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Running NUANCES-FARMSIM to predict greenhouse gas emissions in mixed smallholder crop-livestock systems under different scenarios in Western Kenya

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1 Introduction

African smallholder farming systems are complex, dynamic systems with many interacting biophysical subcomponents (Van Wijk *et al.*, 2009) that strongly influence livelihoods and the farm greenhouse gas (GHG) balance. A modelling tool, NUANCES-FARMSIM, brings together the different production components of African smallholder farm systems, however until now, the model has not included a component to analyze climate impacts. In this communication we test FARMSIM's outputs to predict GHG emissions under different scenarios.

2 Materials and Methods

We ran FARMSIM for a representative case study farm of the highlands of Western Kenya. Each of the components of the model (livestock, crop, soil and manure management) have already been tested (Rufino *et al.*, 2007; Tittonell *et al.*, 2008). We followed IPCC guidelines (IPCC 2006) to calculate emissions for four scenarios related to Kenyan policies and plans of agriculture intensification and climate change action (Table 1). We ran the model several times to average the interferences of stochastic values in the model outputs (e.g. sex of the new calves).

Table 1: Inputs, parameters and scenarios for FARMSIM

	CT[1]	FERT	FEED	FERT+FEED
Cropping sub-system *(0,8 ha of maize; 0,4 ha Napier grass)*				
NPK fertiliser to maize (kg ha^{-1})[2]	0 0 0	72 34 84	0 0 0	72 34 84
Livestock sub-system *(Frisian cows (1 lactating cow, 1 calf); Calving interval=2 years (Deterministic))*				
Supplementation with concentrates: In all stages (kg month-1 per head)	0	0	60	60

[1] Scenarios: CT=Control; FERT=Fertilizer Rise; FEED=Feeding improved through concentrates; FERT+FEED: Fertilizer rise and improved feeding
[2] Fertilizers are added every 6 months (2 seasons, the annual added amount is twice the amount indicated in the table)

3 Discussion

Farm components and total farm GHG emissions (Fig. 1 & Fig. 2)
The fertilizer rise scenario (FERT) showed a 22% increase in total farm emissions from the control (CT), due to an increment of N-inputs in soils. With the rate of fertilizer applied (144 Kg N ha^{-1} $year^{-1}$), the N_2O emissions of soils are almost doubled (97% increase). Improving the livestock feeding by adding supplementation in the form of concentrates (FEED, 60 Kg $month^{-1}$ $head^{-1}$) resulted in a 24% increase in total farm emissions, mainly because it also led to an increment of the dry matter intake of the cow (concentrates supplement the diet, they do not replace napier grass). We observed an increase in GHG emissions from the manure management system, due to an increase in the nitrogen content of cow excreta, which in turn results in manure with higher nitrogen content and a slight increase in soil emissions. Finally, the scenario which combines fertilizer rise and improved feeding (FERT+FEED), resulted in an increment of 52% of the farm emissions.
Maize production and milk production (Fig 3 & Fig 4.)
Adding fertilizer (FERT) increased the production of maize by 6% on average (287 Kg ha^{-1} $year^{-1}$). Improving the feeding (FEED) resulted in a 160% increase in milk production (869 L $year^{-1}$). Fertilizer in the maize fields did not have a significant effect on milk production –in spite of the maize stover flow to the cows–, whilst improving the feeding resulted in a slight increment in maize production by 0,13%. The combination of both treatments (FERT+FEED) brought an increase both in maize and milk production. Note that the CT and FERT scenarios do not produce milk in the 4th year, while the scenarios with supplements (FEED and FEED+FERT) do produce milk.
GHG emissions per product (Table 2).
Emissions per unit of output are reduced as the production increases in the case of the feeding improved scenario (FEED), but not for the fertilizer rise (FERT) or the combination of fertilizer rise and feeding improved (FERT+FEED).

