Technology development for the mitigation of climate impact of agriculture in China

Xiaoyuan YAN, Guangbin ZHANG, Jing MA
Institute of Soil Science, Chinese Academy of Sciences
Technology development for carbon sequestration and GHG mitigation in agroecosystem

**WP1**
Common technology for carbon sequestration, GHG mitigation, and their assessment

**WP2**
Technology integration and demonstration for rice paddy ecosystem

**WP3**
Technology integration and demonstration for upland crop ecosystem

2013～2016

4.3 M USD

24 Institutions

4.3 M USD
Carbon sequestration

- Straw burying

CH₄ mitigation

- Oil sunflower

N₂O mitigation

- Biochar
- Nitrification inhibitor
- Rice-duck system

Drought resistant cultivar

Mulching cultivation
1. Carbon sequestration - straw deep burying

Key Points
- Straw buried to 25cm
- Maize-soybean rotations
- Applying decomposition maturing agent and chemical fertilizer
- High power engineering and five-furrow plough
1. Carbon sequestration - straw deep burying

Northeastern China, high SOC, low temperature

Increase straw humification rate

Increment after 6 years (0-40cm) Ton C/ha/yr

<table>
<thead>
<tr>
<th>Method</th>
<th>Change of SOC, ton C/ha/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow plow, straw</td>
<td>-0.231</td>
</tr>
<tr>
<td>Straw mulching</td>
<td>0.454</td>
</tr>
<tr>
<td>Surface incorporation</td>
<td>0.703</td>
</tr>
<tr>
<td>Straw deep burying</td>
<td>0.786</td>
</tr>
</tbody>
</table>

0 d  30 d  60 d  90 d  120 d  150 d
2. Carbon sequestr. – increase crop residue input

Lower reach of Yellow river, slightly saline soil, low SOC

**Single** oil sunflower cropping

- June
- July
- Aug.
- Sep.

**Double** oil sunflower cropping

- April
- May
- June
- July
- Aug.
- Sep.
- Oct.
- Nov.

**Recommendation**

**Key Points**

- Film mulching in early spring
- Delayed harvest in autumn
- New cultivars
- Make use of saline and alkaly soil
- Take full advantage of heat source
- Increase straw input
2. Carbon sequestr. – increase crop residue input

- Economy increase 30%
- Straw input increase 28%
- SOC increase 0.2t C/ha/yr
3. Biochar Production from Crop Residue

**Straw > Biochar_{max} > Control > Biochar_{min}**
3. Biochar Production from Crop Residue

Pilot continuous biogas-energy pyrolysis system

- continuous rollaway bed kiln for torrefaction and pyrolysis
- a biogas subsystem for thermal energy supply
- auxiliary facilities for cooling biochar and eliminating atmospheric emissions
3. Biochar Production from Crop Residue

Increase organic carbon content

Little effect on CH$_4$ emission

![Graph showing the effect of biochar on methane flux](image)

- **Biochar Production from Crop Residue**
- **Increase organic carbon content**
- **Little effect on CH$_4$ emission**
4. Production of low cost nitrification inhibitor

Akiyama et al., 2010, GCB
Nitrapyrin was found to inhibit nitrification, 1964

**Traditional**
- Four steps, recovery 30%
- Many equipments, high pressure vessels needed
- High toxicity of intermedium, explosive
- Many by-products and contaminants because of high temperature
4. Production of low cost nitrification inhibitor

**New technology**

- One step, recovery 88%
- Few equipment, ordinary pressure vessel
- Low risk
- Less contaminants

**Patented in China and Germany**

![Chemical reaction](image)
4. Production of low cost nitrification inhibitor

Field tests

Rice, maize, wheat, cotton, vegetable
1-3 years’ observation
4. Production of low cost nitrification inhibitor

Mitigation effects

Varying 8.75% ~ 59.6%, mean 27.7%
Decomposition of nitrapyrin in soils

\[
\text{Cl} \quad \text{CCl}_3 \\
\downarrow \quad \downarrow \\
\text{Cl} \quad \text{N} \quad \text{CHCl}_2 \\
\downarrow \quad \downarrow \\
\text{Cl} \quad \text{N} \quad \text{COOH} \quad \text{Cl} \quad \text{N} \quad \text{CH}_2\text{Cl} \\
\downarrow \quad \downarrow \\
\text{HO} \quad \text{N} \quad \text{COOH} \\
\downarrow \\
\text{CO}_2, \text{H}_2\text{O}, \text{N}_2
\]

Plant growth hormone
5. \( \text{CH}_4 \) mitigation in rice-duck system

A rising rice cultivation system in south China

**Incentives:**
- Improving economic income
- Saving pesticide
5. \( \text{CH}_4 \) mitigation in rice-duck system

- **8% yield increase**
- **Reduced ineffective tillering**
- **Increased 1000-seed weight**
5. $\text{CH}_4$ mitigation in rice-duck system
5. \( \text{CH}_4 \) mitigation in rice-duck system

![Chart showing \( \text{CH}_4 \) flux (mg/m\(^2\)/h) over time and seasonal emission with 20% reduction.](chart.png)
Carbon sequestration

CH$_4$ mitigation

N$_2$O mitigation

1. Straw burying
2. Oil sunflower
3. Biochar
4. Nitrification inhibitor
5. Rice-duck system
6. Mulching cultivation
7. Drought resistant cultivar
In particular in 2010, all of the 5 provinces suffered from a serious drought disaster

**50 days**

**6.4 million ha**

**5.6 billion U.S. dollars**
6. Plastic film mulching cultivation for rice

Seasonal drought in hilly area
Winter-flooding rice cultivation technology
6. Plastic film mulching cultivation for rice

