species, namely cattle, camels, horses, buffaloes, etc., have provided draught power for diverse operations in developing countries for many years. These include cultivation, weed control and transportation. However, the transportation function is considered less important compared with cultivation (Dawson and Barwell, 1993). Some studies have shown that farmers with access to animal draught power tend to have larger farms than those not owning draught animals, suggesting that access to draught power increases the land cultivated (Francis, 1988; Sumberg and Gilbert, 1992). In the Ethiopian highlands, ownership of draught oxen facilitated the preparation of land in good time to allow the sowing of highly priced crops when the cultivation period was short, due to drought conditions. In central Nigeria, access to draught animals decreased the time for land preparation for upland rice from 315 hours/ha to 94 hours/ha (Lawrence *et al.,* 1997). The saved time from upland cultivation makes the cultivation of lowland inland valley plots possible, and hence availability of multiple crops harvests within one season (Agyemang and Smith, 1999). In some production systems (e.g. Ethiopian highlands, Senegal), cows are being used to provide draught power in addition to their primary role of milk production (Agyemang *et al.*, 1991; Zerbini *et al.*, 1994; Lhoste, 1986). This practice potentially reduces the number of animals, especially bulls, kept by households, and hence variable costs in keeping livestock.

It is likely that the use of draught power will continue to expand in developing countries in Asia and Africa, in part due of the high cost of imported machinery. The number of integrated projects involving animal traction has increased tremendously in West Africa during the last 20 years (Hoste *et al.,* 1992). One estimate shows that an estimated 30 million tractors would be required to replace the 300 million draught animals used on small farms in Asia (CAST, 1999; Ramaswamy, 1985).

4. Emergence, Development and Evolution of Agriculture – Livestock Integration

Agriculture (crop, tree and horticulture husbandry) and livestock as enterprises can emerge and develop separately under a given set of conditions. When some or all of the conditions change in a given direction, agricultural and livestock enterprises could develop linkages. Okike (2002) relates the developments that lead to linkages with the factors of land and labour. Okike (2002) uses the example crop farmers and pastoralists to illustrate the development of crop-livestock "interactions" and crop-livestock "integration" as follows:

At the lowest level of interactions of factors characterized by relative abundance of land and extensive farming, crop and livestock start off as independent enterprises with very little interactions. Later, pressure on land leads to increased frequency of cultivation of the same plot and a decrease in arable land per capita. Crop farmers are faced with problems of declining soil fertility and increasing demand for labour for crop production while pastoralists become constrained by the unavailability of feed in adequate quantity and quality for livestock production. A this point, bilateral exchanges of manure and draught power for crop residues and later for cash ensue between pastoralists and crop farmers. When participating pastoralists and crop farmers are contended with these exchanges and make no further effort to address their farming constraints, only crop-livestock *interactions* are said to be occurring. Some farmers, however, become induced to own both crop-livestock in order to exploit the synergies and complementarities of crop-livestock interactions leading to crop-livestock *integration.* Special features for agriculture-livestock interaction can be depicted in the resource flows and management influences shown in Figure 5 (STA, 1998). In these systems the livestock component may not have a permanent presence in the set up. Figure 5 illustrates the main associations between the livestock kept by pastoralists and the cropped land farmed by settled agriculturalists. This is generally a transient association that occurs at times of the year when crop residues or other feed resources are available on farms and allows the transfer of nutrients in animal manure and urine to the cropped land. The incidence of tsetse fly may also affect the extent of penetration by transhumant pastoralists of the more humid areas in which cropping is concentrated (STA,1998).

With respect to the more intensive form of crop-livestock integration, Figure 6 represents, in its most extreme form, the other end of the spectrum of crop -livestock interactions (STA, 1998). Here, crops and livestock are tightly integrated in association with the same land, year-round, and under the management of the same household. In situations where population densities are high, this type of system can be almost completely closed. The effects of inputs of inorganic fertilizers are, when compared with those of organic matter additions, relatively localized and predictable in terms of the immediate crop production response although this may exert downstream effects on, for example, fodder availability and quality.

4.1 Need for greater integration

As Okike (2002) points out, sometimes, agricultural intensification is associated with negative environmental impacts such as soil mining and severe degradation (when crops are grown with little or no inputs) and underground water pollution with non-biodegradable chemicals (Delgado *et al.,* 1999). It is also the case that because of the land-detached nature of industrial livestock production, units tend to concentrate in peri-urban and urban areas, causing massive and increasing damage to the environment. The nutrient cycling that was previously carried out on-farm is no longer occurring. Nutrients are loaded onto limited space, and very often discharged untreated into open waters (Lead Team, undated).

There are also a number of diseases associated with increasing intensity of production and concentration of animals on limited space. Many of them pose a threat to human health; industrial and intensive forms of animal production may be a breeding ground for emerging diseases (Nippah, BSE, Avian Flu), with unknown consequences. Public health is also threatened by other forms of livestock food safety problems, such as those manifested by the recent dioxin scandal in Europe, antibiotic resistance and other residue issues (Lead Team, undated).

Poor animal welfare results from industrialized livestock production. Lack of legislation / enforcement, concentrated rearing units, inappropriate transport and slaughtering facilities, lack of awareness of animal welfare, etc. are issues that are of increasing concern (Lead Team, undated).

In the context of increased and sustainable agricultural production, there appears to be little option than to encourage food production systems that utilize and strengthen traditional and natural exchanges between crop and livestock farming, especially through crop-livestock integration (Smith *et al.,* 1997; Okike *et al.,* 2001; Okike 2002). The conclusion above is further justified if social dimensions of industrial production are considered. For example, rapid growth in scale of operation in industrialized production is a common feature globally, but particularly in monogastric production in Asia, and in many countries, these industrial forms enter into direct competition with land-based, small scale production, sometimes supplanting them. Furthermore, industrial livestock production generates substantially lower income than the same volume of output in smallholder farms. Benefits, at production level, accrue to a few. While cheap animal protein favours indirectly also poor consumers, the poverty and equity effects, as regards livestock production, are on balance largely negative.

4.2 Views on the drivers of agricultural intensification

Several hypotheses have been proposed to describe the processes, pathways and driving forces of the evolution of agriculture from extensive to intensive systems. Boserup (1965) and those who subscribe to his view, assert that pressure on a fixed land base from human population growth is the most important source of technological change in agriculture – involving a movement from slash-and-burn through a shortening in fallow periods to continuous cultivation with external input use (Okike, 2002). According to this hypothesis the influence of pressure on land is so essential for intensification to occur that there will be low demand for fertilizers and other yield-increasing technologies, including the use high-yielding varieties and animal traction in sparsely populated areas (Binswanger, 1986; Pingali et al., 1987).

Increase market demand has also been put forward is a driver of intensification, although the proponents of this hypothesis acknowledge that the overall effects on the intensification pathway will not differ from those due to the pressure of land from population growth (Pingali *et al.,* 1987; Okike, 2002).

Induced innovation or technical change as they attract the use of resources, mainly labour and land, reflected in their relatively prices and their relation to products, are also put forward as a drivers to intensification in the sense that they determine the pace of agricultural transformation (Hayami and Ruttan, 1985). Market access has also been proposed as an alternative driver to intensification, based on the argument that in some highly human populated areas, there has not been any tangible agricultural change as would be expected from population pressure on land.

The trend is however, that increasingly market-driven (demand and access) intensification is getting more and more attention, along side population-driven intensification. The overall assessment on the various views on the evolution of intensified agriculture is that the emergence of intensive systems is driven more by the various interactions among biophysical factors especially land availability and quality, population growth and access to markets than any single factor (Okike, 2002).

4.3 Nature of agriculture and livestock associations and trends: the land scarcity and urbanization model.

From the discussion on the various drivers of intensification of agriculture, it can be anticipated that there will be degrees of associations between agricultural and livestock enterprises in any given geographical zone. The associations between farmers traditionally engaged in cereal production and pastoralists referred to in Section 4 serves to illustrate the circumstances and conditions under which associations move from low interactions to closer interactions and to full integration as in mixed farming situations. Within the framework that agriculture and livestock enterprises in virtually all ecozones can be categorized on the basis of nearness to major consuming centers (linked with human populations and markets), viz, rural, peri-urban and urban farming, Okike (2002) provided conceptual trends in crop-livestock interactions and integration. The key elements in this conceptual agricultural transformation are land scarcity and urbanization (Figure 7).

The conceptual trends indicate that in the rural production systems crop-systems interactions and integration remain at similar but low levels but increase as land becomes scarce. As production systems develop in peri-urban areas crop-livestock integration peaks and a decline sets in as the communities/locations approach urban situation. On the other hand the development of crop-livestock interactions does not decline and only plateaus in urban environments. In the urban environments two scenarios arise as crop-livestock decouple into highly specialized and intensive crop and livestock units with most of the available land devoted to leafy vegetable production. Production of swine and poultry as well as 'micro-livestock' such as rabbits develop at commercial levels (Okike, 2002). Where integrated systems continue, the resultant integration takes the form of feed imported out of the system to support "stall-feeding" the livestock.

In summary, conceptual trends described above implies that while pressure on land due to demographic factors, high human density and urbanization may trigger the development of integrated systems, at the very extreme scenario of extreme land scarcity and urbanization, vertical integration must decrease or can only continue with huge environmental cost. Horizontal integration can, however, partly ease the bottlenecks encountered with integration in highly populated and scarce land environments.

5. Classification of agricultural-livestock integrated systems and examples of systems in practice

There is some justification for classifying agriculture-livestock integrated systems, as like all crop and livestock systems, development does not imply the expansion of all production activities. As Jahnke (1982) points out within one system, it may imply changes in factor combinations, technologies, intensities and product mixes. In addition, species of livestock and functions may change. Cropping enterprises may change as well in response to demand. Thus, the potential for change and improvement is likely to be different in various production systems. Furthermore, the concept for clearly identifying agricultural-livestock system in broad or narrow groups allows the discussions of their development in concrete policies and strategies.

In this paper two systems of classification, namely Jahnke (1982) on systems in Tropical Africa, and Schiere *et al* (1995; 1997), reflecting different levels of sophistication and complexity of the interactions but also the degree at which markets are influencing the evolution of the systems in different regions of the world.

5.1 Land use based classification

Jahnke (1992) bases his classification of livestock associated systems in tropical Africa on land use. Pastoral systems are excluded from this discourse as in practice these systems are associated with arid zones, too dry for cropping to serve as the base for subsistence (Jahnke, 1982). In West Africa, however, it is known that pastoralists do enter into agreement with cultivators to provide manure *in-situ* or provision of animals for traction in more favourable areas of the arid zone. These arrangements fits the definition of "interaction" as used in this presentation. Similarly, range-livestock systems in form of ranching is excluded in this discussion as ranches rarely interact with crop farming. The key agriculture-livestock systems in tropical Africa, based on Jahnke's (1982) land use considerations are:

a) Pastoral systems in arable areas:

Cropping is th predominant form of land use. The co-existence of arable farming systems and grazing systems may extend into the semi-arid and sub-humid zones. In West Africa, there is a long history of this practice extending even into more humid areas. During the dry season when fodder and water become scarce in the drier north, and at the same time tsetse challenge in reduced in the humid areas pastoralists move southwards with their animals. Both important complementary and competitive relationships develop among pastoralists and indigenous farmers. Jabbar (1993) has described how the development of these casual interactions into near full integration is occurring in the South-West zone of Nigeria. The integration is made possible by the rapid increase in the number cattle in the zone. 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. 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. Furthermore, progression from no cropping to single 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.

(b) Crop-Livestock Systems

Most of the livestock in SSA are held in crop-livestock systems. The mix of crops and livestock species are determined by agro-climatic conditions (the so-called humidity gradient) and human population densities. On the lower end of the rainfall scale millet predominates. As rainfall increases, crops change in their comparative advantage. For example, cassava gains in comparative advantage as conditions become more humid, whereas maize is the optimum crop in the transitional zone between the semi-arid and the sub-humid. The human population pressure measured by intensity influences the land use pattern with long fallow periods in extremely low population densities and almost no fallow period in high density areas. An example of a zone of low humidity and high population is Northern Nigeria, where permanent grain cropping occurs and livestock provide critical inputs of manure into grain production. In general, animal disease pressure, especially tsetse-transmitted trypanosomosis increases with humidity, and the distribution pattern. Thus, crop-livestock integration becomes almost impossible in highly tsetse infested areas. The exceptions to this general relationship are (1) where intermittent migration of susceptible breeds of livestock into infested areas allow the breeds to develop various degrees of adaptation to light tsetse challenge that make them to settle as described for West Africa, and (2) where the indigenous species and breeds of ruminant populations are trypanotolerant as exhibited in Djallonke sheep and goats, and taurine longhorn and short horn cattle of West and Central Africa.

In the crop-livestock systems in lowland tropical Africa, the livestock component, under one management unit of crop production, provides agricultural inputs like work and manure and renders the enterprise more productive and more secure by using residual capacities of production factors with low opportunity costs like non-arable land and excess labour. In Table 5 are the major crop-livestock outputs by production systems and by agro-ecological zones.

(c) Example of interplay of manure and crop residue use: The Case in Kaduna State of Nigeria

The current level of livestock input into crop production in terms of manure, and the use of crop residues for livestock, and projections to 2025 for Kaduna State of Nigeria (approximately 460,530 ha) have been provided by Smith *et al.* (1997). Calculations based on these production rates and on the resident ruminant population of Kaduna State with approximately 460,530 ha of land in Nigeria have been done as an example of the considerable resource that manure represents. Approximately 30, 2.5 and 5 thousand tonnes of nitrogen are produced annually from cattle, sheep and goat manure respectively By 2025, production of faecal and urinary nitrogen could reach 80, 10 and 35 thousand tonnes annually from cattle, sheep and goats, respectively, in that State.

Feeding livestock, particularly during the dry season, is a major constraint to livestock development in SSA (Walshe *et al.,* 1991). It has been projected that ruminant feed requirements in terms of metabolizable energy will increase from 793 x 109 Mcal in 1986/88 to 1405 x l09Mca1 in 2025. Crude protein needs are expected to increase from 40.3 million tonnes to 60.1 million tonnes for the corresponding period (Gollin, 1991; Simpson, 1991; Winrock, 1992). As population increases and agriculture becomes more intensive, the problem of feeding livestock will probably be exacerbated. The conversion of more and more traditional range lands into crop lands will necessitate a heavy dependence on crop residues as a feed resource.

The important role that crop residues will play in the feeding of ruminants relative to range lands is illustrated by Kaduna State (Figure 8). This projection is based on assumptions of a 2% per year expansion of crop lands (Winrock, 1992). By the year 2000 it was projected that, crop residues will have overtaken range lands as the most important feed resource for livestock and by 2020 they are projected to be twice as important as range land (Figure 8).

5.2 Input use based classification

Schiere *et al.* (1995; 1997) base their classification on the kind and degrees of external input use and plant nutrient cycling on the farm. They relate the degree of input use with the so-called outfield/infield ratio, i.e., the area of land available for grazing outside the farm (outfield) in relation to the feed requirements for crop cultivation on the farm (infield). According to this scheme, five systems were identified and described (Lead Team, undated) as follows:

Mixed systems making use of communal grazing.

Mixed systems making use of communal grazing have a high outfield / infield ratio. The area of outfield required to supply enough manure for one hectare of cropland is known to be around 20 – 40 ha. In cases where these pastures are available, it is often neither economic to harvest and conserve fibrous crop residues nor to improve housing for manure collection. In general crop residues are left in the field to be grazed and animals are gathered in corrals or night pens. Manure so collected can be used to sustain crop cultivation. The so formed crop-livestock integration can be within one mixed farming system as well as between specialized livestock and specialized crop farming systems. The system is characterized by throughput of nutrients with a low level of output in terms of animal products such as milk or meat.

Mixed, crop residues

An expansion of area under crop cultivation in general is at the cost of pastureland, having a double impact on the outfield / infield ratio: less pasture land (less outfield) and more cropland (more infield). The reduced availability of outfield implies an increased need to keep and recycle resources on farm. Crop residues become more important and mixed systems emerge where crop residues are the principal feed resource base. The function of animals changes from the collection of nutrients from outfields to cycling of nutrients on infields. This requires different ways of keeping animals: stall feeding instead of grazing; more limitations in the number of animals that can be kept; selection of specific animal types, draught animals or cow calf production; placing of surplus stock in grazing systems; etc. Mix farming increasingly takes place at on-farm level, and traditional forms of exchange of services between crop and livestock farmers start to break down.

