# On-going research activities to mitigate GHGs emission from rice paddy in China

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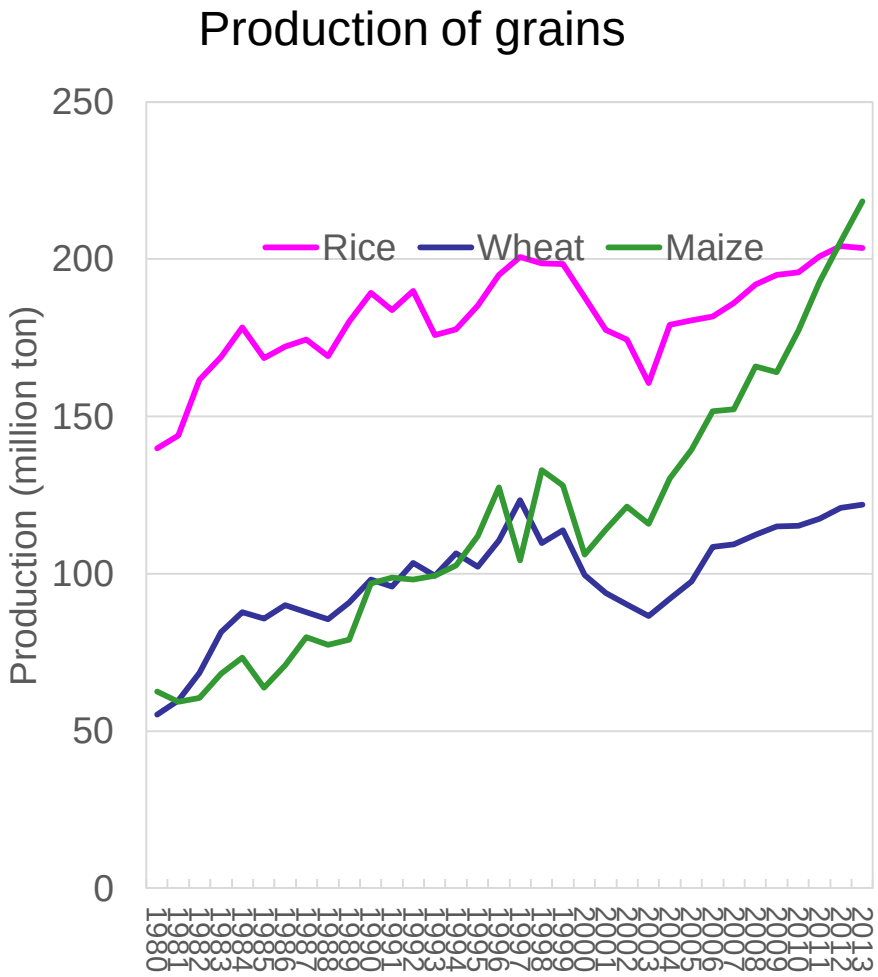
