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Review

Sustainable agricultural practices in Nigeria: The integration of crop-livestock farming

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Integrated crop-livestock is advocated to be very promising in boosting food productivity and soil fertility in Nigeria owing to its numerous synergistic benefits as outlined in this review. Particularly, the system will be very suitable in the savannah regions of the country where livestock production is predominant. Although integrated crop-livestock farming has been in existence in these regions, it is typically cereal based-livestock system resulting in perennial depletion of soil fertility. Introduction of legumes into the system to form cereal-legume-livestock system can function as a key integrating factor through improvement of soil fertility, provision of healthy protein in the human diet and fodder for livestock consumption. This paper therefore, aimed to review the benefits of introduction of legumes like cowpea into the long existing cereal based livestock farming in Nigeria, particularly in the savannah regions of the country in order to boost food security and income of the farmers. The review showed that incorporation of cowpea into the system will in greater measure increase the overall food productivity, ensures sustainability of the soil fertility and substantially improves the income of the farmers in the country.

Key words: Cowpea fodder, soil fertility, food security, nutrient cycling.

INTRODUCTION

Agriculture in West Africa is intensifying in response to increasing population of humans and livestock. Consequently, increased productivity demand is placed upon integrated crop-livestock systems and more emphasis is on the roles of legumes such as cowpea and groundnut (Tarawali et al., 2003). Legumes can function as a key integrating factor in intensifying crop-livestock farming systems through supply of healthy plant protein in the human diet, fodder for livestock, and bringing nitrogen into the farming system through nitrogen fixation (Sanginga et al., 2003).

In this context, cowpea for example, has a wide role in contributing to food security, income generation, and the maintenance of resource base for millions of small scale farmers who grow it in the region. Raising goats, sheep and cattle for human consumption is the dominant form of livestock production by smallholder farmers in Nigeria. Besides providing animal products, livestock offer a means to store wealth and a form of insurance in the absence of properly functioning financial institutions (Moll, 2005). The introduction of livestock in the predominantly cereal-based system of the Guinea

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may stimulate farmers to increase the area cropped with legumes, breaking the cycle of continuous cereal cultivation with its negative impact on soil fertility and the control of biotic pressures (Alvey et al., 2001; Bagayoko et al., 2000). Legume haulms represent high-valued feed for ruminants and their presence on or near the farm could increase the profitability of legume cultivation. The cultivation of dual-purpose legumes such as groundnut, soybean and cowpea for the purpose of providing both edible grain and animal fodder, has rapidly grown in popularity among farmers of the Guinea savannah (Sanginga et al., 2003).

Integrated crop-livestock farming system offers opportunities to promote organic agriculture; and carry-over of carbon and nutrients from one cropping season to the next. In northern guinea savannas of Nigeria, almost all above ground biomass disappears from the field during the dry season but the common practice among farmers in collecting plant residues, feeding them to ruminants over the period of dry season, and returning the manure of the ruminants to the field at subsequent planting helps to reduce carbon and nutrient losses (Franke et al., 2008).

This paper considers the imperatives of agricultural intensification, benefits of integrated crop-livestock including nutrient cycling and soil fertility restoration with particular reference to the features of the Nigerian savannas where these scenarios are prominent. Also highlighted in the review are the potential roles that cowpea play in the system as well as strategies to optimize cowpea fodder yield.

CHARACTERIZATION OF THE REGION AND OF THE CROP AND LIVESTOCK PRODUCTION

Annual rainfall is less than 1000 mm with a growing period of 180 days or less meaning that much of the region experiences a longer (7-9 months) harsh dry season. The growing period shortens on a south-north axis. The sandy soil which is prevalent in this region is generally poor with low organic carbon and cation exchange capacity, and is also deficient in nutrients, especially nitrogen and phosphorus. Cropping is cereal based with maize, sorghum and millet dominating, and the maize and sorghum decreasing in prominence towards the north. Intercropping cereals with grain legumes is common in over 90% of fields, with cowpea and groundnut being the most common legume components. Both grain and residues from cropping and the ruminant livestock are important components of the farming system. Cattle, sheep, goats and to a lesser extent camels, provide milk, meat, traction, manure and cash (Bagayoko et al., 2000).

