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Maize Production Intensification in Integrated Crop-Livestock Systems in West Africa

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Throughout the Guinea savannah of West Africa, settled farmers increasingly combine crop farming with livestock production (Tiffen, 2004, Sanginga et al., 2003). The integration of crop and livestock production is especially visible in intensively farmed and densely populated areas with access to urban markets. Raising goats, sheep and cattle is an important component of the farming system. Besides providing animal food products and draft power, livestock offers a means to store wealth and a form of insurance in the absence of properly functioning financial institutions (McIntire et al., 1992). Mixed crop-livestock farming potentially leads to synergies between crop and livestock production, supposedly improving the overall productivity and resilience of agricultural production. Crop-livestock integration is often being advocated as one of the most promising solutions to soil fertility decline and productivity losses in smallholder farming systems in West Africa. However, the importance of crop-livestock interactions in crop production intensification remains poorly understood. On-farm trials were conducted in northern Nigeria over a period of 4 years to assess the agronomic and economic performance of maize-legume systems with and without the integration of livestock. Goats were kept in zero grazing systems as this is the dominant form of livestock production in densely populated areas. Emphasis was given to nutrient cycling through manure production, crop productivity, and the economics of crop production. Based on a comparison of farmers' traditional farming practice and alternative best-bet options, we aimed to answer the following questions:

- **What quantities of manure can be produced in-situ from residues of cereal-legume rotations in zero-grazing systems, and what is the nutrient content of this manure?**
- **Does the application of in-situ produced manure in combination with mineral fertilizer lead to increased crop production compared to the use of mineral fertilizer alone?**
- **Does the integration of livestock with crops lead to improved economic profitability of crop production when compared to cropping without livestock?**

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The agronomic treatments were as follows:
i. Farmer practice: maize monocrop with 73 kg N/ha; 14 kg P/ha and 23 kg K/ha.

ii. Maize-maize monocrop with 120 kg N/ha and 20 kg P/ha from fertilizer and manure.

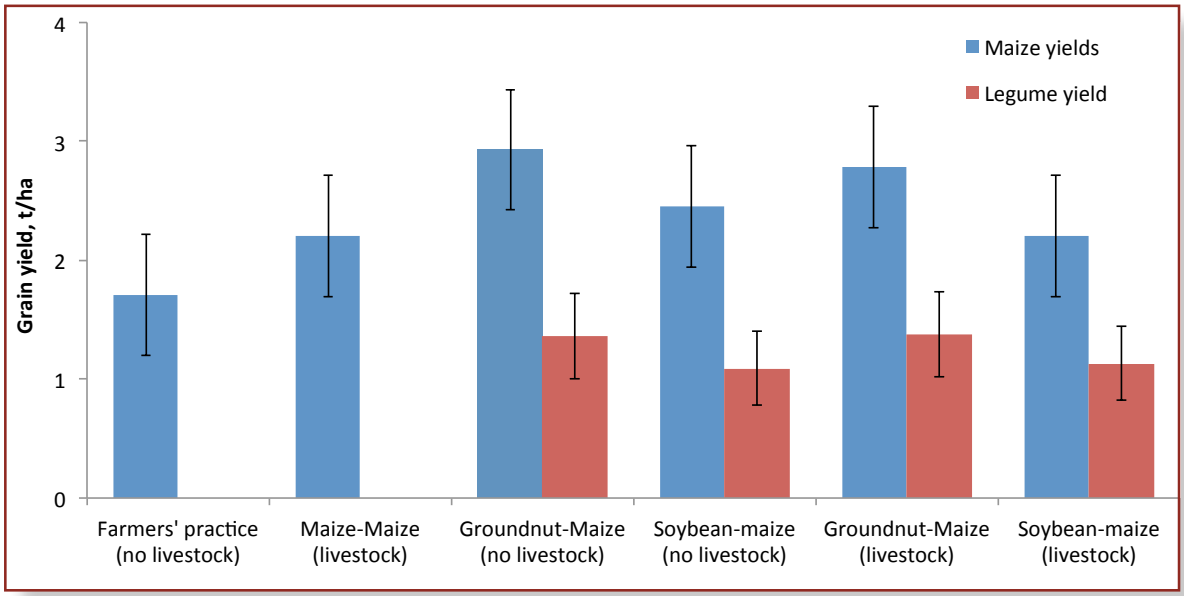

Figure 1. Maize and legume grain yield achieved in different rotations with and without livestock (average across 4 years and 6 sites, error bars represent standard errors of means). The grain price ratio is 1:3.3:1.7 for maize, ground nut and soyabean.

iii. Maize-groundnut rotation with 120 kg N/ha and 20 kg P/ha from fertilizer applied to maize (no livestock) and from a combination of manure manure and fertilizer (livestock system). Groundnut received 10 kg P/ha.

iii. Maize-Soyabean rotation with 120 kg N/ha and 20 kg P/ha from fertilizer applied to maize (no livestock) and from a combination of manure manure and fertilizer (livestock system). Soyabean received 10 kg P/ha.