Mixed, cut and carry

Further increase in land use for crop cultivation often results in restrictions on the free grazing of animals. Tethering and the collection of feed from roadside, other communal land and neighbouring farms then replace grazing on communal land and mixed systems based on cut and carry appear. In short, human labour (men, women and children) replaces the energy used by grazing animals to collect their feed. Consequently, labour availability on the farm can become a major constraint for the number of animals that can be kept. The cut and carry systems therefore are, in general applied by households with access to little land and no better alternative income generation for their labour. Through the collection of feed from the limited outfield areas there is still some import of nutrients on the farm. The high labour cost for collection will stimulate that the feed resources on farm are intensively used. Therefore, the system is characterized by external input through feed from a limited area of outfields and an intensive cycling of feed on farm.

Mixed feed from farm

Farms with access to more land relative to outfield can reduce labour costs by growing more fodder crops on their land. They then can evolve in mixed system with feed from farm. The cultivation of fodder crops on farm can in addition contribute to: prevent erosion (soil cover, boarder vegetation); fix Nitrogen (legume plants shrubs and trees); mobilise nutrients from the soil (catch crops); improve soil structure (organic matter content); provide by-products (fuel and construction wood, flowers for bees); more variation in crop rotation scheme.

In general, it is the combination of benefits that makes farmers decide to plant fodder crops. The primary reason even has not always to be for livestock. The system is characterized by intensive cycling of plant nutrients on farm (infield). However, the lack of outfield in relation to infield will eventually threaten the sustainability of even very efficient recycling systems. Inevitable losses of nutrients from even efficient recycling systems imply a development trajectory of increased mining and decreased outputs. Eventually therefore the throughput needs to be re-established i.e. through inputs from external feed and / or fertilisers. The mixed systems may so evolve into systems using external feed.

Mixed external feed

The mixed external feed system can evolve from any other mixed system but is characterized by input of plant nutrients through external feed for livestock. As such it is a throughput system. The principal differences with the earlier throughput systems mixed communal grazing and cut and carry systems are that the feed is of high quality and that it originates from distant outfields, whereas the other systems rely on feed of moderate to poor quality from local outfields. Table 6 summaries some of the different modes of mixing indicating the extent of use of external nutrient and levels of cycling of nutrients at the farm level.

5.3 Towards true mixed farming systems

In Jahnke's (1982) classification, the term "mixed farming" as opposed to crop-livestock farming was reserved for a more specialized meaning: "the intensification of the output function of livestock of livestock within the farming system parallel to the development of the farm input function (work and manure) and the increased integration of livestock for the benefit of soil fertility and overall farm productivity". For Tropical Africa, Jahnke (1982) referred to the then known case of a form of mixed farming developed autonomously out of traditional farming on the Ukara Island on Lake Victoria.

It has been reported that globally mixed farming systems cover about 2.5 billion hectares of land, of which 1.1 billion hectares are arable rain-fed crop land, 0.2 billion ha are irrigated crop land and 1.2 billion ha are grassland Figure 9 provides data on the contribution of mixed farms to the global meat and milk supply. It is further observed that mixed farming systems in the developing world contain about 67% of the cattle and 64% percent of small ruminants of the world, and that animal numbers are growing in mixed farming systems, especially in humid/sub-humid areas. These trends notwithstanding, only 50% of all meat and milk produced in this system is produced in all developing countries put together. Thus, the critical question can be posed: *Can these farming systems in the developing world meet the growing demand that many developing countries are experiencing* ?

A large body of respected opinion that takes into account environmental concerns seems to agree that of all the systems, mixed farming systems offer the best hope of approaching global demand for meat and milk. Even for those who hold contrary view that in the light of a strong trend towards larger scale production, countries who have limited resources and wishing to meet their demand (or meat and milk) in the most economic way are not likely to turn to mixed farming in short run, agree that in the longer run, mixed farming is an attractive option.

The key enabling factors seems to be access to inputs and attractive markets. Two contrasting situations have been cited in the literature to illustrate this point. The Machakos (Kenya) Case Study illustrates the scenario where a dynamic market and access to inputs has led to a fully sustainable development of a resource poor area, in which the population had increased five fold over the last sixty years.

BOX 1: The Machakos case.

Human pressure and intensification can also work positively. Tiffen et al., (1992) showed clearly that despite a 500% population growth over the last 60 years in semi-arid Machakos district in Kenya, the natural resource base improved. The key factor leading to this success was dynamic market development making farming profitable, generating off-farm employment and supplying the capital for investments in soil and water conservation. Horticulture and smallholder dairy production are the main activities generating the cash for resource conservation, such as terracing. The famine predicted in the 1930's for the Machakos district never occurred.

Thus, it can be said that a sustainable mixed farming system has contributed to a sound environment, improved food security and livelihoods and human well being in general in this semi-arid environment.

The Rwanda example, on the other hand, is said to illustrate a scenario that contributed to a collapse of farming systems, impoverishment and even civil war due to imbalance between cropping activities, animal inputs and human population pressure.

BOX 2: Mixed farming in Rwanda

Prior to the colonial period, Tutsi and Hutu, the major ethnic groups of Rwanda, had a working relationship which balanced the nutrient flows in the farming system. This was accomplished by the Hutu herding Tutsi cattle in return for receiving excess male offspring, manure and milk. As a result the Hutu farmland maintained or increased in soil fertility. The ensuing trend when the balance was disturbed is described below by de Haan *et al.*, (2000).

In the 1940's human and animal populations started increasing, and land previously reserved for grazing was converted into cropping lands. For example, from 1948 to 1991, population density in the Gikongoro province increased from 100 people/sq. km to 287 people/sq. km. Farm size became smaller and livestock forage was reduced. Livestock ownership from 1967 to 1993 decreased from 1 in 2 households owning cattle in 1 to 4 (Figure 9). *These changes resulted in a reduction in nutritional quality and access to food since fewer animal products, pulses or cereals were being produced and people were relying more on tubers.*

This led to continuous cultivation and increased vulnerability to soil erosion; reduced pastures and resulted in fewer animals and less manure; and farmers were forced to try buying manure. Over 40% of survey respondents cited lack of manure as a major reason for declining soil fertility. This combination of poverty, population pressure and resource degradation led to the eruption of one of the worst civil wars in modern times. Livestock provided an important and stabilizing component of the farming system by maintaining soil nutrients. Their increasing absence contributed to the destabilization of a previously balanced system. While it is certainly not clear whether this drama could have been avoided, one might assume from this analysis that improved incentives and technologies for smallholder development, including, for example the introduction of high yielding small ruminants, could have reduced the downward spiral in resource degradation.

5.4 Global trends

Some general trends in human population growth, consumption of various livestock products (milk, meat), use of cereal for feeds, etc, have been clearly established (Dlegado *et al.,* 1999). The projected growth rates for both human growth and consumption of livestock products have been shown to be higher in developing countries as a region than in developed world.

Different production techniques and system will be employed in the various regions of the world to meet the projected demand of livestock products. Globally, intensification of production systems is occurring, principally because the natural resource base is fixed, and grazing resources are diminishing. Mixed farming systems involving crops and livestock are seen as the most benign production systems, from an environmental perspectives. The overall current trend in production points to specialization in either crop or livestock production. This development path, apparently greatly influenced by existing installed infrastructure, relative price ratios between inputs and outputs and economies of scale of production, is more common in the developed world and East Asia.

In the rest of the developing world, depending on the ecological zone, intense integration of agriculture and livestock is occurring. In sub-Saharan Africa, the highland zone is the most intensively farmed. The semi-arid zone is the next region moving fastest towards fuller crop-livestock in response to increase pressure. In the sub-humid zones, crop-livestock systems are evolving where the animal disease pressure has reduced through human activities.

The intensification of production on-going in several regions of the developing world is putting on new demands for services which in many situations the public sectors are ill-prepared to handle. There is therefore a trend to redistribute the roles of public and private sectors (de Haan, 1995). Public service responsibilities which can be sub-contracted to the private sector is happening in the areas of animal health, for example vaccination campaigns contracted to veterinarians in North and sub-Saharan Africa. Similarly, extension is being subcontracted in Latin America.

Services which are now traditionally considered private such as clinical health care, animal breeding (AI), and credit are being increasingly provided by private providers in North Africa, Latin America and, sub-Saharan Africa.

5.5 Emerging key issues for Agriculture Livestock Integration.

It is reasonable to assume that pressure on land in many regions of the developing world will continue as human capital needed to take the population to higher levels are already on the ground and nothing much can be done in stopping this from happening. From the information and analyses in the previous sections, if the human growth factor and the associated urbanization factors are taken as "given", the major forces that drive agriculture and livestock integration are nutrient flows and balances, and input and output markets (and associated infrastructure). The impacts of crops and livestock activities on the environment, and how Agriculture-Livestock integrated systems can serve as a vehicle to reduce poverty among the poor, for example, through a better understanding of the poor's dependency on livestock, are also issues of global concern.

5.5.1 Nutrient flows and balances

According to de Haan *et al.,* (2000) nutrient balance status (negative or positive) alone can be used as the dividing line between mixed farming systems in developing and the developed world. In the developing world, the mixed farming systems are basically nutrient-deficit. This means that the net balance of key nutrients N,P, and K brought into the farming systems inorganic fertilizers, feed, nitrogen fixed by leguminous plants and transfer from grazing areas outside of the farm) from those exported in animal products or lost from the land to the air or groundwater, is negative. In Table 7 estimates of expected nutrient balance on mixed farming systems (as classified by Schiere, *et al.,* (1995; 1997)) are made under two scenarios with low or high external inputs, and on low or high nutrient cycling on farms.

In general a negative balance can trigger off a series of reactions depending on what actions are taken. For a mixed crop-livestock farming system at a point of separation into specialized crop and livestock activities, under population pressure, continued absence of external inputs, the arable land part of the system will experience increased rates of nutrient depletion (including flora and fauna biodiversity loss) and soil erosion (de Haan et al., (2000). This, in turn, lead to a downward spiral of mono-culture with lower quality of food crops, increased under nutrition and famine (Cleaver and Schrieber, 1994).

Thus, in the developing world situations the issues of concern would typically include soil erosion, soil fertility, non-renewable energy resources and biodiversity. In the developed world, where nutrient surpluses do usually occur, as a result of massive imports of nutrients, the challenges are of the management of nutrient overloads through technologies and policies.

Unfortunately, nutrient loading or surpluses is also an emerging issue in fast growing developing country economies especially in East Asia. Two converging trends are believed to have led to this situation in the Green Revolution areas. In these areas where irrigated mixed farming is an important system, intensified crop production is pursued, a legacy of the Green Revolution. The use of improved "dwarf" cereal varieties has meant a reduction of crop residues in terms of quantity but also quality, available for ruminant livestock feeding. However, the increased grain yields had made cereals available for intensive production. Demand for livestock products is also rising. The combination of these trends has promoted the development of intensive industrial units, which combined with high fertilizer use has led to nutrient loading, as is the case in the Pujab State of India.

5.5.2 Markets

The role of outputs markets as a driver of intensification was referred in Section 4.2. In that context market demand acts similarly as population pressure to promote mixed crop-livestock production. It is also the case that when population densities are high but markets, inputs and technologies are not readily available, intensity of land use increases, and mixed crop-livestock production becomes the most efficient and sustainable mode of food production because of complementarities between crops and livestock raising (Winrock, 1992).

Given all the advantages listed for mixed farming systems including crop-livestock systems in the developing world context it may be considered desirable to have policies to promote such complementarities and synergies. Although markets can develop autonomously, support to market development such as infrastructure development as road and transportation system are usually in the domain of public investment. As crop livestock systems quickly decouple into separate specialized production with developed market, the question could be asked as to what extent should the state support market development.

It would appear that there is dilemma in the sense that as the Machakos example showed, the dynamic input markets were a key to the success while in other situations developed output markets hastens specialization. This apparent contradiction suggests that actions and policies towards agriculture-livestock integration should take into consideration other location-specific circumstances. Strategies designed to raise the productivity of specific mixed crop-livestock systems must consider the stage of development of the target are in relation to intensification and nature of crop-livestock interactions, the availability and cost of inputs, and whether or not policies favour mixed farming (Mohammed-Saleem, 1995). Thus, it is still possible within an overall policy framework of development of mixed systems to deliberately move livestock production towards an industrial model especially in densely populated systems.

5.5.3 Impact of crop and livestock activities on the environment

In principle, undistorted process of crop livestock integration mitigates the negative effects of expansion of cultivation by reducing pressure on the remaining rangelands. Furthermore, mixed farming systems represent, at least partially, a closed system, which allows the waste products from one enterprise (crop residues), which would otherwise be loaded on to the natural resource base, are used by other enterprise which returns its own waste products (manure) back to the first enterprise (de Haan *et al.* 2000).

In practice the balance gets distributed by practice such as overgrazing, which then lead to other problems as erosion and degradation. However, the greatest negative impacts from agriculture activities on the environment begin to occur when the systems become subjected to further population and market pressures. Examples are Peri-urban based mixed crop-livestock systems that get converted to become urban systems as towns and cities expand. Depending on the scale of production and the enterprise involved (dairy production, poultry, etc) the health risks to humans could be substantial. Improper use of semi-fresh poultry manure spread on vegetables by farmers in Ghana may significantly increase harmful microbes on vegetables (Drechsel *et al.*, 1999). Similarly, offensive smell from dung of ruminants kraaled near residential areas could be a nuisance to residents. Since urban agriculture is developing widely in many of the large cities in Africa, the problems of solid waste management could become a continental one. In fast growing developing countries of South-East Africa where nutrient loading is becoming a problem, the level of pollution may be rising as well. As industrialized countries are already experiencing nutrient surpluses that are seeping into surface or ground water, the problem of pollution from intensified production can be described as a global one.

5.5.4 Livestock-specific factors that limit agriculture-livestock integration, and their relationship with poverty

In terms of agro-ecological zones, only drier arid zones (annual rainfall of 0-200 mm) cannot support crop production. As humidity increases, the range of possibilities for crop production increases dramatically as the number of cultivable crop species increases. On the other hand humidity *per se* does not limit livestock production except indirectly through disease pressure. Thus, the livestock component is a major determinant as to whether crop-livestock integration can occur. Within a given socio-economic circumstances or context, the two most important factors are the genetic make-up (genotype) reflected as species, breeds, etc) and disease or health (also influenced by the genotype).

a) Species and breeds of livestock

Agriculture and livestock integration is not possible in large areas of the wetter semi-arid, sub-humid and humid zones of SSA because of trypanosomosis. Where this harsh condition occurs, susceptible breeds and species may not survive without heavy treatment costs. Tolerant breeds may also suffer productivity losses at high level of infections. People, especially the poor, living in the affected zones or areas are therefore literally excluded from the possibilities of reducing their level of poverty through the denied benefits from crop-livestock integration. Given the large area that trypanosomosis occurs in SSA, the issue of how to make livestock production a possibility in better watered (therefore high feed potentials) areas need to be addressed at continental level, at the minimum. The rippling effects of lack or drastically reduced rural development potential in large areas, and the implications on livelihood maintenance of the millions of poor people living in the affected areas should be of a global concern. Programmes seeking to alleviate these constraints need to be coordinated in a holistic manner to enable them benefit from targeted funding support.

b) Disease and health

Animal diseases continue to constrain livestock productivity, agricultural development and poverty alleviation in many regions of the developed world in a variety of different ways (Perry *et al.,* 2002). All the four broadly grouped disease types, (Perry *et al.*, 2000) endemic, epidemic (sometimes termed transboundary diseases), zoonotic diseases and food-borne diseases, can at various degrees affect livestock, and in some cases directly affect the people who keep them or eat their products. Thus, problems posed by these diseases could be of localized or global significance.

The impacts of diseases were classified into two by Swallow (1997) as those impacts associated with “overt disease” and those associated with “disease risk”. While the overt disease impacts acted mainly through loss of livestock productivity (production losses, treatment costs, market disruption, reduced crop production through loss of manure, draught, etc), disease risk influenced species and breed choice, management practices and preventive control costs, and unrealized livestock productivity – or lost potential.

Irrespective of the impact type, the household incomes levels and assets accumulation capacity are affected by these diseases. In some cases the number of animals available are reduced or eliminated entirely by diseases, making integration with crop inefficient or impossible. In some cases, the diseases exclude the use of livestock, and prevent their interaction with other natural resources. The poor of the society are said to be especially vulnerable to the impact of livestock diseases. Pathways through which animal diseases can minimize or limit agriculture-livestock integration as a system operated by large segment of the poor, include erosion of their household assets (financial, human, social, natural and physical assets; Perry *et al.,* 2002). The negative impact of animal diseases can be so pervasive that even the poor who do not keep livestock are also affected.

