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BACKGROUNDER

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Livestock and soil fertility: exploiting the natural balance

In the great drylands of western Africa, lying between the Sahara Desert to the north and humid zones to the south, tens of millions of people live by growing the food they eat. The 'agropastoral' survival tactics evolving in this region over the last several thousand years centre on keeping cattle, sheep and goats to see households through poor to ruinous cropping seasons, when little or no grain is harvested. When rainfall permits, livestock production is combined with cultivation of millet and sorghum. With the addition of daily milk, and occasion ally meat, these two cereal crops form the basis of every meal.

Having evolved in parallel with grasslands, ruminants help sustain as well as exploit rangeland ecologies. But the natural balance that exists between range and stock is today being put at risk by expansion and intensification of cropping to supply grain to a growing human population. To some extent, this imbalance can be corrected by fertilising dryland soils. Wide use of external inputs in Sahelian agri culture, however, will not occur for some time due to the high cost of inorganic fertilisers. Local resources will therefore have to be used more efficiently than ever. As this report explains, small-scale farmers can rely on the manure their ruminant animals produce to augment and sustain their cropping.

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CATTLE, SHEEP AND GOATS DO MORE than spend their days grazing and producing milk and meat. They also collect, transport, convert and deposit nutrients. Livestock are thus key to improving nutrient management in resource-scarce farming systems. Healthy soils are rich in both organic matter and nutrients. The soils of the Sahel are deficient in both. Long-term fertility trials on the savanna soils of West Africa show just how important animal manures are in making crop production more viable and sustainable as well as less risky.

ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE

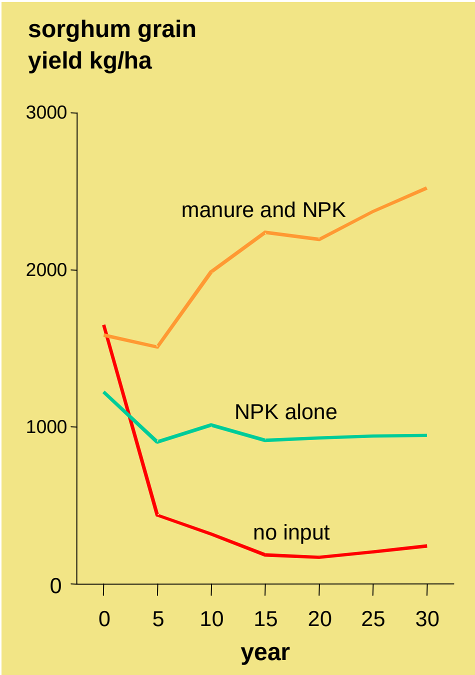

Figure 1a. Effects of applying manure and artificial fertilisers on sorghum crops in Burkina Faso over 30 years.

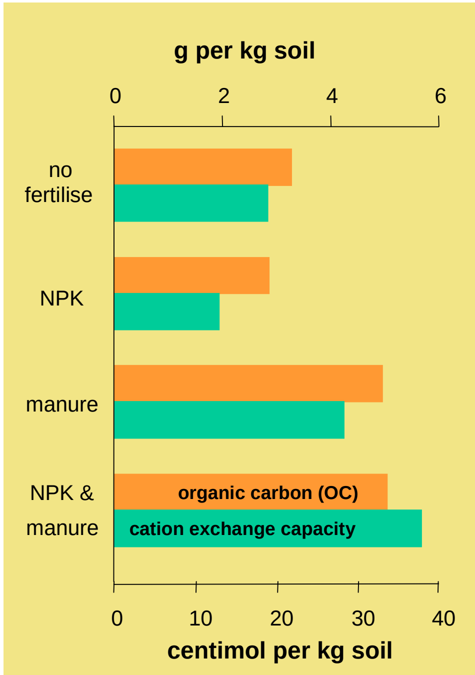

Figure 1b. Effects of constant use of manure and artificial fertilisers on savanna soils in Nigeria over 45 years.

Manures alone will not be enough to generate the large increases in crop productivity needed to feed Africa's growing populations, but strategic combination of manure with small quantities of artificial fertiliser *can* sustain steady increases in crop yields. Figure 1a shows that application of inorganic fertilisers to tropical soils leads to a *stagnation* in crop yields if used as the sole amendment over prolonged periods. Figure 1b gives results of a 45-year trial running in Nigeria, which demonstrate that exclusive use of inorganic fertilisers leads to a reduction in organic carbon levels and a decrease in cation exchange capacity compared to unfertilised, but cultivated, control plots. In sharp contrast, manure as a soil amendment influences these parameters positively. Addition of manure also improves soil structure, biological activity and water-holding capacity.

The uptake of nutrients from soils to plants to animals and, through animals, back to soils, is under intense scrutiny by scientists from the International Livestock Research Institute and the Sahelian C entre of the International Crops Research Institute for the Semi-Arid Tropics.

