

A synthesis of the crop–livestock production systems of the dry savannas of West and Central Africa

G. Tarawali

Abstract

This report presents a review of the crop–livestock systems of selected West and Central African countries, with emphasis on the farming systems and soil fertility management practices involving manure and crop residues. It also discusses the use of animal traction and the constraints to and opportunities for crop–livestock integration. The information was acquired by visiting the targeted countries and consulting the available literature in addition to holding intensive discussions with researchers/farmers and making field visits. In the review, new methods such as a holistic approach taking cognizance of farmers’ decision-making for certain technologies are considered imperative for sustainable crop–livestock integration at the farm level of the West and Central African dry savanna. It is also stressed that the consortium of four international centers—the International Crops Research Institute for the Semi–Arid Tropics (ICRISAT), the International Institute of Tropical Agriculture (IITA), the International Livestock Research Institute (ILRI), and the International Fertilizer Development Centre (IFDC), with their NARS partners are the best implementers of such a strategy.

Résumé

Ce rapport présente une revue des systèmes mixtes agriculture–élevage de certains pays d’Afrique de l’Ouest et du Centre et met l’accent sur les systèmes de production et les pratiques de gestion de la fertilité du sol impliquant le fumier et les résidus culturaux. Il aborde aussi l’utilisation de la traction animale de même que les contraintes et opportunités de l’intégration culture–élevage. Les informations ont été obtenues lors des visites aux pays ciblés, en consultant la documentation disponible, et par suite d’intenses discussions avec les chercheurs et paysans, et des visites sur le terrain. Dans la revue, de nouvelles méthodes telles que l’approche holistique prenant en compte le libre arbitre des paysans face à certaines technologies, sont jugées impératives pour une intégration durable de l’association culture–élevage au sein des exploitations dans la zone de savane sèche de l’Afrique de l’Ouest et du Centre. Il a été également souligné que le consortium des quatre centres

internationaux, à savoir l’Institut international de recherche sur les cultures des zones tropicales semi-arides (Icrisat), l’Institut international d’agriculture tropicale (Iita), l’Institut international de recherche sur l’élevage (Ilri) et le Centre international pour le développement des engrais (Ifdc) et leurs SNRA partenaires, sont mieux indiqués pour la mise en œuvre d’une telle stratégie.

Introduction

The human population in sub-Saharan Africa (SSA) in 1990 was 489 million and it is growing at an annual rate of 3.2%. It is projected to reach 1.3 billion by 2025 (Bulatao et al. 1990). Per capita food production in SSA has meanwhile been declining.

Over the past 25 years, the numbers of all the major domestic animal species in SSA have increased (Winrock 1992). Total tropical livestock units (TLUs) rose from 112 million in 1961–1963 to 168 million in 1986–1988 (TLU = 250 kg). The combined pressure of human and animal populations on natural resources may lead, among other things, to excessive deforestation, soil degradation, and loss of biological diversity. Restoring these degraded lands may take decades, and for affected areas, effective and economic methods of rebuilding their former productive capabilities may not even be available.

In view of the above factors, new and sustainable agricultural systems that not only support increased food and feed production but also conserve the natural resource base will have to be found, otherwise the millions of resource-poor farmers who depend directly on these production systems will be adversely affected.

The potential problems outlined for SSA are more acute in the dry savanna region. This region occupies more than 50% of the total land area, accounts for 57% of the cattle, sheep, and goat populations of SSA; and has a low cropping potential/intensity and fragile environment. The dry savannas are seasonally dry tropics and subtropics with rainfall of 500–1000 mm (FAO 1993). It is anticipated that sustainable food production in this harsh environment could only be achieved through crop–livestock integration. It is against this background that researchers from selected countries in West and Central Africa were assembled at this workshop to work out strategies for promoting sustainable crop–livestock integration. Seven countries (Burkina Faso, Ghana, Mali, Niger, Nigeria, Senegal, and Chad) are involved. These countries were selected because their national research activities, farming systems, and agroecological zones relate to the mandates of

the four international centers that developed the concept of the workshop (Icrisat, Iita, Ilri, and Ifdc) and the existing partnerships amongst the stakeholders. Representatives from each country provided a report on the crop–livestock systems of their countries. The final objective of the workshop was to develop a full funding proposal for integrated, holistic, on-farm crop–livestock research. In order to complement these efforts, a consultant was also appointed to review the major crop–livestock systems of West and Central Africa, with emphasis on the following:

- *major crop–livestock systems in the region*
- *soil fertility management (manure and crop residues)*
- *use of animal traction*
- *constraints to and opportunities for crop–livestock integration.*

This information was sourced by visiting all the selected countries and consulting the available literature, holding intensive discussions with farmers/extension personnel/scientists and making field visits.

Farming systems

The principal field crops are millet, sorghum, cowpea, pigeon pea, cotton, and groundnut (Norman 1974; N'tare 1989; McIntire et al. 1992; INRAN 1996; Ngawara et al. 1996; Williams et al. 1998). There are also garden crops such as tomatoes and okra, but few perennials. Cereal–legume intercropping is the main cropping system. The cash crops are groundnut mostly in the north and cotton in the south. Except for the cotton and vegetable growers whose enterprises are profitable, small-scale farmers in the dry savannas do not apply fertilizer. This means that most peasants are dependant on manure or traditional approaches to soil fertility. Cropping usually takes place during the wet season but a unique feature in Nigeria and Chad is the evolution of the dry-season cowpea in lowland *fadama* and irrigated areas (Singh and Tarawali 1997) and the dry-season sorghum (*berbéré*) usually transplanted in lowland areas (*bas fonds*) where the crop survives on residual moisture. Both crops provide additional grain for humans and fodder for livestock at the critical time of the dry season. In Nigeria, the areas growing dry-season cowpea were formerly cultivated with wheat (especially in Kano State) where fertilizer scarcity and high prices have forced growers to look for alternatives.