Based on a typology linked with the new livelihood strategies approach (DFID, 2000), Perry *et al.,* (2002) categorize animal diseases as those that exacerbate asset insecurity (examples being endemic diseases, common zoonoses), those that limit market opportunities (examples being zoonoses, epidemic and food-borne diseases) and those diseases that limit livestock-based intensification of farming systems (e.g. endemic diseases, of which trypanosomosis is an example).

Given the number of poor people in the developing world who support their livelihoods from livestock, and the proportion of livestock kept in mixed crop-livestock systems, and the risks they are exposed to themselves through zoonotic diseases, the global efforts on Research for Development to alleviate the impact of diseases need to be sustained and renewed in some cases to reduce their impact on the poor. Private enterprises role in the delivery of veterinary health care services in support of mixed crop-livestock systems must be promoted in the regions concerned.

6. Addressing constraints and impediments to agriculture-livestock mixed systems through Policy pressures and technological options.

6.1 Policies

As alluded to in the previous sections the demand for livestock products (meat and milk) in the developing world is expected to skyrocket over the next decades as a result of growing human population, rising income and growing urbanization (Delgaldo *et al.,* 1999). This large rise in demand for milk and meat is expected to produce significant changes in the livestock industry, as it will require much more intensive forms of production. Most of the expected increases in the production are to come from crop-livestock mixed systems. Peri-urban and urban production systems would contribute increasingly to the phenomenon. Yet, the structural evolution of the livestock sector is said to be occurring in a policy and institutional void. From other perspectives, the development of agriculture (crop, tree, horticulture) - livestock integration has been constrained by negative policies. Negative policies have also often limited the beneficial impact of crop-livestock integration and exacerbated its negative environmental impact. According to de Haan *et al.* (2000), the implicated policies were instigated in some countries to provide cheap food for urban dwellers through protection of markets, provision of subsidies on inputs (fertilizers, feed, fuel, mechanization, etc) and thus serve as disincentives for the use of on-farm products such as crop-residues, animal draught power and manure. These actions consequently contributed to the decline in mixed farming with subsequent negative environmental effects. Other policy pressures that have contributed to negative environmental impacts are exchange rates and import-export policies and inappropriate land tenure systems. Examples of these policies and where they were applied are summarized in Table 8.

Policy options that can mitigate negative impacts on crop-livestock integration include phasing out of subsidies on in-organic fertilizer and mechanization, improved land tenure for mixed farmers, improved extension to inform and motivate on crop-livestock integration, and stimulating non-farm rural employment. Phasing out subsidies will enhance the use of home grown feeds, organic fertilizer and animal traction. For the high densely populated areas the greater reliance of market forces should be accompanied by outside-sector employment promotion policies that will nourish market development for intensive crop and livestock production. For the other areas with intermediate density, focus should be on both infrastructure and markets.

6.2 Technology options

It is recognized that mixed farming systems in developing world are basically operating under negative nutrient balance and often requires some external inputs to move them to positive status. Nevertheless, some technologies easily adaptable to small to medium farm situations can be employed to basically control soil erosion, improve nutrient recycling and to improve efficiency of production of efficiency. Technologies that target the following improvement areas would be required (de Haan *et al.,* 2000):

Improvement of soil cover through the use of alternative crops for mulching, and introduction soil management techniques such as conservation tillage, bench terracing, strip cropping, contour farming, etc.;

Improvement of feed production and quality to reduce the pressure on grazing areas and improve internal nutrient transfers. Technologies to do so include:

a) introduction of fodder shrubs and trees to reduce soil erosion and improve soil fertility. Several mixed farming systems suing fodder shrubs and trees have been developed. An example is the agro-forestry system with three strata (grass, fodder shrubs, and tree crops, such as introduced in Indonesia (Devendra, 1994);

b) improvement in feed quality for example through urea treatment of feeds, as reportedly successfully used now by more than 5 million farmers in China (La Bragen, pers.com.) and through increased efforts in plant breeding to correct the grain bias of the green revolution "dwarf" varieties and raise nutrient quality of the crop residues; and

Reduction of nutrient losses from manure and improved efficiency of their application by:

a) promotion of stall feeding which doubles the effective availability of nitrogen and phosphorus; and

b) strategic supplementation for specific classes of animals (lactating animals) to improve the efficiency of limited amounts of available feed.

*Increased production efficiency***,** and thereby farm income, resulting in improved purchasing power for soil improvement and conservation methods. They include:

a) within breed improvement;

b) where appropriate, changing to small ruminant production or to optimal combination of ruminant and non-ruminant species; and

c) strategic supplementation of lactating and growing animals.

d) Disease control through improved prevention of diseases through artificially induced population immunity, improved prevention through genetic resistance, improved therapy of diseases, improved understanding epidemiology and economics, and improved delivery and adoption of disease control technologies.

Acknowledgements

I am grateful to Niyi Adediran of the International Trypanotolerance Centre, Banjul, for the sourcing some of the literature used for this paper. The superb secretarial support of Ms Florence Muthigani is greatly appreciated. The assistance of Wanjiku Kagira-Kargbo is also acknowledged.

Selected Reading I

Aarts, H.F.M. (1996). Efficient Nutrient Management in Dairy Farming on Sandy Soils. Report "De Marke" no 18, AB-DLO Report 67, Wageningen, The Netherlands.
Ababa, Ethiopia. 206 pp.

Abassa, K.P. (1995). " Improving food security in Africa; the ignored contributions of livestock". Joint ECA/FAO Agriculture Division. Addis Ababa, UNECA/FAO. 48 pp.

Aboagye, G.S., Ahunu, B.K. and Awumbilla, B. (1999). "On-farm survey of cattle and small ruminants of Ghana: Testing of population gathering methodology and characterization of the production systems". Draft Research Report. International Livestock Research (ILRI), Animal Genetic Resources Group, Addis Ababa, Ethiopia. 79pp.

Adepetu, J.A., Obi, A.O. and Aduayi, E.A. (1979) Changes in soil fertility under continuous cultivation and fertilization in south western Nigeria. Nigerian Journal *of* Agricultural Science 1, 15-20.

Agyemang, K. (2000a). " Towards sustainable food security in Africa: Contribution from an ignored source – Livestock Agriculture". A discussion Paper; Adventist Development and Relief Agency. Food Forum Workshop 16-19 October, 2000. Washington DC. USA

Agyemang, K. (2000b). "A background review paper for the proposed GEF/UNDP Project: In-situ conservation of endemic livestock in West Africa". A final report to the International Livestock Research Institute. 105 pp.

Agyemang, K. and Smith, J.W. 1999. Counting the costs and benefits of implementing multi-country research projects: The case of the peri-urban Inland Valley Dairy Project in West Africa. In: (O.B. Smith; ed.). Urban Agriculture in West Africa. Contributing to food security and Urban Sanitation. p. 169-183.

Agyemang, K., Abiye Astatke, Anderson, F. M. and Woldeab W/Mariam. (1991) A study on the effects of work on reproductive and productive performance of crossbred dairy cows in the Ethiopian highlands. *Tropical Animal Health and Production,* 23: 241-249.

Agyemang, K., Ouologuem, B., Yapi-Gnaore, Barje, P.P. and Adediran, S.A. 1999. Small.........

Agyemang, K.**,** Sonko, E., Badjie, B., Saho, E., Ceesay, M., Touray, M. and Corr, N. 1989. A preliminary Survey on socio-economic aspects of cattle herd ownership and management and of milk disposal and utilisation patterns in four villages: EEC Project Working Document No. 4. International Trypanotolerance Centre, Banjul, The Gambia.

Akinbamijo, o.O., Fall, S.T. and Smith, O.B. (2002). Advances in crop-livestock integration in West Africa Cities. ITC, Banjul, The Gambia, ISRA, Senegal, IDRC/CRDI Ottawa, Canada. pp213

Armour, **C., Duff, D. and Elmore, W. (1994). The Effects of Livestock Grazing on Western Riparian and Streams Eco-systems. Am. Fisheries Soc. 19 (9): 9-12.**

Audru, J. (1995). Elevages sur parcours en zones tropicales humides and sub-humides dAfrique. CIRAD-EMVT, Montpellier.

Baker, L. (1994) Genetic resistance to gastro-intestinal parasitism in small ruminants. ILCA Annual Programme Report, 1993. ILCA, Addis Ababa, pp 106-109.

Baldwin, **R.L.,Donovan, K.C. and Becket, J.L. (1992). California Animal Nutrition Conference, May 1992, University of California, Davis, CA.**

Barnes, **D., Forster, C.F. and Hrudey, S.E. (1984). Surveys in Industrial Wastewater Treatment: Food and Allied Industries. Pittman Publishing Limited, London, U.K.**

Bationo, A. and Mokwunye, A.U. (1991) Role of manures and crop residue in alleviating soil fertility constraints to crop production: with special reference to the Sahelian and Sudanian zones of West Africa. In: Mokwunye, A.U. (ed.), Alleviating Soil Fertility Constraints to Increased Crop Production in West Africa. Kluwer Academic Publishers, Dordrecht, pp 217-225.

Bauer, S., Steinbach, J., Willeke-Wetstein, C., Abresch, J.-P. and Schmidt, A. (1995). Review and Development of Environmental Impact Assessment (EIA) Tools for Livestock Production Systems. FAO/GTZ Consultancy Report, University of Giessen, Germany.

Behnke, R.H. andKerven, C. (1994). Redesigning for Risk:Tracking and Buffering Environmental Variability in Africas Rangelands. Natural Resource Perspectives, Number 1. ODI, London, U.K.

Behnke, R.H., Scoones, I. and Kerven, C. (1993). Range Ecology in Disequilibrium. Overseas Development Institute/International Institute for Environment and Development Commonwealth Secretariat, London, U.K.

Blackburn, H.D. (1995). Comparison of Performance of Boer and Spanish Goats in two U.S. Locations. Journal of Animal Science 73:302-09.

Blackburn, W.H., Knight, R.W. and Wood, M.K. (1982). Impact of Grazing on Watersheds; a state of knowledge. Tex. Agr. Exp. Sta MP 1496. 32 pp.

Bojo, J. (1996).The Economics of Wildlife:Case Studies from Ghana, Kenya, Namibia and Zimbabwe. AFTES Working Paper No. 19. World Bank, Washington D.C.

Bojo, J. and Casells, D. (1995). Land Degradation and Rehabilitation in Ethiopia; a reassessment. AFTES Working Paper 17. World Bank, Washington D.C.

Bonny, S. (1993). Is Agriculture using more and more Energy? A French case study. Agricultural Systems, 43, 51-66.

Bos, J.F.F.P. and de Wit, J. (1996). Environmental Impact Assessment of Landless Monogastric Livestock Production Systems. In: Livestock and the Environment: Finding a Balance. FAO/World Bank/USAID. Rome.

Boserup, E. (1981) Population and Technological Change: A Study in Long-term Trends. University of Chicago Press, Chicago.

Bourn, D., Milligan, K. and Wint, W. (1986). “Tsetse, Trypanosomiasis and Cattle in a Changing Environment. Livestock Systems Research in Nigeria’s Subhumid Zone”. Proceedings of the Second ILCA/NAPRI Symposium held in Kaduna, Nigeria. 29 October – 2 November 1984, ILCA, Addis Ababa.

Bourn, D., Wint, W., Blench, R. and Woolley, E. (1994). “Nigerian Livestock Resources Survey”. *World Animal Review* 78: 49-59.

Bourne, D. and Wint, W. (1994). Livestock, Land use and Agricultural Intensification in Sub-Saharan Africa. Pastoral Development Network (paper 37a). ODI, London, U.K.

Bouwman, A.F. (1995). Compilation of a Global Inventory of Nitrous Oxide. PhD Thesis, Wageningen International University. Wageningen, The Netherlands.

Bouwman, A.F., Batjes, N.H. (ed.) and Bridges, E.M. (1992). Methodology and data used to estimate natural N2O emissions. Paper presented at World inventory of soil emissions potentials: proceedings of an international workshop, 24-27 August 1992, Wise Report 2, Wageningen, the Netherlands.

Brand, R.A. and Melman, A.G. (1993). Energie inhoudnormen van de veehouderij; deel 2 proceskaarten. (Energy values of inputs of animal husbandry). TNO, Instituut voor milieu- en energietechnologie, Apeldoorn, The Netherlands.

Brandjes, P., de Wit, J., van Keulen, H. and van de Meer H.B. (1995). Environmental Impact of Manure management. Impact domain study for the FAO/WB Study on Livestock and the Environment, Final draft, International Agricultural Centre, Wageningen, The Netherlands.

Breman, H., and de Wit, C.T. (1983). Rangeland Productivity in the Sahel. Science, 221 (4618): 1341-47.

British Society of Animal Science-Kenya Agricultural Research Institute

Brown, K., Pearce, D., Chewings, V.H. and Swanson, T. (1993). Economics and the Conservation of Global Biological Diversity. Working Paper # 2 GEF, Washington D.C.

Bruenig, J. (1991). Tropical Forest Report. Government of the Federal Republic. Bonn, Germany, 118 pp.

Brumby, P. J. 1986. International Livestock Centre for Africa. Objectives, Activities and Future. ILCA, Addis Ababa, Ethiopia.

Brumby, P. J. 1986. International Livestock Centre for Africa. Objectives, Activities and Future. ILCA, Addis Ababa, Ethiopia.

Budd, L.T. (1999). *DFID-funded tsetse and trypanosomosis research and development since 1980:* Vol. 2. Economic Analysis Dept for International Development. UK. 123pp

Bureau of Land Management. (1994). Noxious Weed Action Plan for the Bureau of Land Management Fiscal 1995 and beyond. 29 pp. Government Printing Office, Washington D.C.

Burton, B.T. 1980. *Human Nutrition.* Third Edition. Tata McGraw-Hill Publishing

bution of livestock as we enter the new millennium. Paper presented at the

Carrera, M. and Toutain, B. (1996). Impact de lElevage sur les terres de parcours. Working Document, Livestock Environment Study, CIRAD-EMVT, Montpellier, France.

CAST (Council for Agricultural Science and Technology). 1999. *Animal Agriculture*

Ceasar, **J. (1992). La Production biologique des Savanes de Côte dIvoire et son utilization par lhomme. Maissons Alforts CIRAD-EMVT.**

Challenges, opportunities and targets for animal production.

Chartier, P. (1996). La relance du secteur elevage dans les pays de la zone Franc après la dévaluation. Rapport détude. Ministère de la Coopération, Paris.

Chiumenti, R., da Borso, F. and Donanton L. (1994). Dust and Ammonia Reduction in Exhaust Air from Piggeries Using a Mechanical Wet Separation System. In: Proceeding of 7th Technical Consultation of the European Cooperative Research Network on Animal Waste Utilization, Bad Zwischenahn, Germany, 17-20 May 1994.

Christiaensen, L., Tollens, E. and Ezedinma, C. (1995). Development Patterns under Population Pressure: Agricultural development and the cassava-livestock interaction in smallholder farming systems in sub-Saharan Africa. Agricultural Systems 48:51-72.

CIAT (1994). Annual Report (1993). Centro International de la Agricultura International. Cali, Colombia.

Claxton, J. and Leperre, P. (1991). "Parasite Burdens and Host Susceptibility of Zebu and N'Dama Cattle in Village Herds in Gambia". *Veterinary Parasitology* 40: 293-304.

Cleaver, K. and Schreiber, G. (1994). The Population, Agriculture and Environment Nexus in Sub-Saharan Africa, (Revised). Agriculture and Rural Development Series No. 9. Technical Department Africa Region. World Bank. Washington D.C.

Conway, G.R. and Pretty, J.N. (1991). Unwelcome Harvest - Agriculture and Pollution. Earthscan Publications Ltd. London.

Coppock, D. Layne. (1996). Dynamics of Semi-Arid Pastoral System under Induced Change in Southern Ethiopia. In: Proceedings of the Fifth International Rangeland Congress. Society for Range Management, Denver, Colorado.

Cornell, R. L. and Evans, S. A. 1937 . On the value and limitations of tissue vaccines against rinderpest. Journal of Comparative Pathology 50: 122-135.