Farm sizes in Nigeria for example are generally small, ranging from about 3 to 6 ha; each field is usually 1 ha or less and one farmer rarely owns contiguous fields (Ogungbile et al., 1999). A typical cropping pattern shows that at the onset of the rainy season, cereals are sown in rows with wide inter row spacing. Two-three weeks later, a grain type cowpea (short duration) is sown in alternate inter row spacing, followed by a fodder type cowpea (or dual purpose, late maturing) in the remaining inter rows about three weeks later. Cereals will be harvested first, together with the grain type cowpea. Grain type cowpea will give a reasonable grain yield, but virtually no crop residue (Tarawali et al., 2003).

The remaining dual-purpose/fodder type of cowpea is left to grow over the rest of the field, until the rain ceased and the leaves begin to show signs of wilting. At this stage, any grain on the plants is harvested, and the residue is cut and rolled up for storage on house roofs or in tree forks. The stored residue is fed to ruminants during the dry season, or in some cases, sold in local market leading to substantial contribution to farmer’s income during this period of scarcity. The leaves of cereal stalks are stripped off after harvesting and fed to ruminants, while the stalks are used for building or as fencing materials. Ruminants within farm compounds are supplemented with the cowpea or groundnut residues and manure is collected with household wastes. At the start of the next cropping season, the “compost” of manure and house hold wastes are spread on the crop fields before land preparation (Singh et al., 2003).

OPPORTUNITIES AND CHALLENGES OF CROP-LIVESTOCK INTENSIFICATION

In sub-Saharan Africa, the population may reach 1.2 billion by 2025, with a demographic shift from about 30% urban population to at least 50% (Tarawali et al., 2004). These changes will mean an increasing demand for crops and livestock and even if production expands at the rate of 3% annually, it is likely that at least 21% of the children, about 39 million, will remain under nourished (ILRI, 2000). Some studies have indicated that through changes in dietary requirements in response to urbanization (Ehui et al., 1998), livestock demand in particular is likely to increase dramatically, from an increase of 2.5% for mutton, pork, and poultry to 4.2% for beef between 1993 and 2020 (Delgado et al., 1999).

Within sub-Saharan Africa, more than 40% of the current regional population is in West Africa (FAO, 2000), meaning that the opportunities and challenges presented by the intensification scenario will be heightened in the region. One of the responses of farming systems to agricultural intensification is the integration of crop and livestock production (McIntire et al., 1992). As crop farmers seek to increase production, their cropping activities spread into marginal land, fallow periods become reduced or absent, and consequently, the demand for nutrient inputs is raised. In the absence of reliable and cheap supplies of inorganic fertilizers, manure from transhumant livestock becomes more important. At the same time as livestock keepers enlarge their herds, crop residues from crop farmers increasingly become the major feed resources because there is no longer marginal or fallow land for grazing. Estimates have shown that ignoring crop residues as feed resources would result in serious feed shortages (Naazie and Smith, 1997). Fodder scarcity owing to climate change is already triggering conflict between herd's men and settled farmers in various parts of Nigeria (APS, 2008).

In these scenarios, crop farmer may begin to have their own livestock for ready access to manure and simultaneously sell off some of the marginal lands to livestock keepers, who settle and begin crop farming, using the manures from their animals (and possibly traction) as an input (Okike et al., 2001). In the dry savannas of West and Central Africa, integrated crop-livestock is already a common feature of the farming system. For example, the dry savannas consisting of the drier part of the northern Guinea Savannas, plus the Sudan Savannas representing more than 50% of the total land area of sub-Saharan Africa, with a significant proportion located in West Africa are practicing crop-livestock integration. Over 40% of the total ruminant livestock in West and Central Africa are in this region (Winrock, 1992).