It appears that throughout the dry savannas of West and Central Africa, the predominant breeds of cattle are the Zebu in the north and the N'dama in the south. The small ruminants are mostly sheep and goats, both the tall Sahelian type in the north and the dwarf type usually found in the south. The bulk of feed for animals comes from natural pasture. Cereal residues are available from November/December after grain harvest but these are exhausted only after 3–4 months (February/March) (De Grandi 1996). Cowpea haulms and other leguminous hay are cut and stored for feeding special animals such as oxen, small ruminants, and donkeys (Agyemang et al. 1993). In Nigeria (dry-season cowpea) and Chad (dry-season sorghum), additional grazing resources are available from April and may last for 1 or 2 months. Since cotton is grown almost everywhere in the dry savannas of the region, cottonseed cake is often exploited by some countries for the supplementary feeding of animals. This resource is fairly cheap in countries such as Chad but expensive in others such as Burkina Faso, Ghana, and Mali. In Cameroon (although not participating in the study), a government policy precludes transporting cottonseed cake from the north (main livestock producing area) to the south, where there are fewer livestock. Such a measure keeps this important resource within the reach of the farmers.

Another interesting practice in northern Ghana is that farmers defoliate maize tops and cut leaves from standing maize (before grain harvest) to feed animals as a way of alleviating the late wet season/early dry season feed stress partly caused by the restricted movement of animals during the cropping season. A clear advantage of this method is that the animals benefit from the more nutritious green material. Materials such as pigeon pea are extensively used for feeding animals in northern Ghana.

Soil fertility management

Inherent poor fertility of the soil and low use of organic and inorganic fertilizers have been identified as some of the greatest constraints to increasing agricultural productivity in the West and Central African dry savannas. In intensively cultivated areas, the use of chemical fertilizers alone to alleviate soil fertility leads to acidification (Bationo et al. 1995) and scientists have claimed that productivity in these farming systems could only be maintained/sustained through the efficient recycling of organic material such as manure or crop residues in combination with mineral fertilizers and by adopting

rotations with grain legumes (cowpea and groundnut) and forage legumes such as *Stylosanthes*.

Manure for soil management

The use of fertilizer by farmers in the dry savannas of West and Central Africa is becoming limited while regular manuring is becoming more widespread. There are two principal methods employed in manuring cropland: the most common method is corralling whereby animals are penned overnight on fields (and moved around) between cropping seasons. The second system, which is very popular in intensively cultivated areas, is the stabilization technique whereby confined livestock deposit manure overnight and the material is transported to crop fields by carts, bicycles, or human beings just before the rains (Powell and Williams 1995). A modified version of this technique is practiced in Senegal, whereby farmers build stables and select traction animals in the first instance to deposit manure in constructed pits. This is mixed with straw to form compost, which is then applied on crop fields at the beginning of the cropping season. This system proved to be uneconomic with bulls alone, but has now been extended to include cows, which have the advantage of producing manure, milk, and power. Industries have been set up in certain areas of Senegal to promote this concept (Fall and Diouf 1998).

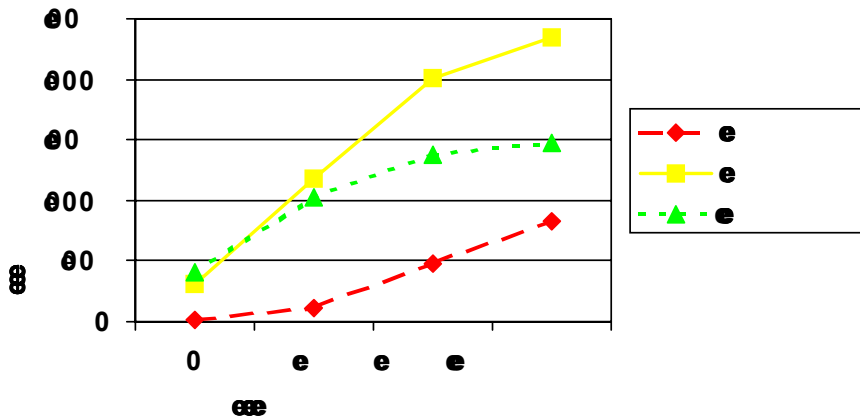
Generally, manure is applied on the surface of crop fields but in Burkina Faso, farmers dig holes in the crop fields to deposit manure there and sow their crops during the rainy season. This is a traditional method and is called *Zai* (Critchley 1991). *Zai* is the name in the local Moore language and it describes wide and deep planting holes. These are usually 15 cm deep, 30 cm in diameter, and spaced 90 cm apart. The *Zai* (holes) accumulate run-off water which improves plant growth and the manure or compost in each *Zai* further improves crop yields. It was reported that this technique can lead to yield increases of about 40–60% in the first season and there is evidence that yields may continue to rise for several years as fertile deposits are built on the fields. A similar practice has been recorded in northern Cameroon for growing trees.

Though the *Zai* technique shows great promise in boosting/sustaining crop yields in the dry savannas, it is only practiced by farmers who can afford the labor; also, not enough

scientific data have been acquired to demonstrate its efficiency. Interestingly, the Information Centre for Low-External-Input and Sustainable Agriculture (ILEIA), a Dutch-sponsored organization mandated to promote low-input agriculture in developing countries through NGOs, is currently conducting on-farm trials to study the efficacy of the *Zai* system which the Ghanaian farmers had learned during a field trip to neighboring Burkina Faso (ILEIA 1998a).