Council on Agriculture Science and Technology (CAST) (1996). Grazing on public lands. Ames, Iowa. pp.70.

crop-livestock systems in sub-Saharan Africa: an option or an imperative?
cultivation of rice and maize: a comparison. *J. Agric. Sci. (Cambridge),*

Cunningham, E.P. (1992). Selected Issues in Livestock Industry Development, EDI Technical Materials. World Bank, Washington D.C.

Cunningham, E.P. (1995). Global Impact Domain - Animal Genetic Resources. Consultancy Report on Livestock and the Environment.

Dawson, J. and Barwell, I. 1993. Roads Are Not Enough: New Perspectives on Rural

De Haan C. (1995). Development support and Livestock services In: Livestock Development Strategies for Low Income countries Ed: R.T. Wilson, S. Ehui and S. Mack. FAO Rome, Italy and ILRI, Nairobi, Kenya. Pp23-27

de Haan, C. (1988). "Research Requirements for Livestock Development in Tsetse – Affected Areas". In: *Livestock Production in Tsetse Affected Areas of Africa.* Proceedings of a meeting held in Nairobi, Kenya from the 23rd to 27th November 1987. ILCA/ILRAD, 1988. pp. 459 – 465.

De Haan, C. (1996). Rangeland Development in a Developing World. In: Proceedings of the Fifth International Rangeland Congress. Society for Range Management, Denver, Colorado.

De Haan, L. and Nissen, J. L. (1985) Animal Health Services in SubSaharan Africa: Alternative Approaches. World Bank, Washington DC.

De Leeuw, P. N. and Reid, R.. 1995. Impact of human activities and livestock on the

De Ridder, N. and Wagenaar, K.T. (1984). A Comparison between the Productivity of Traditional Livestock Systems and Ranching in Eastern Botswana. ILCA Newletter 3(3):5-7. International Livestock Centre for Africa, Addis Ababa.

De Vries, C. (1996). Lessons Learned in the Regulation of Nutrient Management in Europe. Babcock Institute Technical Workshop: Nutrient Management, Manure and the Dairy Industry.

De Wit J., Westra, P.T. and Nell, A.J. (1996). Environmental Assessment of Landless Ruminant Production Systems. Working Document Livestock and the Environment: Finding a Balance. FAO/World Bank/USAID. Rome.

.

Debrah, S. and Sissoko, K. 1990. Sources and Transfers of Cash Income in the Rural Economy: the Case of Smallholder Mixed Farmers in the Semi-arid Zone of Mali. African Livestock Policy Analysis Network Paper No. 25, International Livestock Centre for Africa, Addis Ababa, Ethiopia.

Delgado, C., Courbois, C. and Rosegrant, M., 1998. Global food demand and the contri-

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S. and Coubois, C. (1999). *Livestock to 2020: The Next Food Revolution.* Food, Agriculture and the Environment. Discussion paper 28. IFPRI, Washington, D.C.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S. and Courbois, C. 1999. Livestock to
Developing Countries. World Bank, Washington D.C.
Development, Morrilton, Arkansas.

Devendra, C. (1994). Mixed Farming Systems in Asia. Consultants Report. FAO.

Devendra, C. (1995) Mixed farming and intensification of animal production systems in Asia. In: Livestock Development Strategies in Low income countries

Diate, A. (1984). Country Report- Senegal. Presented at the first meeting to coordinate the activities in West Africa for the Programme for the Control of African Animal Trypanosomiasis and Related Development held in Bobo-Dioulasso. FAO, Ougadougou, Burkina Faso.

d'Ieteren, G.D.M. (1994) Trypanotolerant livestock, a sustainable option for increasing livestock production in tsetse affected areas. In: Rowland G.J. and Teale, A.J. (eds), Towards Increased Use *of* Trypanotolerance: Current Research and Future Directions. Proceedings of a workshop, ILRAD and ILCA, Nairobi, Kenya, April 26-29, 1993, pp. 3-11.

Doùtressoulle, G. 1947. L'èlévage en Afrique Occidentale Française. Larose, Paris, 298 pp. Cited in Rege *et al.* 1994.

Dregne H., Kassas M. and Rozanov, B. (1991). Status of Desertification and Implementation of the United Nations Plan to combat Desertification. Desertification Control Bulletin 20, 6.

Dreze, J. and Sen, A., 1989. *Hunger and public action.* Oxford, Clarendon Press.

Eckert J.B., Baker, B.B. and Hanson, J.D. (1995). The Impact of Global Warming on Local Incomes from Range Livestock Systems Agricultural Systems 48: 87-100.

Economics, Univ. of New England, Armidale, Australia.

Edelman, M. (1992). The Logic of the Latifundio: the large estates of northwestern Costa Rica since the late nineteenth century. Stanford University Press. 478 p. Stanford, California.

El-Swaify, S.A. (1991). Land-based Limitations and Threats to World Food Production. Outlook on Agriculture, 20 (4), p. 235-242.

Engelbrecht, W. and van der Walt, P. (1993). Notes on the Economic Use of the Kruger National Park Koedoe 36 (2) 113-119.

English, J., Tiffen, M. and Mortimore, M. (1993). Land Resource Management in the Machakos District, Kenya 1930-1990. World bank Environment Paper 5. Washington D.C.

Epstein,H. (1971). *The Origin of Domesticated Animals of Africa.* Vol. 1. New York, NY, USA. Pub. Africana

Experimental Agriculture, 22:15-24.

FAO (1986). African Agriculture: The Next 25 Years. Annex 11. The Land Resource Base. ARC/86/3. FAO, Rome.

FAO (1990). The Technology of Traditional Milk Products in Developing Countries. FAO Animal Production and Health Paper No. 85. Rome.

FAO (1992) The role of ruminant livestock in food security in developing countries. FAO Committee on World Food Security, 17th Session, 23-27 March 1992, Rome, 33pp.

FAO (Food and Agriculture Organization of United Nations), 1997. FAOSTAT database.

FAO/UNEP(1984). Provisional methodology for assessment and mapping of desertification. FAO. Rome.

Ferguson, W. (1967). "Muturu Cattle of Western Nigeria: II. Survivability, Reproductive and Growth Performance in Areas of Light Glossina Palpalis Density". *J. West African Sa. Ass.* 12:37-44.

Fernandez- Rivera, S., Williams, T. O. Hiernauz, P. and Powell, J. M. (1995). " Faecal Excretion by *Ruminants, and Manure Availability for Crop Production in Semi-Arid West Africa*". In: (Eds). J. M. Powell, S. Fernandez – Rivera, T. O. Williams and C. Renard. Livestock Sustainable Nutrient Cycling in Mixed Farming Systems of Sub-Saharan Africa. Volume II. Technical Papers. ILCA, Addis Ababa, Ethiopia. Pp. 568.

Fisher, M., Rao, I.M., Ayarza, M.A., Lascano, C.E. and Sanz, J.I. (1995). Carbon Storage by Introduced Deep-rooted Grasses in the South American Savannas. Science September 15 1995.

Francis, P. A. 1988. Ox draught power and agricultural formation in Northern Zambia.

G. M. 1999. Alternative food-security indicators: revisiting the frequency and

Gardner, B.L. and Rausser, G.C. Handbook for Agricultural Economics, Elsevier,

Geerts, S. and Holmes, P. H. (1998). " Drug management and parasite resistance in bovine trypanosomiasis in Africa". *PAAT Technical and Scientific Series No. 1.* FAO, Rome, Italy, pp 31.

General Accounting Office (1988). Rangeland Management: More emphasis needed on declining and overstocked grazing allotments. GAO, Washington D.C.

Gifford, R.C. (1992) Agricultural engineering in development: Mechanization strategy formulation. Vol.l. Concepts and principles. FAO Agricultural Bulletin 99/1 FAO, Rome, 74pp.

Gilmanov, T.G. (1996). The State of Rangeland Resources in the Newly Independent States of Former USSR. Fifth International Rangeland Congress, Society for Range Management, Denver Colorado.

Gollin, D. (1991) Status, Trends, and Directions *of* Animal Agriculture in Sub-Saharan Africa. Winrock International, Morilton, Arkansas.

Goodland, R. (1996). Environmental Sustainability and Eating Better. The Case against Grain-Fed Meat. Mimeograph, Arlington.

Grashuis, J. and van Vliet, N. (1958). Doelmatige Varkensvoeding Hoogland, The Netherlands.

Grootenhuis, J.G., Njuguna, S.G. and Kat, P.W. (Eds) (1991). Wildlife Research for Sustainable Development: Proceedings of an International Conference held by the Kenya Agricultural Institute. Nairobi.

Gryseels, G., Astatke, A., Anderson, F. M. and Assemanew, G. 1984. The use of single

Gryseels, G. 1988. The role of livestock in the generation of smallholder farm income

Habib, G., Basit Ali Shah, S., Wahidullah, Jabbar, G., Ghufranullah (1991). Importance of Urea Molasses Blocks on Animal Production (Pakistan), International Atomic Energy Agency, International Symposium on Nuclear and Related Techniques in Animal Production and Health, Vienna, Austria, 15-19 April 1991.

Haddad, L. 1997. Overview. . In : Achieving food security in Southern Africa.

Hammond, K. and Leitch, H.W. (in press). The FAO Global Program for Management of Farm Animal Genetic Resources. Journal of Animal Science.

Hanson, L.B. (1995). Breeding Schemes. In: Proceedings of the National Dairy Genetics Workshop. Orlando: American Dairy Science Association.

Hayami, Y. and Ruttan, V.W. (1985). Agricultural Development; An international perspective. Baltimore, The John Hopkins University Press. Revised Edition.

Hecht, S.B. (1992). Logics of Livestock and Deforestation: The case of Amazonia. In: Development or Destruction, The Conversion of Tropical Forest to Pasture in Latin America, Bolder: Westview Press. 7-25.

Heij, G.J. (ed.) (1995). Additioneel Programma Verzurings Onderzoek. Eind rapport derde phase. Rijks Instituut voor Volksgezondheid en Milieu (RIVM). Bilthoven.

Hemingway, R.W. and Karchey, J.J. (1989). Chemistry and Significance of Condensed Tannins. Plenum Press. New York.

Hendratno, C., Nolan, J.V. and Leng, R.A. (1991). Importance of Urea Molasses Multinutrient Blocks for Ruminant Production in Indonesia. International Atomic Energy Agency, International Symposium on Nuclear and Related Techniques in Animal Production and Health, Vienna, Austria, 15-19 April (1991).

Hendy, C.R.C., Kleih, U., Crawshaw, R., and Phillips, M. (1995). Interactions between Livestock Production Systems and the Environment: Impact Domain: Concentrate Feed Demand. FAO Consultancy Report for Livestock and Environment Study.

Henglian, X. (1995). The Production of Rural family Biogas in China. In: Proceedings of the Workshop of Peri-Urban Livestock Wastes in China, Beijing, China. FAO, Rome.

Hiernaux, P. 1996. The Crisis of Sahelian Pastoralism: Ecological or Economic?.

Higham, R. (1991). Leather Industry, Case Study No. 3. Conference on Ecologically Sustainable Industrial Development. United Nations Industrial Development Organization (UNIDO). Geneva.

Holling, C.S. (1995). Sustainability: The Cross-scale Dimension. In: M. Munasinghe and W. Shearer (eds). Defining and Measuring Sustainability, The Biogeophysical Foundations. The International Bank for Reconstruction and Development/World Bank, Washington D.C. Ch 4 pg 65-76.

Hoste, C. H., Chalon, E., D'Ieteren, G. and Trail, J. C. M. (1992). *Trypanotolerant Livestock in West and Central Africa. Volume 3 – A Decade's Results.* ILCA monograph 2. International Livestock Centre for Africa, Addis Ababa, Ethiopia 206 pp.

Houghton, R.A. (1991). Tropical Deforestation and Atmospheric CO2 Climate Change 19 (1-2) 99-118.

http//faostat.fao.org/default.htm. Accessesd September and December, 1997.

IAR (Institute of Agricultural Research) (1974) Report to the Board *of* Governors, 1973-1974. Samaru, Zaria.

IFAD (1995). Common Property Resources and the Rural Poor in Sub-Saharan Africa. Rome.

IFPRI (1995). Global Food Projections to 2020. Implications for Investment. Food, Agriculture and Environment Discussion Paper 5 International Food Policy Research Institute, Washington D.C.

IIED (1994). RRANotes, Number 20. IIED, London.

ILCA (1979b). *Trypanotolerant Livestock in West and Central Africa. Volume 2. Country Studies*. ILCA Monograph 2. International Livestock Centre for Africa, Addis Ababa. pp 303.

ILCA (1979a). *Trypanotolerant Livestock in West and Central Africa. Volume 1. General Study*. ILCA Monograph 2. International Livestock Centre for Africa, Addis Ababa. pp. 147.

ILCA (International Livestock Centre for Africa), 1992. ILCA 1991 Annual Report and

ILCA(International Livestock Centre for Africa) (1994). Improving Livestock Production in Africa:Evolution of ILCAs programme 1974-94. ILCA, Addis Ababa, Ethiopia.

ILRI (1996) Back to local breeds for more food. Livestock Research for Development (ILRI newsletter) 2(1), 5-6.

IPPC (Intergovernmental Panel on Climate Change). (1990). Climate Change:The IPPCResponse Strategies. World Meteorological Organization. United Nations Environment Programme, Geneva.

Ismail, T. and Thai, C.D. (1990). Report of the Small Ruminant Collaborative Research Support Project (SR-CRSP) Indonesia Workshop. US Agency for International Development, Washington D.C.

J.W. Copland (ed.). Draught Animal Power for Production. ACIAR

Jabbar, M. A. 1995. Market niches for increased small ruminant production in Southern

Jabbar, M.A. (1993). "Evoling crop-livestock farming systems in the human zone of West Africa. Potentials and research needs". *Outlook on Agriculture* 22: 13-21.

Jahnke, H.E. (1982) Livestock Production Systems and Livestock Development in Tropical Africa. Kielers Wissechoftoverlag Vank, Kiel.

Jahnke, H.E., Tacher, G., Keil, P. and Rojat, D. (1988). "Livestock Production in tropical Africa, with special reference to the tsetse affected zone". In: *Livestock Production in tsetse affected areas of Africa.* ILCA/ILRAD Nairobi, Kenya.

Jansen, J.C.M. and de Wit, J. (1996). Environmental impact assessment of livestock production in mixed irrigated systems in the (sub) humid zones. Consultancy Report. International Agriculture Centre, Wageningen, The Netherlands.

Jodha, N.S. (1992). Common property resources, A Missing Dimension in Development Strategies. World Bank Discussion Paper 169. Washington D.C.

Johansen, K. (1995). Anaerobic Digestion of Combined Waste. In: Proceedings of the Workshop of Peri-Urban Livestock Wastes in China. Beijing. FAO, Rome.

Jones, J.R. (1990). Colonization and Environment, Land settlement projects in Central America. Tokyo. United Nations University Press.

Jongbloed, A.W. and Lenis, N.P. (1992). Excretion of Nitrogen and Some Minerals of Livestock in Nitrogen Flow. In: Pig Production and Environmental Consequences, Wageningen, The Netherlands. EAAP, Publication no. 69.

Jordan, A. M. (1979). " Trypanosomiasis Control and Land Use in Africa". *Outlook on Agriculture*. 10: 123-129.

Jordan, A. M.(1988). "The role of tsetse in African animal trypanosomiasis". In: *Livestock Production in Tsetse Affected Areas of Africa.* Proceedings of a meeting held in

Nairobi, Kenya from the 23rd to 27th November 1987. ILCA/ILRAD, 1988. pp. 37-42.

Jordan, A.M. (986). *Trypasomosiasis control and African rural development.* Longman, London, 357 pp

Jutzi, I. Haque, J. McIntire and J.E.S. Stares. Management of vertisols in

Kaasschieter, G.A. (1991). Slachterij projecten in ontwikkelingslanden, ervaringen en richtlijnen. Directorate General International Cooperation, The Hague, The Netherlands.

Kaimonitz, D. (1995). Livestock and Deforestation in Central America. EPTD Discussion Paper no 9. IFPRI Washington D.C. and IICA Coronado, Costa Rica.

Kamuanga, M., Tano, K. and d'Ieteren, G. (1999). "Farmers' Preferences of Cattle Breeds, Their Market Values and Prospects for Improvement in West Africa: A Summary Review". A Paper Presented at the 25th Meeting of the International Scientific Council on Trypanosomiasis Research and Control (ISCTRC), September 27-October 2, 1999, Mombasa, Kenya.