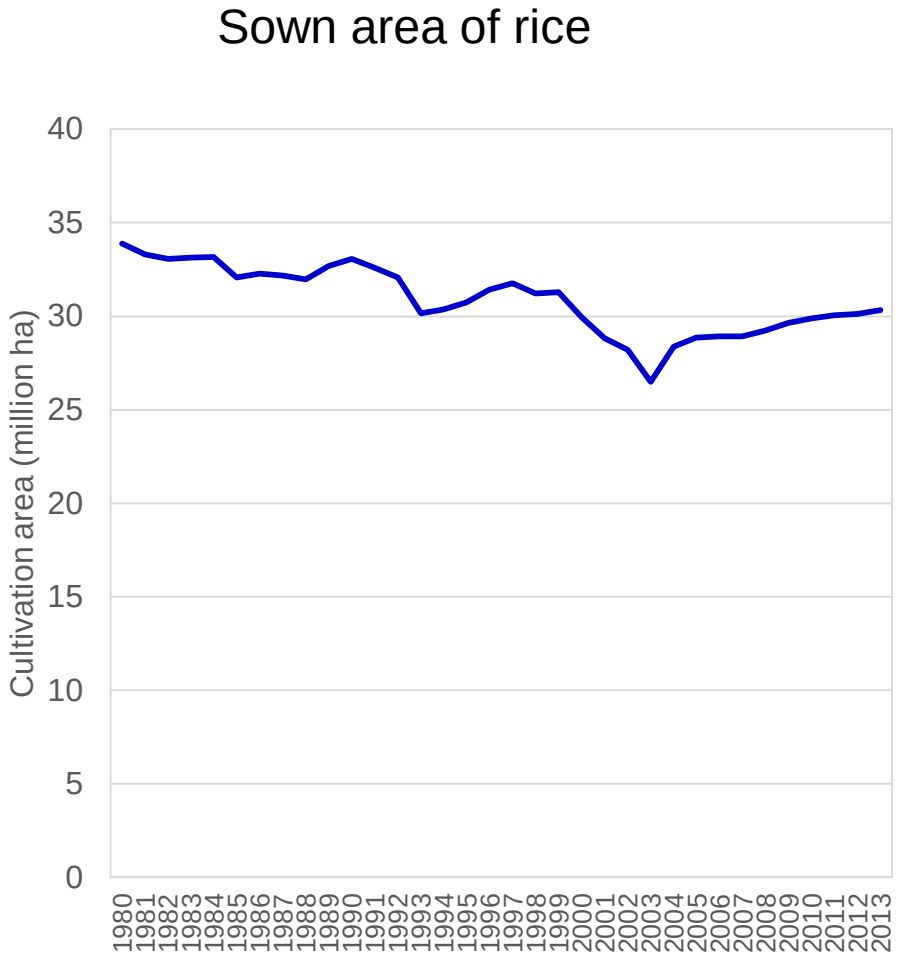
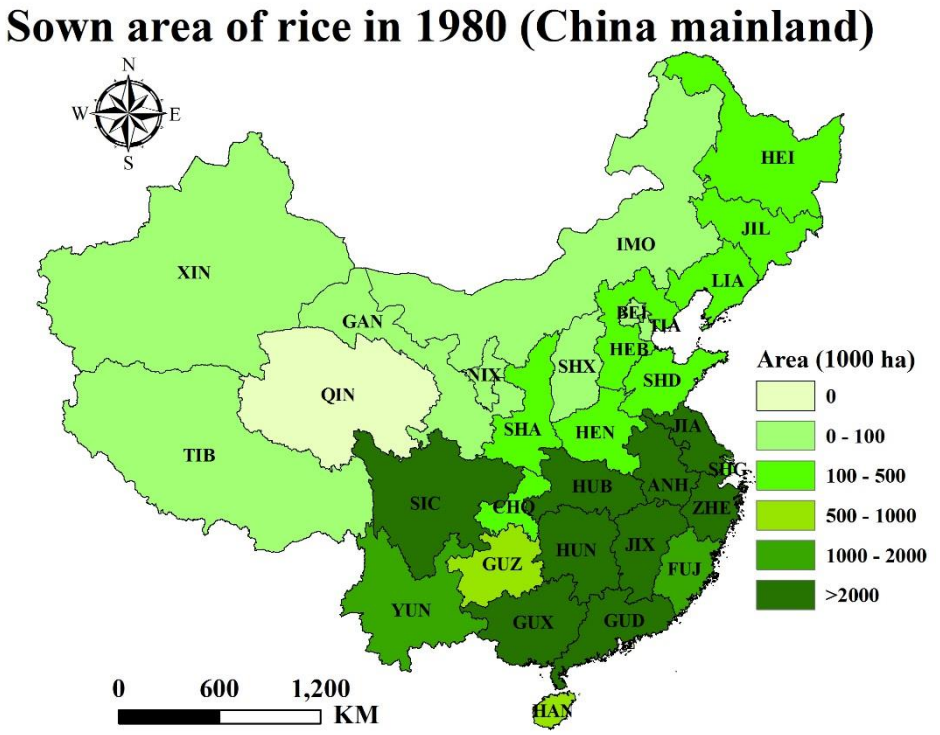
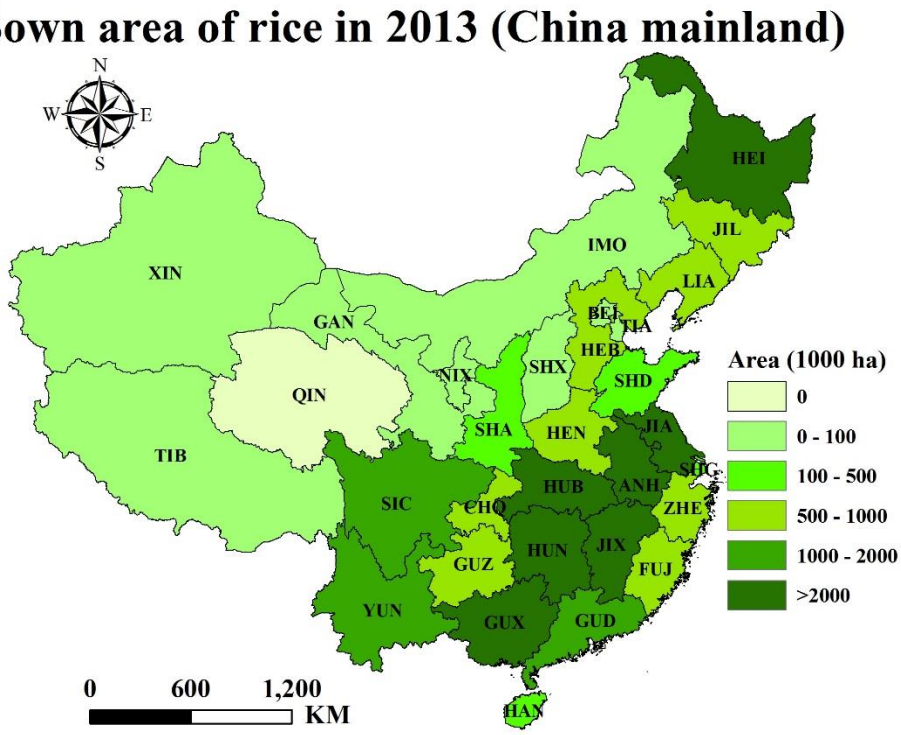
# Rice production in China



