Assessment of Environment-friendly Rice Farming through Life Cycle Assessment (LCA)

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Sustainable Development

"Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.“

the Brundtland Commission report Our Common Future (1987)

Social
Equity
Participation
Empowerment
Social Mobility
Cultural Preservation

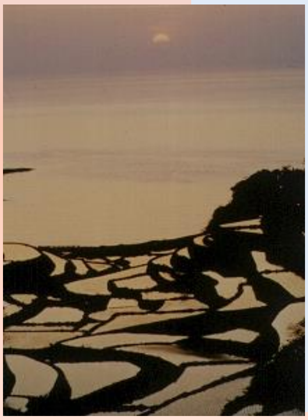
Economic
Services
Household Needs
Industrial Growth
Agricultural Growth
Efficient Use of Labor

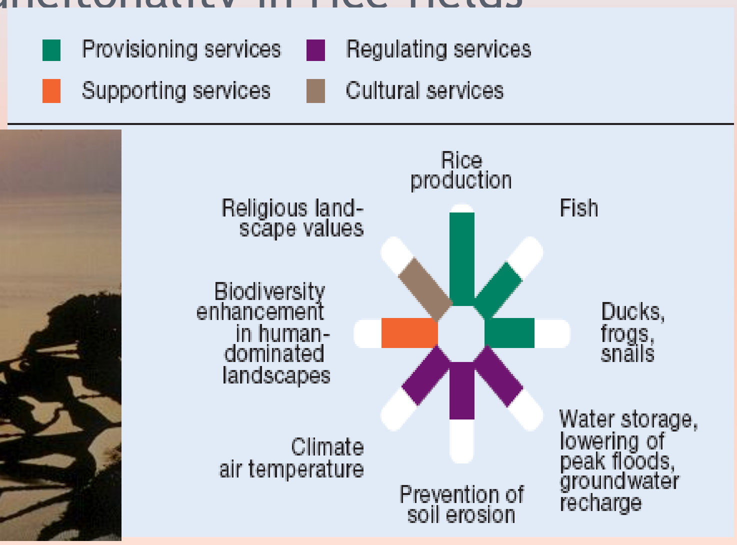
Environment
Biodiversity
Natural Resources
Carrying Capacity
Ecosystem Integrity
Clean Air and Water

Sustainable Agriculture/Farming

- Economic : Productivity, Income, Labor saving
- Social: Equal access to resources use
- Environment:
  - Maximizing environmental services (benefits)
    - Valuation of multifunctionality, ESS
    - Payment for GAP, Environment friendly farming
  - Minimizing environmental impacts through farming
    - EIA (Environment Impact Assessment),
    - LCA (Life Cycle Assessment)

Multifuncitonality in rice fields





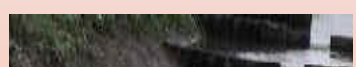
Source: Adapted from Foley, J., R. DeFries, G.P. Asner, C. Barford, G. Bonan, S.R. Carpenter, F.S. Chapin, and others, 2005, "Global Consequences of Land Use," *Science* 309 (22 July): 570–74; chapters 6 and 14 in this volume.

Agri-envrionment measure by Shiga prefecture, Japan
Direct payment for better farming practices (2003)

Promotion of Environment friendly agriculture ->
Direct payment and certification mark for the product

Chemical reduction	>=50%	>70%
plum, persimmon, etc	100,000	+20,000
Tea	100,000	+20,000
Rape seed	20,000	-

Source: Hashimoto(2005)