Kang, B.T. (1993) Changes in soil chemical properties and crop performance with continuous cropping on an Entisol in the humid tropics. In: Mulongoy, K. and Merekx, R. (eds), Proceedings *of* an International Symposium on Soil Organic Matter Dynamics and Sustainability *of* Tropical Agriculture. John Wiley, Chichester, pp 297-305.

Kang, B.T. and Balasubramanian;-V (1990) Long-term fertilizer trials on Alfisols in West Africa. In Transactions *of* XIV International Soil Science Society Congress, Kyoto, Japan, Vol. 4. ISSS, Kyoto,

Kay, C.E. and Walker, J.W. (In press 1997). A Comparison of Sheep and Wildlife grazed Willow Communities in the Greater Yellowstone Ecosystem. SID Sheep Research Journal.

Kesseba, A.M. (1995) Strategies for sustainable agriculture in subSaharan Africa: some issues and options. Alley Farming Research and Development: Proceedings *of* the International Conference on Alley Farming, Ibadan, 14-18 September, 1992. Alley Farming Network for Tropical Africa in collaboration with the International Institute of Tropical Agriculture, the International Centre for Research on Agroforestry and the International Livestock Research Institute. IITA, Ibadan.

King, M.K. (1983). Livestock and Water Needs in Pastoral Africa in Relation to Water and Forage ILCA Research Report 7:94 pp. Addis Ababa, Ethiopia.

Kiss, A. (1990). Living with Wildlife. World Bank Technical Paper Number 130, Washington D.C.

Kitazawa, Y. and Kitazawa, T. (1980). Influence of Application of a Fungicide, an insecticide, and Compost upon Soil Biotic Community. In:Soil Biology as Related to Land Use Practices. D.L. Dinal (ed.). Environmental Protection Agency. Washington D.C.

Kjekshus, H. (1977). Ecology Control and Economic Development in East African History. University of California Press, Berkeley and Los Angeles, CA pp 215.

Knudsen, O. and Nash, J.D. (1990). Redefining the Role of Government for the 1990s. World Bank Discussion Paper 105, Washington D.C.

Kristjanson, P.M; Swallow, B.M; Rowlanda, G.J; Kruska, R.L. and de Leeuw, P.N. (1999). "Measuring the costs of African andimal trypanosomosis, the potential bendits on control and returns to research" *Agricultural systems* 59:79-98

Kyoto, Japan, December 4-9.

lactation of F1 crossbred cows. In: (Eds.) P. Starkey, E. Mwenya and J. Stares.

Larson, G.A., Roloff, G. and Larson, W.E. (1988). A New Approach to Marginal Agricultural Land Classification. Journal of Soil and Water Conservation. Vol. 40. No. 1. P. 103-106.

Lawrence, P. R., Dijkman, J. T. and Jansen, H.G.P. 1997. The introduction of animal

Le Houerou, H.N. (1989). The Shrublands of Africa. In: "The biology and utilization of shrubs". Academic Press: 119-143.

Ledec, G. (1992). The Role of Bank Credit for Cattle Raising in Financing Tropical Forestation. A case study of Panama. Ph.D. Thesis, University of California, Berkeley.

Leijen, C., Beukeboom, J. and Venneboer, H. Jansen. (1993). Energie in de intensieve veehouderij. Informatie en Kennis Centrum Veehouderij, Ede, The Netherlands.

Leng, R.A. (1991). Improving Ruminant Production and Reducing Methane Emissions from Ruminants by Strategic Supplementation. U.S. Environmental Protection Agency, Washington, D.C. EPA/400/1-91/004.

Levin, S.A. (1995). Scale and Sustainability: A Population and community perspective. Ch 7 p 103-116.

Lhoste, P. (1986). "L'utilisation de L'energie Animale en Afrique Intertropicale" Report Presented at the "Méthodes de Recherches sur lar Systémes Délevage en Afrique Intertropicale" Workshop held in Mbour from 2-8 February 1986. ISRA, Dakar, Senegal.

Lhoste, P. 1986. L'utilisation de L'energie Animale en Afrique Intertropicale Report Presented at the "Méthodes de Recherches sur lar Systémes Délevage en Afrique Intertropicale" Workshop held in Mbour from 2-8 February 1986. ISRA, Dakar, Senegal.

Mabbutt, J.A. (1985). Desertification of the Worlds Rangelands. Desertification Control Bulletin 12: 1-11.

Mabbutt, J.A. and Floret, C. (1980). Case Studies in Desertification. UNESCO 279 pp.

Mainguet, M., Guyot, L., Chemin, M.-C. and Braunstein, A. (1992). Modifications to the Sahelian and Sudanian ecosystems in Western Mali. In: Dregne, H.E. (1992). Degradation and Restoration of Arid Lands. Texas.

Maldidier, C. (1993). Tendencias actuales de la frontera agricola en Nicaragua. Managua. Nitlapan-UCA.

Manale, A.P. (1991). European Community Programmes to Control Nitrate Emissions from Agricultural Activities: An Evaluation of Their State of Implementation and Effectiveness. Washington D.C. Environmental Protection Agency.

Mason, L. L. 1951. Classification of West African Livestock. Tech. Comm. No. 7. Edinburgh. U. K. Commonwealth Bureau of Animal Breeding and Genetics.

Mattioli, R. C., Pandey, V. s., Murray, M. and Fitzpatrick, J. C. (2000)." Immunogenetic influences on tick resistances in African cattle with particular reference to trypanotolerant N'Dama (*Bos taurus*) and trypanosusceptible Gobra Zebu (*Bos indicus*) cattle. *Acta Tropica* 75: 263-272..

Mattioli, R. C., Bah, M., Faye, J., Kora, S. and Casama, M. (1993). A Comparison of field tick Infestation on N'Dama, Zebu and N'Dama X Zebu Crossbred Cattle. *Veterinary Parasitology_* 47: 139-148.

Mattioli, R. C., Faye, J. A. Bah, M. and Jabang, B. (1994). "Experimental Trypanosoma Congolense infection on naturally occurring ticks in N'Dama and Gobra Zebu Cattle". *Parassitologia* 36: 305-311.

Mattioli, R.C., Cassama, M. and Kora, S. (1992). "A comparative study of gastro intestinal nematode egg output in N'Dama, Zebu and N'Dama x Zebu crossbred cattle". *Parastitologia* 34: 109 – 113

Maxwell, D., Ahiadeke, C., Levi, C., Arma-Klemesu, M., Zakariah, S. and Lamptey,

Mayeux, H.S., Johnson, H.B. and Polley, H.W. (1993). Global Change and Vegetation Dynamics. Chap 7. In: James, L.F., Evans, J.O., Ralphs, M.H. and Childs, R.D. (ed.) Noxious Range Weeds. Westview Press, Boulder CO. p.p. 62-74.

McIntire, J. (1988). "Introduction to econmic analysis in the African Trypanotolerant Livestock" Network. In: *Livestock Production in tsetse affected areas of Africa.* Proceedings of a Meeting held 23-27 Nov. 1987, Nairobi, Kenya. ILCA/ILRAD 1988.

McIntire, J. Bourzat, D. and O. Pingalli, (1992). *Crop-Livestock Interactions in Sub-Saharan Africa,* World Bank, Washington, DC

McIntire, J., Bourzat, D. and Pingali, O. (1992) Crop-livestock Interactions in Sub-Saharan Africa. World Bank, Washington DC.

McIntire, J., Bourzat, D. and Pingali, P. (1992). Crop-livestock interaction in sub-Saharan Africa. World Bank, Washington D.C. pp 246.

McIntire, J., Bouzart, D. and Pingali, P. 1992. *Crop-Livestock Interactions in Sub-*

McNeely, J.A., Miller, K.R., Reid, W.V., Mittermeier, R.A. and Werner, T.B. (1990). Conserving the Worlds Biological Diversity. IUCN, WRI, CI, WWF-US, World Bank. Gland, Switzerland and Washington D.C.

Mearns, R. (1996). When Livestock are Good for the Environment: Benefit-sharing of environmental goods and services. Invited paper for the World Bank/FAO Workshop, "Balancing Livestock and the Environment". Washington, D.C., an associated event to the Fourth World Bank Conference on Environmentally Sustainable Development.

Meghen, C., MacHugh, D.E. and Bradley, D. G. 1994. Genetic Characterisation and West African Cattle. World Animal Review, 78: 59-67.

Menault, J.C. (1993).Effets des feux de savanes sur le stockage et lemission du carbone et des elements-trace. Secheresse, 4: 251-63.

Milchunas, D.G. and Lauenroth, W.K. (1993). Quantitative Effects of Grazing on Vegetation and Soils over a Global Range on Environments Ecological Monograph 63 (4) 327-66.

Mohamed-Saleem, M.A., Suleiman, H. and Otsyina, R.M. (1986) Fodder banks: for pastoralists or farmers. In: Haque, I., Jutzi, S. and Neate PJ.H. (eds), Potentials *of* Forage Legumes in Farming Systems *of* Sub-Saharan Africa. Proceedings of Workshop, ILCA, Addis Ababa, Ethiopia, 16-19 September 1985, pp. 212-231.

Mohammed, TA. (1990) Peri-urban Cattle Agropastoralists in the Derived Savannahs of Oyo State, South West Nigeria. ILCA, Ibadan.

Mohammed-Saleem, M.A. (1995). Mixed farming systems in sub-Saharan Africa: In: Livestock Development Strategies for Low Income countries Ed: R.T. Wilson, S. Ehui and S. Mack. FAO Rome, Italy and ILRI, Nairobi, Kenya. Pp 93-100

Mortelmans, J. and Kageruka, P. (1976). "Trypanotolerant cattle breeds of Zaire". *World Animal Review* 19: 14-17.

Msellati, (1995). Rangeland Management in the North Africa and Iran, A World Bank sector Study, World Bank, Washington D.C.

Muller, P. (1985). The Environmental Impact of Tsetse control in the Adamaoua Plateau of Cameroon. Report to the World Bank University of Saarbrucken, Germany.

Muller, Z.O. (1980). Feed from Animal Wastes: State of knowledge. Animal Production and Health Paper No. 18. FAO. Rome.

Murray, M. (1988). "Trypanotolerance, its Criteria and Genetic and Environmental Influences". In**:** *Livestock Production in Tsetse Affected Areas of Africa.* Proceedings of a meeting held in Nairobi, Kenya from the 23rd to 27th November 1987. ILCA/ILRAD, 1988.

Murray, M. and Gray, A. R. (1984). "The Current Situation on Animal Trypanosomiasis in Africa". *Preventive Veterinary Medicine*, 2: 23-30.

Murray, M., Morrison, W. I. And Whitelaw, D. D. (1982). *Host Susceptibility to African Trypanosomiasis:Trypanotolerance.* pp. 1-68.

Murray, M., Stear, M. J., Trail, J. C. M., D'Ieferen, G. D. M., Agyemang, K. and Dwinger, R. H. (1991). "Trypanosomiasis in Cattle. Prospects for Control". In: J. B. Owen and R. F. E. Axford (eds), *Breeding for Disease Resistance in Farm Animals.* CAB International, Wallingford, UK. pp. 203-223.

Murray, M., Trail, J.C.M. and d'Ieteren, G.D.M. (1990) Trypanotolerance in cattle and prospects for the control of trypanosomiasis by selective breeding. Office International des Epizooties (OIE) scientific and technical review 9, 369-386.

Murray, M., Trail, J.C.M. and Grootenhuis, J.G. (1984) Trypanotolerant livestock: potential and future exploitation. Outlook on Agriculture 13, 43-51.

Mwangi, Z.J. and Zulberti, C.A. (1985). Optimization Wildlife and Livestock Production. Wildlife/Livestock Interfaces on Rangelands. Inter-African Bureau of Animal Resources, Nairobi.

Myers, N. (1981). The Hamburger Connection: How Central Americas Forests became North Americas Hamburgers. Ambio 10 (1):3-8.

Nagel, P. (1993). LIncidence de la lutte contre la Tse-tse sur les resources naturelles. Réunion sur les aspects techniques et de développement du programmes de la lutte contre la Trypanosomiase Tropicale. FAO, Rome 15 pp.

Nairobi, Kenya.

Narjisse, H. (1996). The Range Livestock Industry in Developing Countries: Current assessment and prospects. Fifth International Rangeland Congress, Society for Range Management, Denver, Colorado.

Narrod, C., Reynnells, R. and Wells, H. (1994). Potential Options for Poultry Waste Utilization: A focus on the Delmarva Peninsula. Washington D.C.: United States Department of Agriculture and the Environmental Protection Agency.

National Research Council (1989). Alternative Agriculture. National Academy Press. Washington D.C.

Nelson, R. (1990). Dryland Management, the "Desertification problem". World Bank Technical paper 116, World Bank, Washington D.C.

NEPAD (2002)

Nicholson, C. F., Rutherfold, A. S. Staal, S. J., Thorpe, W., Thornton, P. and Krouka, R. (1999). "The Impact of Income Growth and Urbanisation on Dairy Consumption in Developing Countries". (Draft) International Livestock Research Institute, Nairobi, Kenya.

Nigeria. Oxford Agrarian Studies 24.

Norton-Griffiths, M. and Southey, C. (1995). The Opportunity Costs of Biodiversity Conservation in Kenya. Ecological Economics 12: 125-139.

nutrition in Eastern and Southern African region. UNICEF-ESARO.

OECD (1996). Developing OECD Agri-Environmental Indicators. Mimeograph. July 30, 1996. Organization for Economic Cooperation and Development. Paris, France.

Okantah, S.A., Gyawu, P., Asante, Y., Oddoye, E.O.K., Obese, F.Y., Abudulai, M. and Mumuni, A. (1995). "Characterisation of peri-urban dairy production in Ghana". A.R.I., Achimota, Ghana.

Okike, I., (2000). Socio-economic implications of emerging urban food production systems In: Advances in crop-livestock integratin in West African cities. O.O. Akinbamijo, S.T. fall, O.B. Smith (eds) ITC, Banjul, The Gambia, ISRA, Senegal, IDRC/CRDI Ottawa, Canada

Oldeman, L.R., Hakkeling, R.T.A. and Sombroek, W.G. (1991). World Map of the Status of Human Induced Soil Degradation. An explanatory note. ISRIC/UNEP, Wageningen, The Netherlands.

Oliver, J. 1983. Beef Cattle in Zimbabwe. J. Agric. Res. 21: 1-17.

Omiti, J. 1995. *Economic analysis of crop-livestock integration: the case of*

Otchere, E. (1983). The productivity of White Fulani (Bunaji) cattle in pastoralists herds on the Kaduna Plains of Nigeria" . ILCA Programme Document, Kaduna Nigeria.

Ottichilo, W.K. (1996). Wildlife-Livestock Interactions in Kenya. Invited paper for the World Bank/FAO Workshop, "Balancing Livestock and the Environment", Washington D.C., an associated event to the Fourth World Bank Conference on Environmentally Sustainable Development.

Outlook on Agriculture, 26(4):237-246.

oxen for crop cultivation in Ethiopia. *ILCA Bulletin,* 18:20-25.

Oxford, UK.

p. 1-20.

Pastoral Development Network Paper 39a. Overseas Development Institute,

Payne, W. J. A. 1964. The Origin of Domestic Cattle in Africa. Empire J. Exp. Agric 32: 97-113.

Perry, B., McDermott, J. and Randolf, T. 2001. Can epidemiology and economics make a meaningful contribution to national animal disease control? Preventive veterinary Medicine 48: 231-260

Perry, b.D., Randolph, T.F., McDermott, Sones, K.R. and Thornton, P.K. (2002). Investing in animal health research to alleviate poverty. ILRI, Nairobi, Kenya. Pp148

Pingali, P, Bigot, Y and Binswanger, H.P (1987) Agricultural Mechanization and the Evolution of Farming Systems in Sub-Saharan Africa. World Bank, Washington DC.

Pinstrup-Andersen, P., Pandaya-Lorch, R. and Babu, S. 1997. A 2020 vision for food,

Powell, J. M. 1986. Manure for for cropping: A case study Central Nigeria.

Powell, J. M., Fernandez – Rivera and Hofs. S. (1994). "Effects of Sheep Diet on Nutrient Cycling in Mixed Farming Systems of West Africa". *Agriculture Ecosystems and Environment* 48: 263-271. pp. 125-134.

Powell, J.M. (1986) Manure for cropping: a case study from Central Nigeria. *Experimental Agriculture 22, 15-24.*

pp. 2025.

Proceedings No. 10.

Programme Highlights , Addis Ababa, Ethiopia.