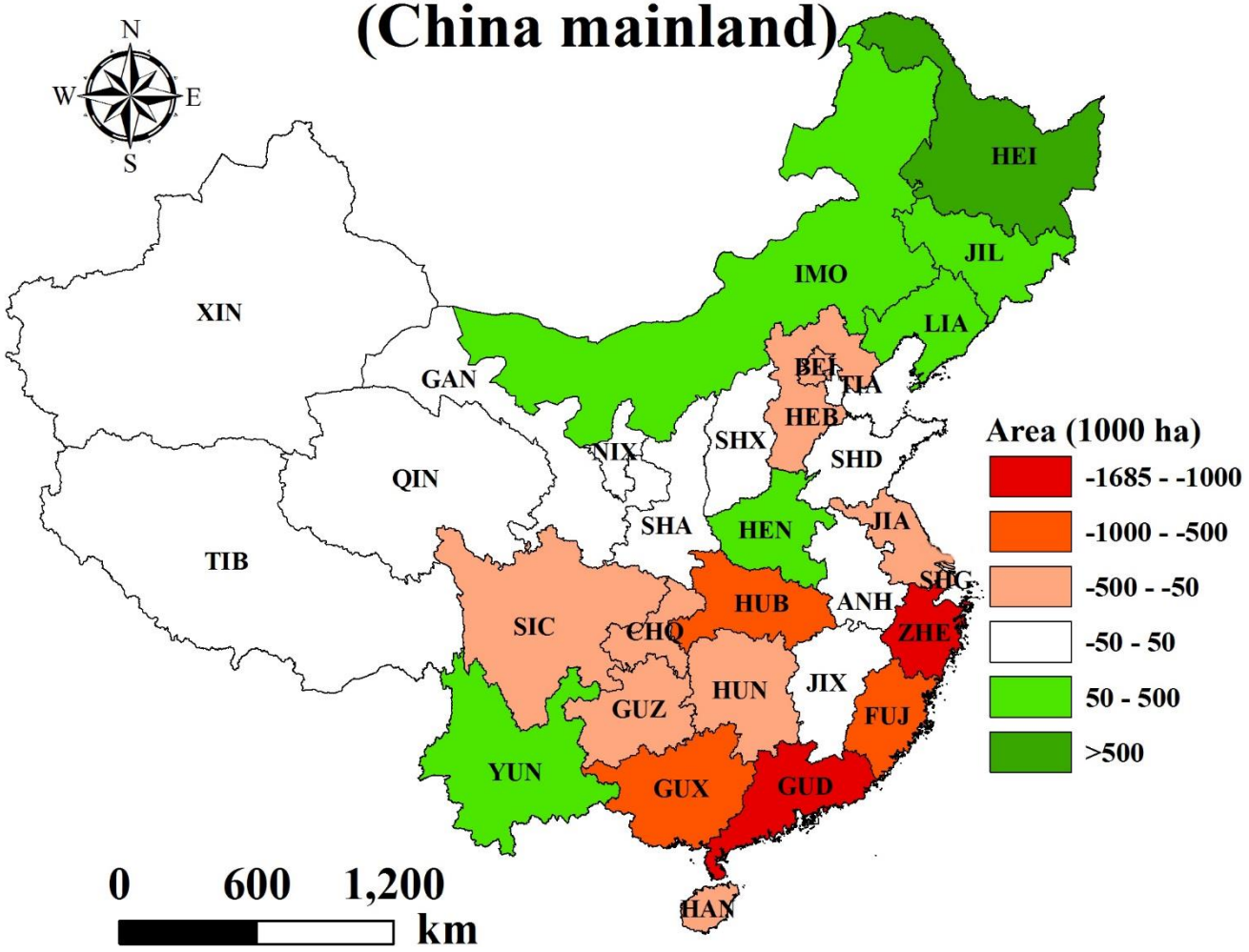



# Spatial distribution rice production



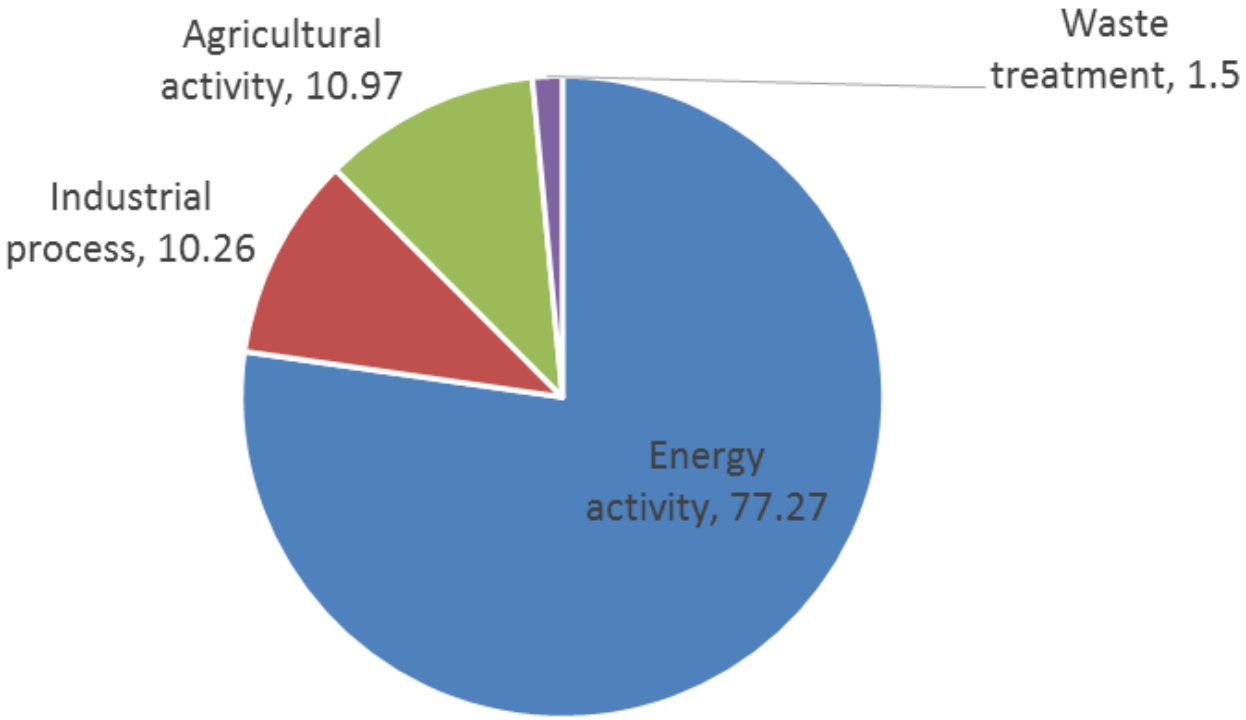



# Changes of sown area of rice from 1980 to 2013 (China mainland)



# Share of agriculture in total GHG

## Second national communication: 2005




Rice paddy: ~2.5% of total emission

# On-going national projects

## MOA project

- **Development of Agricultural GHG monitoring and controlling technology**
  - Monitoring technology, standard and quality control
  - Options for livestock industry
  - Options for grazing pasture
  - Options for uplands in northeast China
  - Options for uplands in northwest China
  - Options for uplands in north China Plain
  - **Options for single-rice paddy**
  - **Options for double-rice paddy**