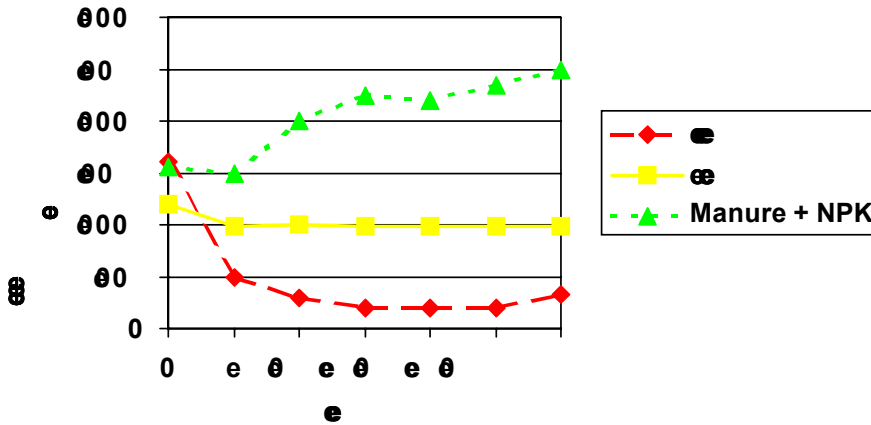
A lot of research has been conducted especially in Burkina Faso, Niger, Nigeria, and Mali to demonstrate the beneficial effects of manure on crop yields and soil conservation. Work done in Nigeria during the pre- and postcolonial eras showed that appreciable yield increases could be achieved following the application of organic manure (Fig. 1) (Lombin and Abdullahi 1977). The effects of applying manure and artificial fertilizers on sorghum crops in Burkina Faso showed that the application of chemical fertilizers to tropical soils leads to a stagnation of crop yields but a combination of manure and NPK resulted in sustainable increases in crop yields (Fig. 2) (Sédogo 1993). In a 45-year-old trial also conducted in Nigeria, it was clearly shown that the use of inorganic fertilizers leads to a reduction in organic carbon levels and a decrease in cation exchange capacity while manure as a soil amendment influences these parameters positively (Fig. 3) (Agbenin and Goladi 1998). Research in Niger has also shown that corralling which returns manure and urine to the soil results in greater crop yields than when manure is applied alone (Fig. 4). Many related studies have ascertained the positive contribution of manure to crop improvement and soil maintenance. (Key references are Powell and Williams 1995 and Renard et al. 1998.) More recently, Schlecht et al. (1997) showed that urination and defecation were highest at the time of getting up and watering. It was therefore suggested that land management practices such as keeping the animals in corralled fields for about 30 minutes after getting up and spreading litter near watering points may allow better capture of manure and N for improving soil fertility.

Some of the problems associated with the use of manure in tropical agriculture are that this resource is usually required in very large quantities to make a significant contribution to crop yield and these amounts are usually not available. Also, because manure is bulky and the amounts necessary to fertilize land efficiently are high, many farmers cannot afford the labor and the relatively high transportation costs (Hesse 1996). These factors



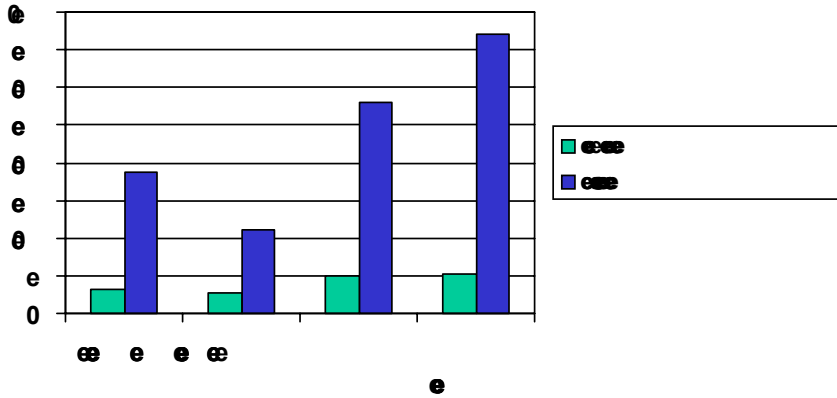
Source: Lombin and Abdullahi (1977).

Figure 1. Long-term effects of manure treatments on crop yield in Nigeria.



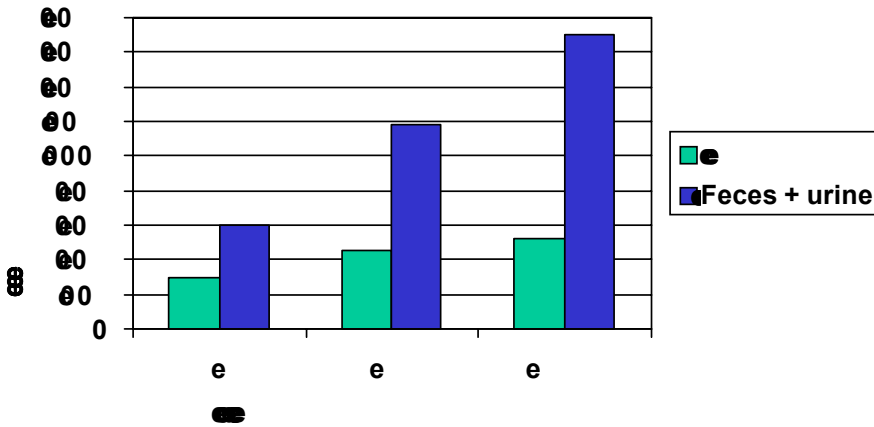
Source: Sédogo (1993).

Figure 2. Effect of applying manure and fertilizer on sorghum crops in Burkina Faso.



Source: Agbenin and Goladi (1998).

