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

20th of August 2019, Montevideo, Uruguay
Farming Systems Design Conference
'Strategies to reduce environmental impacts of agricultural systems'

Birthe K. Paul, Victor Tungani, Carole Epper, Damien Tschopp, Dharani Burra, Chau Thi Minh Long, Sabine Douxchamps

B.Paul@cgiar.org

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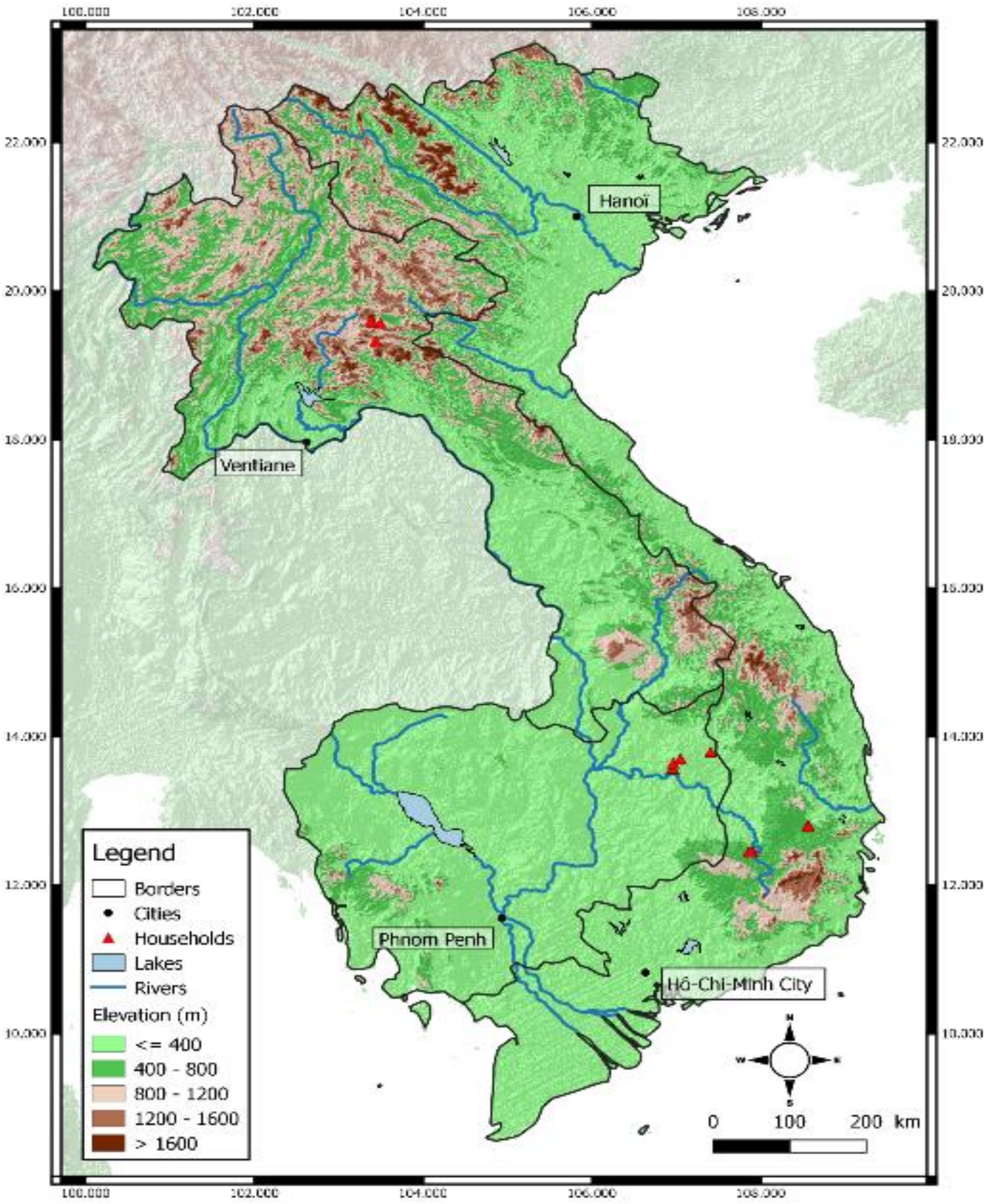
Introduction

- Greater Mekong Subregion: Cambodia, China, Laos, Myanmar, Thailand, Vietnam
- Rapid and profound agricultural transformation from subsistence agriculture to commercial production
- Drivers include infrastructure development, improved market access and government policy
- Growing population and increasing incomes leading to higher demand for animal source foods
- Environmental implications of these developments include rising GHG emissions, nutrient cycling/pollution, deforestation
- Sustainable intensification pathways are needed

Introduction: study sites

Three contrasting study sites to capture different levels of agricultural transition:

