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

N. Hatcho, Y. Matsuno, K. Kochi, K. Nishishita
Faculty of Agriculture, Kinki University

Content

• Background
• Study site and method
• Results
• Discussion and Conclusion
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
- Households 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)
Multifunctionalilty in rice fields

- Provisioning services
- Regulating services
- Supporting services
- Cultural services


Agri-environment 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

<table>
<thead>
<tr>
<th>Chemical reduction</th>
<th>&gt;50%</th>
<th>&gt;70%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td></td>
<td></td>
</tr>
<tr>
<td>up to 3 ha</td>
<td>50,000</td>
<td>25,000</td>
</tr>
<tr>
<td>above 3 ha</td>
<td>+10,000</td>
<td>+5,000</td>
</tr>
<tr>
<td>Vegetable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Open Field</td>
<td>600,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Fruit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grape, peach, etc</td>
<td>300,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Plum, persimmon, etc</td>
<td>+60,000</td>
<td>+20,000</td>
</tr>
<tr>
<td>Tea</td>
<td>100,000</td>
<td>+20,000</td>
</tr>
<tr>
<td>Rape seed</td>
<td>20,000</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: Hashimoto(2005)

Is Environment Friendly Farming really friendly to environment?

Fish ladder: PF-Drainage canal

Source: Hashimoto(2005)
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 assessing environmental viability of rice farming

![Study Site and Method](image)
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)**

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**
  - 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

<table>
<thead>
<tr>
<th>Inputs</th>
<th>T-N fertilizer (kg/ha)</th>
<th>T-P fertilizer (kg/ha)</th>
<th>Chemicals (insecticide/herbicide) (kg/ha)</th>
<th>Water consumption (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONV</td>
<td>76(0)</td>
<td>16</td>
<td>2.4</td>
<td>1,174</td>
</tr>
<tr>
<td>EFF</td>
<td>70 (55)</td>
<td>19</td>
<td>1.1</td>
<td>879</td>
</tr>
</tbody>
</table>
Results: Life Inventory Analysis

- Emission of GHG by different farming practices.

<table>
<thead>
<tr>
<th>Process</th>
<th>CO₂ Emission (kg-CO₂ equivalent /0.1 ha(%))</th>
<th>CH₄</th>
<th>N₂O</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conv*</td>
<td></td>
<td></td>
<td></td>
<td>803.2</td>
</tr>
<tr>
<td>EFF**</td>
<td></td>
<td></td>
<td></td>
<td>686.4</td>
</tr>
</tbody>
</table>

**CO₂ Emission Coefficient**
- CH₄ 15.98 kg/0.1ha
- N₂O 0.0067 kg/kg-N

Sensitivity analysis

- CH₄ emission coefficient
  ▫ 10 kg/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 minimal application of chemical fertilizer
Impact on eutrophication by different farming practices

- PO₄ –equivalent
  - Characterization values:
    - 0.42 kg/kg, 3.06 kg/total-P, 0.022 kg/COD

(Unit: Kg of PO₄ equivalent)

<table>
<thead>
<tr>
<th></th>
<th>CONV</th>
<th>PO₄ equiv.</th>
<th>EFF</th>
<th>PO₄ equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total-N</td>
<td>2.05</td>
<td>0.86</td>
<td>1.00</td>
<td>0.42</td>
</tr>
<tr>
<td>Total-P</td>
<td>0.381</td>
<td>1.17</td>
<td>0.27</td>
<td>0.83</td>
</tr>
<tr>
<td>COD</td>
<td>21.5</td>
<td>0.47</td>
<td>8.93</td>
<td>0.20</td>
</tr>
<tr>
<td>Total</td>
<td>2.50</td>
<td>2.50</td>
<td>1.45</td>
<td></td>
</tr>
</tbody>
</table>

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

![Diagram showing 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