Figure 3. Effects of the constant use of manure and artificial fertilizer on savanna soils in Nigeria over 45 years.



Source: Powell et al. (in press).

Figure 4. Effects of cattle feces and urine on pearl-millet grain yields in Niger.

are an impediment to manure use. Because the potential of manure in terms of quantity is limited, it is recommended that research concentrates on improving the quality of manure. For instance, the effects of different animal husbandry practices, feeds, and methods of manure storage on the quality of the feces should be investigated at the farm level. Also strategic combinations of manure and fertilizer applications for sustainable crop yields should be determined. In general, if manuring is practiced, then the next step for successful crop–livestock integration is to improve on the use of manure.

Crop residues for soil management

The general crop residue management practice in the dry savannas of West and Central Africa is that legume haulms are generally removed for animal fodder and cereal stover is often grazed by cattle but utilization is never complete (Van Raay and de Leeuw 1971). The unused residues are either gathered and burned or allowed to decay on the fields, thereby contributing to soil fertility improvement. Basically, in Niger, all the crop residues are cut from the fields and carried to feed animals. This is a unique situation as hardly any crop residues are left on the field for soil improvement (Mrs M. Dicko, personal communication). Also in Ghana, virtually all crop residues are used for feeding animals and for fuel. A new system that is emerging in Mali is that farmers cut the remains of stubble after crop residue grazing and take them to animal sheds where the latter is mixed with manure and urine to form a rich compost which is applied on the fields at the beginning of the rainy season (B. Traoré, personal communication).

Research in the region has illustrated the positive effects of various crop residue (CR) management practices on grain yields and soil maintenance. In Nigeria, it was shown that incorporated ash or chopped straw maintained exchangeable K and Mg and higher crop yields, while the corresponding plots from which crop residues had been removed showed a drastic reduction in these elements (Jones 1976; Bagayoko et al. 1996; Tables 1 and 2).

In Niger, Bationo et al. (1993) have reported a large positive and additive effect of CR and fertilizer on millet while the control plots (no fertilizer; no CR) declined in yield, emphasizing the need for soil amendments if crop yields are to be maintained on these soils (Table 3). Applications of CR have also been found to increase soil organic matter

Table 1. Yields of maize grain and stover (kg/ha).

Residue treatment	Grain		Stover	
	P ₀	P ₁	P ₀	P ₁
Burn	2132	3397	5187	6437
Incorporate	2100	3314	4613	6315
Remove	1705	3260	4106	6143
S.E. (±)	213		336	

All values are means of three replicates of two levels of nitrogen fertilizer. Differences between nitrogen levels and between phosphate levels were highly significant for both grain and stover.
Source: Jones (1976).

Table 2. Effect of crop residue treatment on sole cropped millet, Cinzana, Mali, 1991–1995.

Millet residue treatment	1991	1992	1993	1994	1995
Removal	1265	1514	1392 b	1290	1860
Left on surface	1492	1720	1095 c	1293	1800
Incorporation	1413	1674	1596 a	1318	1908
CV %	22	24	30	24	15

Averages followed by the same letter are not significantly different ($P < 0.05$)
Source: Bagayoko et al. (1996).

Table 3. Effect of crop residue and fertilizer on pearl millet grain and stover yields at Sadoré, Niger.

Treatment	Grain yield (kg/ha)			
	1983	1984	1985	1986
Control	280	215	160	75
Crop residue (no fertilizer)	400	370	770	745
Fertilizer	1040	460	1030	815
Crop residue plus fertilizer	1210	390	1940	1530
LSD _{0.05}	260	210	180	200

Source: Bationo et al. (1993).

content (SOM), P availability, effective cation exchange capacity (ECEC), and pH (thereby alleviating Al toxicity and Mo deficiency) (Bationo et al. 1993; 1995). CR also leads to an increase in the total numbers of soil bacteria (Hafner et al. 1993) and decreases soil temperatures (Buerkert et al., unpublished). Complementary research on crop residues from national scientists in Niger includes the promotion of CR for soil protection, fences, and contour bands (Moctar Karimou, personal communication).

Crop residues have a lot of potential in maintaining soil fertility but many researchers working in this area have admitted that there are some problems associated with their exploitation and some gaps which call for additional research. For instance, sometimes most of the crop residues are utilized as fodder; also the incorporation of crop residues into the soil may require more labor or machinery and many stem borers are harbored in stovers. Since considerable amounts of CR would be required to achieve sustainable increases in crop yield, future research should consider the combination of lime with these materials while alleviating soil problems such as acidity (Bationo et al. 1995). In the northern part of Burkina Faso, it was shown that mulching with 6 t/ha of *Loudetia togoensis* (a plant that is unappetizing to animals and provides poor forage) increased the grain yield of sorghum (140 kg/ha with no mulch versus 774 kg/ha with mulch) and this is partly because mulching reduces water loss by 64%. Without mulching, production is limited by water and it is promoted where manure is not available in large quantities and fertilizers are too expensive. Other potential areas of research that have been identified include:

- *Quantifying tradeoffs between the different uses of CR and assessing the effects of organic and inorganic fertilizers on grain and fodder yields.*
- *Determining the critical levels of SOM for the different soil types, climates, and cropping systems.*
- *Investigating the effects of CR on soil biological and physical properties and soil conservation.*

A very debatable issue on soil management using organic amendments is whether to use the crop residues directly as organic fertilizer or indirectly in the form of manure. There is currently an ongoing ILRI–IITA trial in selected moist savanna Ecoregional Program for the Humid and Subhumid Tropics of Sub-Saharan Africa (EPHTA) benchmark and pilot sites that tries to address this issue; this approach could be extended to the dry savannas.