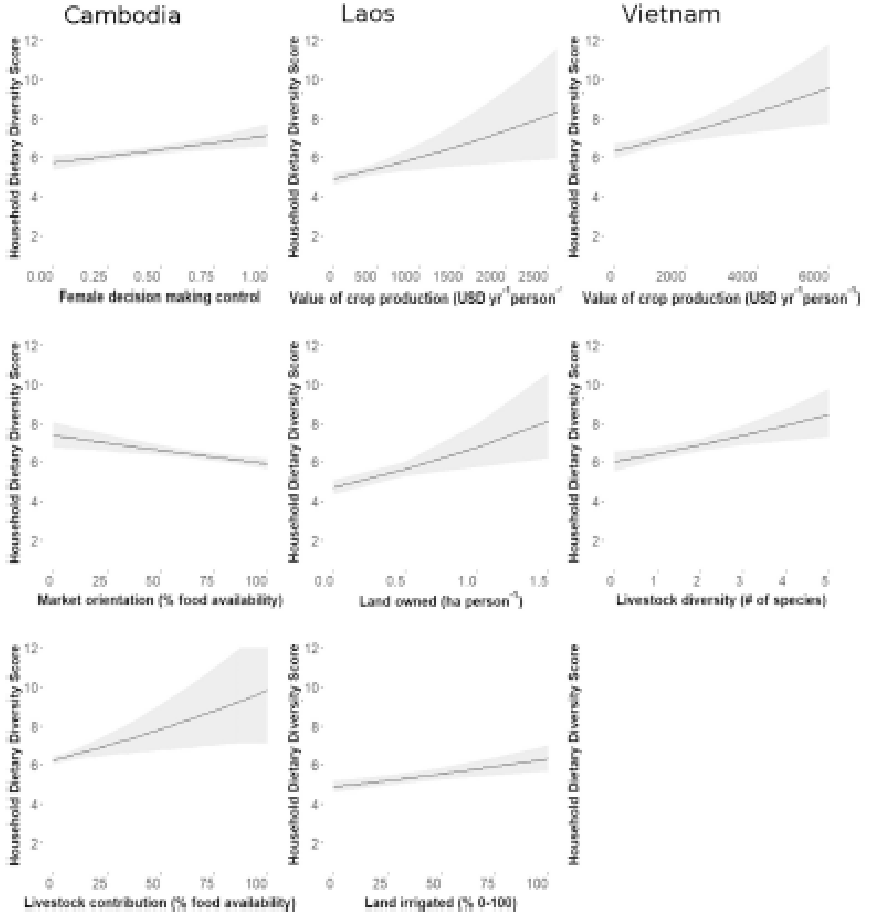
- **XiangKhouang region, Laos**: mixed crop-livestock, 1200 masl, 16 persons/m^2, subsistence oriented
- **Ratanakiri province, Cambodia**: low input monoculture, 200-400 masl, 17 persons/m^2
- **Central Highlands, Vietnam**: intensive agricultural production, 400-800 masl, 110 persons/m^2, market oriented



Introduction: Household dietary diversity

		Cambodia		Laos		Vietnam	
Household Dietary Diversity Score (median):		6		5		7	
Agricultural Transition		Level	CV*	Level	CV*	Level	CV*
Market Orientation	Market Orientation for FA	High	(-)***	Low	(-)*	High	
Specialisation	Crops	Low		Med		Med	
	Livestock	High		Med	(-)**	High	(-)**
Intensification	N Fertiliser	Low		Low	(+)	High	
	Irrigation	Low		Low	(+)***	High	
Farm Characteristics	Land Owned	High	(+)	Low	(+)**	Low	
	Livestock Holdings	Low		High		Low	
Farm Performance	Value Crop Production	Med	(+)*	Low	(+)**	High	(+)***
	Crop Productivity	Low		Med		High	
	Value Livestock Production	Low		Med		High	
	Livestock Productivity	Low		Med	(-)	High	
	Livestock Contribution to FA	Low	(+)**	Low		Low	
Other HH Char's	Female Decision Control	Med	(+)**	Med		Med	
	Off-farm Income	Med	(+)*	Low	(+)*	High	