Major constraints to agricultural productivity in the region include the long dry season, which results in crop stress due to drought at the beginning and, end of the wet season and a shortage of ruminant fodder during the harsh, dry period. The capture and storage of excess rainfall and the use of resource-efficient irrigation remain the only guaranteed means of maintaining cropping intensification. Other strategies that can increase water productivity directly or have indirect water saving benefits include reducing soil evaporation through use of cover crops and conservation agriculture practices, planting more water-efficient crop varieties, enhancing soil fertility to increase yields per unit of water utilized, decreasing runoff from cultivated land, reducing crop water requirements through microclimatic changes, reusing wastewater for agricultural purposes. Currently, about 2 million hectares are irrigated by reused wastewater (Knox et al., 2012). Conservation agriculture, precision-irrigated agriculture and the resulting improved water productivity require specialized tools and equipment; incentives are needed to ensure that these inputs are adopted in areas where the expansion of commercial agricultural is desirable (Pretty et al., 2006). The poor soils and incidences of pests and diseases also have negative effects on crop production (both grain and fodder). Moreover, inputs such as fertilizers and pesticides to counteract these negative forces are generally scarce or priced well above the means of the small holder farmers.

In the dry savannas, crop and livestock enterprises are closely integrated, with reciprocal benefits from crop residues as fodder for livestock, while livestock provide manure and traction that contribute directly to crop production. The mixed crop-livestock farming systems currently contribute to over 50% of the world's meat and over 90% of milk (ILRI, 2000). This system is recognised to have the greatest potential for intensification (De Haan et al., 1997). Increasing food demand due to expanding population places increased pressure on these systems to raise productivity.

In some cases, where production of mixed farming system has intensified, the full implications of use of non-leguminous crops have not been considered, as for example, soil is mined and severely degraded and livestock waste products become less in quality (Delgado et al., 1999). In this context, the situation in the dry savannas of West Africa, where integrated crop and livestock production systems have existed for many decades, but now face the pressure to produce more is ripe for interventions that address these opportunities. Cowpea which can contribute both to crop-livestock production system and directly to soil fertility through better quality manure has the potential to make major contribution to the system.

CONTRIBUTIONS OF COWPEA TOWARDS INCREASED AND SUSTAINABLE PRODUCTIVITY IN MIXED SYSTEMS

Soil fertility attributes

As legume, cowpea can contribute to soil fertility, mainly through its nitrogen fixing abilities. Part of the nitrogen fixed will remain in the soil in the roots, and thereby contribute to the soil fertility for subsequent crops. Some nitrogen fixed in the crop will eventually return to the soils as manure after residues are fed to livestock. In terms of the direct effects of cowpea in rotation with cereals, Manu et al. (1994) reported a comparison of on-station and on-farm studies in Niger where cowpea-millet intercrop and cowpea-millet rotations were used. On farmer's field, rotation with cowpea gave 2.6 times more millet grain and 3.3 times more residues, than the intercropped, non-rotated treatment. Bagayoko et al. (2000) reported that cowpea can supply 35 to 40 kg N ha^{-1} in a cowpea-millet rotation, and Carsky and Berner (1995) presented similar figures for cowpea rotation with maize.

In addition to the direct benefits of improved livestock production and health that results from feeding cowpea fodder, the quantity and quality of manure from such better fed animals will be improved and therefore, when returned to the soil at the beginning of the growing season, contribute more towards the maintenance of soil fertility. Schlecht et al (1995) reported that the manure nitrogen in gramme nitrogen/tropical livestock unit/day (g /TLU/ day) was on average 25% higher in animals receiving supplements. Feed quality affects nitrogen and phosphorus quality of manure with dietary legume addition having the potential to improve manure quality. Inclusion of cowpea and other feeds could be expected to alter dietary nitrogen relative to the needs of rumen microbes and the ruminant animal itself. The addition of small levels of cowpea to a diet of cereal stover could be expected to meet the needs of rumen microbes to improve digestion and intake (De Haan et al., 2010). Completely replacing cereals stover with cowpea haulms as the forage source with wheat bran increases dietary nitrogen well above the needs of both the rumen microbes and the animal. This diet would likely result in excess nitrogen excretion by the animal. Because of the relatively high availability of nitrogen, it is expected that much would be excreted in the urine rather than faeces. Combining cereal stover with legumes, grains and or by product feeds creates diets which match nitrogen needs for growth while supplying energy for good rates of gain and other soil nutrients and reducing excessive nitrogen that might lead to negative environmental consequences (Koralagama et al., 2008).