Potentially high CH$_4$ emission from winter flooded rice paddy

Y = 0.2846e$^{0.0861x}$
R$^2$ = 0.885

6. Plastic film mulching cultivation for rice

Plastic film mulching cultivation

Winter-flooding cultivation

Water-saving 70%

Plastic mulching cultivation

Fallow season

Rice season

Fallow season

Rice season
6. Plastic film mulching cultivation for rice
6. Plastic film mulching cultivation for rice

- Significant drought resistance effect
- Low temperature resistant
- Pesticide-saving
- Labor-saving
- Better crop yield
GHG emissions

Winter Fallow season

Flooding

Rice season

Flooding

Conventional cultivation

Rainfed

Conventional cultivation

Water-saving irrigation

Plastic film mulching
GHG emissions

CH$_4$ fluxes

![Graph showing CH$_4$ fluxes over time](image-url)
GHG emissions

$N_2O$ fluxes

![Graph showing $N_2O$ fluxes over time]

- PM
- FR
- FF

$N_2O$ flux (µg N m$^{-2}$ h$^{-1}$)

Time periods:
- 2013/10/1 to 2014/9/26
- 2014/10/1 to 2015/9/26
Multiple effects of film mulching

- CH4
- N2O
- GWP
- Yield
- GHGI

% Relative to FF

GHG emissions
## Economic Assessment

### GHG emissions

<table>
<thead>
<tr>
<th></th>
<th>YIELD gain</th>
<th>Input cost</th>
<th>Labor cost</th>
<th>GWP benefit</th>
<th>Net profit</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM to FF</td>
<td>-73</td>
<td>-109</td>
<td>672</td>
<td>190</td>
<td>680</td>
</tr>
<tr>
<td>PM to FR</td>
<td>600</td>
<td>-109</td>
<td>672</td>
<td>45</td>
<td>1208</td>
</tr>
</tbody>
</table>

USD /ha
Mitigation of $\text{N}_2\text{O}$ by EEFs

Enhanced Efficiency Fertilizers

PM

PM+DCD

\[
\text{H}_2\text{N} - \text{N} - \text{NH}_2
\]

Dicyanamide – 5% of the applied urea

PM+NP

\[
\text{Cl} - \text{Cl} - \text{Cl}
\]

6-chloro-2-trichloromethyl pyridine – 0.24% of urea-N

PM+CRF

Jinzhengda thermoplastic resin-coated urea – 42%N
Mitigation of $N_2O$ by EEFs

$N_2O$ fluxes
Mitigation of $N_2O$ by EEFs

CH$_4$ fluxes

![Graphs showing CH$_4$ fluxes over time for different treatments with PM, PM+DCD, PM+CRF, PM+CP, and PM+CRF]
Mitigation of $N_2O$ by EEFs

Multiple effects of EEFs

% relative to PM

N2O  CH4  GWP  YIELD  GHGI

PM  PM+DCD  PM+CP  PM+CRF
### Mitigation of $N_2O$ by EEFs

#### Economic Assessment

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Changes relative to PM</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yield gain</td>
<td>Fertilizer cost</td>
</tr>
<tr>
<td>PM + DCD</td>
<td>64</td>
<td>-168</td>
</tr>
<tr>
<td>PM + NP</td>
<td>59</td>
<td>-28</td>
</tr>
<tr>
<td>PM + CRF</td>
<td>31</td>
<td>-110</td>
</tr>
</tbody>
</table>

**USD/ha**
Ratoon rice

<table>
<thead>
<tr>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
</tr>
</thead>
</table>

**Single rice**

**Ratoon rice**

This technology increases soil temperature → Early rice transplanting (15-20 day) → Harvest twice → Increase rice yield
# Ratoon rice

<table>
<thead>
<tr>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>August</th>
<th>September</th>
<th>October</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PM</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apr. 26/28</td>
<td></td>
<td></td>
<td></td>
<td>Aug. 19/20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transplanting</td>
<td></td>
<td></td>
<td></td>
<td>Harvest</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>PM+RR</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Oct. 20/27</td>
</tr>
<tr>
<td>Apr. 9/10</td>
<td></td>
<td></td>
<td></td>
<td>Aug. 10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transplanting</td>
<td></td>
<td></td>
<td></td>
<td>Harvest</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Ratoon rice

CH₄ fluxes

![Graph showing CH₄ fluxes over two years]

- **PM+RR--Main crop season**
- **PM--Main crop season**
- **PM+RR--Ratoon season**

**CH₄ flux (mg m⁻² h⁻¹)**

- **PM**
- **PM+RR**
Ratoon rice

N$_2$O fluxes

**PM+RR--Main crop season**

**PM--Main crop season**

**PM+RR--Ratoon season**

---

**PM**

**PM+RR**

---

N$_2$O flux (µg N m$^{-2}$ h$^{-1}$)

2016/4/1 to 2016/10/28

---

N$_2$O flux (µg N m$^{-2}$ h$^{-1}$)

2017/4/1 to 2017/10/28
Ratoon rice

Multiple effects of ratoon rice

![Graph showing changes relative to PM% for CH4, N2O, GWP, YIELD, and GHGI under PM and PM+RR conditions.](chart.png)
Summary

Deep bury
Increase production
Biochar

Film mulching
- CH$_4$↓ 32% ~ 67%
- N$_2$O↑ 16% ~ 265%
- GWP↓ 29% ~ 64%
- GHGI↓ 41% ~ 63%

Production of low cost N fertilizer
Average reduction of 27% N$_2$O

Enhanced efficiency fertilizer
- N$_2$O↓ 22%
- GHGI uncertain

Rice-duce system
20% reduction CH$_4$

Ratoon rice
- CH$_4$↑ 1%
- N$_2$O↑ 78%
- GWP↑ 11%
- GHGI ↓ 8%
Thank you for your attention!