Animal traction

The use of draft animals was introduced to West and Central Africa in the early nineteenth century by the English and French colonial administrations to promote cash-crop production (groundnut, cotton, and oil seeds) and improve the quality of diet (which was predominantly carbohydrate) of the small-scale farmers and raise their income (Lynn 1953; Rouspard 1987; Musa 1989). However, in the middle of the century, interest in animal power dwindled because of governments' favorable policy of tractorization in the region. The subsequent failure of mechanization resulted in a major boost again in animal traction and since then, the concept seems to have been promoted in various degrees by policymakers and development agencies. In West and Central Africa, animal traction tends to be more developed in Senegal, Nigeria, and Mali (McIntire et al. 1992). Cattle (mainly bulls) are employed for traction, while donkeys, camels, and horses are used for the transportation of loads and humans (in Senegal, horses are also used for traction). Since the introduction of animal power to most West and Central African countries, the bull was singled out as the only animal to be trained for draft work. However, as pointed out by Musa (1989), all animals can be used for draft work and in Senegal, it is acknowledged that using cow traction is more profitable because this animal has the advantage of producing milk, manure, and power.

In most West and Central African countries producing cotton, groundnut, and rice, all farm operations (plowing, seeding, weeding, fertilizer application, and harvesting) are done by animal power whereas only the plow is used by subsistence farmers. Many researchers (Gefu et al. 1990; Jansen 1993) identified the constraints to the adoption and expansion of animal traction in the West and Central African region as lack of knowledge, disease outbreaks, the use of young animals, lack of suitable implements, lack of capital, and the need for subsidy. A lot of work has been done on the development of implements but there is still insufficient information on the feeding and nutrition of draft animals, responses to work, health, and the tractability of different breeds. Research into improved forms of equipment using cheap and locally available materials is also imperative for small-scale farmers.

Crop–livestock integration

In the context of most West and Central African countries, livestock and crop production systems are an integral part of one another (Kallah and Adamu 1988). Crop residues provide fodder for livestock (Van Raay and de Leeuw 1971; Alhassan et al. 1983) while, occasionally, grain provides supplementary feed for productive animals. Animals improve soil fertility through manure and urine deposition and animal power for farm operations and transport. Sale of animals sometimes provides cash for farm labor and agricultural inputs. There are several examples of completely integrated crop–livestock production systems where sustainable increases in both crop and livestock production have been achieved after considerable periods (30–40 years) of continuous cropping without resulting in land degradation. Some of them are the close settled zone (CSZ) of Kano in northern Nigeria (Harris 1995), Banamba in Central Mali (Abou Berthe, personal communication), and Batalay in southern Chad (K.N. Ngwara, personal communication). The key success to these farming systems is effective crop–livestock integration involving the recycling of nutrients within the system.

It is therefore recommended that future research focus on how to improve the efficiency of the nutrient cycling concept. A particular challenge facing farmers is to minimize nutrient losses through good management (Powell and Valentin 1997); improved feed production, quality, availability, and more efficient feeding systems; new ways to capture and conserve nutrients excreted by livestock; improved manure spreading techniques; and cropping systems that reduce nutrient losses and can improve livestock impacts on the soil environment. A cross-country analysis of the various crop–livestock production systems is shown in Appendix 1.

Constraints to crop–livestock production and integration

Some of the key constraints to crop production include:

- *low moisture caused by erratic rainfall*
- *low soil fertility*
- *diseases, insect pests, and parasitic weeds*

Appendix 1. Cross-country analysis of crop–livestock integration and researchable issues in the dry savannas of West and Central Africa.

Feature	Burkina Faso	Cameroon	Ghana	Mali	Niger	Nigeria	Senegal	Chad	Research issues and institutions
% land area that is dry savanna (500–1000 mm rainfall)	66	6	7	20	16	27	53	26	
Crop agriculture									
Cereal–legume intercropping			Maize–tobacco system is common.	Emphasis on cotton for cash.	Emphasis on cowpea.	Dry season cowpea cropping in <i>fadama</i> and irrigated areas.	Emphasis on groundnut for cash.	Dry season sorghum (<i>berbéré</i>).	Dual-purpose crop varieties. IITA, ICRISAT, NARS.
Mainly millet, sorghum with cowpea. Groundnut and cotton as a cash crops. Sandy, fragile soils with low nutrient content limit crop production.									
Livestock agriculture									
Cattle, sheep and goats are important. Production often limited by feed availability; animals depend mainly on natural pasture in the wet season with crop residues and agroindustrial by-products in the dry season.	Agro-industrial by-products exported to other countries.	Government policy to retain cotton seed cake in dry savanna where livestock are common.	Defoliation of maize before grain harvest to provide fodder. Use of pigeon pea.	Identification of sorghum variety (Malisor 92.1) that can stay green after harvest.		Dual-purpose and dry season cowpea for fodder.		Dry season sorghum for fodder.	Improved fodder; health ILRI, NARS.
Manure for soil management									
Manure use is important because of decline in fertilizer use/availability. Main systems are corraling or stabilization; with manure applied to crop fields, especially those near the homestead.	Zai system Manure used in combination with locally available Burkina Rock Phosphate.								Appropriate combinations of manure + fertilizer. Optimizing nutrient capture IFDC/ICRISAT, ILRI, NARS.
Crop residues for soil management									
Legume haulm removed for fodder; cereal residues grazed, but some left on fields. Residues either burned or allowed to decay for soil improvement				Unused cereal residues are cut and mixed with manure to make compost.				Use of cotton seed cake as soil ameliorant.	Appropriate combinations of crop residues and fertilizer. Minimizing nutrient loss. IFDC/ICRISAT, ILRI, IITA, NARS.
Animal traction									
Traction using cattle and equines (for transport) is common, especially where cash crops are grown. Use of animal traction is important in alleviating labor constraint, especially for timely crop planting.	Donkeys also used for traction.	Donkeys used for traction.			Cattle for carts.		Use of cows for traction (well advanced). Also donkeys and horses for traction.		Feeding of traction implements; tractability of different breeds; use of cows ILRI/NARS.