*CV = Correlated Variation

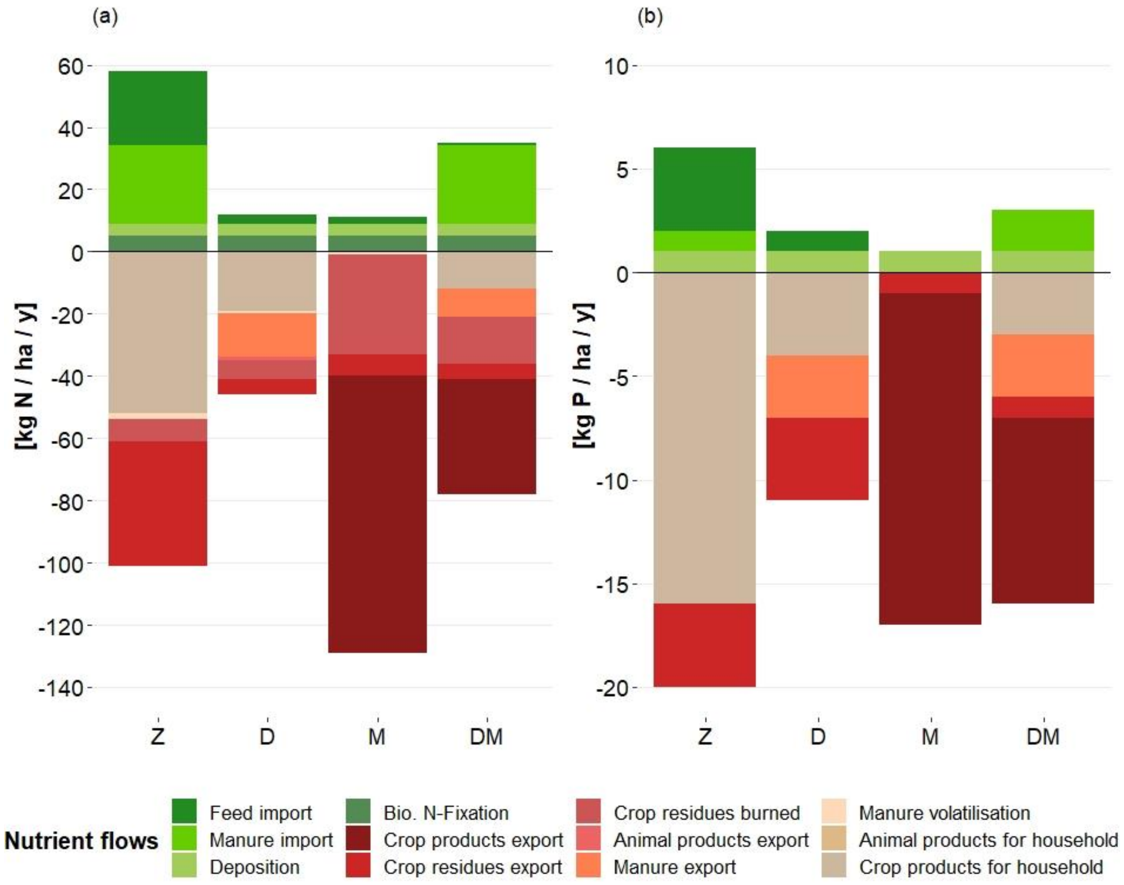


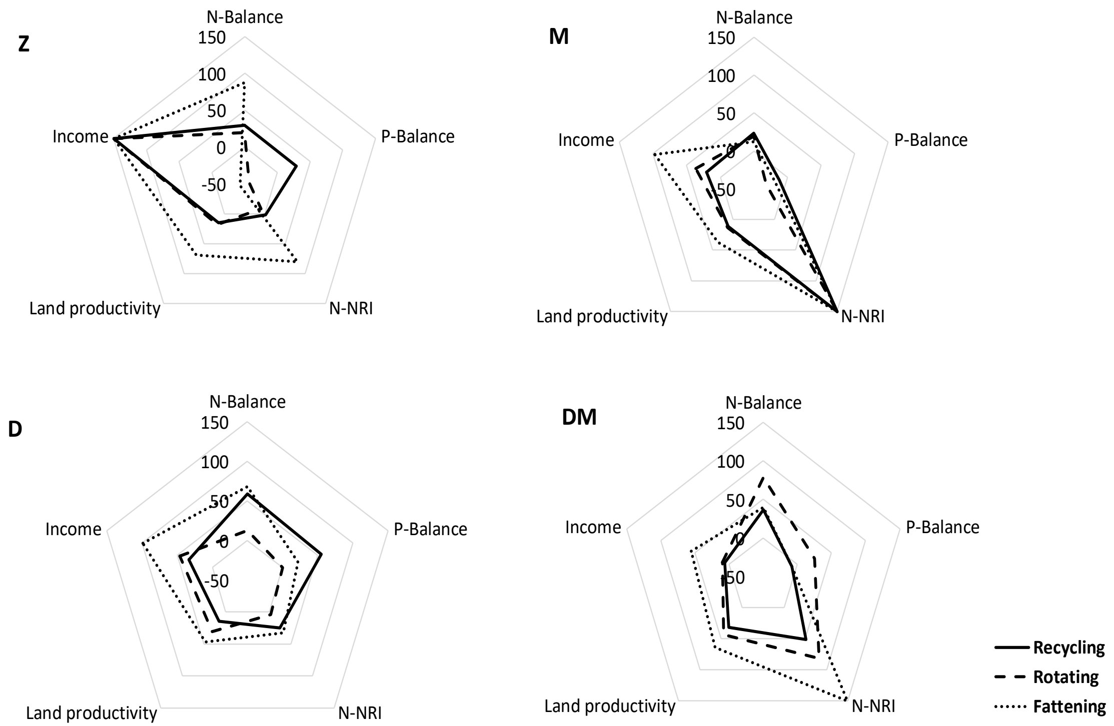
*, **, and *** indicate significance levels for variables.
[a]CV = Correlated Variation.

Drivers of dietary diversity and agricultural transition pathways are site-specific

Ritzema, R.S., Douxchamps, S., Fraval, S., Bolliger, A., Hok, L., Phengsavanh, P., Long, C.T.M., Hammond, J., van Wijk, M. 2019. Household level drivers of dietary diversity in transitioning agricultural systems: Evidence from the Greater Subregion. *Agricultural Systems,* 176, 102657.

Introduction: Nutrient balances in Laos





Principles for sustainable intensification of these systems: no residue burning, stay diverse, integrate livestock, use small amounts of P fertilizer

Epper, C., Paul, B.K., Burra, D., Phengsavanh, P., Ritzema, R., Syfongxay, C., Groot, J.C.J., Six, J., Frossard, E., Oberson, A., Douxchamps, S. Nutrient flows and intensification options for smallholder farmers of the Lao uplands. *Revisions submitted to Agricultural Systems.*

Introduction: Cattle fattening impacts in Vietnam

Profitability (USD/farm/year)

Returns		Baseline	Forage-based cattle fattening sc.	Grain-based cattle fatting sc.
	Gross margin crops	5093.24	4238.99	5481.54
	Risk crop margin	0	0	0
	Gross margin animals	38.41	2837.18	1569.37
Costs				
	Fertilizers/Manure costs	598.07	577.94	165.53
	Crop protection costs	62.59	92.19	49.14
	Hired casual labor costs	376.74	508.37	316.91
	Hired regular labor costs	0	379.11	0
Totals				
	Operating profit (+return farm. labor)	4094.25	5518.56	6519.33
	Change from baseline		**35%**	**59%**
	Own labor costs	702.82	702.84	504.08
	Return to own labor	3.92	5.28	5.82
	Home consumption	551.78	211.64	211.64

SOM balance (kg/ha)

		Baseline	Forage-based cattle fattening sc.	Grain-based cattle fatting sc.
Inputs				
	Root biomass and stubble	557	604	536
	Surface residue retention	0	0	0
	Own manure	759	2377	0
	Imported manure	0	0	0
Outputs				
	Manure degradation	688	2156	0
	SOM degradation	536	536	536
	Erosion losses	0	0	0
Balance				
	Balance	93	290	1
	Change from baseline		**212%**	**-99%**