Weed dynamics

There is some evidence that cowpea may help to reduce the number of viable *Striga hermonthica* seeds in the soil through stimulating suicidal germination of the seed. *S. hermothica* is parasite on cereal plants, and causes huge crop losses (Berner et al., 1996). Carsky and Berner (1995) reported that rotation with selected cowpea varieties has a substantial and rapid effect on reducing *S. hermonthica*, with the number of attached *Striga* plants per maize plant being reduced by at least 50% when maize was grown after cowpea. The potential impact of reduced *S. hermonthica* population because of rotation with cowpea will result in better soil fertility arising from higher stover of cereals which will ultimately be converted into manure. Farmers' awareness of the roles of cowpea for soil fertility and *S. hermonthica* reduction is to some extent, demonstrated by the fact that they usually interchange the legume and cereal rows each year, and the cereal will benefit at the "micro level" from the cowpea grown in the previous year.

The system affect weed composition and its occurrence by changing the pool of management practices applied to the area, which will change the nature and amount of resources available for weeds, and help excluding from the system those weed species highly specialized in exploring a single or a few environmental resources, leaving room for less specialized and more flexible plant species (Gurevitch et al., 2009), which are usually not troublesome weeds. Understanding not only the level of occurrence but also the composition of the weed community under different cropping system is important to achieve efficient weed control. Management systems with low soil disturbance allow formation of a more diverse weed seed bank in soil. Rotation of crops with livestock help to break weed cycles thus reducing production costs and environmental risks posed by the use of agro-chemicals (Germani et al., 2015).

Animal feed and animal production

Cowpea residue is one of the most nutritious fodder resources for ruminant livestock (Tarawali et al., 1997). Farmers in the dry savannas deliberately grow cowpea varieties and use management practices/cropping systems which favor forage production, even at the expense of grain production (Steiner, 1982). Harvesting at the end of the wet season, before the dry season becomes severe, gives the best quality fodder, and this is preserved throughout the storage period. If the fodder is harvested late, when dry season is already underway quantity is reduced, and quality becomes poorer (Tarawali et al., 1997).

Cowpea fodder as a feed supplement increases animal live weight gain during the dry season. Schlecht et al. (1995) reported an experiment where Zebu cattle (bulls of about 250 kg live weight) were supplemented with 1 kg cowpea hay at night and 0.5 kg fresh rice feed meal in the morning per day per animal during the second half of the dry season. The animals were allowed to graze as usual for the rest of the day. It was found that the supplemented group gained 95 kg compared to 62 kg for the unsupplemented group. In many regions, cowpea fodder is particularly valued as a supplement for fattening livestock in the period leading up to Muslim festivals when sheep are traditionally slaughtered. Most farmers sell cowpea fodder during the dry season when feed shortage is critical and there is the belief that income from fodder sales is comparable to that of grains there by contributing substantially to farmer's annual income (ICRISAT, 1991).

From 1 ha of improved cowpea, a farmer could benefit by an extra 50 kg meat per annum from better nourished animals, with over 300 kg more cereal grain as a result of improved soil fertility directly from the cowpea and better manure from the animals (Tarawali et al., 1997). Other benefits include, better fed traction animals would work harder, timely land preparation and better crop yields. Relwani et al. (1970) recommended the use of cowpea in combination with cereals for lactating cows, to maintain milk yields of 5 L day^{-1}. Better fed ruminants would give more milk and are likely to be more productive (that is, increased weight grains mean that young animals will come into oestrus earlier). Providing more nutritious fodder also means that the comparatively indigestible parts of cereals (stalk) that are used as fodder are likely to be better consumed. Intake of more fibrous materials usually improves with the addition of better quality material to the diet.