- *lack of inputs and infrastructure*
- *other problems include labor shortages, low resource base, inadequate marketing facilities.*

For the livestock sector, the major technical and socioeconomic constraints are:

- *low feed supply*
- *animal diseases and lack of veterinary facilities*
- *conflicts between agropastoralists and arable farmers*
- *loss of cattle through theft*
- *as in the crop sector, inadequate infrastructure including transportation, marketing, extension services, and credit and input distribution systems*
- *livestock owners prefer a large herd size for social prestige as opposed to a small herd size of good quality.*

In addition, some of the specific constraints that militate against fostering crop–livestock integration include:

- *Ox-plowed ridges are believed to accelerate leaching and the erosion of nutrients.*
- *Competition for resources such as land, labor, capital, management, and water by the crop and livestock sectors.*
- *Land use and tenure policies that inhibit livestock mobility and limit farmers' access to manure and livestock access to feed.*
- *Unavailability of implements for traction animals.*
- *Keeping livestock in villages to produce manure sometimes fails because shortage of feed and water encourages transhumance.*
- *Since manure is bulky and is required in large quantities, high labor and transportation costs may be involved.*
- *Wrong targeting of crop–livestock integrated systems.*
- *Lack of research on holistic approaches; this requires in-depth knowledge of integrated crop–livestock systems.*

- *Farmers are reluctant to grow improved forages; this is related to the whole systems approach.*
- *Bias, including policies, towards the crop sector to the detriment of livestock production.*

Opportunities for crop–livestock integration

- *The farming systems in West and Central Africa are basically agropastoral and the proportion of mixed farmers is increasing, giving the opportunity for farmers to collect manure and use animal power.*
- *Intensification of agriculture which is currently occurring in most farming systems favors crop–livestock integration.*
- *Poor soil fertility, unavailability or increases in prices of fertilizers, and labor shortages, have forced farmers to rely on alternatives such as manure and traction.*
- *In Senegal, there is scope for improving the efficiency of the integration by diversifying the use of animals. For instance, the use of cows for traction will also provide milk and manure. Farmers can also crop in the wet season and engage in livestock enterprises in the dry season.*
- *Livestock enterprises are more lucrative than crop farming so it is advantageous to integrate livestock into farm activities.*
- *Integration of crop and livestock systems will help in reducing conflicts between farmers and agropastoralists.*
- *Integration promotes sedentarization: pastoralists will have access to facilities for their animals and animals will contribute more manure and urine.*
- *Many indigenous, emerging, and developed technologies are available to support sustainable crop–livestock integration. These include improved cereal and grain legume varieties, cropping systems, weed and nutrient management strategies, the eradication of most livestock diseases, and the development of modeling and all-year-round feed packages for animals.*

Conclusions and recommendations

Admittedly, solutions that address the evolving intensification of agriculture and the wide range of associated problems in the dry savannas are unlikely to come from any one source but from a greater integration of the various approaches to improve crop and livestock enterprises in addition to the following ongoing and future research efforts.

Crop and livestock improvement

- *Optimizing the impact of high yielding grain legumes (cowpea, pigeon pea, groundnut, etc.) and cereals (sorghum, millet, maize, etc).*
- *Controlling weeds, pests, and diseases is imperative in any agenda.*
- *Increasing animal resistance to disease and parasites; improving the productivity of indigenous livestock.*

Feed resources development

- *Upgrading feed quantity, quality, and soil productivity by the targeted integration of grain and forage legumes with cereal crops in rotations, intercropping, undersowing systems, etc.*
- *Future research approaches need to concentrate on the genetic improvement/enhancement of the quality and quantity of crop residues.*
- *Promoting animal traction in feed resources and crop production.*
- *The possibility of importing fodder from wetter ecological zones to the dry savanna needs to be considered both in terms of logistics and socioeconomics.*

Soil and nutrient management

- *Improving the efficiency of nutrient cycling in crop–livestock systems.*
- *Strategic combinations of manure and fertilizers.*

- *Indigenous systems such as the Zai technique should be studied to understand their merits so as to provide a building block for future interventions.*
- *Optimizing the utilization of crop residues in soil management.*

Socioeconomic factors

Systems modeling and GIS applications, combined with socioeconomic information, such as identification of areas where market driven intensification is ongoing and impact is likely to be greater (Ndubuisi et al. 1998), should have a role in optimizing the targeting of new technologies. For instance, an approach needs to be included encompassing the “whole system” while aspects including the determinants of farmer decision-making and opportunities for using technologies (such as improved varieties, cropping systems, better ruminant nutrition, weed and nutrient management) to enable existing sustainable systems to address the challenges of increased intensification need to be included.

Establishing effective input (e.g., fertilizer) and support services (e.g., veterinary delivery systems); establishing infrastructure (e.g., roads, processing, and marketing facilities); and strengthening government institutions are important.

An appropriate strategy would be to select technologies with the highest potential impact from the above areas, in order to form a holistic package for testing and dissemination with a view to maximizing total productivity at the farm level. This holistic approach should be supported by socioeconomic information such as determinants of farmers’ decision making for certain technologies as well as the development of tools to assess whole farm impacts of new interventions. A newly initiated trial, jointly executed by ICRISAT, IITA, and ILRI on crop–livestock systems, involving the use of improved sorghum and cowpea varieties, pesticides, and cattle manure with limited fertilizer in an intercropping context, is a step in the right direction. A similar approach could be used to develop new scenarios; for instance, animal traction using cows that have been shown to be more profitable, could be combined with the best feeding regime, including dual-purpose cowpea to produce high quality manure and well fed animals (in good condition) for farm operations. The best cereal–legume intercropping combinations could be planted in such a system using the optimum fertilizer, manure management practice (e.g., *Zai* method).