Qusman Badiane, O. and Delgado, C.L. (eds) *(1995) A 2020 Vision for Food, Agriculture, and the Environment in Sub-Saharan Africa.* International Food Policy Research Institute, Washington DC.

Ramaswamy, N. S. 1985. Draught animal power----socio-economic factors. In:

Rege, J.E.O., Aboagye, G.S. and Tawah, C. L. (1994). "Shorthorn cattle of West and Central africa. I. Origin, Distribution , Classification and Population Statistics". *World Animal Review* 78:1-14.

research issues, and overview. In : Achieving food security in Southern Africa.

Results. ILCA Monograph 2. . International Livestock Centre for Africa, Addis

Reynolds. Small ruminant research and development in Africa. ILCA,

RIM (Resource Inventory and Management Limited) *(1992) Nigerian Livestock Resources.* RIM, Jardine House, 1 Wesley Street, St Helier, Jersey.

Ronan, T., L., MacHugh, D. E., Bradley D.G. and Sharp, P.M. 1994. Evidence for Two Independent Domestications of Cattle. Proc. Natl. Acad. Sci. USA. 91: 2757-2761.

Saharan Africa. Winrock International Institute for Agricultural

Saharan Africa. World Bank, Washington, D.C.

Sansoucy, R., Jabbar, M. A., Ehui, S. and Fitzhugh, H. 1995. Contribution of livestock

Schiere, J.B. and Wit, J. (1995). Livestock and farming systems research II. Development and classifications. Pp 39-61. In: J.B. Schiere, cattle, straw and systems control. Royal Tropical Institute, Amsterdam pp 216

Schiere, J.B., Oomen, G.J., and Ibrahim, M.N.M. (1997). Mixed crop-livestock farming. Different systems and their trade offs. Invited paper at the annual workshop of the South African Society of Animal Sciences, University of Zululand, Faculty of Agriculture, Empangeni, October 1997. South Africa.

Schlecht, E., Mahler, F., Sangari, M., Susenbeth, A. and Becker, K. *(1995)* Quantative and qualitative estimation of nutrient intake and fecal excretion of zebu cattle grazing natural pastures in semiarid Mali. In: Powell, J.M., Fernandez-Rivera, S., Williams, T.O. and Renard C. (eds), *Livestock and Sustainable Nutrient Cycling in Mixed Farming Systems of SubSaharan Africa. Volume II: Technical Papers, pp 85-97.*

Scoones, I. 1994. Living with uncertainty: New directions in pastoral development in

security in Southern Africa. New challenges, new opportunities.

severity of 'coping strategies'. *Food Policy*, 24:411-429.

Shapiro, B. 1994. Nutrition effects of crossbred cows adoption in Debre Berhan.

Shaw, A. P. M. and Hoste, C. H. (1987). *Trypanotolerant Cattle and Livestock Development in West and Central Africa.* Vol. II. FAO Animal Production and Health Paper 67/2. FAO, Rome.

Shaw, A.P.M. (forthcoming). "Economic aspects of tsetse trypanosomisis control/eradication. West African considerations". (In preparation)

Simpson, J.R. *(1991)* Global situation of animal agriculture in developing developing countries. University of Florida, Gainesville, Florida.

Smallholder dairy production in the context of crop-livestock systems in the inland Valleys of West Africa: A synthesis of results of a semi-detailed and detailed characterization in Nigeria, Mali and Cote d'Ivoire. ILRI, Ibadan, Nigeria. 31 pp.

Smith, J., Weber, G., Manyong, V .M. and Fakorede, M.A.B. *(1995):* Systems dynamics and heterogeneity.

Smith, J.W., Naazie, .A., Larbi, A., Agyemang, K. and Tarawali, S. 1997. Integrated
Smith, O.B. (2000). Overview of urban Agriculture and food security in West Africa. In: Advances in crop-livestock integration in West African cities. O.O. Akinbamijo, S.T. fall, O.B. Smith (eds) ITC, Banjul, The Gambia, ISRA, Senegal, IDRC/CRDI Ottawa, Canada. pp 17-36
South African Society of Animal Science (South Africa). p. 381-396.
Speth, J. G. 1994. Towards sustainable food security. CGIAR, Washington, D.C. (USA).
STA (Stirling Thorne Associates) (1998). Crop-Livestock Interactions. A Review of opportunities for Developing Integrated models pp 51
Stewart, J. L. (1951). "The West African Shorthorn Cattle. Their value to Africa as trypanosomiasis resistant animals". *Veterinary Record* 63:454-457.
sub-Saharan Africa. ILCA, Addis Ababa, Ethiopia.
Sumberg, J. and. Gilbert, E. 1992. Agricultural mechanization in The Gambia: Drought,
Swallow B.M.(2000). Impacts of trypanosomosis on African agricultue. PAAT Technical and Scientific series No 2. FAO of the United Nations, Rome. 52 pp.
Swallow, B.M. (1997). Impacts of trypanosomosis in African agriculture. In: Proc. 24th ISCTRC Meeting, 29 September – 4th October 1997. Maputo, Mozambique, OAU/STRC. Nairobi, Kenya. pp 515 – 536.
Swaminathan. M.S. 1995. Population, environment and food security. Issues in
Tarawali, G. and Ikwuegbu, O.A. *(1993)* The potential of forage legumes in soil management for sustainable livestock and crop production in the subhumid zone of central Nigeria. Paper presented at the Third Wye International Conference on Sustainable Agriculture held at Wye College, UK, *31* August to *4* September, *1993. 20 pp.*
Tarawali, G. and Pamo, E.T *(1992)* A case for on-farm trials of fodder banks on the Adamawa plateau in Cameroon. *Experimental Agriculture 28, 229-235.*
Tarawali, S. (1997)
the Ethiopian highlands. PhD Thesis, Dept. of Agric. and Resource
The role of caged layer waste as nitrogen supplement to fibrous crop residues
Thenkabil, P. S. and Nolte, C. (1995). *Mapping and Characterising Inland Valley Agroecosystems of West and Central Africa.* Resource and Crop Management Monograph No. 16. International Institute of Tropical Agriculture (IITA), Ibadan Nigeria.
tional Conference on Sustainable Contribution of Fisheries to food security,
to food security and sustainability in developin countries. In: (Eds.) R.T.
Todaro, M.P. *(1969)* A model of labour migration and urban unemployment in less developed countries. *American Economic Review 59, 138148.*
UNECA (United Nations Economic Commission for Africa). 1992. Survey of economic
UNICEF (United Nations Children Education Fund). 1992. Household food security and
Unpublished. ILCA, Addis Ababa, Ethiopia.
USDA (United States Department of Agriculture). 1990. Cited in Abassa, 1995.
von Kaufman, R. (1986). "An introduction to the Sub-humid Zone of West Africa and the ILCA Sub-humid Zone Programme". In: *Livestock Systems Research in Nigeria's Subhumid Zone*. Proceedings of the Second ILCA/NAPRI Symposium held in Kaduna, Nigeria. 29 October – 2 November 1984, ILCA, Addis Ababa (Eds: R. von Kaufmann, S. Chater and R Blench).
von Kaufmann, R., Chater, S. and. Blench, R.(eds). (1986). " Livestock Systems Research in Nigeria's Subhumid Zone." Proceedings of the Second ILCA/NAPRI Symposium held in Kaduna, Nigeria. 29 October – 2 November 1984, ILCA, Addis Ababa
Wagenaar, K.T. Diallo, A. sayers, A. R. (1986). *Productivity of Transhumant Fulani Cattle in The Inner Niger Delta of Mali.* ILCA Research Report. No. 13. ILCA, Addis Ababa. 57pp
Walshe, MT, Grindle, J., Nell, A. and Bachmann, M. *(1991) Dairy Development in Sub-Saharan Africa: a Study of Issues and Options.* World Bank, Washington DC.
Warren, A. 1991. Report to the United Nations. University College, London.
Waters-Bayer, A. (1998). Dairying by settled Fulani Agro-pastoralists in central Nigeria. Farming Systems and Resource Economics in the Tropics. Vol 4. Wissenschaftsverlag Vauk Kiel 1988.
Westlund, L. 1995. Apparent Historical Consumption and Future Demand for Fish

Williams, T.O. , De Rosa, D.A. and Badiane, o. (1995. In: Livestock Development Strategies for Low Income countries Ed: R.T. Wilson, S. Ehui and S. Mack. FAO Rome, Italy and ILRI, Nairobi, Kenya pp 47-53
Wilson, R.T. (1989). "Livestock production in Central Mali: economic characters and productivity in Sudanese Fulani Cattle in the agro-pastoral system". *Tropical Agriculture (Trinidad)* 66:49-53.
Wilson, S. Ehui and S. Mack. Livestock Development Strategies for Low
Wilson, S. Ehui and S. Mack. Livestock Development Strategies for Low
Windmeijer, P. N., van Duivenbooden, and Andriesse, W. eds. (1994). "Characterisation of Rice-Growing Agroecosystems in West Africa". Technical Report 3. Semi-Detailed Characterisation of Inland Valleys in Cote D'Ivoire. Vol. 1. Main Report. DLO Winnad Staring Centre for Integrated Land, Soil and Water Research (SC-DLO), Wagenigen, Holland.
Winrock (Winrock International). 1992. *Assessment of Animal Agriculture in Sub-*
Winrock International *(1992) Assessment of Animal Agriculture in Sub-Saharan Africa.* Winrock International Institute for Agricultural Development, Morrilton, Arkansas.
Winrock. (Winrock International), (1992). *Assessment of Animal Agriculture in Sub-Saharan Africa. Winrock International Institute for Agricultural Development*, Morritton, Arkansas.
Workshop, *9-12* July *1995,* Kellogg Center, Michigan State University, East Lansing, Michigan.
World Bank (2001)
World Bank, (1984). *Towards Sustained Development in Sub-Saharan Africa. A Joint Programme of Action*. World Bank, Washington, DC, USA.
World Bank, 1986. Poverty and hunger. Issues and Options for Food Security in
Zerbini, E., Tekele, G., Alemu, G.W. and Abuje, A. 1994. Effect of draft work on

FAO (1992) The role of ruminant livestock in food security in developing countries: 2nd Adhoc Consultations with FSAS donors 27 October 1989. FAO Rome (Mimeo).

TAC/CGIAR (1992). Review of CGIAR priorities and Strategies. Part 1. TAC Secretariat, FAO, Rome (Mimeo).

De Haan, C., Steinfeld, H. and Blackburn, H. (2000?) Livestock and Environment- Finding a balance.

Drechsel, P., Amoa, P., Cofie,O.and Abaidoo, R. C. (200). Increasing use of poultry in Ghana. Is farmers' race consumers' fate?. Urban agriculture Magazine 1:25-27.

NEPAD (2002) Comprehensive Africa Agriculture Development Programme (CAADP)- Draft. 73pp.

DFID (2000) Sustainable livelihoods guidance sheets. Institute of Development Studies. www.livelihoods.org

Selected Reading II

Abassa, K. P. 1995. Improving food security in Africa: the ignored contribution of livestock. Joint ECA/FAO Agriculture Division. Addis Ababa, UNECA/FAO 48 pp.

Agyemang, K., Sonko, E., Badjie, B., Saho, E., Ceesay, M., Touray, M. and Corr, N. 1989. A preliminary Survey on socio-economic aspects of cattle herd ownership and management and of milk disposal and utilisation patterns in four villages: EEC Project Working Document No. 4. International Trypanotolerance Centre, Banjul, The Gambia.

Agyemang, K., Abiye Astatke, Anderson, F. M. and Woldeab W/Mariam. (1991) A study on the effects of work on reproductive and productive performance of crossbred dairy cows in the Ethiopian highlands. *Tropical Animal Health and Production,* 23: 241-249.

Agyemang, K., Ouologuem, B., Yapi-Gnaore, Barje, P.P. and Adediran, S.A. 1999. Small Smallholder dairy production in the context of crop-livestock systems in the inland Valleys of West Africa: A synthesis of results of a semi-detailed and detailed characterization in Nigeria, Mali and Cote d'Ivoire. ILRI, Ibadan, Nigeria. 31 pp.

Agyemang, K. and Smith, J.W. 1999. Counting the costs and benefits of implementing multi-country research projects: The case of the peri-urban Inland Valley Dairy Project in West Africa. In: (O.B. Smith; ed.). Urban Agriculture in West Africa. Contributing to food security and Urban Sanitation. p. 169-183.

Barrett, C. (forthcoming). Food security and food assistance programs. In: (eds.). Gardner, B.L. and Rausser, G.C. Handbook for Agricultural Economics, Elsevier, Amsterdam, Netherlands.

Braun, J., von. 1994. Employment for poverty reduction and food security: concepts, research issues, and overview. In : Achieving food security in Southern Africa. International Food Policy Research Institute (IFPRI), Washington, D.C. p. 1-20.

Brumby, P. J. 1986. International Livestock Centre for Africa. Objectives, Activities and Future. ILCA, Addis Ababa, Ethiopia.

Burton, B.T. 1980. *Human Nutrition.* Third Edition. Tata McGraw-Hill Publishing Company Ltd., New Delhi.

CAST (Council for Agricultural Science and Technology). 1999. *Animal Agriculture and Global Food Supply.* Task Force Report No. 135. Ames, Iowa. 92 pp.

Dawson, J. and Barwell, I. 1993. Roads Are Not Enough: New Perspectives on Rural Transport Planning in Developing Countries. International Forum for Rural Transport and Development Occasional Paper IT Transport. Ardington, Oxford, UK.

De Leeuw, P. N. and Reid, R.. 1995. Impact of human activities and livestock on the African environment: an attempt to partition the pressure. In: (Eds.) R.T. Wilson, S. Ehui and S. Mack. Livestock Development Strategies for Low Income Countries. ILCA, Nairobi, Kenya.

Debrah, S. and Sissoko, K. 1990. Sources and Transfers of Cash Income in the Rural Economy: the Case of Smallholder Mixed Farmers in the Semi-arid Zone of Mali. African Livestock Policy Analysis Network Paper No. 25, International Livestock Centre for Africa, Addis Ababa, Ethiopia.

Delgado, C., Rosegrant, M., Steinfeld, H., Ehui, S. and Courbois, C. 1999. Livestock to 2020: The Next Food Revolution. Food, agriculture, and the Environment Discussion Paper 28. IFPRI-UN/FAO-ILRI.

Delgado, C., Courbois, C. and Rosegrant, M., 1998. Global food demand and the contribution of livestock as we enter the new millennium. Paper presented at the British Society of Animal Science-Kenya Agricultural Research Institute Conference on food, lands and livelihoods: setting research agendas for Animal Science, January 27-30, Nairobi, Kenya.

Dodd, J. L. 1991. Animal agriculture and dsertification/degradation in sub-Saharan Africa. University of Wyoming, Laramie, USA.

Dreze, J. and Sen, A., 1989. *Hunger and public action.* Oxford, Clarendon Press.

FAO (Food and Agriculture Organization of United Nations), 1997. FAOSTAT database. http//faostat.fao.org/default.htm. Accessesd September and December, 1997.

Francis, P. A. 1988. Ox draught power and agricultural formation in Northern Zambia. *Agricultural Systems,* 27: 15-28.

Gryseels, G., Astatke, A., Anderson, F. M. and Assemanew, G. 1984. The use of single oxen for crop cultivation in Ethiopia. *ILCA Bulletin,* 18:20-25.

Gryseels, G. 1988. The role of livestock in the generation of smallholder farm income in two vertisols areas of the central Ethiopian highland. In: (eds) S. C. Jutzi, I. Haque, J. McIntire and J.E.S. Stares. Management of vertisols in sub-Saharan Africa. ILCA, Addis Ababa, Ethiopia.

Haddad, L. 1997. Overview. . In : Achieving food security in Southern Africa. In : Achieving food security in Southern Africa. New challenges, new opportunities. IFPRI, Washington, D.C. p. 3-15.

Hiernaux, P. 1996. The Crisis of Sahelian Pastoralism: Ecological or Economic?. Pastoral Development Network Paper 39a. Overseas Development Institute, London, UK. 20pp.

Hoste, C. H., Chalon, E., D'Ieteren, G. and Trail, J. C. M. 1992. Trypanotolerant Livestock in West and Central Africa. Volume 3: A Decade's Results. ILCA Monograph 2. . International Livestock Centre for Africa, Addis Ababa, Ethiopia. 206 pp.

ILCA (International Livestock Centre for Africa), 1992. ILCA 1991 Annual Report and Programme Highlights , Addis Ababa, Ethiopia.

