Environmental impacts of rice cropping in Thailand:
combining techno-economic analysis and LCA, towards eco-efficiency analysis

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What contribution of LCA to the rice sector?

Considering the rice sector and its « livelihood-environment-food security-poverty » nexus,

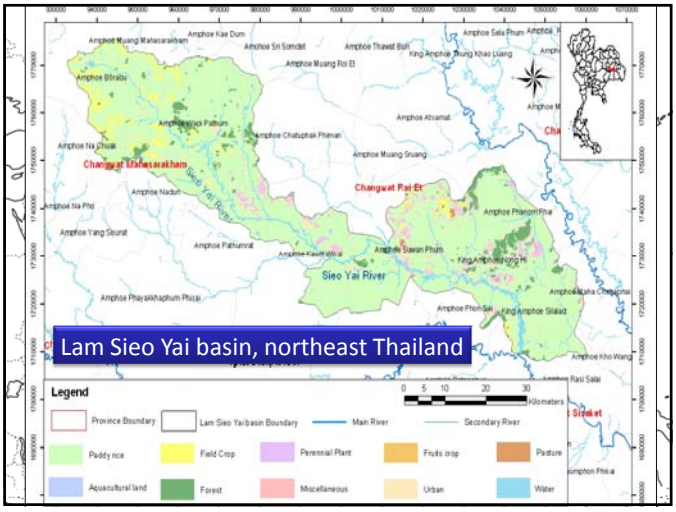
- The question IS NOT:
  What is the environmental impact of rice production?
- The question IS:
  Can one identify rice production systems that have relatively low environmental impact while yielding reasonably good yields, at low cost, insuring an acceptable income to farmers
- And related issues: are alternative systems worth the effort (e.g. organic rice, GAP rice)

Combining techno-economic and environmental analyses: concepts and framework

Productivity: which result obtained per unit factor mobilized
Efficiency: how much of a factor for one unit result obtained (FU)
Productivity = 1 / Efficiency

Techno-economic performances refer to productivity of factors
Mass product or value per unit factor
LCA refers to efficiency = we are talking the same language here

System under investigation: Decision-Making Unit DMU
A cropping system with:
- a sequence of operations within a timeframe,
- production factors and resources mobilized, with a value
- and output product or service, with a market value
- emissions of pollutants
- use of resources



Lam Sieo Yai basin, northeast Thailand

The research setting: cropping systems under investigation

- 2 basins x 3 cropping styles Rainfed WS – Irrigated DS – Irrigated WS
- 6 x 20 samples = 120 paddy fields as DMUs under scrutiny in 2010-2011

Thailand: 2281					
North: 3238			North East: 2125		
Nam Mae Lao Basin: 3319			Lam Sieo Yai Basin: 2219		
Average of study farms: 3487 (N=60)			Average of study farms: 2763 (N=60)		
Rainfed 3410 (N=20)	Irrigated – Dry 3415 (N=20)	Irrigated – Wet 3635 (N=20)	Rainfed 2731 (N=20)	Irrigated – Dry 2610 (N=20)	Irrigated – Wet 2948 (N=20)

- Then among those, different planting practices:
  - Sowing dry seeds (popular in the North East, and North rainfed)
  - Sowing wet / soaked seeds (popular in the North irrigated)
  - Nursary + transplanting

Indicators for techno-economic performances

- Yield (land productivity)
- Production costs (total and as per input, factor or resource used)
- Gross and net income per input, factor or resource used
- Land use and productivity
- Water use and productivity (CWR, IWR)
- Energy use and productivity (fossil energy, human energy, animal-draft energy and renewable energy)
- Fertilizer use and productivity
- Pesticides use and productivity
- Labor mobilized and productivity (hired and family labor)

Techno-economic performances: results

Techno-Economic performance	Reference Unit	Rice cropping system					
		RE	IRR (wet)	IRR (dry)	RE	IRR (wet)	IRR (dry)
		Ref. Unit/ha			kg of paddy rice/Ref. Unit		
Land productivity	ha	1	1	1	2,500	2,781	2,406
Labour productivity	man hr.	7.89	8.61	16.48	317	323	146
Fertilizer Productivity	kg of fertilizer	625	687	687	4.00	4.05	3.50
Pesticide productivity	kg of active matter	5.07	10.34	11.57	493	269	208
Water productivity	m^3	6,285	7,785	7,256	0.398	0.357	0.332
Green Water productivity	m^3	6,285	6,284	1,172	0.398	0.443	2.053
Blue Water productivity	m^3	0.268	1,500	6,083	9,333	1.854	0.396
Energy productivity	MJ	17,123	19,585	21,105	0.146	0.142	0.114
Production cost	baht	20,858	22,239	23,415	0.120	0.125	0.103
Gross income	baht	28,521	31,730	28,875	0.088	0.088	0.083
Net income	baht	7,663	9,491	5,460	0.326	0.293	0.441
		EER:	1.80		1.76		1.41

Energy balance excludes the energy involved in infrastructural construction (irrigation system, access roads, buildings, etc.)

