Agricultural intensification pathways and agro-environmental trade-offs in the Greater Mekong

Paul, B.K.[1], Tungani, V.[1], Epper, C.[2,3], Tschopp, D.[2,3], Burra, D.[2], Chau, L.[4], Douxchamps, S.[2]

[1]International Center for Tropical Agriculture (CIAT), Nairobi, Kenya

[2]International Center for Tropical Agriculture (CIAT), Hanoi, Vietnam

[3]ETH Zurich, Switzerland

[4]Western Highlands Agriculture & Forestry Science Institute (WASI), Buon Ma Thuot, Vietnam

1. Introduction

The Greater Mekong area is undergoing socio-economic change with growing population, incomes and increasing demand for animal-source foods. Traditional diverse and subsistence-oriented agriculture is being replaced by market-oriented production focused on a few (cash) crops. In the Central Highlands of Vietnam for instance, local government advocates for development of the beef value chains to meet the high domestic demand and create economic opportunities for smallholder farmers (Stür, et al., 2013). However, rapid intensification can have environmental trade-offs including loss of (agro)biodiversity, deforestation, nutrient pollution, and greenhouse gas (GHG) emissions.

2. Materials and methods

Survey data from approximately 1300 households in Laos (XiengKhuang province), Cambodia (Ratanakiri province), and Vietnam (Central Highlands) was used for this study (Figure 1a). The survey was administered using the Rural Household Multi-Indicator Survey tool (RhoMIS) (Hammond et al. 2016). A market orientation and production diversity score was calculated for each household. Households were then categorized into four distinct farm types: low diversity and low market orientation (LDLM), low diversity high market orientation (LDHM), high diversity low market orientation (HDLM), and high diversity high market orientation (HDHM). 24 farms across classes and sites were selected – eight farms in each country, two representing each farm type (Figure 1b). Additional data collection from these 24 farms included a more detailed household survey, soil samples, and nutrient flow maps. The farming systems were simulated and compared with the whole-farm bio-economic optimization model FarmDESIGN (Groot et al. 2012).
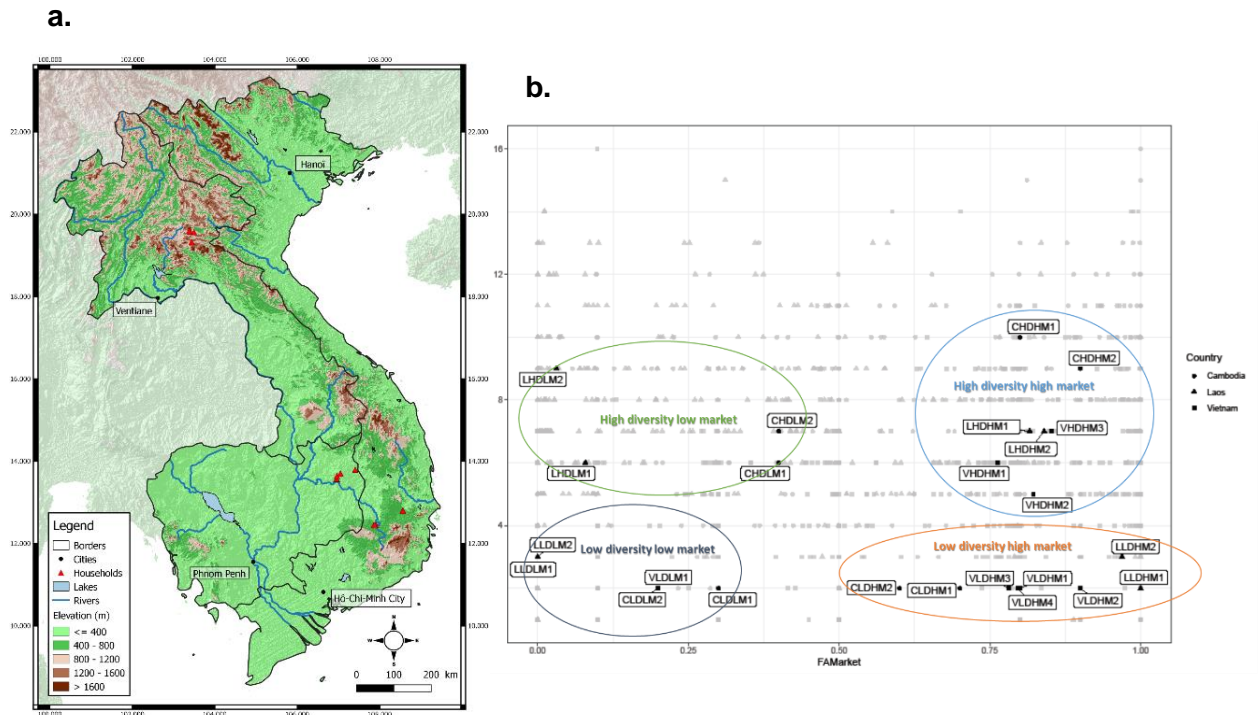
Figure 1: *Location of farming systems for bio-economic modeling in Laos, Cambodia and Vietnam (a); and modeling farming systems and all approximately 1300 RHoMIS households scored along market orientation and production diversity (b).*