Jabbar, M. A. 1995. Market niches for increased small ruminant production in Southern Nigeria. Oxford Agrarian Studies 24.

Kayongo, S.B., Wanyoike, P.N., Mbungua, P. N., Nyagah, P.N. and Martho, T. E. 1992.

The role of caged layer waste as nitrogen supplement to fibrous crop residues commonly fed to sheep and goats. In: (Eds.) B. Rey, S.H.B. Lebbie and L. Reynolds. Small ruminant research and development in Africa. ILCA, Nairobi, Kenya.

Lawrence, P. R., Dijkman, J. T. and Jansen, H.G.P. 1997. The introduction of animal traction into inland valley regions. Manual labour and animal traction in the cultivation of rice and maize: a comparison. *J. Agric. Sci. (Cambridge),* 129:65-70

Lebbie, S. H. B. 1996. Livestock and Food Security in Smallholder production systems in Africa: Beyond meat and milk. In: Food Security in Africa. Challenges, opportunities and targets for animal production. South African Society of Animal Science (South Africa). p. 381-396.

Lhoste, P. 1986. L'utilisation de L'energie Animale en Afrique Intertropicale Report Presented at the "Méthodes de Recherches sur lar Systémes Délevage en Afrique Intertropicale" Workshop held in Mbour from 2-8 February 1986. ISRA, Dakar, Senegal.

Maxwell, D., Ahiadeke, C., Levi, C., Arma-Klemesu, M., Zakariah, S. and Lamptey, G. M. 1999. Alternative food-security indicators: revisiting the frequency and severity of 'coping strategies'. *Food Policy*, 24:411-429.

McIntire, J., Bouzart, D. and Pingali, P. 1992. *Crop-Livestock Interactions in Sub-Saharan Africa*. World Bank, Washington, D.C.

Omiti, J. 1995. *Economic analysis of crop-livestock integration: the case of the Ethiopian highlands*. PhD Thesis, Dept. of Agric. and Resource Economics, Univ. of New England, Armidale, Australia.

Pinstrup-Andersen, P., Pandaya-Lorch, R. and Babu, S. 1997. A 2020 vision for food, agriculture, and the environment in Southern Africa. In : Achieving food security in Southern Africa. New challenges, new opportunities. International Food Policy Research Institute (IFPRI), Washington, D.C. p. 16-56.

Powell, J. M. 1986. Manure for for cropping: A case study Central Nigeria. *Experimental Agriculture*, 22:15-24.

Ramaswamy, N. S. 1985. Draught animal power----socio-economic factors. In: J.W. Copland (ed.). Draught Animal Power for Production. ACIAR Proceedings No. 10.

Sansoucy, R., Jabbar, M. A., Ehui, S. and Fitzhugh, H. 1995. Contribution of livestock to food security and sustainability in developin countries. In: (Eds.) R.T. Wilson, S. Ehui and S. Mack. Livestock Development Strategies for Low Income Countries. An FAO/ILRI Publication. pp 182.

Scoones, I. 1994. Living with uncertainty: New directions in pastoral development in Africa. Intermediate Technology Publications Ltd. pp. 210.

Shapiro, B. 1994. Nutrition effects of crossbred cows adoption in Debre Berhan. Unpublished. ILCA, Addis Ababa, Ethiopia.

Smith, J.W., Naazie, .A., Larbi, A., Agyemang, K. and Tarawali, S. 1997. Integrated crop-livestock systems in sub-Saharan Africa: an option or an imperative? *Outlook on Agriculture,* 26(4):237-246.

Speth, J. G. 1994. Towards sustainable food security. CGIAR, Washington, D.C. (USA).

21 pp.

Sumberg, J. and. Gilbert, E. 1992. Agricultural mechanization in The Gambia: Drought, donkeys and minimum tillage. *African Livestock Res.,* 1:1-10.

Swaminathan. M.S. 1995. Population, environment and food security. Issues in Agriculture 7. CGIAR, Washington, D.C.

UNECA (United Nations Economic Commission for Africa). 1992. Survey of economic and social conditions in Africa (1989-1990). Addis Ababa, Ethiopia.

UNICEF (United Nations Children Education Fund). 1992. Household food security and nutrition in Eastern and Southern African region. UNICEF-ESARO.

USDA (United States Department of Agriculture). 1990. Cited in Abassa, 1995.

Warren, A. 1991. Report to the United Nations. University College, London.

Waters-Bayer, A. (1998). Dairying by settled Fulani Agro-pastoralists in central Nigeria. Farming Systems and Resource Economics in the Tropics. Vol 4. Wissenschaftsverlag Vauk Kiel 1988.

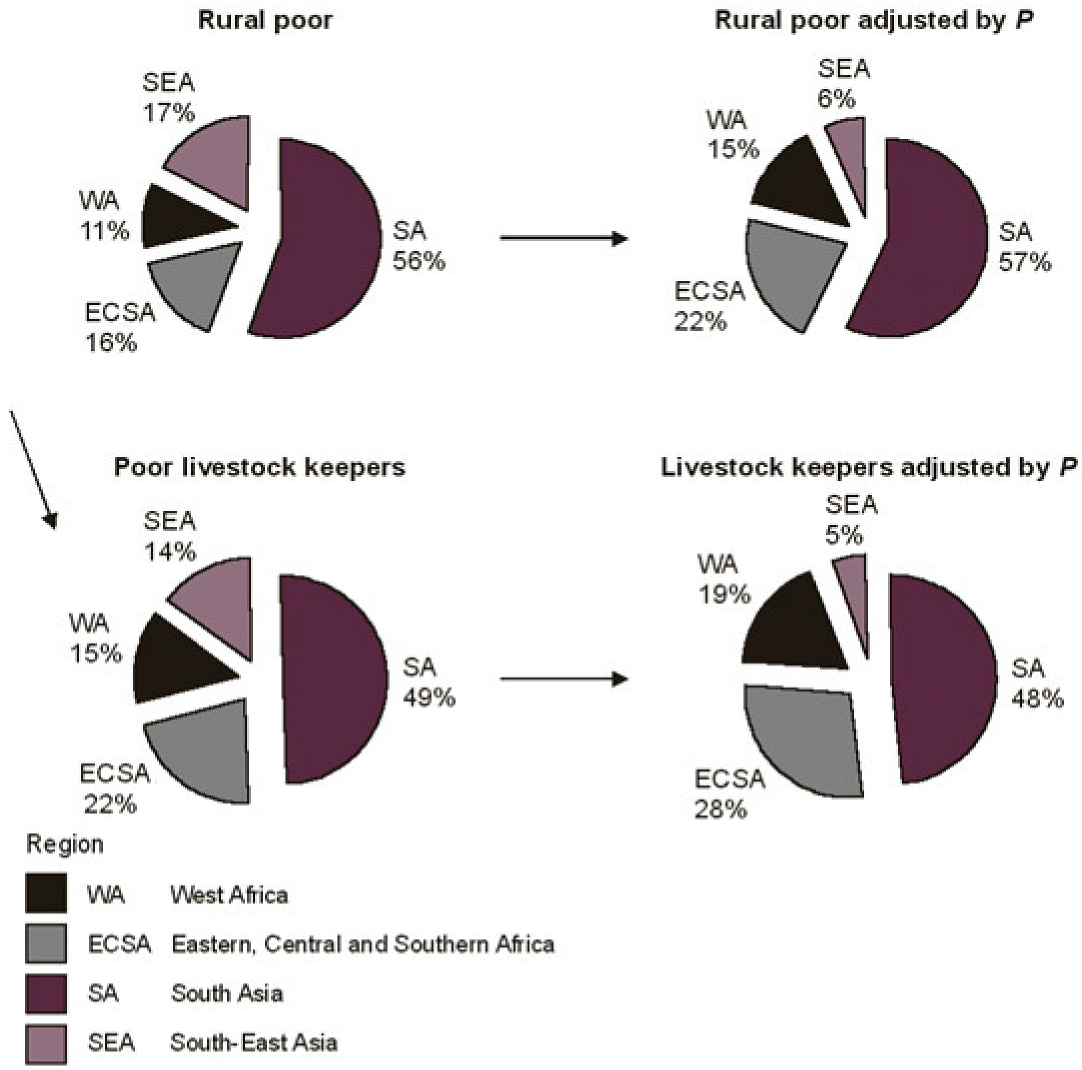
Westlund, L. 1995. Apparent Historical Consumption and Future Demand for Fish and Fishery products---Exploratory Calculations. Paper presented at the International Conference on Sustainable Contribution of Fisheries to food security, Kyoto, Japan, December 4-9.

Winrock (Winrock International). 1992. *Assessment of Animal Agriculture in Sub-Saharan Africa.* Winrock International Institute for Agricultural Development, Morrilton, Arkansas.

World Bank, 1986. Poverty and hunger. Issues and Options for Food Security in Developing Countries. World Bank, Washington D.C.

Zerbini, E., Tekele, G., Alemu, G.W. and Abuje, A. 1994. Effect of draft work on lactation of F1 crossbred cows. In: (Eds.) P. Starkey, E. Mwenya and J. Stares. Improving animal traction and technology. 490 pp.

Figure 1. Regional distribution of poverty for different poverty measures



Source: Perry et al., (2002).

Figure 2. Distribution of poverty by livestock production system and by region (based on *P*-adjusted numbers of rural poor)

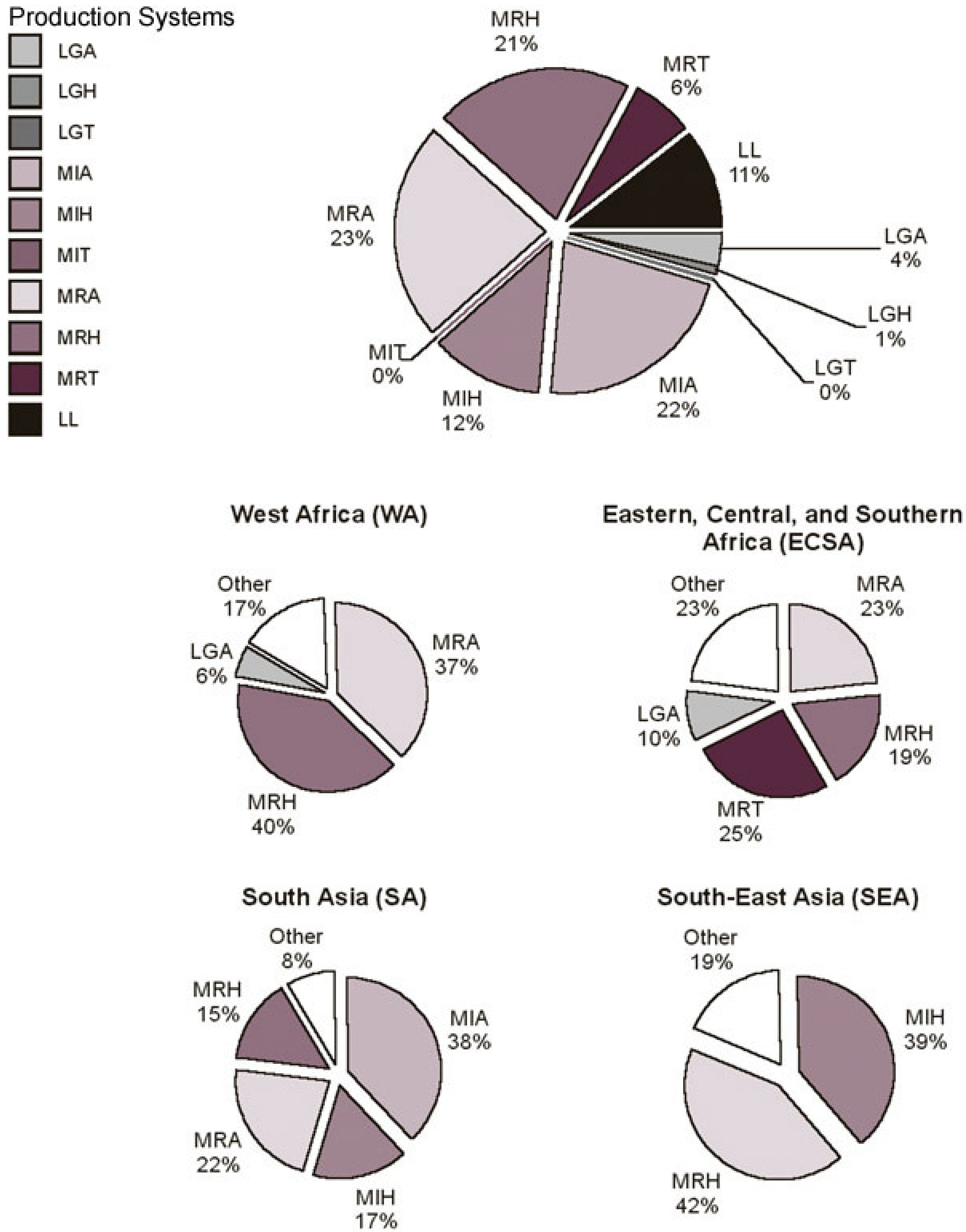


Figure 1: *A general, schematic representation of the components of agricultural systems and their interactions.*

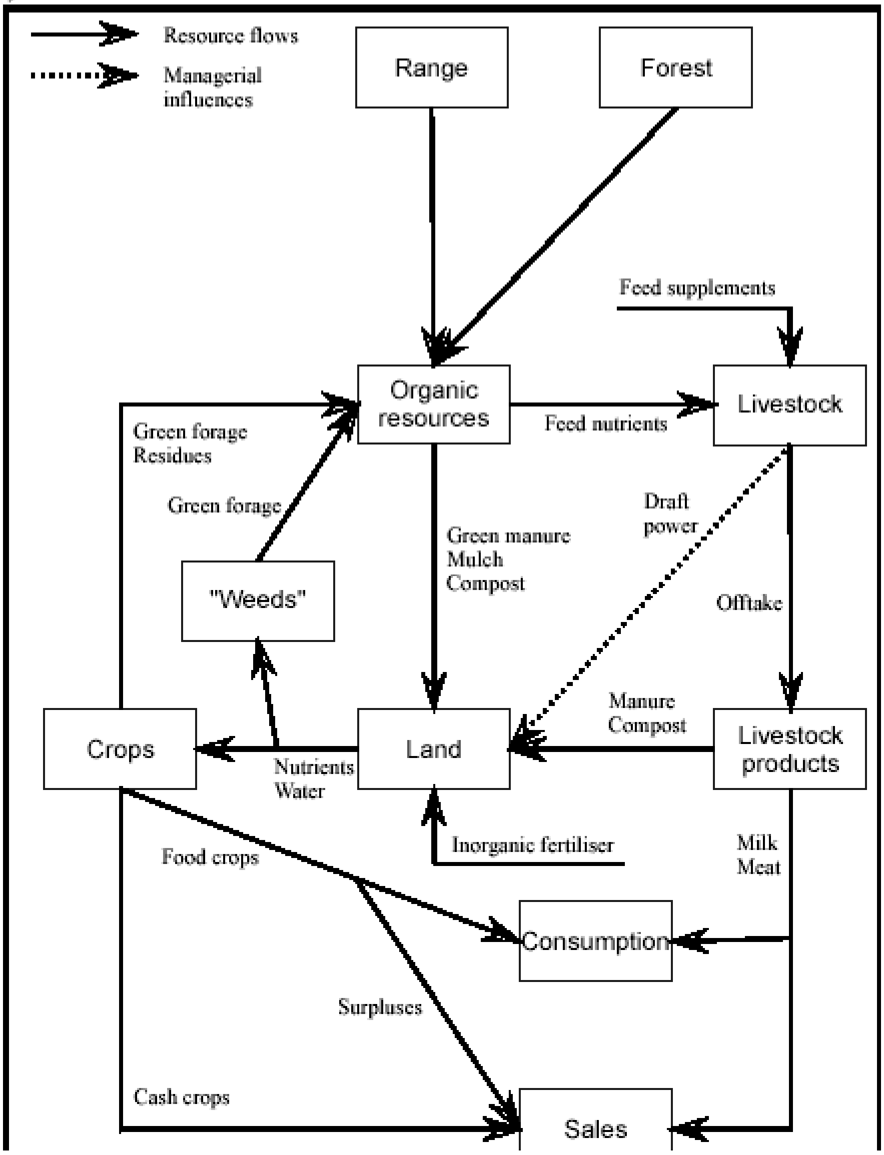


Figure 4: Defining the area of focus from the components of soil-plant-animal interactions.