Framework for environmental impact analysis

Input-related categories:
Land
Energy
Water

Output-related categories:
Air acidification
Water eutrophication
Global warming potential (100y)
Stratospheric ozone depletion
Freshwater aquatic ecotoxicity

Impacts = env. damage / FU

- **System Boundary**: cradle-to-farm gate
- **Functional Unit:** 1 kg of paddy Hom Mali rice
- **Characterization method** CML baseline 2000/world, 1995 methodology with SimaPro software

Framework for environmental impact analysis

Field operations
Tillage operations
Tillage operations
Sowing
Water management
Fertilizing
Application of plant protection products
Cutting grasses
Harvesting

Pesticide product	Active ingredient
Roundup	Glyphosate
Polydon	Calcium carbonate + Isoprocab
R-S-5-G	Metaldehyde

LCI

Commercial Name
Hua-Wua-Kun-Tai 46-0-0
Hua-Wua-Kun-Tai 15-15-15
Hua-Wua-Kun-Tai 16-16-8
Hua-Wua-Kun-Tai 16-20-0

Labour, Water

Direct emission	
Emission to air	Methane (CH_4)
	N_2O
	NO
	NH_3
Emission to water	Nitrates
	Phosphorus
	glyphosate
	Calcium carbonate + Isoprocab
	Metaldehyde
Emission to soil	glyphosate
	Calcium carbonate
	Metaldehyde

1 kg of paddy Hom Mali rice

Environmental impacts: results of LCIA

Impact indicator		Reference unit	Rice cropping system					
			RE	IRR (wet)	IRR (dry)	RE	IRR (wet)	IRR (dry)
			Ref. Unit/ha			Ref. Unit/1 kg of paddy rice		
Output-related indicators	GWP_{100}	kg CO2-eq	7,801	14,040	13,265	3.12	5.05	5.51
	EP	kg PO4-eq	178	207	214	0.07	0.07	0.09
	AP	kg SO2-eq	107	111	110	0.043	0.040	0.046
	ODP	mg CFC-11-eq	217	243	236	0.087	0.087	0.098
	FWAE	kg 1,4-DB eq	1,630	2,253	2,178	0.652	0.810	0.905
input-related indicators	WU	m^3	6,281	7,790	7,247	2.51	2.80	3.02
	LU	ha	1.0	1.0	1.0	0.00040	0.00036	0.00042
	EU	MJ	17,123	19,585	21,105	6.87	7.04	8.79

Addressing eco-efficiency

- "A measure that expresses a process' contributions to **sustainability**" (Van Passel et al., 2007)
- A ratio: "Product or service value / Environmental damage" (WBCSD, 2000) = FU mass or value or else / potential env. Damage => **multiple ratios**
- "Multiple individual ratios uneasy to communicate, sometimes with ambiguous results or interpretation" (Sanjuan et al., 2010)
- Towards aggregation, single index ? A problem of priority, choice, policy, goals, perceptions, etc.
- One may also consider « Net return per environnemental impact » setting aside production costs and focusing on net income: what added value at production level per unit pollution?

Eco-efficiency: results

Impact indicator	Reference unit	Lam Sieo Yai Basin		
		RE	IRR (wet)	IRR (dry)
		(Baht/Ref. unit)		
GWP100	kg CO2-eq	3.85	2.38	2.18
EP	kg PO4-eq	169.01	161.51	134.98
AP	kg SO2-eq	281.69	301.51	263.16
ODP	mg CFC-11-eq	138.09	137.46	122.57
FWAE	kg 1,4-DB eq	18.41	14.81	13.26
WU	m3	4.77	4.29	3.98
LU	ha	30,000	33,333	28,571
EU	MJ	1.75	1.70	1.37

TVP = Market price: 12 THB / FU

Net return to environmental impact: results

Impact indicator	Reference unit	Lam Sieo Yai Basin		
		RE	IRR (wet)	IRR (dry)
		(Baht/Ref. unit)		
GWP100	kg CO2-eq	1.18	0.79	0.42
EP	kg PO4-eq	51.69	53.84	25.76
AP	kg SO2-eq	86.15	100.50	50.22
ODP	mg CFC-11-eq	42.23	45.82	23.39
FWAE	kg 1,4-DB eq	5.63	4.94	2.53
WU	m3	1.46	1.43	0.76
LU	ha	9,175	11,111	5,452
EU	MJ	0.53	0.57	0.26

Net income: 3.67, 4.00, 2.29 THB / FU respectively

Addressing techno- and eco-efficiency

- Maximizing production or net income while minimizing production costs
- Maximizing production or net income while minimizing environmental impacts

Weighted and non-weighted Data Envelopment Analysis will be used… to be continued, on-going research