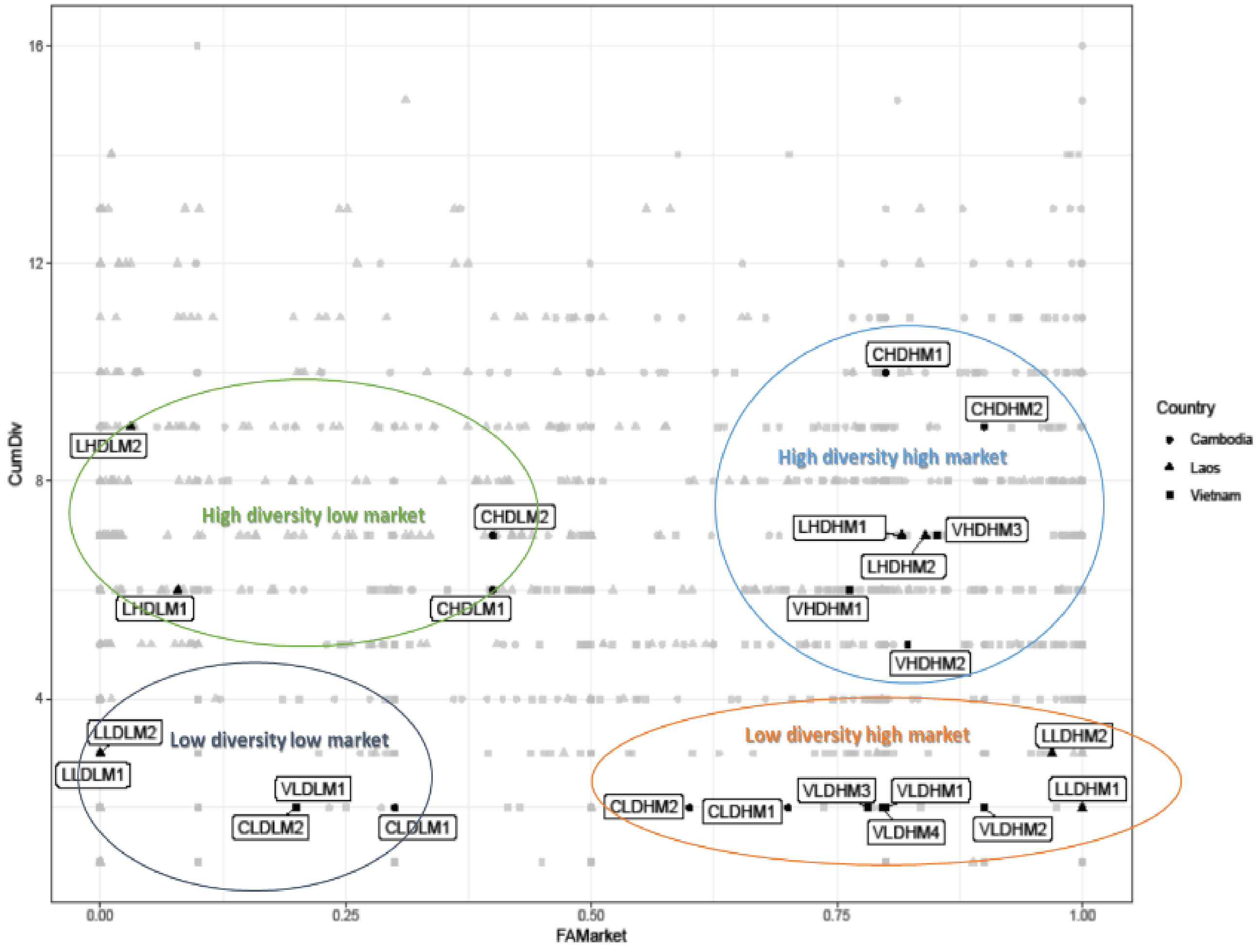
Birnholz, C., Bolliger, A., Tan Khanh, T., Groot, J., Paul, B. (2017). Bio-economic evaluation and optimization of livestock intensification options in the Central Highlands of Vietnam. *Working Paper No. 433. International Center for Tropical Agriculture (CIAT)*, Nairobi, Kenya. 31 p. http://hdl.handle.net/10568/79446

Study objectives

Systematic exploration of agro-environmental trade-offs of various intensification pathways across the Greater Mekong

- Describe farming systems and quantify agro-environmental performance and trade-offs in sites of various stages of agricultural transition
- Assess how market orientation and production diversity influence agro-environmental trade-offs
- Explore alternative future intensification pathways

MM: Household survey



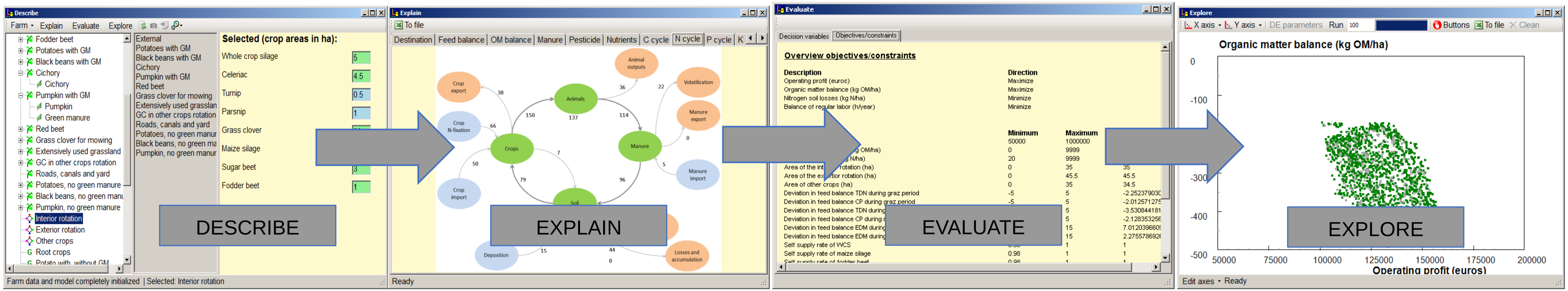
1,300 households sampled using the RHoMIS survey tool from Dec 2015 – Mar 2016

- Market orientation and production diversity score was calculated
- Households were then categorized into four farm types
  - Low diversity low market orientation (LDLM)
  - Low diversity high market orientation (LDHM)
  - High diversity low market orientation (HDLM)
  - High diversity high market orientation (HDHM)