3. Results – Discussion

The sites represent various farming systems and stages of intensification. Farmers in the Central Highlands of Vietnam have intensified production on relatively small farms (0.5 - 3 ha), focusing on major cash crops such as cassava, cashew, coffee, and pepper under high input use, especially mineral fertilizers. Cattle are mostly improved breeds under cut-and-carry feeding, often with improved varieties of Napier grass (*Pennisetum purpureum)*. Farmers in XiengKhuang, Laos, are practicing diverse subsistence-oriented agriculture, while slowly moving towards more market-oriented production. Larger local cattle herds, as well as a variety of crops including rice, tea, pasture, and vegetables are found. Farming systems in Ratanakiri, Cambodia, rely on relatively recent forest clearing and could therefore exploit larger farm sizes (3.5 – 10.5 ha) for rubber, cashew, and cassava for markets in Vietnam and China, with hardly any livestock except chicken.
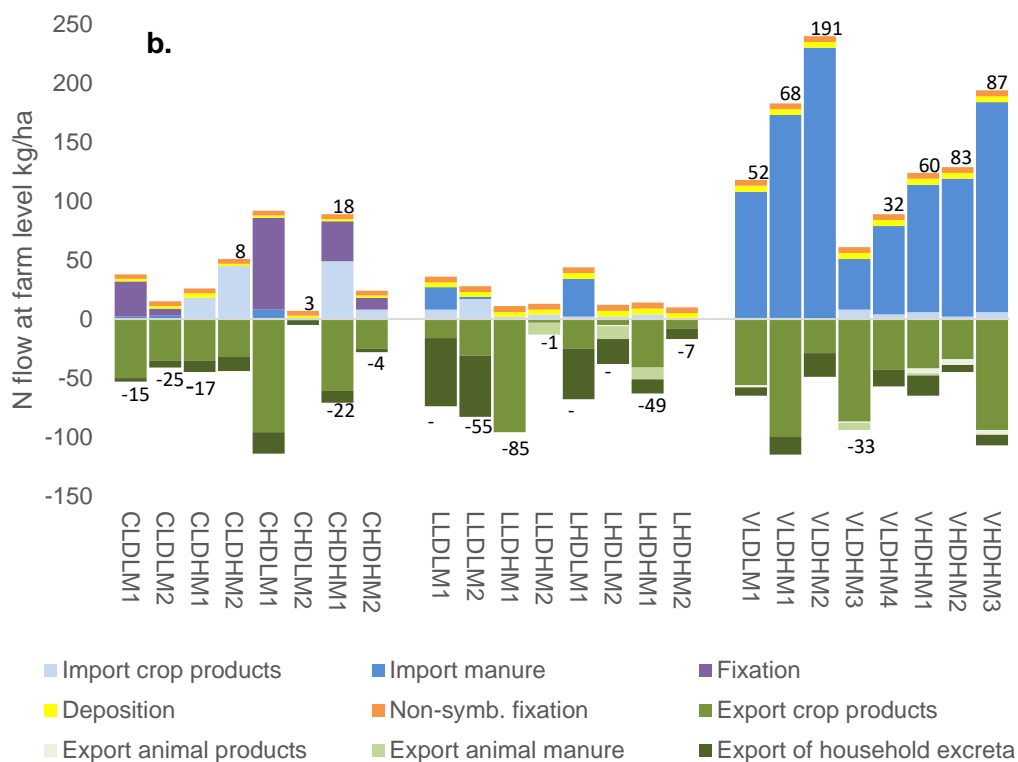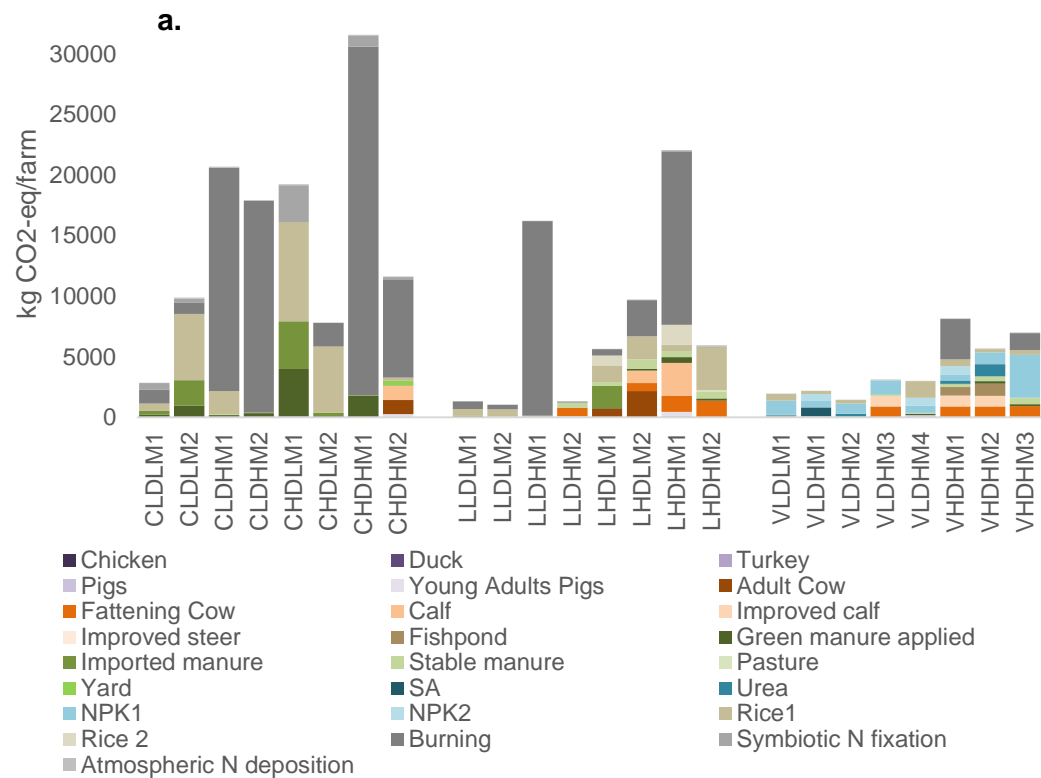
a.

