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The risk of declines in soil fertility and crop productivity due to decreased livestock presence in agropastoral zones of West Africa

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1 Introduction

In West Africa, food security and living standards improvement are still major issues in rural areas. Until the 20th century, the main feature of agricultural systems in semi-arid and sub-humid areas was livestock, crop and tree integration. At landscape level, livestock traditionally drove nutrient transfers from rangelands to croplands (Fig. 1). These transfers were essentials for making crop productions sustainable (Dugué, 1998; Manlay *et al.*, 2004; Schlecht *et al.*, 2004). Sincemid-1900's the traditional crop-livestock systems are impacted by climate change, population growth and resulting land use change. Cropland extension was done at the expense of range lands leading to a decrease in biomass available for livestock (Lericollais, 1999). Livestock are consequently relegated to areas with low population densities and to sylvo-pastoral regions, i.e. arid areas were climatic constraints are too limiting for crop activities.

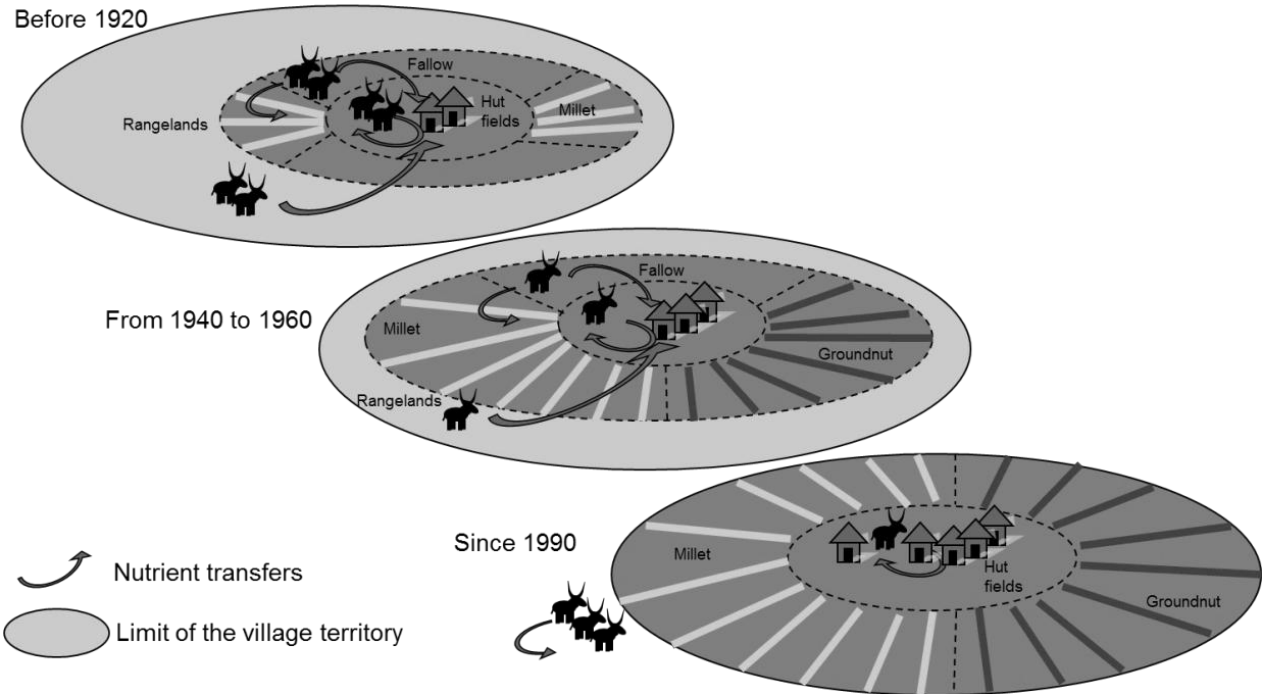

Fig. 1. Land-use change and dynamic of livestock-based nutrient transfers in village territories in semi-arid and sub-humid areas of West Africa during the 20th century

These dynamics emphasized tensions around biomasses (crop residues, manure) and led to the decline in wooded parkland and soil fertility. Increase in food demand, from cities in particular, emphasized the exports of agricultural products from rural areas to cities (cereals, hay, meat, etc.). While mineral fertilizers are poorly used, these dynamics are resulting in a negative nutrient balance that questions the sustainability of the resulting farming systems (Smaling *et al.*, 1997; Sanchez, 2002). The growing demand in livestock products in West Africa cities also represents an attractive market that may support the development of intensive livestock systems not any more based on free grazing but where animals are kept in-barns and fed with byproducts of the local agroindustry as feed concentrates. This study examines whether the reintroduction of livestock in landscapes affects the functioning and performances of agricultural territories.