Same RHoMIS dataset used as in Ritzema et al. 2019

MM: Whole farm modeling

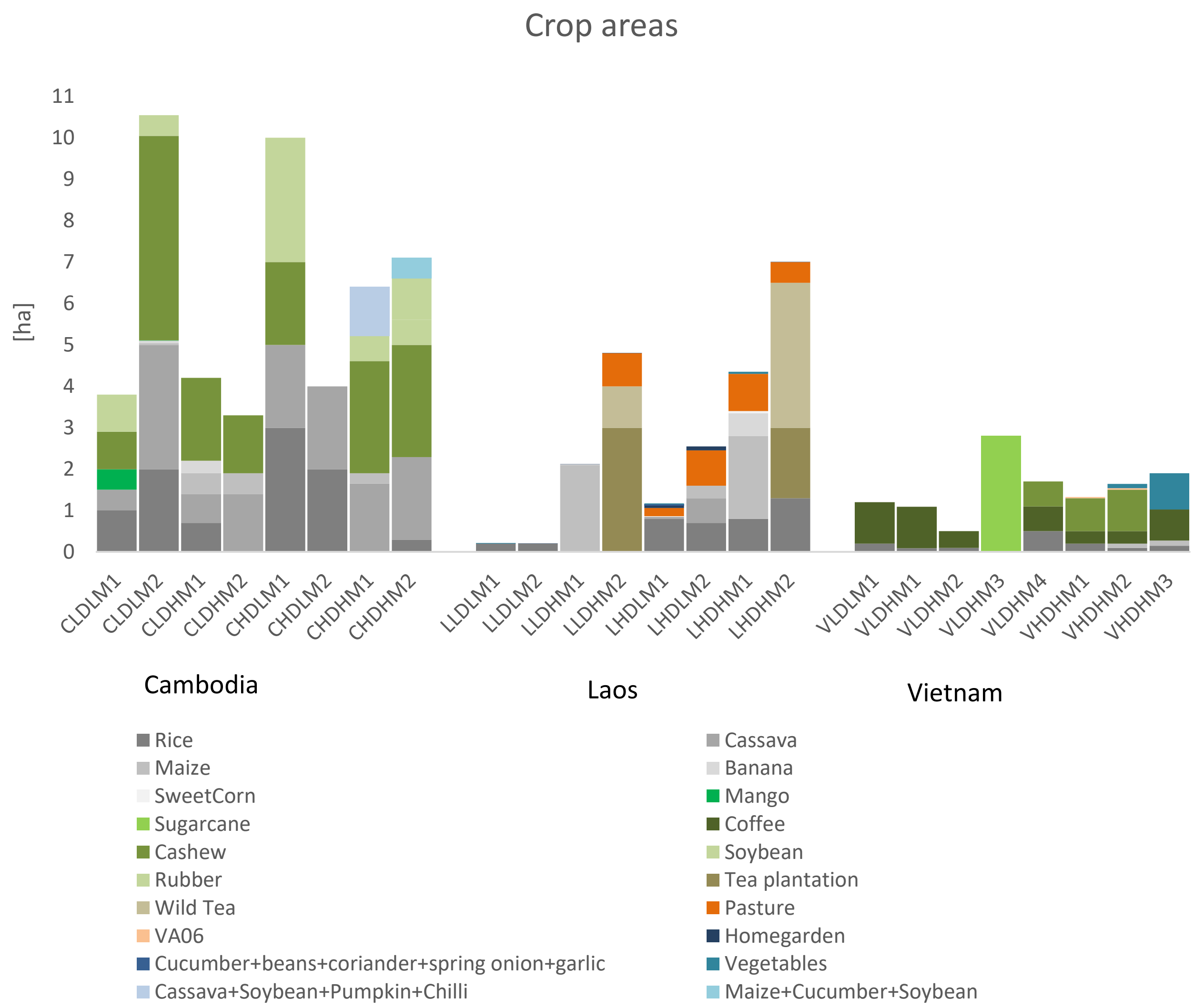
- Random selection of 24 households for farming system modeling: eight households per country, two per type (in Vietnam only three types represented as low market situation uncommon)
- Additional data collection included a more detailed household survey, soil samples, and nutrient flow maps
- Farming systems modeled and compared with whole-farm bio-economic model FarmDESIGN



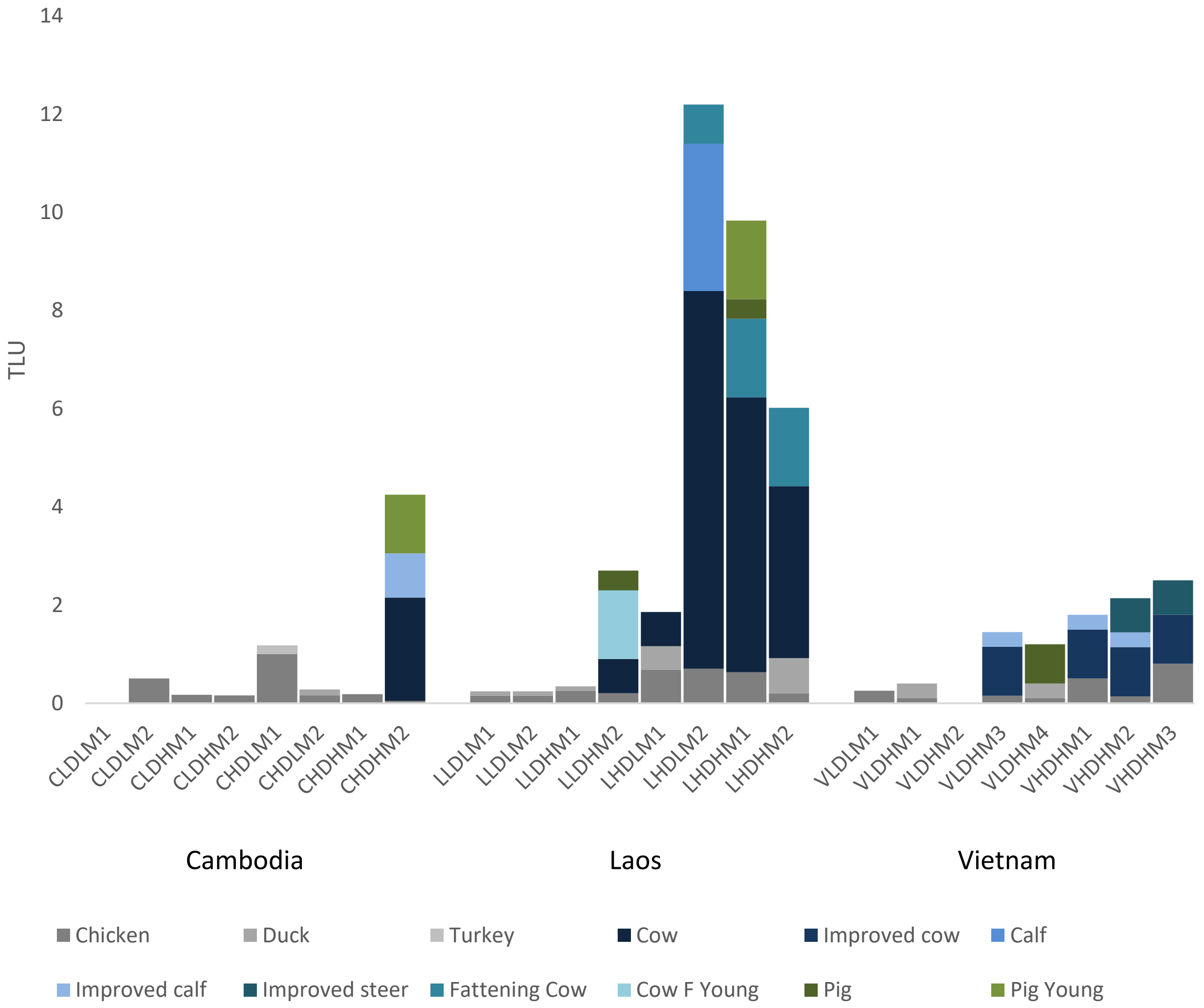
MM: Approaches to farming system selection