Against this background, the consortium of international centers (ILRI, IITA, ICRISAT, IFDC, and the Centre for Overseas Research and Development [CORD]) with complementary expertise, regional institutions, and NARS partners would be the best implementers of such a broad field of activities. The joint program should be promoted as a fully integrated resource management/commodity production systems project rather than the commodity-based programs, which unfortunately had in the past been the final objectives of the research centers. Other advantages of this collaboration are that the centers try to address present and evolving intensification/agricultural problems. Playing this role collectively rather than individually adds value to research investments. It is imperative that such an interdisciplinary and interinstitutional approach will ensure the development of appropriate techniques that will match the ecozones and the farming systems.

References

- Agbenin, J.O. and J.T. Goladi. 1998. Long-term soil fertility trend in the savanna as influenced by farmyard manure and inorganic fertilizer. Pages 21–29 *in* Soil fertility management in West African land-use systems, Proceedings of the regional workshop, edited by G. Renard, A. Neef, K. Becker and M. Oppen, 4–8 March 1997, University of Hohenheim, Germany, ICRISAT, Niamey, Niger and INRAN, Niamey, Niger.
- Agyemang, K., D.A. Little, and B.B. Singh. 1993. Emerging evidence of highly integrated crop–livestock farming systems in northern Nigeria: a case study from Kano State. *Cattle Research Network Newsletter* 12: 7.
- Alhassan, W.S., O.W. Ehoche, I.F. Adu, and A.T. Obilana. 1983. Crop residue potential of agricultural development projects. (a) Chemical composition of crop residues. NAPRI Annual Report, Shika, Zaria, Nigeria.
- Bagayoko, M., S.C. Mansou, S. Traoré, and K.M. Eskindrige. 1996. Pearl millet/cowpea cropping system yields and soil nutrient levels. *African Journal of Crop Science* 4: 453–462.
- Bationo, A., A. Buerkert, M.P. Sedogo, B.C. Christianson, and A.U. Mokwunye. 1995. A critical review of crop residue use as soil amendment in the West African semi-arid

tropics. Pages 305–322 in *Livestock and sustainable nutrient cycling in mixed farming systems of sub-Saharan Africa*. Volume II, edited by J.M. Powell, S. Fernandez-Rivera, T.O. Williams and C. Renard. International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia.

Bationo, A., C.B. Christianson, and M.C. Klaij. 1993. The effect of crop residues and fertilizer use on pearl millet yields in Niger. *Fertilizer Research* 34: 251–258.

Bulatao, R.A., E.E. Bos, P.W. Stephens, and M.T. Vu. 1990. *World population projections, 1989–1990 edition: short and long-term estimates*. The World Bank, Washington, DC, USA.

Critchley, W. 1991. *Pour protéger nos terres. Conservation des eaux et du sol en Afrique sub-Saharienne. Réseau d'Information des Terres Andes et de l'Institut pour l'Environnement et le Développement*. Published by Oxfam, Oxford, UK. 83 pp.

De Grandi, J.C. (ed.). 1996. *L'évolution des systèmes de production agropastorale par rapport au développement rural durable dans les pays d'Afrique soudano-sahélienne*. Collection FAO: Gestions des exploitations agricoles. No. 11. Food and Agriculture Organization, Rome, Italy. 162 pp.

Fall, A. and N. Diouf. 1998. *Role and future potential of working equines in West Africa with reference to Senegal*. Isra (Institut Sénégalais de Recherches Agricoles), Dakar, Senegal. 13 pp.

FAO (Food and Agriculture Organization). 1993. *Atlas of African Agriculture*. FAO, Rome, Italy.

Gefu, J.O., E.O. Otchere, E.S. Gwani, and H.U. Ahmed. 1989. *Draught animal power research and development in Nigeria. A bibliography*. NAPRI (National Animal Production Research Institute), Ahmadu Bello University, Shika, Zaria, Nigeria. 23 pp.

Hafner, H., J. Bley, A. Bationo, P. Martin, and H. Marschner. 1993. Long-term nitrogen balance for pearl millet (*Pennisetum glaucum* L.) in an acid sandy soil of Niger. *Zeitschrift für Pflanzenernährung und Bodenkunde* 156: 164–176.

Harris, F. 1995. Nutrient dynamics in the Kano close-settled zone. ILEIA Newsletter December 1995, Volume 11 Number 4: 16–17.

Harris, F. 1996. Intensification of agriculture in semi-arid areas: lessons from the Kano close-settled zone, Nigeria. International Institute for Environment and Development, London, UK. 20 pp.

Hesse, J.H. 1996. The integration of crop production and livestock husbandry on farm level in Northern Ghana. A study prepared for the farming systems-oriented agricultural research in Northern Ghana. Savanna Agricultural Research Institute, Nyankpala, (SARI), Ghana. 39 pp.

ILEIA. 1998. (Information centre for Low-External-Input and Sustainable Agriculture). Review and Planning Workshop 9–12 March 1998. ILEIA, Leusden, The Netherlands. 29 pp.

INRAN (Institut National des Recherches Agronomiques du Niger). 1996. Programme d'amélioration des productions animales. INRAN, Niamey, Niger. 76 pp.

ILRI (International Livestock Research Institute). 1997. Livestock and soil fertility: exploiting the natural balance. ILRI, Addis Ababa, Ethiopia. 7 pp.

