Contribution of Nitrous Oxide in Life Cycle Greenhouse Gas Emissions of Novel and Conventional Rice Production Technologies

Md. Khairul Alam\(^1\); Wahidul K. Biswas\(^2\) and Richard W. Bell\(^1\)

\(^1\)Land Management Group
School of Vet. and Life Sciences
Murdoch University, WA

\(^2\)Sustainable Engineering
Curtin University, WA
Background
Wetland rice production and global budget of GHGs
GHGs from agriculture counting direct agricultural emissions plus input production and energy use

Adapted from Bellarby et al. 2008
Fig. Production, consumption and transfer of CH$_4$ to the atmosphere in rice field (Adapted from Le Mer and Roger, 2001)
Fig. N₂O production in soil through microbial transformations
Novel technologies to cope with the paucity of labour and water
Constraints

- **CH₄ emission**
- **N₂O emission**
- **Additional fuel consumptions**
- **N₂O emission**

**Puddled transplanting**

**Direct seeding**

**Mechanical transplanting**

**System of Rice Intensification**
Fig. Trade off between CH$_4$ and N$_2$O under wetland rice conditions
A novel solution – Non-puddled transplanting of rice
Non-puddled transplanting of rice/NP rice
**Objectives:**

- To assess the contributions of N$_2$O to life cycle GHG emissions for CT and NP with crop residue retention levels.

- To determine the hotspots contributing significantly to the GHG emissions within the system boundaries by a LCA study.

- To identify the causes for the predominant GHG emissions during the pre– and on–farm stages of rice production.
Methods
Methods

Study site: Alipur, Rajshahi
Closed Chamber method

Closed chamber for microbial respiration

Chamber - (30 cm length × 30 cm width × 60 cm height)
Chamber base - 31 cm length × 31 cm width × 7 cm height,
Chamber groove - 1 cm × 2.5 cm (width × deep)

Closed gas chambers for CH₄ and N₂O

60 cm length × 30 cm width × 100 cm height
Transport (Fertilizer, Seeds, Pesticides, Machines)  

Paddock for pre-farm activities  

Output: CO₂, CH₄ and N₂O  

C storage (CS)  

System Boundary of SLCA
SLCA for field paddy production

- goal and scope definition
- inventory analysis
- impact assessment and interpretation.
Greenhouse gas emissions calculated for the following practices:

- Conventional puddled transplanting with low residue retention (CTLR)
- Conventional puddled transplanting with high residue retention (CTHR)
- Non-puddle transplanting with low residue retention (NPLR)
- Non-puddle transplanting with high residue retention (NPHR)
Life cycle inventory

**Pre–farm emissions**

**Chemicals**
- Fertiliser
- Pesticides
- Herbicides

**Farm machinery**
- Plough/PT/VMP
- Harvester

**Transport**
- Trucks
- Shipping

**On–farm emissions**
- Farm machinery
- Soil

Ref: Alam et al. 2016; Journal of Cleaner Production 112(5): 3977-3987
## Impact assessment

### Global warming potential (GWP)

<table>
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<tr>
<th>Greenhouse gas</th>
<th>Time horizon</th>
<th>20 years</th>
<th>100 years</th>
<th>500 years</th>
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</thead>
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<tr>
<td>Carbon dioxide</td>
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<tr>
<td>Methane</td>
<td>72</td>
<td>25</td>
<td>7.6</td>
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<td>Nitrous oxide</td>
<td>289</td>
<td>298</td>
<td>153</td>
<td></td>
</tr>
</tbody>
</table>

Source: IPCC, 2013
Results
2a. Pre-farm

- 7-11% of total LCA emission.
- Lower than any other paddy LCA in the world.

**Causes:**
- Lower level of input used
- Use of natural gas as a feed stock
- Light vehicles used

**Legend:**
- CT = Conventional puddled transplanting
- NP = Non-puddle transplanting
- HR = High residue retention (NPTHHR)
- LR = Low residue retention (NPTLR)
2 b. On-farm emission (kg CO2eq/tonne rice)

Rice establishment technique

- CTLR
- CTHR
- NPLR
- NPHR
Fig. 2c. Total emissions showing contributions from different sources.
Production of inputs 7%
Transportations of inputs 3%
CO2 emission from paddock 9%
CH4 emission from paddock (CO2 eq) 62.5%
N2O emission from paddock (CO2 eq) 3.5%
Farm machinery use 15%
Production of inputs 7%
Transportations of inputs 3%
CO2 emission from paddock 9%
CTLR (100 years time horizon)
Production of inputs: 6%
Transportation of inputs: 2%
CO₂ emission from paddock: 10%
CH₄ emission from paddock (CO₂eq): 67%
N₂O emission from paddock (CO₂eq): 3%

CTHR (100 years time horizon)

CTHR (100 years time horizon)
Production of inputs: 9%
Transportation of inputs: 3%
CO2 emission from paddock: 10%
CH4 emission from paddock (CO2 eq): 60%
N2O emission from paddock (CO2 eq): 2%

Farm machinery use: 16%
Production of inputs: 9%
Transportation of inputs: 3%
CO2 emission from paddock: 10%

NPLR (100 years time horizon)
Production of inputs: 7%
Transportations of inputs: 3%
CO₂ emission from paddock: 9%
N₂O emission from paddock (CO₂ eq): 2%
CH₄ emission from paddock (CO₂ eq): 64%
Farm machinery use: 15%
Production of inputs: 7%
Transportations of inputs: 3%
CO₂ emission from paddock: 9%
NPHR (100 years time horizon)
Different practices

CH₄ (CO₂-eq) emission

- CTRL
- CTHR
- NPLR
- NPHR

CH₄ (CO₂-eq)
Different treatments

N2O (CO2-eq)

- CTRL
- CTHR
- NPLR
- NPHR

N2O (CO2-eq) emission
Conclusions
The CTHR emitted about 1.4 times more GHG emissions for one tonne rice than NPLR.

Applying NPLR in the wetland rice system of the EGP can reduce GHG emissions to 1.1 tonne CO$_2$–eq tonne$^{-1}$ rice production.

The on–farm stage contributed the highest portion of the total GHG emissions.

CH$_4$ was the predominant GHG from 1 tonne of rice production.

N$_2$O emission contributing only 2-3.5 % of the total LCA GHG.

We recommend additional SLCA studies for all the crops of the cropping system.

Ref: Alam et al. 2016; Journal of Cleaner Production 112(5): 3977-3987
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