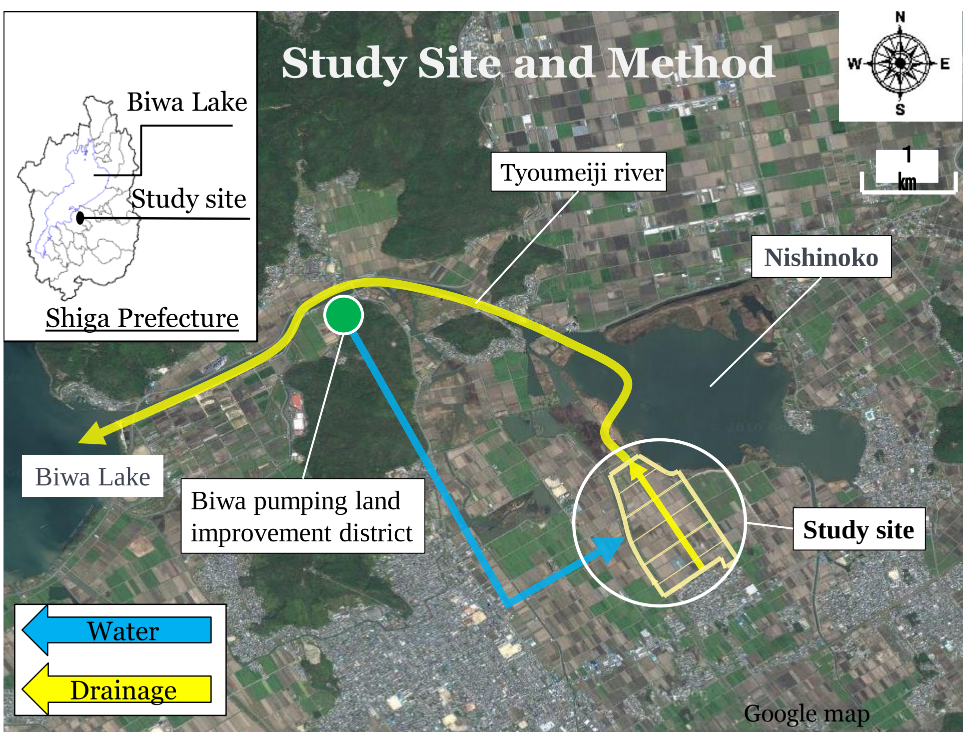


Is
Environment Friendly Farming
really
friendly to environment?

Fish ladder:PF-Drainage canal

Holistic analysis of environmental impacts by farming

- Questions:
  - large mechanized vs. small intensive farming
  - Organic vs. chemical fertilizer,
  - Ponding vs. wet-dry irrigation
- LCA : analyze environmental impacts of a product
  - raw material extraction, processing/production, distribution, use, disposal.
- Apply LCA (LCI) method for asseessing environmental viability of rice farming



Site conditions

- Crop
  - Rice (Koshihikari)
  - Land preparation: Late April, Growing season: May-September
- Soil: fine gley soil
  - pH 5.4-5.8,
  - T-C 2.7-2.5%,
  - T-N 0.19-0.18%,
  - P2O5 25.8-28.5%,
  - CEC 20.1-19.4 me,
- Rainfall
  - Rainfall during the growing season is 768 mm

Holistic analysis of environmental impacts

LCI : environmental outputs by different inputs

➡ Impacts on GHG/ Eutrophication (water pollution)

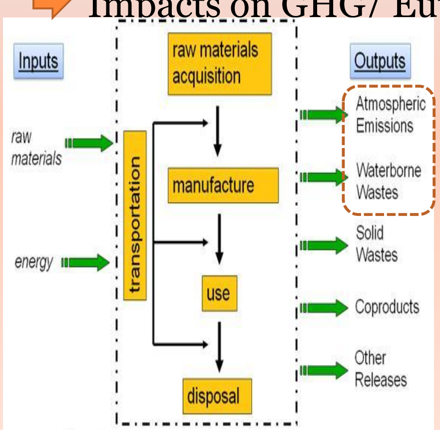
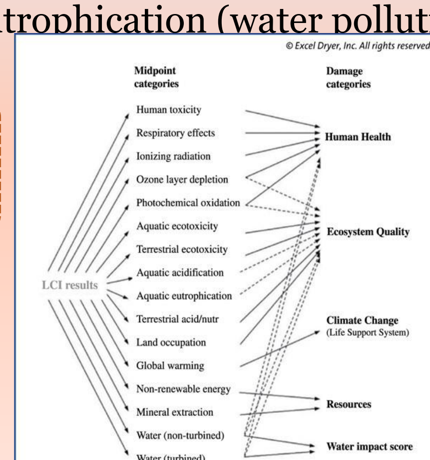


Figure 2. Inputs and outputs for a life cycle assessment.



A schematic of IMPACT 2002+ impact assessment system

Scope of analysis

- Comparisons of Environment Friendly Farming (EFF) and Conventional Farming (CONV)
  - EFF: 50% reduction of chemical inputs + water saving practices
- Outputs from whole production processes of rice farming
  - Land preparation-seedling-nursery-puddling -transplanting-weeding-fertilizer /chemical application – harvesting – threshing-drying
  - Energy use:(electricity, gasoline/light oil by fuel efficiency

- Machinery
  - production energy by weight: 10 MJ/kg
  - Expected life period: 6-8 years

