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"Multi-functional **farming systems** in a **changing world**"

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FSD5

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FOREWORD

Eight years after the launching of the FSD (Farming Systems Design) initiative in Catania (2007), the European Society for Agronomy (http://www.european-agronomy.org) has been mandated to organize its fifth symposium with the specific objective to strengthen the interdisciplinary and methodological focus of FSD. The overall objective is to promote research and capacity building on methodologies for the analysis and design of Agricultural Systems on a worldwide level. The research focus of this FSD community is the farm system level, the interactions and feedbacks at lower and higher levels of integration and the tools and methods required for understanding and implementing multi-functional farming systems expressing good trade-offs between agricultural production and ecosystems services. In a time when challenges for farming systems are increasingly defined by other systems operating at higher scales (food security, climate change, natural resource conservation, poverty alleviation….) it is important to keep an active scientific community sustaining innovation and capacity building on farming systems and their interfaces with those embedding systems and global issues.

These proceedings are aimed to serve as a compendium of the on going research in the FSD domain when considered worldwide and across the various sectors of agriculture (including fish-based systems). They include all the presentations (orals and posters) selected by the Scientific Committee of the 5th Farming Systems Design conference held in Montpellier (France) from September 7 to 9, 2015 (http://fsd5.european-agronomy.org/). A part of these communication have also been selected to compose special issues of major journals in the domain (Agricultural Systems and European Journal of Agronomy) and others will give raise to individual submissions in other journals.

The major achievements and challenges of the FSD approach are browsed through the 6 short sessions of the symposium "Farming Systems Design in Action: Methods, Achievements and Challenges" and are further developed and illustrated in the thematic sessions covering:

- *The grounds of the FSD approach* in quantitative analysis of crops (session T1. Assessing performances and services of cropping systems) and farms (T2. Assessing performances and services of farming systems).
- *The research frontiers on methodologies* for systems experiments at field level (W3. Cropping systems design: what can we do with field experiments and expert knowledge?), support of transition pathways at farm level (W4. Farms in transition), integrated analysis (T7. Scaling up from farm to landscape and multiscale scenario analysis of agricultural systems) and design (T8. Co-design and co-innovation with farmers and stakeholders) of agricultural systems.
- *A specific focus on crop models* (T3. Crop modelling and yield gap analysis for agricultural systems analysis and design) *and farm models* (T4. What's new with bio-economic models for the analysis and design of agricultural systems?) and the way they can be developed and used to sustain system's analysis and design.
- *Three typical challenges* on which the multi-scale and multi-domain FSD approach is likely to bring significant breakthrough: T5. Designing Climate Smart Agricultural Systems; T6. Designing sustainable agricultural systems with legumes; W6. Pathways for sustainable intensification of African agriculture?
- *Applications of the FSD approach to specific types of farming systems*: W1. Animal-based systems and crop-livestock interactions at farm and territory level; W7. Aquaculture systems, W2. Annual crops based systems; W5. Silvo-arable and silvo-pastoral systems.

Prof. Jacques Wery

(FSD5 Chair and ESA Executive Secretary)

Soil nutrient balance, economic performance and scenarios for closing nutrient gaps in heterogeneous smallholder farm systems in south-western Burkina Faso

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1 Introduction

Cobo *et al.* (2010) reviewed nutrient balance studies in Sub-Saharan Africa, which showed widespread nutrient mining. Most of these studies' findings revealed large negative balances, raising the issue of the sustainability of land management practices in Sub-Saharan African farming systems. It is hard to find studies that focused on the soil sub-component nutrient balance for different farming systems. Furthermore, the relationship between soil nutrient balance and a farm's economic performance needs to be investigated. This may help improve the efficiency of policy intervention, as well as contribute to the body of knowledge for farm design. This study's main objectives were to analyse the soil nutrient balances of different farm types and their linkage with farm economic performances and to evaluate scenarios for replenishing soil nutrients in smallholder farms.

2 Materials and Methods

The study was conducted in Ioba Province in the southwest region of Burkina Faso, where Thiombiano and Le (submitted) identified five main types of agricultural livelihood systems (hereafter referred to as farm types): i) farm type I – better-off, cotton-and livestock-based farms; ii) farm type II – better-off, non-farm activities preference farms, iii) farm type III – pro-poor, labourless and landless farms; iv) farm type IV – medium-income, labour-rich, marketable food crop-oriented and educated farms and v) farm type V – poor, insecure land-tenure, livestock-based farms. By using the Nutrient Monitoring (NUTMON) Framework (De Jager *et al.,* 1998), 15 farms representing the five farm types (three replications per type) were monitored during a full year for cropping, livestock and off-farm activities and related nutrient flows. Soil nutrient (nitrogen, phosphorus and potassium [N, P and K]) balances were calculated for the whole farm system and the soil subsystem. The relational soil nutrient balance-economic performance was investigated for the five farm types by using two dimensional diagrams. We evaluated three management scenarios for replenishing soil nutrients. The business-as-usual (BAU) scenario represents the actual practices. The intensification of mineral fertiliser use (IMF) scenario involves the increasing use of mineral fertilisers for replenishing soil nutrients. The recycling crop residues (RCR) scenario replenishes soil nutrients through enhancing the use of crop residues for fertilising crops.