FOOTNOTES &
DATA SOURCES

Figure 1a.
A 3:1:1 ratio of NPK (nitrogen, phosphorus, potassium) was used in this experiment. Initial yields were apparently affected by previous cropping history; the long-term trends show a characteristic decline in plots provided no inputs.

Sédogo. P.M.. 1993. Evolution des sols ferrugineux lessivés sous culture: influences des modes de gestion sur la fertilité. Thèse Doctorat, Abidjan, Université Nationale de Côte d'Ivoire.

Figure 1b.
Experimental rates of NPK applications: N applied at 48–135 kg ha^{-1} as $(NH_4)_2SO_4$ from 1950–1968 and as $CaNH_4(NO_3)_3$ from 1969–1994, P at 18–54 kg ha^{-1} as single superphosphate, and K at 29–58 kg ha^{-1} yr^{-1} as muriate of potash (KCl).

Agbenin, J.O., and Goladi, J.T., in press. Long-term soil fertility trend in the savanna as influenced by farmyard manure and inorganic fertiliser. In: *Soil Fertility Management in West African Land Use Systems,* University of Hohenheim, ICRISAT and INRAN, Niger, 4–8 March 1997, © Margraf Verlag Weikersheim, Germany.

Economic and physical survival in the Sahel is won in earnest. Poor soils and variable climate, which in good years produces rain in just three out of five 'seasons', make cropping highly risky.

Without animals, which continue to produce milk and meat in all but the severest and longest droughts, human life and livelihood in the Sahel would be impossible.

Scientists are analysing a host of biological processes and socio-economic trade-offs involved in nutrient transfer. They are looking for modifications in agropastoral systems that will increase nutrient availability and nutrient cycling efficiency. And they are testing new ideas and methods to crank up these systems to higher levels of productivity and sustainability.

The agropastoralists of the Sahel graze their livestock each day on common rangelands that lie beyond the cropped land that surrounds the villages. Village stock thus spend the day collecting nutrients from the range and fallows and converting those nutrients through rumination and metabolic processes into forms more readily available to plants. After returning to the village each evening, the animals are tethered overnight on the crop lands, where they deposit most of the nutrients they have ingested all day. Up to 95% of the nitrogen and phosphor us nutrients consumed by livestock are again excreted: nitrogen is voided in both urine and faeces, phosphorus predominantly in faeces.

As efficient as this 'mobile composting' system is for recycling nutrients back to soils and crops, no farmer struggling to wrest a living from the fragile drylands of West Africa will ever have enough livestock ma nure to apply it every year over all of her cultivated fields. Fortunately, the residual benefits of manure on soil fertility mean that farmers do not have to manure every part of their fields every year. Rather, farmers can manage manure application rates on cropping areas simply by rotating the tethering sites of their animals among those areas.

This tethering rotation, which enables even the poorest live stock farmer to gain the benefits of 'precision manuring', offers several research opportunities for fine-tuning agropast oral farming systems for higher and sustainable yields.

Precision manuring is important. On fragile soils farmed by people with few natural resources other than their own, it can be essen tial. What has traditionally been ignored by scientists—but not by farmers—is that soil quality and crop yields vary as greatly in the Sahel as rainfall does, and not only from one season to the next and from one field to the next but also from one small part of one field to the next. Aware of these 'short-distance and –time' variations in soil properties, research focus ing on village management of grazing is now developing ways farmers can use livestock to better manage this microvariability. Over time, these methods will help farmers to even out the variations in their soil fertility and crop yields. Large-scale farmers may be able to afford to ignore 'bad spots' of land. Farmers with leas than a hectare of dryland cannot. And know well they cannot. Research can help.

Night-tethering of small stock in Niger.

By strategic use of night-tethering, Sahelian farmers apply manure on the 'bad spots' and 'tired soils' of their cropping fields most in need of the transfusions of nutrients and organic matter that manure deposits provide them.

When farmers apply livestock-based precision manuring, urine as well as faeces is deposited on their croplands. As Figure 2 indicates, this bonus has dramatic impacts on yields of cereal staples, which, in the Sahel, may mean the difference between a household's having enough or not enough calories to see them through to the next harvest.

DATA SOURCE

Powell, J.M., Ikpe, F.N., Somda, Z.C., and Fernández-Rivera, S.