Jansen, H.G.P. 1993. Ex-ante profitability of animal traction investments in semiarid sub-Saharan Africa: Evidence from Niger and Nigeria. *Agricultural Systems* 43: 323–349.

Jones, M.J. 1976. The significance of crop residues to the maintenance of fertility under continuous cultivation at Samaru, Nigeria. *Samaru Research Bulletin* 259: 117–125.

Kallah, M.S. and A.M. Adamu. 1988. The importance of animal feces as fertilizer. National Animal Production Research Institute, Ahmadu Bello University, Zaria, Nigeria. 9 pp.

Lombin, G. and A. Abdullahi. 1977. Long-term fertility studies at Samaru, Nigeria. II. Effect of farmyard manure on monocropped cotton, sorghum and groundnuts and a rotation of the three crops under continuous cultivation. *Samaru Miscellaneous Papers*, Ahmadu Bello University (ABU), Zaria. 14 pp.

Lynn, C.W. 1953. Mixed farming in Nigeria. Institute for Agricultural Research, Ahmadu Bello University (ABU), Zaria.

- McIntire J., D. Bourzat, and P. Pingali. 1992. Crop-livestock interaction in sub-Saharan Africa. World Bank Regional and Sectoral Studies. The World Bank, Washington, DC, USA. 246 pp.
- Musa, H.L. 1989. Development and use of animal drawn implements in Nigeria. Pages 112–119 *in* Proceedings of the first national workshop on animal traction in Nigeria, Shika, Zaria, June 1989, edited by J.O. Gefu and E.O. Otchere. NAPRI (National Animal Production Research Institute), Ahmadu Bello University, Shika, Zaria, Nigeria.
- Ndubuisi, A., J. Zeddies, V.M. Manyong, and J.W. Smith. 1998. Crop-livestock integration along the gradient of resource-use intensification in the Northern Guinea Savanna of Nigeria. *Quarterly Journal of International Agriculture* 37: 105–115.
- Ngawara, K.N., K. Koulmasse, and G. Dehala. 1996. Etude sur les systèmes de production au Tchad. Comité Permanent Inter-Etats de Lutte contre la Sécheresse dans le Sahel. 145 pp.
- Norman, D.W., B.S. Emmy, and H. Henry. 1982. Farming systems in the Nigerian savannas. Westview Press, Boulder, Colorado, USA.
- Norman, D.W. 1974. Rationalizing mixed cropping under indigenous conditions: The example of northern Nigeria. *Journal of Development Studies* 11: 3–21.
- N'tare, B.R. 1989. Evaluation of cowpea cultivars for intercropping with pearl millet in the Sahelian Zone of West Africa. *Field Crops Research* 20: 31–40.
- Powell, J.M. and T.O. Williams. 1995. An overview of mixed farming systems in sub-Saharan Africa. Pages 21–36 *in* Livestock and sustainable nutrient cycling in mixed farming systems of sub-Saharan Africa. Volume II, Technical Papers edited by J.M. Powell, S. Fernandez-Rivera, T.O Williams and C. Renard. ILCA, Addis Ababa, Ethiopia.
- Renard, G., A. Neef, K. Becker, and M. Oppen (eds). 1998. Soil fertility management in West African land-use systems. Proceedings of the regional workshop, 4–8 March 1997, Niamey, Niger. University of Hohenheim, Germany; ICRISAT, Niamey, Niger and INRAN, Niamey, Niger. 600 pp.

- Rouspard, M. 1987. Nord-Cameroun : Ouverture et Développement. Thèse de l'Université de Paris X-Nanterre, France. 512 pp.
- Schlecht, E., S. Fernandez-Rivera, and P. Hiernaux. 1997. Timing, size and nitrogen concentration of fecal and urinal excretions in cattle, sheep and goats; can they be exploited for better manuring of cropland? Pages 361–367 *in* Soil fertility management in West African land-use systems, edited by G. Renard, A. Neef, K. Becker, and M. Oppen, Proceedings of the regional workshop, 4–8 March 1997, Niamey, Niger; University of Hohenheim, Germany; ICRISAT, Niamey, Niger; and INRAN, Niamey, Niger.
- Sédogo, P.M. 1993. Evolution des sols ferrugineux lessives sous culture : influences des modes de gestion sur la fertilité. Thèse Doctorat, Université Nationale de Côte d'Ivoire, Abidjan.
- Singh, B.B. and S.A. Tarawali 1997. Cowpea and its improvement: key to sustainable mixed crop/livestock farming systems in West Africa. Pages 79–100 *in* Crop residues in sustainable mixed crop/livestock farming systems, edited by C. Renard. Commonwealth Agricultural Bureau International (CABI), Wallingford, United Kingdom.
- Traoré, B. 1998. Production et utilisation de la fumure organique par les exploitations de la zone Mali-sud. Internal Report Septembre 1998 Institut d'Economie Rurale (Ier/Sotuba), Bamako, Mali 20 pp.
- Van Raay, J.G.T. and P.N. de Leeuw. 1971. The importance of crop residues as fodder: a resource analysis in Katsina Province, Nigeria. ABU, Zaria Samaru Research Bulletin 139.
- Williams, T.O., P. Hiernaux, and S. Fernandez-Rivera. 1998. Crop-livestock systems in sub-Saharan Africa: determinants and intensification pathways. International symposium on property rights, risk and livestock development, 27–30 September 1998, DSE Feldanfang, Germany. International Livestock Research Institute, Niamey, Niger.
- Winrock International. 1992. Assessment of animal agriculture in sub-Saharan Africa. Winrock International Institute for Agricultural Development, Morrilton, Wisconsin USA. 125 pp.