Chemical and Water Inputs for EFF and CONV

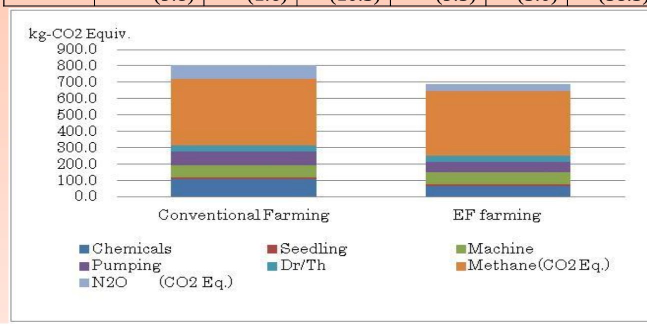
- Environmental friendly farming (EFF)
- Conventional farming (CONV)
- Yields: EFF 5.7 ton/ha, CONV 5.6 ton/ha

Inputs	**T-N fertilizer** (organic component) (kg/ha)	**T-P fertilizer** (kg/ha)	**Chemicals** (insecticide /herbicide) (kg/ha)	**Water consumption** (mm)
CONV	76(0)	16	2.4	1,174
EFF	70 (55)	19	1.1	879

Results: Life Inventory Analysis

- Emission of GHG by different farming practices.
  - (Unit: kg-CO_2 equivalent /0.1 ha(%))

	CO_2					CH_4	N_2O	Total
Process	Chemicals	Seedling	Machine	Pumping	Dr/Th*			
Conv*	108.6 (13.5)	10.7 (1.3)	70.6 (8.8)	87.0 (10.8)	34.1 (4.2)	407.3 (50.7)	84.9 (10.6)	803.2
EFF**	67.0 (9.8)	10.7 (1.6)	70.6 (10.3)	65.1 (9.5)	34.1 (5.0)	401.3 (58.5)	37.6 (5.5)	686.4



Emission coefficient :
CH_4 15.98kg/0.1ha
N_2O 0.0067 kg/kg-N

Sensitivity analysis

- CH4 emission coefficient
  - 10kg/0.1 ha for EFF (Decomposition of organic fertilizer)
  - 5 kg/0.1 ha for CONV (Chemical fertilizer)
- -> 14 kg higher CO2-equivalent for EFF > CONV

- Accurate estimation of CH4/N2O emission needed
  - Wet and dry irrigation can reduce CH4 emission
  - Use of well processed organic fertilizer or minimual application of chemical fertilizer

Impact on eutrophication by different farming practices

- PO_4 –equivalent
  - Characterization values :
  - 0.42 kg/kg, 3.06 kg/total-P, 0.022 kg/COD

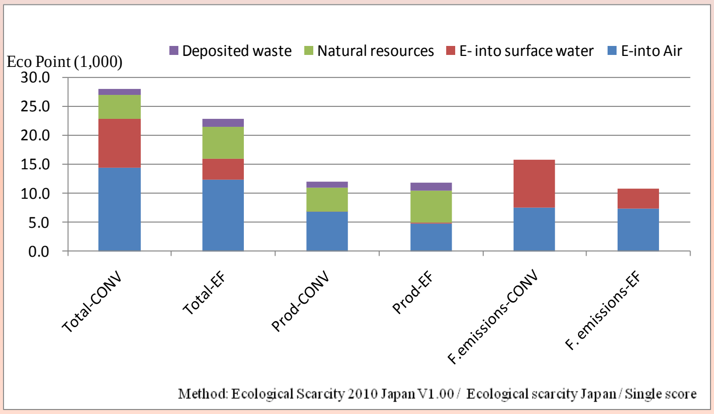
(Unit: Kg of PO4 equivalent)

	CONV	PO_4 equiv.	EFF	PO_4 equivalent
Total-N	2.05	0.86	1.00	0.42
Total-P	0.381	1.17	0.27	0.83
COD	21.5	0.47	8.93	0.20
Total		2.50		1.45

LCA : Normalization and weighting

- LCI has different units for each environmental impacts
  - (CO2-equivalent, PO4-equivalent…)
- Need to convert single unit (eco-point) to enable overall assessment on environment
- Different values attached to different environment impacts by different people
- Weighting factors to allow unification
  - -Questionnaire, Overall policy goals for each environmental factors (Ecological scarcity method)
- Weighting by Ecological scarcity method (May 2011)
  - the maximum permissible flows of the same environmental pressure.(the environmental policy goals)
  - the total present flows of environmental pressure

LCA scores by different farming practices



Prod- : impact by production process, **F.emissions**-: impact by field emission of gases

Conclusion and further studies

- Application of LCA for analyzing sustainable farming practices to minimize environmental impacts
- Combining environmental analysis with economic and social factors
- Further studies
  - Estimation of emission coefficients by field measurements and modeling
  - Analysis on impacts of other categories (biodiversity, human health, resource depletion, ..)
  - From field level analysis to basin level (enhancing cycle mechanism) and land use planning