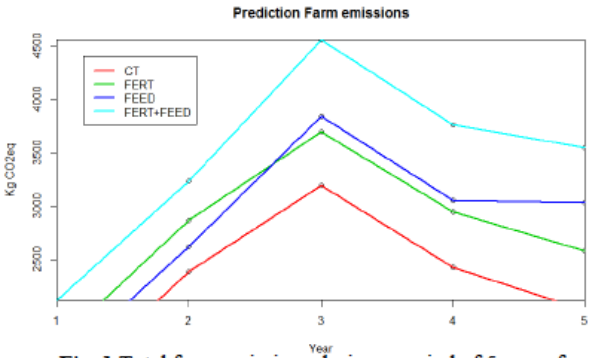

Fig. 1 Total farm emissions during a period of 5 years for the 4 scenarios(CT, FERT, FEED, FERT+FEED)

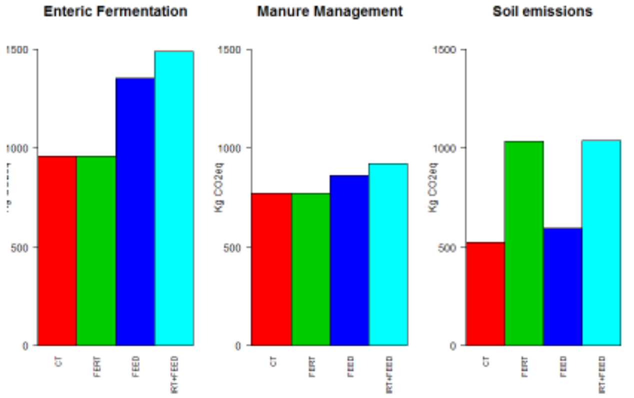

Fig. 2 Contribution of the 4 scenarios to the farm components emitting GHG: Enteric fermentation; manure management and soils

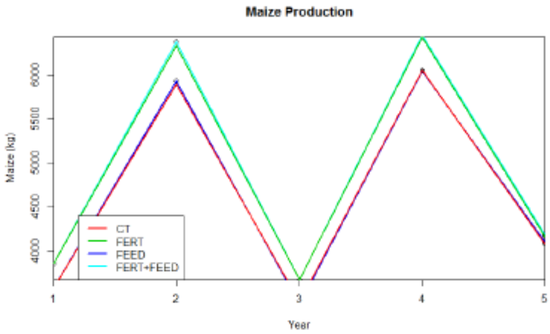

Fig. 3 Maize productionfor a period of 5 years

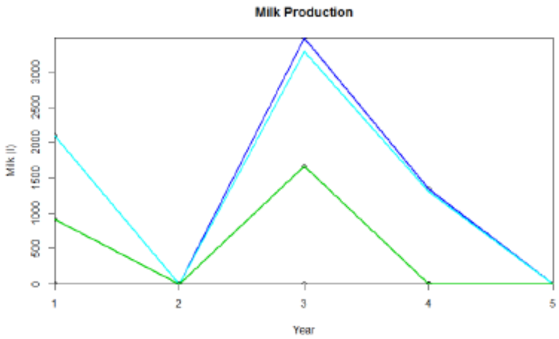

Fig. 4 Milk production for a period of 5 years

Table 2. Emissions per product

	Kg CO2eq l-1 of milk				Kg CO2 eqkg -1 of maize			
Year	CT	FERT	FEED	FERT+FEED	CT	FERT	FEED	FERT+FEED
1	0,70	0,70	0,38	0,42	0,007	0,13	0,01	0,14
2	0	0	0	0	0,10	0,18	0,10	0,17
3	0,73	0,73	0,48	0,56	0,26	0,38	0,28	0,38
4	0	0	1,09	1,24	0,10	0,18	0,11	0,18
5	0	0	0	0	0,10	0,23	0,17	0,23
Average	0,72	0,72	0,65	0,74	0,11	0,22	0,13	0,22

4 Conclusions

FARMSIM can be used to predict GHG emissions and analyze trade-offs and synergies at farm scale. It provides the necessary outputs to study the interaction between the farm components and climate impacts. By calibration, a sub-model will be developed and loosely coupled to the relevant input and output parameters of the NUANCES-FARMSIM model, to examine productivity and climate system trade-offs to identify not only optimal farm management innovations but also constraints to their implementation.

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