Livestock systems reaching the highest levels of intensification may begin to show an increasing reliance on forage grown specifically as livestock feed. Cowpea can also play a role in these systems and forage-type cowpeas have been tested and used for both grazing and hay production. Researchers in Florida (Foster et al., 2009) have tested cowpea forage as a supplement for sheep fed bahiagrass hay compared to other legume hays or soybean meal. Cowpea hay had lower crude protein concentration than groundnut hay but sheep gained between 32 and 51 g/d when cowpea was supplemented with soybean (Chakeredza et al., 2002).

Crop production

Bhatti et al. (1983) recommended forage cowpea for use in Pakistan, recording dry-matter yields of 5.7 Mg ha^{-1} for the best variety. Dry matter yields can be positively associated with days to flower. The longer vegetative period, the more forage was produced (Tyagi et al., 1978). The number of leaves and branches were positively correlated with green fodder yield (Ram et al., 1990). In Australia cowpea is regarded primarily as a fodder crop with grain harvest being an exception (Tarawali et al., 1997). Imrie and Butler (1983) found that seed yield is positively correlated with forage yield in determinate cowpea accessions. In eastern and southern Africa cowpea is grown for human consumption of its leaves and beans, whereas in West Africa cowpea fodder plays a major role in the drier areas. Singh et al. (1997) reported that early and medium maturing varieties yielded higher grain but lower fodder than late maturing and fodder-type cowpea varieties which yielded 5 Mg ha^{-1} of fodder and less grain. This informed the farmer's practice of growing different cowpea varieties for grain and fodder production.

Only a limited number of studies have reported the specific variety of cowpea used and animal response which have been found to differ with cowpea variety and its associated forage quality (Anele et al., 2010). Singh et al. (2003) reported higher weight gain in rams supplemented with the cowpea haulms of variety IT90K-277-2 compared to Dan Ila. Akinlade et al. (2005) reported increased milk yield in cows supplemented with cowpea haulms of variety IT96D-716 compared to 994-DP. Residues of cereal crops are generally nutritionally inadequate to produce high yields of meat and milk. The greater nutritional quality of legume residues allows them to be used as a supplement to livestock diets based on cereal stover and other low-quality forage. One benefit of the use of cowpea and other legume fodders as a supplement is the provision of nitrogen to the rumen microbes, allowing them to improve utilization of the low quality forage. Energy intake is improved by both the addition of a higher energy feed (cowpea) and by increasing the availability of energy through increased digestibility of the lower quality forage (Baloyi et al., 2006).

CONCLUSION AND RECOMMENDATIONS

Integrated crop-livestock is frequently advocated as one of the most promising solutions to soil fertility decline and productivity losses in intensifying systems in Nigeria. Crop residues make up a major component of livestock diets in mixed crop-livestock systems and, therefore, improving the use and nutritional quality of crop residues is important to enhancing farm productivity and profitability. Residues of cereal crops are generally nutritionally inadequate to produce high quality and quantity manure, meat and milk. Introduction of legume fodder as a supplement not only provide nitrogen to the rumen microbes, allowing them to improve utilization of the low quality forage but also increase the availability of energy through increased digestibility. Development of dual purpose cowpea varieties that better feed both human and livestock will give farmers new and better choices for improving levels and efficiency of livestock production. Farming practices that encourages rotation between cereals and legumes as well as application of manure are recommended strategies which will turn around the fortune of agriculture in the region, and hence improve the livelihoods of the ever increasing populations now afflicted by climate change. The entire system is currently being threatened by unpredictable climate challenge. The capture and storage of excess rainfall and the use of resource-efficient irrigation remain the only guaranteed means of maintaining cropping intensification. By restoring soil fertility and reducing weed population yields increases to a much greater extent at both farm and regional levels than by using purchased agro-inputs. Increased livestock productivity in terms of weight gain, milk production and traction make the system not only profitable but also supply the protein requirements of the ever increasing urban populations. Furthermore, one way of tackling the incessant clashes between Fulani cattle rearers and settled farmers in Nigeria could be through the promotion of integrated crop-livestock concept among Fulani herders.

Conflict of interests

The authors have not declared any conflict of interests.

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