b.

Figure 2: GHG emissions per farm (kg CO₂-eq) across farm types and study sites in Cambodia, Laos and Vietnam (a); nitrogen (N) inputs and outputs (kg N/ha) across farm types and sites, with numbers on top or below bars indicating N balance (b).

Although farming systems in the Central Highlands of Vietnam have considerable GHG emissions from mineral fertilizer use, GHG emissions from Ratanakiri (Cambodia) and XiengKhuang (Laos) were higher due to the common practice of cassava and maize residue burning. All farming systems have GHG emissions from rice cultivation (Figure 2a). N balances are mostly negative in the Cambodian and Laos sites, reflecting low input use. In the Lao site, fallowing is still used as traditional soil fertility management technique, balancing nutrient mining during cropping seasons. The large farm areas of recently cleared forest in the Cambodian site does not yet make it urgent to invest in soil fertility, although soybean cultivation contributes to N inputs into the systems through biological N fixation. Farming systems in the Vietnamese site are the only ones applying substantial amounts of N mineral fertilizer, leading to positive balances (Figure 2b).

4. Conclusions

Sustainable livestock intensification could potentially play an important role to mitigate agro-environmental trade-offs and thereby contribute to sustainable intensification. Small herds of well-managed and productive cattle can convert residues into animal-source food and manure for fertilization, while reducing the polluting practice of residue burning. A previous study found that has shown that forage-based livestock fattening can increase operating profits by 35%, while maintaining soil organic matter and decreasing GHG intensities (Birnholz et al. 2017). Multi-objective optimization will elucidate potential agro-environmental impacts of various agricultural intensification pathways, including close crop-livestock integration.

Acknowledgements

References

Birnholz, C., Bolliger, A., Tan Khanh, T., Groot, J., Paul, B.K., 2017. Bio-economic evaluation and optimization of livestock intensification options in the Central Highlands of Vietnam. *Working Paper No. 433. International Center for Tropical Agriculture (CIAT)*, Nairobi, Kenya 31.

Groot, J., Oomen, G., & Rossing, W. (2012). Multi-objective optimization and design of farming systems. *Agricultural Systems, 110*, 63-77.

Hammond, J., Fraval, S., van Etten, J., Suchini, J. G., Mercado, L., Pagella, T., Frelat, R., Lannerstad, M., Douxchamps, S., Teufel, N., Valbuena, D. and van Wijk, M. T., 2017. The Rural Household Multi-Indicator Survey (RHoMIS) for rapid characterisation of households to inform Climate Smart Agriculture interventions: description and applications in East Africa and Central America. *Agricultural Systems* 151, 225-233.

Stür, W., Khanh, T., & Duncan, A. (2013). Transformation of smallholder beef cattle production in Vietnam. *International Journal of Agricultural Sustainability, 11*(4), 363–381.