		Geographic scope	Number of farming systems	Reference
Farming system population modeling		Mali: Koutiala	30	Falconnier et al. 2015
		India: Uttarakhand	42	Ditzler et al. 2018
		Tanzania: Lushoto district	164	Shikuku et al. 2017
		India: Bihar	269	Lopez-Ridaura et al. 2018
		Burkina Faso, Ghana, Senegal	600	Douxchamps et al. 2016
		Rwanda: different districts	884	Paul et al. 2018
		Kenya, Tanzania, Uganda, Ethiopia, Senegal, Burkina Faso	1019	Henderson et al. 2016
		East and West Africa: 7 countries	1800	Ritzema et al. 2017
		Sub-Saharan Africa	13000	Frelat et al. 2018
Farming system type modeling	**Constructed farming systems** from survey averages, government census, expert knowledge, policy documents	India, Ethiopia	4	Mayberry et al. 2018
		India, Ethiopia	5	Mayberry et al. 2017
		Mexico: Yucatan	1	Parsons et al. 2011
		Zimbabwe: Nkayi	6	Descheemaeker et al. 2018
	Real farming systems selected from surveys, multivariate- statistics, purposive selection	Tanzania: Babati	4	Paul et al. in review
		Burkina Faso: Yatenga	2	Rigolot et al. 2017
		China: Gansu	3	Komarek et al. 2012
		Kenya: Vihiga	9	Waithaka et al. 2006
		Mexico: Michoacan	6	Cortez-Arriola et al. 2014
		Ghana: three regions	9	Michaelscheck et al. 2018
		Vietnam: Son La	2	Ditzler et al. 2019
		Brazil: Cerrados	6	Alary et al. 2016