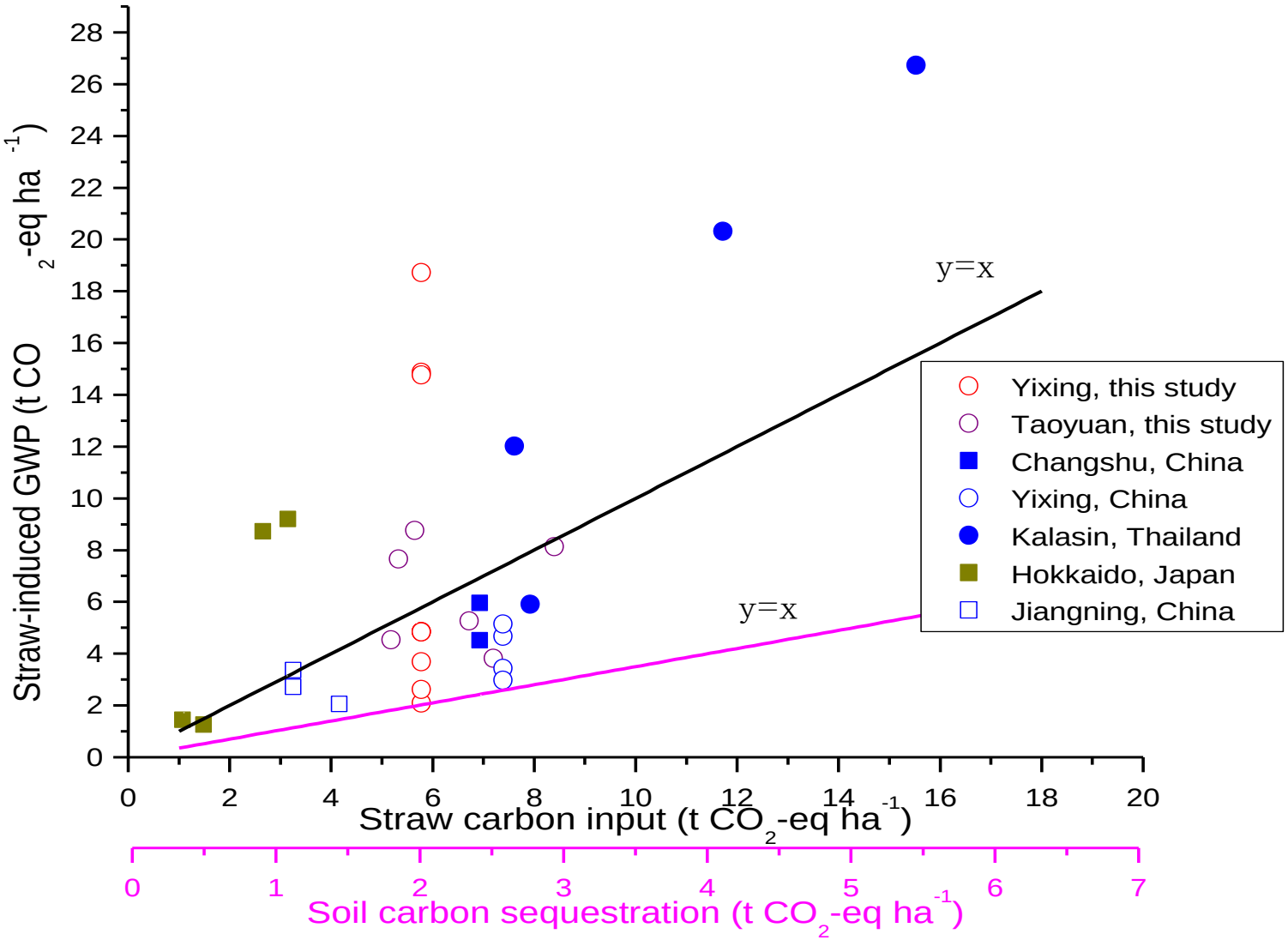
## MOST project

- **Development, integration and demonstration of technologies of carbon sequestration and GHG mitigation for croplands**
  - Core mitigation technology and scaling method
  - **Mitigation options for rice paddy**