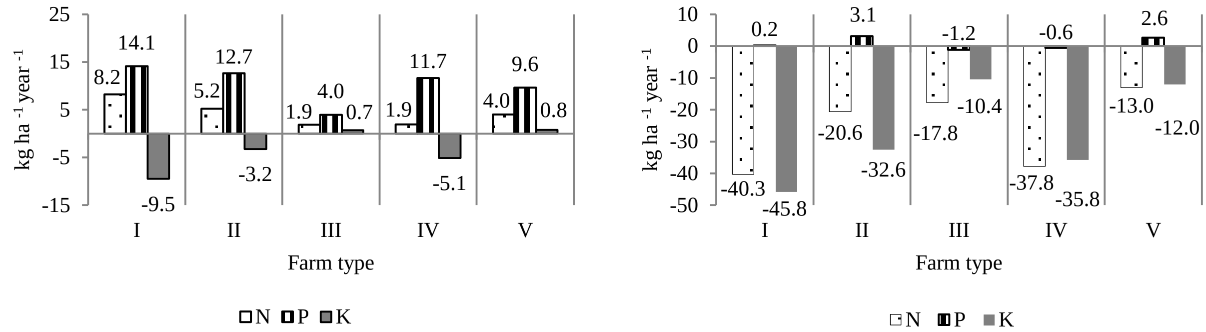
3 Results and Discussion

Nutrient balance analyses revealed heterogeneity across farm types (Figure 1). The whole farm's full nutrient balance showed positive N and P balances for all farm types, with the lowest values for the pro-poor farm type (III). The K balance was negative for the better-off farm types (I and II) and the middle-class farm type (IV). The soil subsystem nutrient balance showed large, negative N and K balances, mainly for better-off farms. These results imply that better-off farms draw their wealth from farm nutrient mining, as observed by Van Der Pol (1992) in northern Mali. Crop and crop residues removal and erosion were the main sources of nutrient depletion. Potassium appears to be limiting for wealthy farmings systems which exhibit negative whole farm full nutrient balance for that nutrient only. The large negative soil subsystem nutrient balances with positive farm full nutrient balances indicates inefficient nutrient resources management within the farming system resulting in nutrient accumulation in livestock production subsystem (unused manure).

The results showed that the middle-class farm type (IV) had the highest crop gross margin per cultivated land unit, while the poor farm type (V) had the lowest crop revenue per land unit. The analysis of the relational soil nutrient balance and crop gross margin per land unit revealed two main cases (Figure 2).

In the first case, farms with a negative soil nutrient balance and a low margin comprised pro-poor, poor and off-farm preference farm types (III, V and II, respectively). They invested less in soil nutrients, due mainly to insufficient resources for poor and pro-poor farms and to the livelihood strategy of off-farm preference farms. Pro-poor and poor farms were likely in a poverty-soil nutrient depletion trap. Low productivity drives poverty, which in return, aggravates nutrient mining. Farms need to recycle locally available resources (crop residues and animal manure) and use soil conservation techniques, as well as N-fixing crops. The owners of the off-farm preference farm type may need training on sustainable soil nutrient management to leverage their incentive to invest in soil fertility.

Farms with a negative soil nutrient balance and a better margin, consisting of better-off cotton-based and middle-class farm types (I and IV), were found in the second case. These farms invested better in soil nutrients but still insufficiently. They would face depleted soil nutrient stock in the future, lose their profitability and become problematic. These farms need to combine mineral fertiliser use and organic fertiliser, which reinforce soil organic matter and fertility. They should also invest in soil conservation practices, as well as in livestock-agriculture integration.



b- Whole farm full nutrient balances **a-**Farm soil subsystem nutrient balances

Fig. 1. Farm nutrient balances

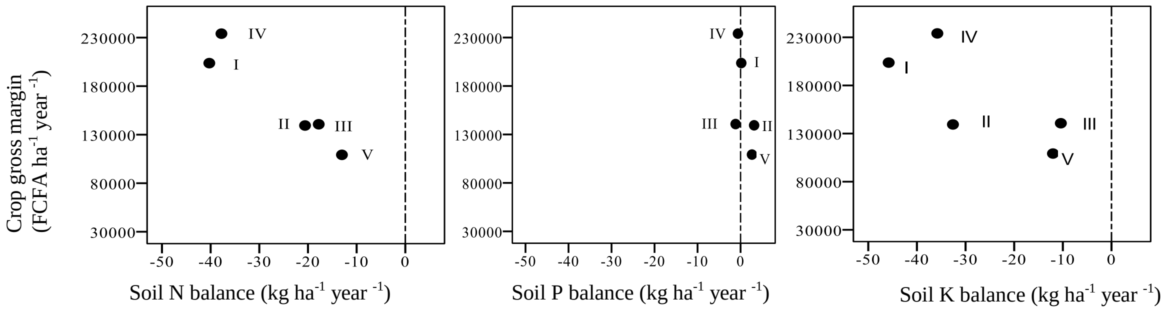


Fig. 2. Farm soil nutrient balance versus crop gross margin

The scenario analysis showed that farms could hardly afford reversing the trend of the nutrient depletion observed in the BAU scenario. In the IMF scenario, farmers should reinvest 72% of the crop gross margin per unit of cultivated land. This seems unaffordable, given that nearly 44% of households in the region live under the poverty line at US$217/person/year (Institut National de la Statistique et de la Démographie [INSD], 2010). Fully recycling crop residues under the RCR scenario improves nutrient balance by 40–90%. However, farmers have to face the labour constraints observed for many farm types and make trade-offs between competing uses of crop residues. Livestock-agriculture integration seems the best option for farmers to maintain productive and sustainable farms.

4 Conclusions

The study confirmed the findings of past research that drew attention to the alarming soil depletion in Sub-Saharan Africa. By investigating soil nutrient balance and farm economic performance, the study showed the nutrient mining-poverty trap in smallholder farms. The scenario analysis indicated that removing the observed nutrient gaps by increasing the use of chemical fertilizers would be costly and inefficient for farmers. Policy interventions and farm design should focus on the subsidiary linkages between livestock and crop production.

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