Can legume crop residues contribute to sustainable intensification of rainfed rice production in Madagascar?

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Rainfed agriculture on smallholder farms across the tropics is crucial for food security and livelihoods when availability of irrigated land is limited. Coarse-textured soils with low organic carbon and poor inherent fertility prevail in these systems (Tittonell and Giller, 2013). In the absence of sufficiently remunerative market, smallholders cannot afford mineral fertilizers so that nutrient inputs are generally limited to manure. Integrated soil fertility management, *e.g.* integration of legumes combined with additional supply of mineral fertilizers, is required to sustainably increase rainfed agriculture productivity (Vanlauwe et al. 2014). In Madagascar, most smallholders do not use mineral fertilizer under rainfed agriculture. Incorporation of Nitrogen (N) rich crop residues could increase nutrient supply and improve N use efficiency (Aggarwal et al., 1997). Nutrient supply from residues is a complex process related to decomposition rates of residue, which is impacted by residue type and climate variability, *e.g* increased temperatures can accelerate residue decomposition while intense rainfall can increase the loss of the precious mineralized N through leaching. The potential contribution of N rich crop residues to increase staple crop productivity is therefore complex to anticipate. Soil-crop models can account for such complexity. This study aims at (i) calibrating the STICS crop model for rice yield modeling in the smallholder context of cool humid uplands in Madagascar and (ii) use the model to explore the effect of incorporation of rice and legume residues for low (25 kg N ha^{-1}) and high (160 kg N ha^{-1}) fertilizer inputs with a variable climate.

The soil-crop model *STICS* (Brisson et al., 2003) was chosen for its capacity to account for soil water and nutrient dynamics during crop cycle for various climates and crop management. Rice experiments (cultivar NERICA 4) carried out in 2016-2017 and 2017-2018 cropping season in Ivory (19°33'S, 46°24'E, 950 m a.s.l) on Ferralsols were used for model calibration and testing. Two previous crops were compared: (i) rice and (ii) *Mucuna cochinchinensis* - *Crotalaria spectabilis* intercropping, combined with two levels of nutrient input, *i.e.* manure only (25 kg N ha^{-1}) or manure and mineral fertilizer (160 kg N ha^{-1}). Residues were incorporated at plowing. Measured data include rice phenology, above ground biomass and plant N, grain yield and in-season soil moisture and soil N.

The calibrated STICS model reproduced adequately rainfed rice emergence, flowering and maturity, with on average an error of less than four days. Simulated in-season soil N and rice biomass agreed with the observations with a relative Root Mean Square Error from 33% to 36% (see Figure 1 for rice residues with high N input treatment). The model could reproduce the additional mineral N supply and plant uptake associated with the incorporation of N rich legume residue for the two fertilizer treatments.

Calibration for grain yield and scenario analysis using historical climate (1980-2010) are on-going and will allow to determine the profitability and risk associated with the different simulated options. This study will contribute to gain new insights on the relevancy of legume residue for sustainable intensification of cropping systems in a tropical smallholder context.

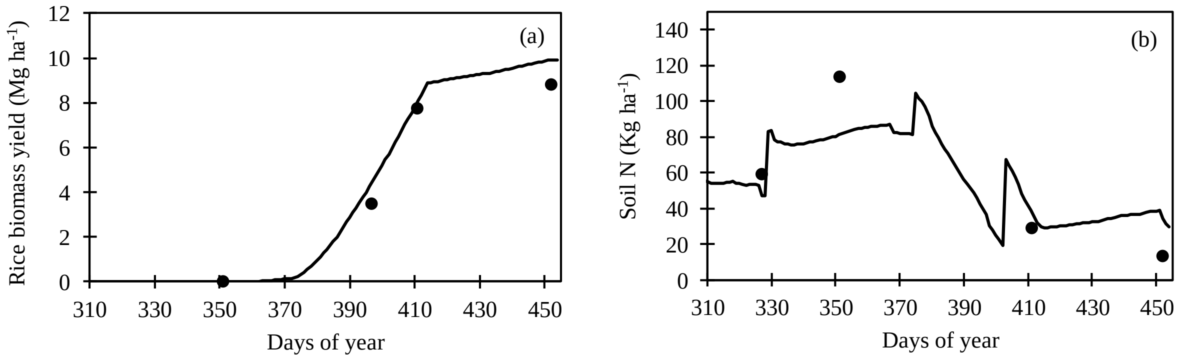

Figure 1: Comparison of observed and STICS simulated rice biomass (a) and soil N (b) dynamics during rice growing cycle for rice residues with manure and mineral fertilizer (160 kg N ha^{-1})

Keywords: upland rice, tropical climate, green manure, soil nitrogen, low-input

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