  - Mitigation options for upland

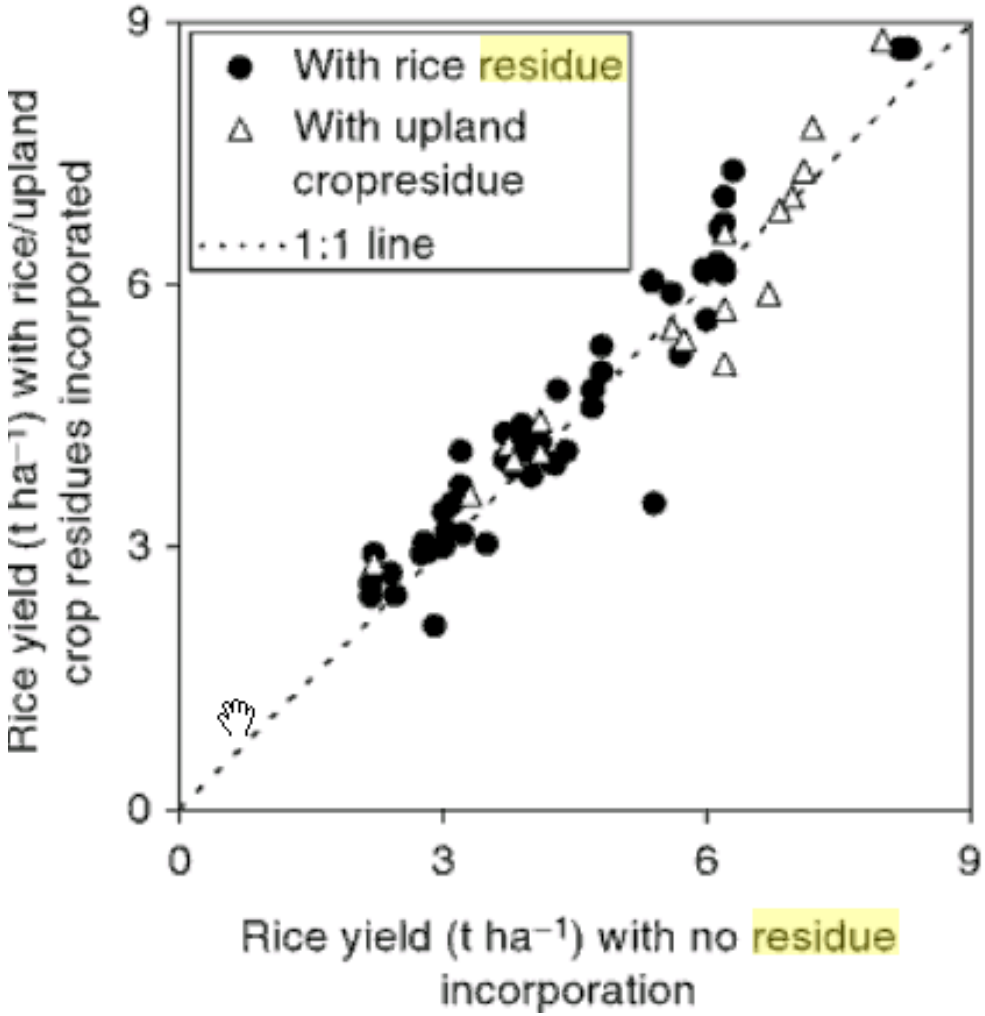
# Mitigation options

1. **Residue management**
2. **Water-saving cultivation**
3. **Water-saving rice variety**
4. **Rice-duck cultivation**
5. **Multiple technology integration**