Results: Farming systems diversity



Results: Farming systems diversity



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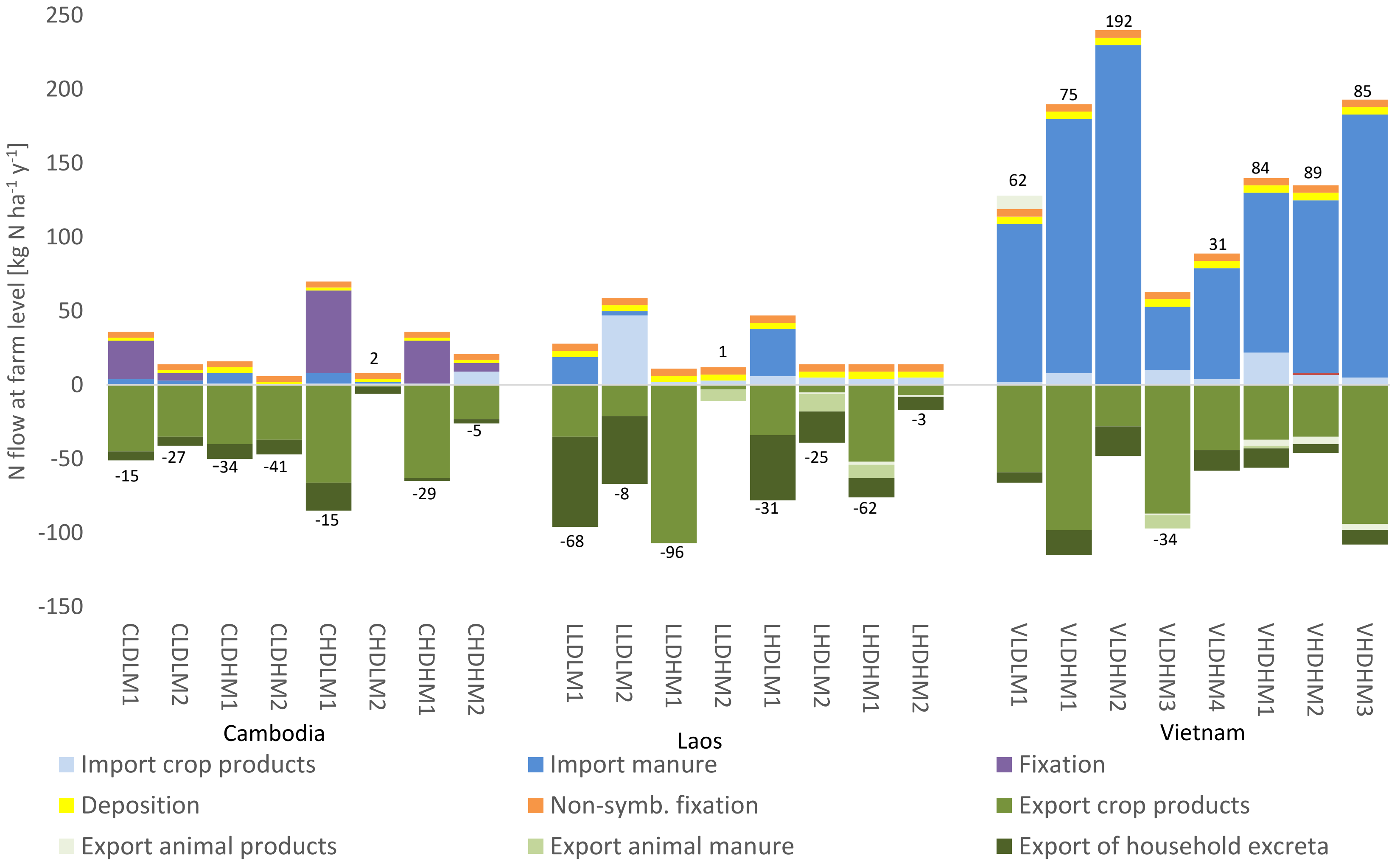
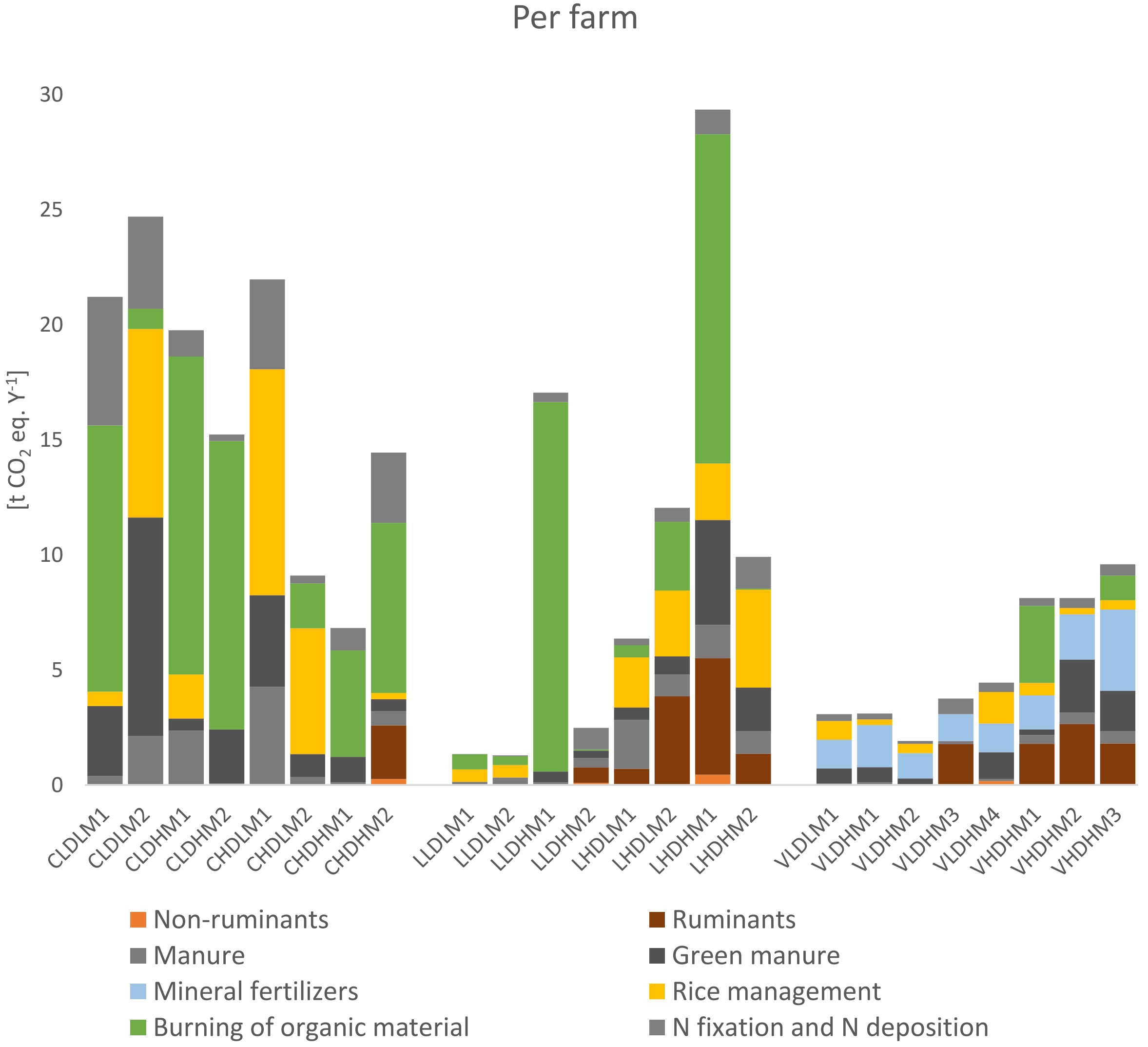
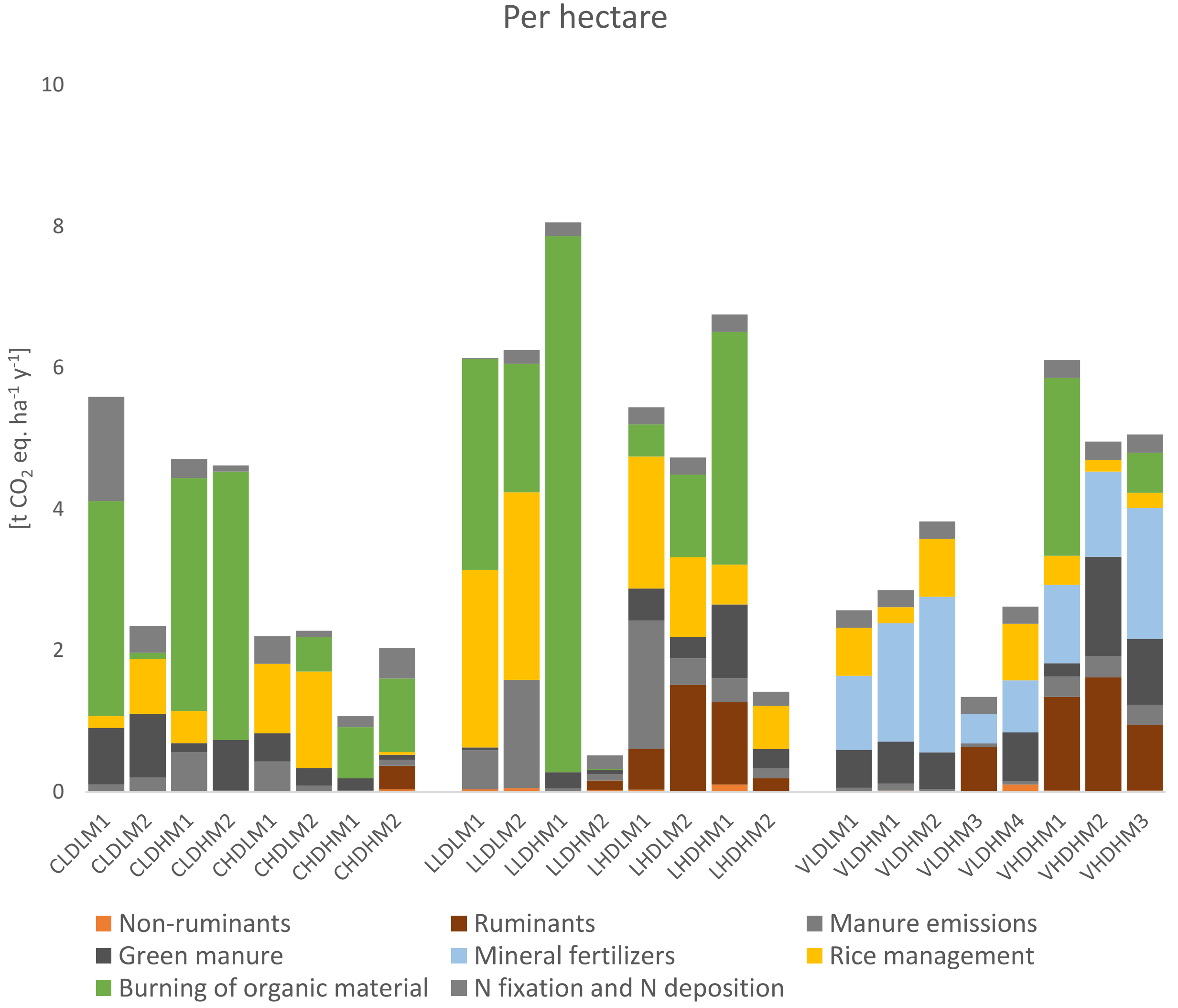
Results environmental impacts: N balance