In all cases all crop residues were removed after harvesting. Nutrients were recycled through manure in the crop-livestock systems, but no organic resources were added to the systems with no livestock.

The results indicated that the agronomic and economic performance of the 2-year soybean-maize or groundnut-maize rotations was considerably better than that of a maize monocrop **(Figure 1; Table 1)**. The economic analysis showed that prices of legume residues, grain, and labor had a large impact on the profitability of groundnut and soybean. Groundnut and soybean required considerably more labor (per ha and per t of grain) than maize. Labor availability, also constrained by labor market imperfections, could limit the adoption of these legumes. The actual value of legume resides in the region is uncertain, but it is likely that this value reflects the benefits of livestock keeping. The presence of livestock at or nearby the farm is likely to increase the value of legume stover, thereby stimulating farmers to incorporate more legumes into their cereal-based rotations.

Groundnut was a better source of fodder than the dual-purpose soybean variety, as groundnut provided more stover biomass with a higher N concentration. The 2-year groundnut-maize rotation with livestock produced the largest amounts of manure (2.9 t/ha/yr compared with 2.3 t/ha/yr for soyabean-maize rotation and 2.0 t/ha/yr for maize monocrop). The groundnut-maize rotation also gave the highest carry-over of nutrients through manure from one season to the next, on average 40 kg N, 7 kg P and kg 53 K/ha, covering approximately one-third of the expected N, P, and K uptake by maize (data not shown). The advantage of lower mineral fertilizer costs in groundnut-maize and soybean-maize rotations with livestock was offset by higher labor costs for manure application and slightly lower values of maize grain. Overall, no clear agronomic or economic benefits for crop production were observed from the combined application of manure and mineral fertilizer over the application of mineral fertilizer alone. This is in contrast with experimental studies in the region reporting higher cereal yields following the application mineral fertilizers combined with organic inputs. The quantity of manure applied in the current trial (2.0 - 2.9 t/ha) was well below the amounts used in other studies (2.5 - 10.0 t/ha annually) , but represent the amounts of manure typically applied by farmers. Manure could be valuable to crop production in ways other than assessed in the current trial, for example by improving soil fertility in the long-term (> 4 years), or direct impacts on production when manure is concentrated on small plots (e.g. nearby the homestead).

Table 1. Summary of the partial budget analysis of different treatments (average across years and sites).

Rotation	Farmers' practice	Maize-maize	Legume-maize, no livestock			Legume-maize, livestock		
Crop	Maize	Maize	Groundnut	Soybean	Maize	Groundnut	Soybean	Maize
Value of grain (US$/ha)	369	475	1,303	573	615	988	411	538
Costs (US$/ha)								
Labour for manure application	0	29	0	0	0	0	0	40
Other labour	213	288	482	269	284	484	270	284
Animal traction	72	72	72	72	72	72	72	72
Total costs (US$/ha)	422	549	573	360	567	575	361	531
Net Benefits (US$/ha)	-33	-74	731	214	48	413	50	7

The results of the trial showed little impact of integrated crop-livestock production on the agronomic and economic performance of crop production. The results also showed no evidence that integrated crop-livestock production is imperative for the sustainable intensification of crop production in the region. While benefits of crop-livestock production may occur under circumstances different from the current trial, we reckon that the increasing adoption of integrated crop-livestock production in the Guinea savannah is, to a certain extent, driven by factors other than those currently assessed. These may include the overall systems' benefits on included in this study, such as the role of livestock in provision of draft power and as a means for farmers to store wealth.

We reckon that in non-degraded soils in the West African Guinea savannah, maize production intensification can be viably achieved with proper use of mineral fertilizer, without necessarily using livestock manure in the short-term. More emphasis should be placed on appropriate management of nutrients and practicing rotation of maize with grain legumes.

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