2 Materials and Methods

The study focused on two villages within the groundnut basin of Senegal that adopted contrasting agricultural strategies; the first one kept a relatively traditional system based on livestock free-grazing (Diohine), while the second developed a system based on livestock fattening (Barry Sine).
Partial nitrogen (N) balances at plot, household and village levels were the indicators used to assess the sustainability of observed agricultural systems. The balances were built on a systematic inventory of biomass flows based on household survey: 44 households and 420 plots in Diohine and 74 households and 620 plots in Bary Sine.

3 Results – Discussion

Household scale nitrogen balances (13 kgN.ha^{-1} for Diohine, 25 kgN.ha^{-1} for Barry Sine) and village scale's ones (9 kgN.ha^{-1} for Diohine, 25 kgN.ha^{-1} for Barry Sine) demonstrate that Barry Sine village is more sustainable in terms of soil fertility maintenance (Table 1). Its higher nitrogen balances are mainly due to a larger use of manure (on average 1.83 kgN.ha^{-1} in Diohine, 2.86 kgN.ha^{-1} in Barry Sine). The introduction of the livestock fattening activity in farming systems improves animal presence at landscape level (0.96 TLU.ha^{-1} in Diohine, 2.31 TLU.ha^{-1} in Barry Sine), and provides an additional nitrogen input in the agro-ecosystem through imported concentrate feeds (3.14 kgN.ha^{-1} in Diohine, 17.6 kgN.ha^{-1}in Barry Sine). The cash-flow generated by the selling of fattened animals gives farmers better access to mineral fertilizers. An equivalent of 1 kgN.ha^{-1}is used on average in Diohine, versus 6 kgN.ha^{-1} in Barry Sine.

Table 1. Main village characteristics and performances for the 2012-2013 campaign

Village	Human population density (inhabitants.km^{-2})	Livestock stocking rate (UBT.ha^{-1})	Crop grain productivity (kgDM.ha^{-1})	Crop residues productivity (kgDM.ha^{-1})	Livestock productivity (kgLW.ha^{-1})	Nitrogen Balance (kgN.ha^{-1})	Nitrogen use efficiency (dmnl)
Diohine	180	0.96	400	2070	25	8.5	0.15
Bary Sine	320	2.31	510	3150	213	24.9	0.64

Livestock reintroduction in villages improve N use efficiency at both household and village scales (0.15 in Diohine, 0.64 in Barry Sine). However similar plot scale nitrogen balances (-20 kgN.ha^{-1} in Diohine, -23 kgN.ha^{-1} in Barry Sine) point out that Barry Sine's livestock fattening manure management is not optimal. There is still room for progress in N use efficiency through the improvement of manure management (urine collection via straw bedding, better manure transport facilities, covered manure heaps, in-soil manure incorporation), especially in Barry Sine where most of the manure is managed contrary to Diohine where most of the manure is directly deposited on-fields (Audouin, 2014).

4 Conclusions

Livestock was a strong driver of nutrient transfers from rangelands to croplands at landscape level and an essential component of sustainable soil fertility management in traditional crop-livestock systems based on free grazing. Due to growing population in rural areas, land use change results in a significant reduction of rangelands to the profit of croplands. The gain of such an expansion in terms of staple crop production is not evident because livestock stocking rate in villages is negatively affected resulting in a reduction of manure available for crop fertilization. To counter the resulting unbalance in nutrients, this study shows that livestock can be reintroduced in crop-livestock landscapes via the promotion of fattening livestock systems. Livestock intensification is also the opportunity to indirectly intensify cropping systems and then feed more people in rural areas. This new livestock system also revolutionizes the manure management system. The "animal driven" system is replaced by a "human driven" system including manure collection, storage and spreading. Farmers are requiring new knowledge and new equipment to entirely benefit from the larger manure available. New manure management systems aiming nutrient conservation along the biomass recycling have also to be designed to improve the nutrient use efficiency and the productivity of the new farming systems generated.

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