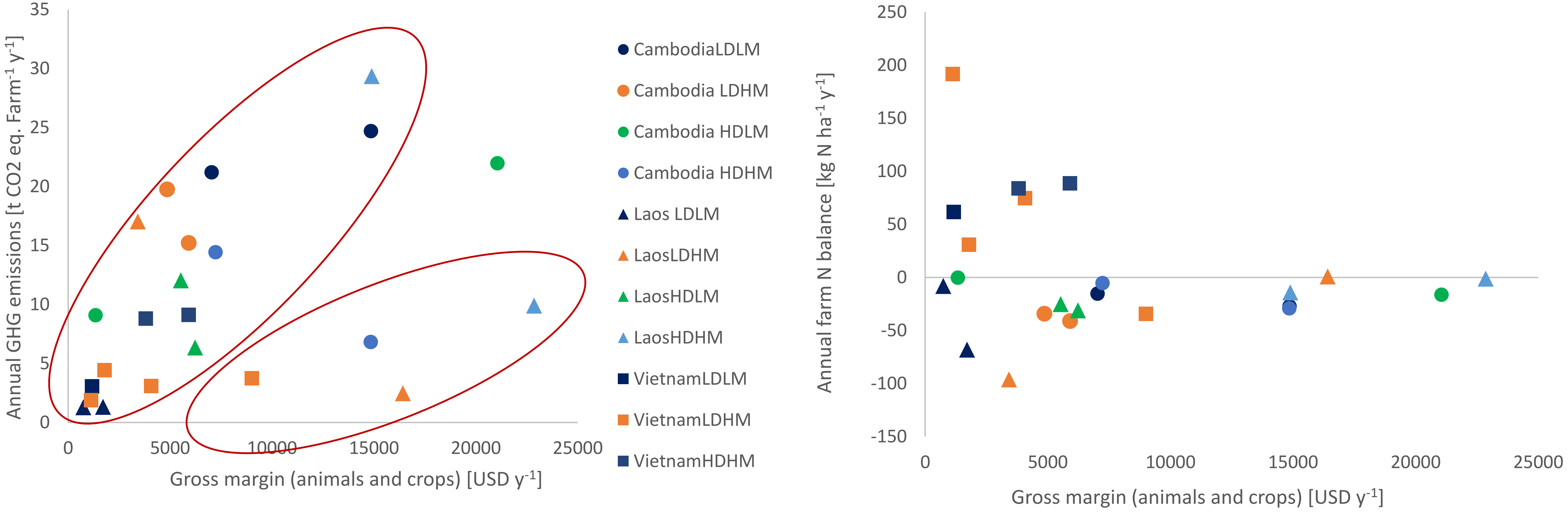


Results environmental impacts: GHG emissions





Agro-environmental trade-offs



Conclusions

- Intensification not always leading to higher environmental impacts – e.g. residue burning a large GHG source in Cambodia and Laos
- Nutrient management: In Vietnam risk of nutrient pollution, other countries need more inputs through fertilizer, manure recycling and residue use (mulching or feeding) instead of burning, integration of legumes
- Between-country trends seem to be more important in determining environmental impacts than market orientation or diversity – though statistical analysis is pending
- Potential role of livestock in sustainable intensification and mitigating agro-environmental trade-offs – converting residues into animal source food and manure for fertilization, reducing residue burning
- Optimization can explore potential agro-environmental impacts of various agricultural intensification pathways

Thank you!

Funding from

- BMZ through project 'Hands and Minds Connected to Boost Eco-efficiency in Smallholder Livestock-Crop Systems: Participatory approaches in Laos, Cambodia and Vietnam'
- CGIAR Research Programs on Livestock and Humidtropics
- ETH Zurich Plant Nutrition Group

Thanks to Lyda Hok, RUA in Cambodia and Seuth Phengsavan, NAFRI in Laos for advice

All pictures by Birthe Paul, Neil Palmer and Georgina Smith, CIAT

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International Center for Tropical Agriculture - CIAT

Headquarters and Regional Office
for South America and the Caribbean

+57 2 445 0000
Km 17 Recta Cali-Palmira
A.A. 6713, Cali, Colombia

ciat@cgiar.org
ciat.cgiar.org

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