Manure and urine effects on pearl millet yield and soil chemical properties, submitted to *Experimental Agriculture.*

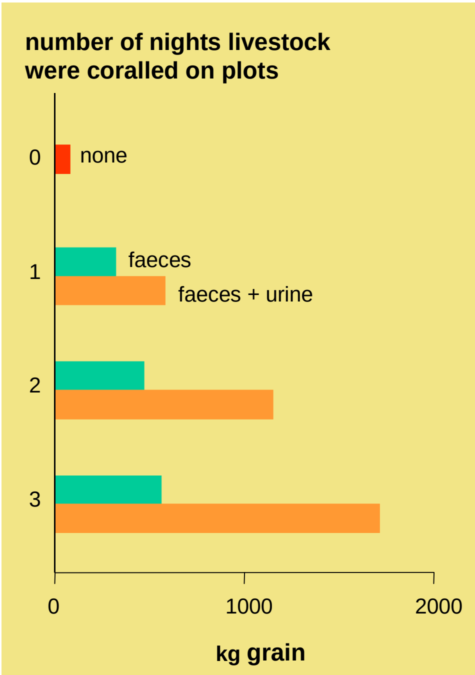

Figure 2. Effects of cattle faeces and urine on pearl-millet grain yields in Niger.

The results in Figure 2 above were obtained by coralling six cattle overnight in moveable 4 × 4 metre pens for either 1, 2 or 3 nights on plots of sandy soil in Niger. For comparison, amounts of faeces (manure without urine) equivalent to that deposited each night by the penned cattle were applied by hand to other plots.

The results show that application of faeces produced signifi cantly more millet. The most dramatic effect on yield, however, was produced by the addition of both faeces and urine. Increases in yield occurred not only in response to extra nutrients provided by rising application rates of faeces and urine, but also in response to increases in the availability of phosphorus due to the presence of urine in the soil, which raises soil pH. Furthermore, the residual effects of applications of faeces and urine continued to increase soil fertility significantly in the second and third years after initial application.

The benefits of animal faeces and urine deposits on croplands are well known in Asia, where livestock perform the added service of controlling weeds as well as helping to maintain soil fertility when grazed under plantation crops such as rubber trees.

Cattle grazing under rubber in Asia.

Small-scale farmers in Asia face similar problems to those in West Africa: they too cannot afford to purchase large amounts of inorganic fertilisers to feed their soils so that their cropping remains productive and sustainable. But Asian farmers face additional constraints due to the region's higher population densities. Farming here characteristically is done on tiny plots of land that—because the humid and sub-humid climate allows it and increasing food needs drive it—are cropped continuously. Thus, Asian farmers have to turn the nutrient crank on their smallholdings even faster than African farmers.

More livestock are raised in Asia than in any other region of the world, although animals here are commonly kept in stalls in people's back yards rather than on range- or croplands. Asian farmers long ago met the challenge of deteriorating cropping soils due to intensification by using livestock to help recycle nutrients more efficiently. Scientists working to improve nutrient management on West Africa's fragile drylands are analysing Asian mixed smallholding systems to elucidate the princi ples being employed there, some of which will be highly pertinent to farming systems in Africa, which are beginning now also to intensify at a high rate.

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For more background and details on the research reported here, please see ➤ *Livestock and Sustainable Nutrient Cycling in Mixed Farming Systems of Sub-Saharan Africa,* Volume II, Technical Papers, ed. by J.M. Powell, S. Fernández-Rivera, T.O. Williams and C. Renard, ILCA, 1995, and ➤ *Soil and Crop Growth Variability in the Sahel,* by J. Brouwer and J. Bouma, Information Bulletin No. 49, ICRISAT and the Agricultural University of Wageningen, 1997.

Beginning more than a century ago, dire predictions were made by agricultural experts about the impending crash of unsustainable farming systems in developing regions. In the late nineteenth century, for example, after rapid population growth on Java began to force farmers to move into marginal upland areas, the colonial government predicted widespread soil exhaustion and decline in yields. Despite such gloomy prophesies, these upland areas today—over one hundred years later—represent 42% of the land used for annual crop production and support an average population density of some 600 persons per square kilometre. Farmers thus appear to have mitigated some of the worst consequences of continuous cropping on marginal uplands. This is largely because the Javanese farmers effectively integrated livestock production into their intensive cropping systems and devised systems for rearing livestock that effectively recycle nutrients *and* do so in economically efficient ways.

Livestock are managed in the highly intensified sytems of Asia purposely to produce manure as well as food and traction. Within these systems are demonstrably effective principles that can be applied to sustain intensification in parts of Africa and other regions. The first order of business for ILRI as it moves into Asia, therefore, is to learn what is already known from those who have long practical experience, i.e., the small-scale farmers who have evolved sustainable practices in mixed crop-and-livestock agriculture. Scientists can then help farmers in other eco-regions apply this expertise in ways that will sustain productivity gains for the benefit of future as well as present generations.

Sustainable small-scale farming in Java is based on use of livestock to produce manure to feed continuously cropped soils. The *'kandang'* animal enclosure shown here houses 4–6 sheep on a bamboo slatted floor over a pit where animal faeces, urine and rejected feed accumulate to form high-quality compost. This is used to fertilise the rice, maize and pulses that sustain the household. Javanese smallholders spend up to 6–8 hours a day collecting roadside grasses to feed their 'backyard' livestock. They make this investment in animal feed because their continued food security rests largely on the manure their animals produce.