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Crop-Livestock Integration improves the Energy Use Efficiency of smallholder mixed farming systems - the case of western Burkina Faso

O.Ida Bénagabou [*±1, 2, 3], Melanie Blanchard [1,2], Jonathan Vayssières [2], Mathieu Vigne [2], Eric Vall [2], Philippe Lecomte [2], Valérie Bougouma [3] & H.Bismark Nacro [3]

[1] CIRDES -URPAN
[2] CIRAD-UMR Selmet
[3] UPB, IDR
[*] Speaker
[±] Corresponding author: idadec@yahoo.fr

1 Introduction

Increased food production to cover growing population needs, while limiting its impact on the environment, is a major challenge faced by the global agricultural sector. In sub-Saharan Africa mixed farming systems dominate. Crop Livestock Integration (CLI) is seen as a crucial pathway for supporting production and strengthening the resilience of family households facing economic and climate changes. Few quantitative studies demonstrate such potential. Indeed, based on three main biotechnical pillars, animal draft, manure production and crop residue storage, integration enhances the use of local renewable resources for production, including the cycling of co-products as resources for another activity within the system (Lhoste, 1987). The cycling of biomass and energy is regarded as an essential property for ensuring ecosystem sustainability (Allesina & Ulanowicz 2004). Based on a diversity of mixed farming systems, the study analyzes the quantitative links between diverse energy flows which are indicators for identifying biomass management practices that are alternatives to using external inputs.

2 Material and Methods

The study was undertaken on eight mixed farms in Koumbia (western Burkina Faso). The panel covered the diversity of farms observed in the cotton zone, including 3 Crop Farmers (CF), 2 Crop-Livestock Farmers (CLF) and 3 Livestock Farmers (LF) (Vall et *al*., 2006). A conceptual model was designed to inventory the gross energy flows between the system and its environment (inflows, outflows) and the internal flows between compartments (humans, cattle, crops and manure, fodder and feed stocks; Fig. 1). An Ecological Network Analysis (ENA, Finn, 1980) was applied to the matrix of flows to describe the ecological functioning of these agro-ecosystems and calculate indicators describing the cycling (Cycling Index, CI) and autonomy (A) of the farms and the proportion of flows into the network caused by CLI practices (CLID). The gross energy efficiency (GEE) was also calculated, as well as other indicators describing integration practices, such as the amount of manure available per Tropical Livestock Unit (OM) and the amount of crop residues and fodder available per Tropical Livestock Unit (FOD).

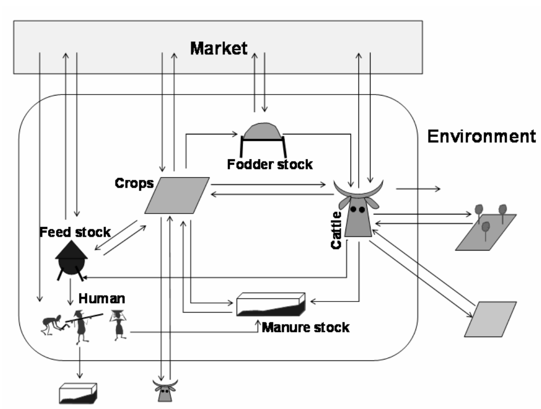

Fig. 1. Conceptual model of gross energy flows for mixed farming systems

3 Results and discussion

Applying an ENA to western Burkina mixed farming systems showed variable levels of cycling ($0.03<CI<0.50$) and autonomy ($0.17<A<0.70$) within and between farm types (Table 1). This variability resulted from a diversity of CLI farming practices (straw, forage crops, manure, compost, digester sludge). ENA applications to eastern Africa and Madagascar gave similar results for nitrogen cycling in mixed systems (Rufino et *al*., 2009; Alvarez *et al.*, 2013).

Moreover, we found that the integration indicator (CLID) and the indicators describing practices (OMand FOD) were higher among crop and crop-livestock farmers, i.e. farms with a stocking rate below 2 TLU.ha^{-1}. Livestock farmers had low to medium levels of integration. Indeed, the large TLU number (> 8TLU.ha^{-1}) of these farms led them to drive their cattle to the surrounding rangelands to meet their forage needs. It decreased their autonomy for locally available common resources and reduced the potential for manure collection and cycling. Also, even though in absolute terms they often stored larger amounts of forage than the other two types compared to the size of the herd, this amounted to small quantities.

Table 1. Gross energy efficiency, cycling and crop-livestock integration indicators for western Burkina mixed farming systems

Farm number	Livestock stocking rate (TLU.ha^{-1})	CI (Dmnl)	GEE (Dmnl)	Autonomy (Dmnl)	CLID= (Dmnl)	OM (kgDM. TLU.year^{-1})	FOD (kgDM.TLU^{-1}.year^{-1})
CF2	0.8	0,50	0,18	0,67	0,57	213	570
CF3	0.6	0,23	1,15	0,70	0,65	564	692
CF7	0.5	0,13	1,93	0,70	0,46	322	788
CLF5	1.7	0,37	0,27	0,59	0,55	752	367
CLF6	0.7	0,30	1,12	0,65	0,49	994	276
LF1	8.5	0,12	0,24	0,37	0,34	278	120
LF4	9.8	0,17	0,29	0,40	0,36	287	78
LF8	35.9	0,03	0,26	0,17	0,20	124	0

The cycling index (CI) was positively correlated with CLID for all farmers, i.e. CLI practices improved energy cycling on farms. The gross energy use efficiency (GEE) varied in turn from 0.18 to 1.93 and was positively correlated with autonomy (Fig. 2). Indeed, storage crop residues led to increased autonomy limiting imports and thus improved the gross energy use efficiency. Crop and crop-livestock farmers left a large amount of crop residues in the field that was subsequently consumed by other herds, thereby reducing energy cycling opportunities on the farm. It thus appeared that a stocking rate of 1.5 TLU ha^{-1}enabled a balance between needs and resources and provided favorable conditions for biomass cycling and optimum farm autonomy.

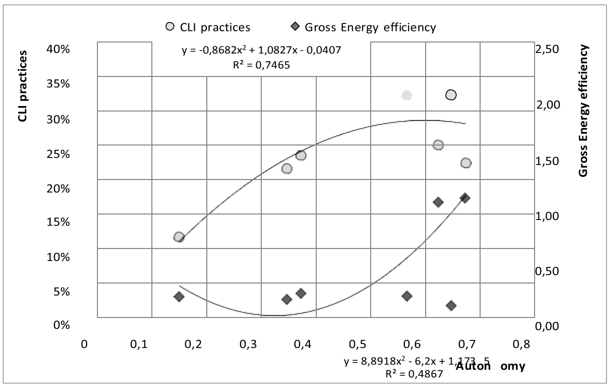

Fig. 2. Relations between autonomy (A) and gross energy efficiency (GEE)

4 Conclusions

Using original indicators, this study confirmed that better crop-livestock integration increases the energy use efficiency and autonomy of farms. The variable levels of energy use efficiency, cycling and autonomy were the consequences of a wide diversity of CLI practices. It showed a lower degree of autonomy and cycling for livestock farmers than for crop and crop-livestock farmers. This diversity indicated that there is still plenty of leeway for improving integration and efficiency, as expected (Blanchard *et al*., 2013; Semporé *et al*., 2013).

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