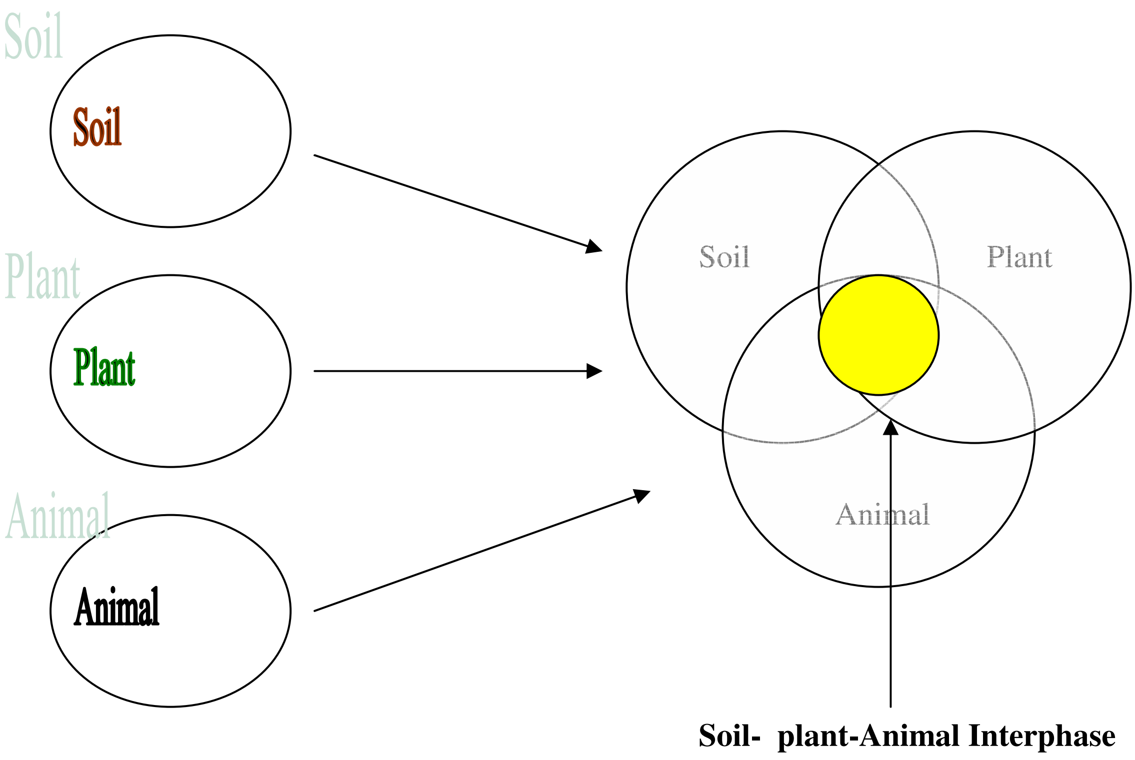


Figure 5: Schematic representation of interactions between settled agriculture and livestock belonging to pastooralists

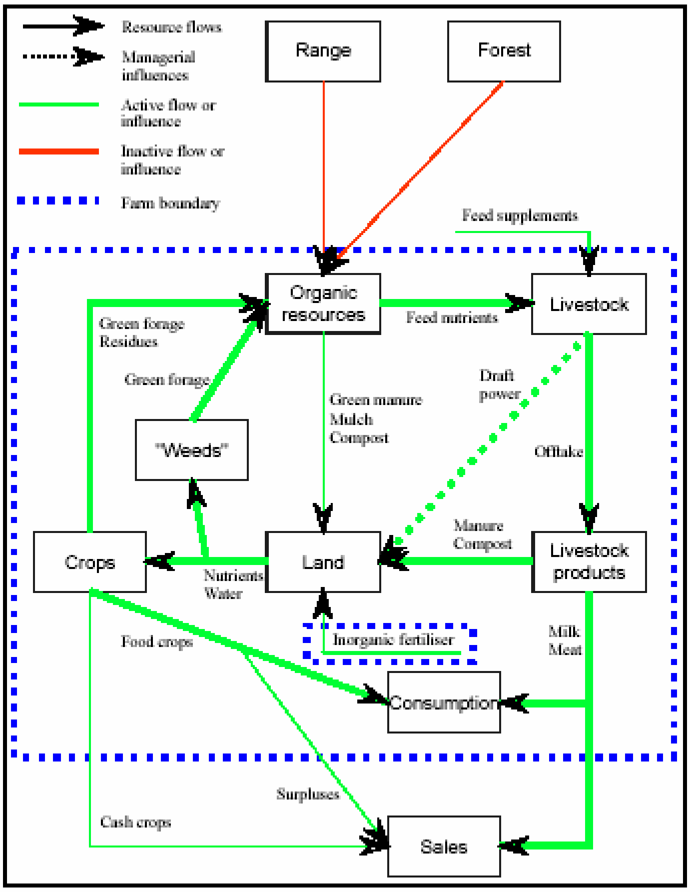


Figure 3: *Schematic representation of a farming system based on the integration of crops and livestock.*

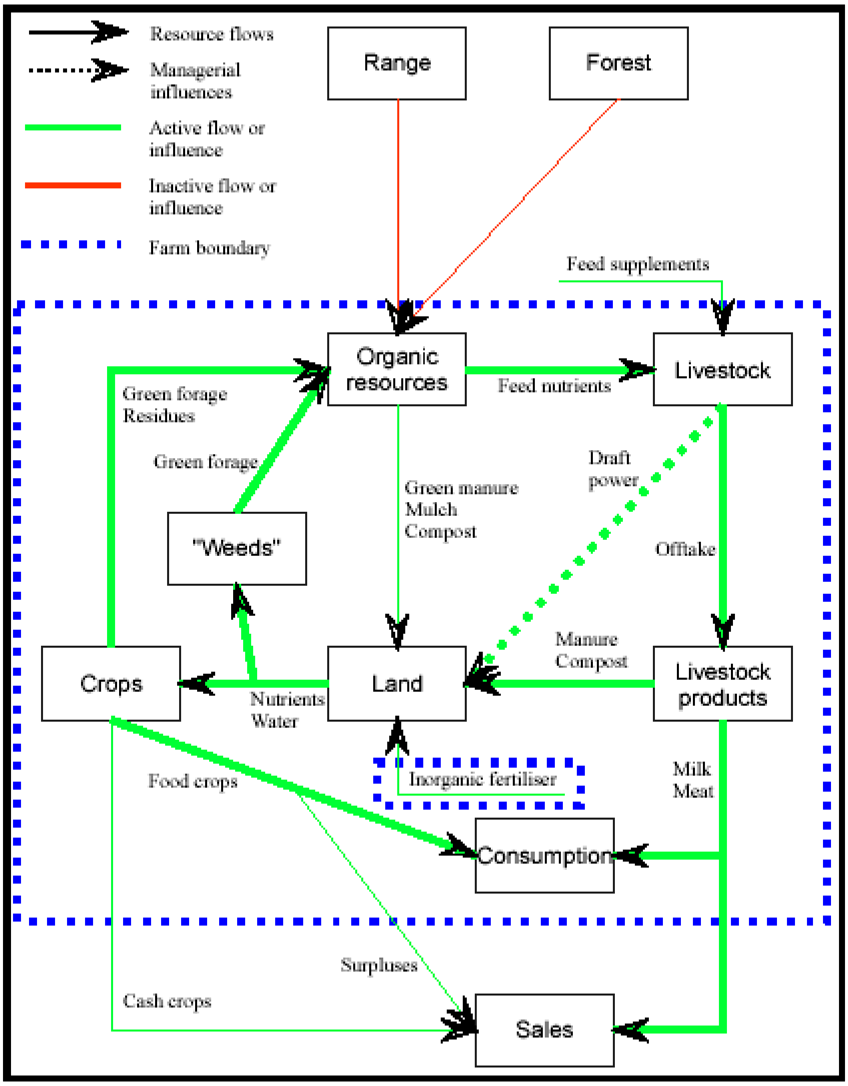
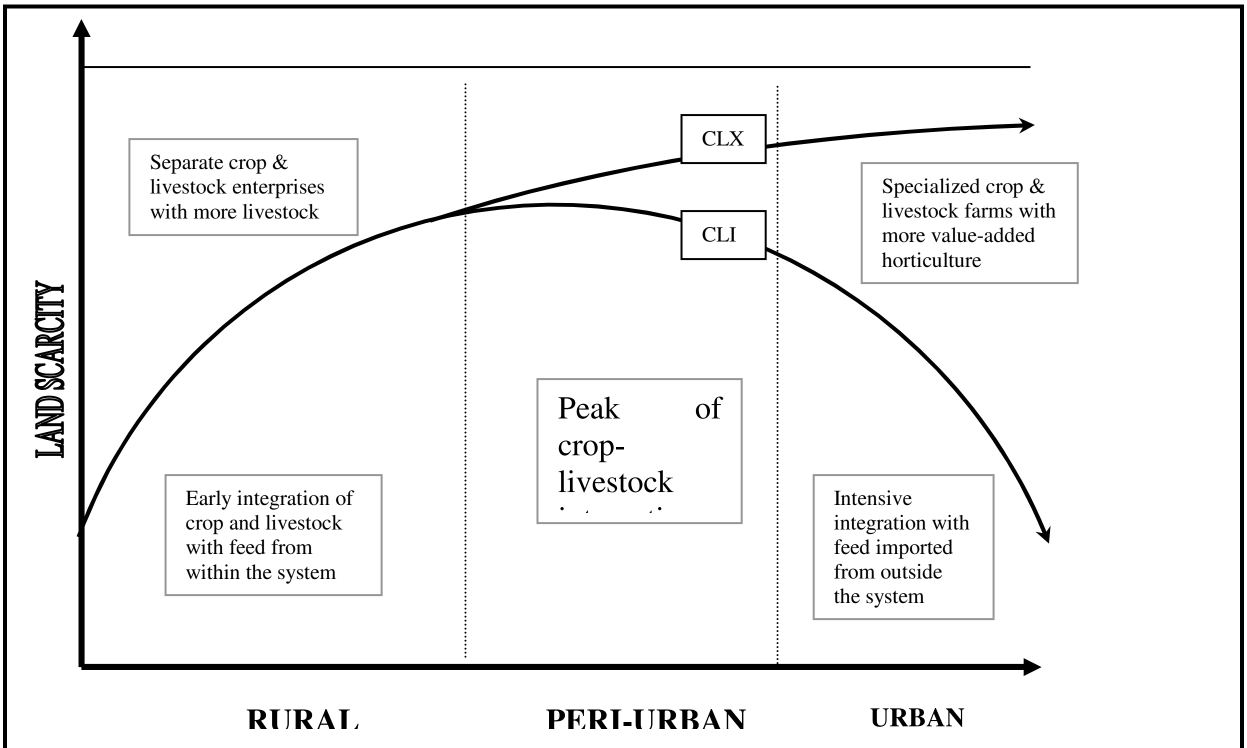


Figure 7: Conceptual trends in crop-livestock interactions and integration as agricultural transformations involving land scarcity and urbanization occur.



NB: CLX = crop-livestock interactions, CLI = crop-livestock integration.

Figure 8: Relative importance of crop residues and range as feed sources of Kaduna State, at 10% utilization of crop residues. Source: ILRI (1996).

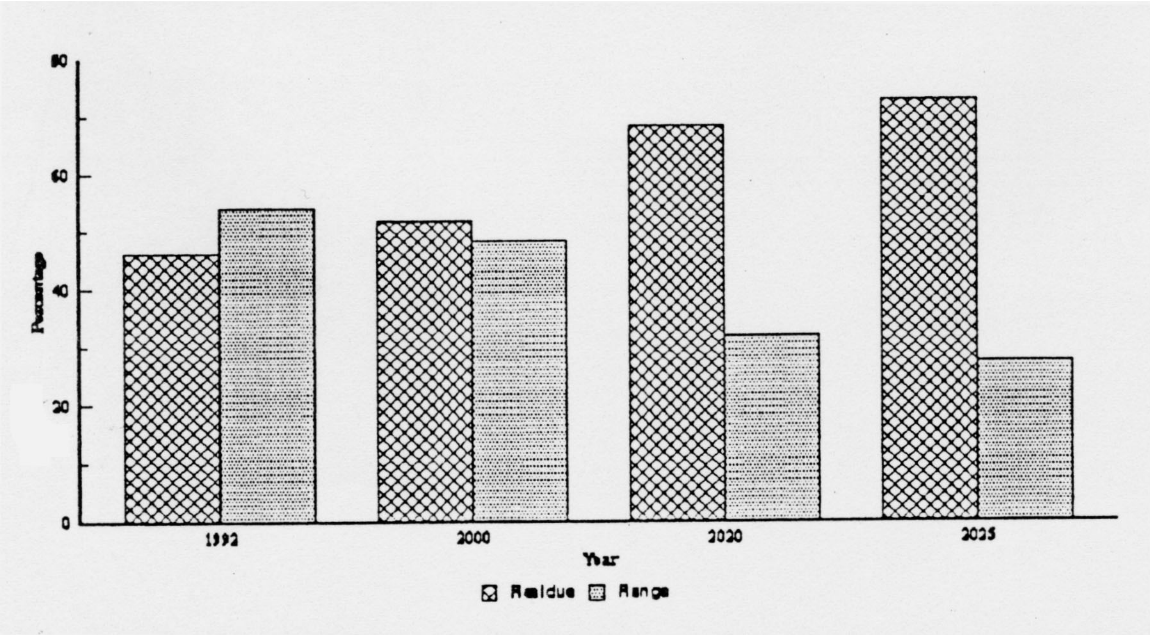


Table 1. Human and livestock populations (millions) in developed and developing countries, 1960 and 1990

Item	Developed countries			Developing countries		
	1960	1990	% change	1960	1990	% change
People	977	1251	28	2097	4138	97
Large ruminants	343	404	18	692	1029	49
Small ruminants	573	591	3	792	1217	54
Pigs	235	341	45	171	515	201
Poultry	2274	4465	96	1648	6305	283

Source: FAO, 1992

Table 2: Shares of Crops, Livestock and Trees in Total Agricultural Output (US$ billion/year) in developing Regions, 1987-1989

Commodity group	Region				Total	Per cent share
	Asia	SSA	LAC	WANA		
Crops	222	35	74	33	364	57
Livestock	64	10	36	12	122	19
Trees	73	19	25	2	119	19
Total	20	2	10	1	33	5
Per cent Share	59	10	23	8		

Source: TAC/GGIAR, 1992

Table 3: Relative Importance of Livestock Products in Developing Regions, 1987/1989

Commodity Group	Region				Total
	Asia	SubSaharan Africa	Latin America and Caribbean	West Asia and North Africa	
All commodities (US$ billion/year)	379	66	145	48	638
Per cent share of					

Crops	59	53	51	69	57
Livestock	17	15	25	25	19
Trees	19	29	17	4	19
Fish	5	3	7	2	5

Table 4: Contribution (per cent) to Total Value of Livestock Output by Developing Regions and Agroecological Zones, 1988 – 1989

Agroecological Zone Zone	Developing Region				
	Asia	SSA	WANA	LAC	Total for region
Warm arid and semiarid tropics	7.8	4.2	-	2.3	14.2
Warm subhumid tropics	3.4	1.2	-	4.5	9.2
Warm humid tropics	4.7	1.0	-	4.6	10.3
Cool tropics	-	1.6	-	5.2	6.8
Warm arid &semiarid tropic (summer rain)	12.0	-	-	1.8	13.8
Warm subhumid tropics (summer rain)	4.6	-	-	0.8	5.5
Warm/cool humid subtropics (summer rain)	10.9	-	-	4.6	15.5
Cool subtropics (summer rainfall)	9.2	-	-	4.6	13.8
Cool subtropics (winter rainfall)	-	-	10.0	0.9	10.9
Total for region	52.6	8.0	10.0	29.3	100.0
Total value (US $ billion)	63 398	9 718	12 175	35 593	121 424

Table 5: Major Agriculture Systems in Sub-Saharan Africa

Zone	Crop/livestock integration	Major Agriculture Systems	Major livestock output
Humid	Pure crop	Forest/permanent trees: roots/ cereals (trypanotolerant livestock)	Periurban milk
Subhumid	Crop/livestock	Cereals (maize/sorghum)-livestock	Meat, milk, power
Highland	Well integrated crop-Livestock	Cereals (wheat/teff)-livestock	Power, meat, milk
Semiarid	Livestock-crop	Cereals (sorghum/millet)-livestock	Milk, power
Arid	Pure livestock	Pastoral	Milk, meat