# Effect of straw application



# Effect of crop residue on rice yield

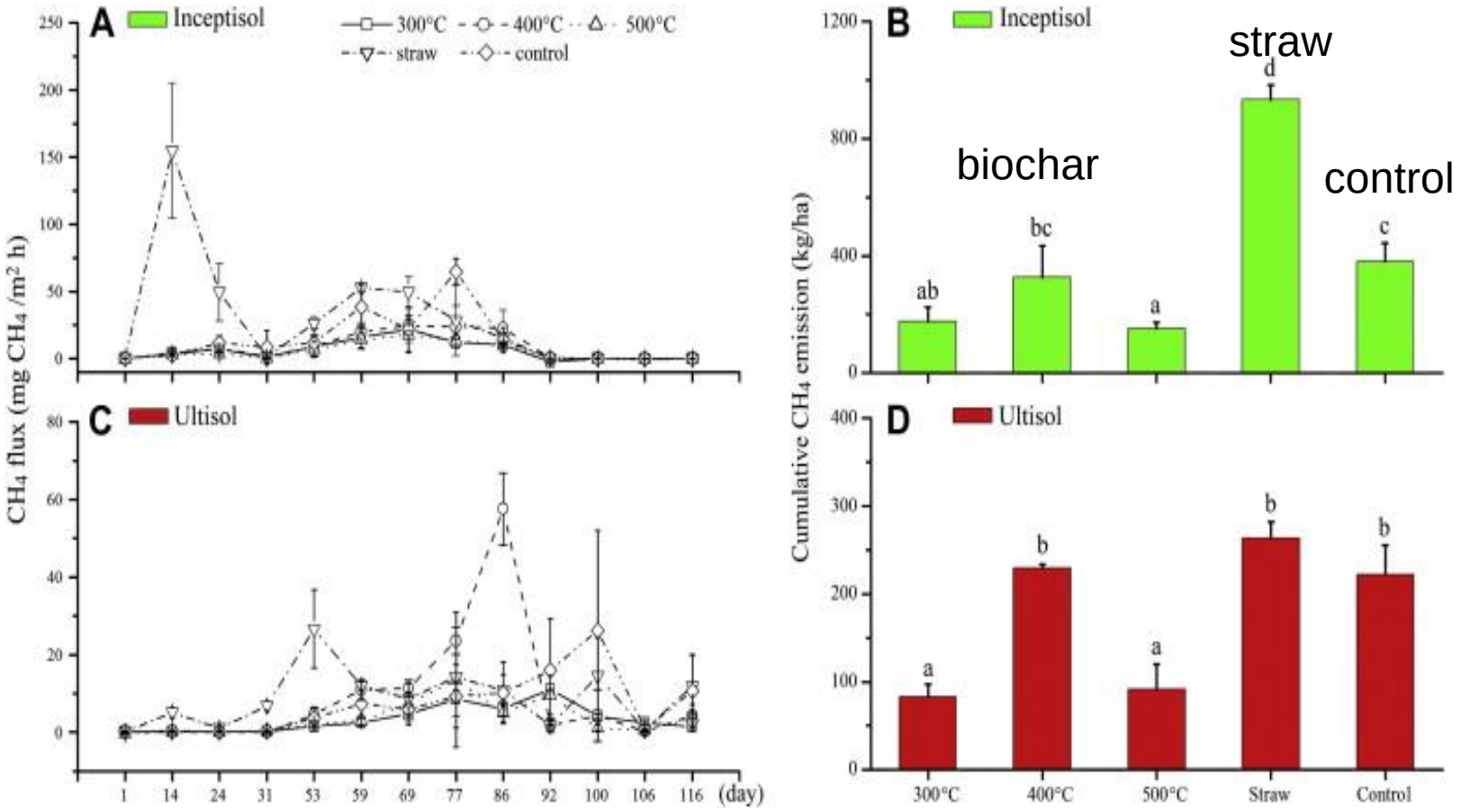



**Singh et al., 2008, Advances in Agronomy**

# 1. Residue management

## Biochar application

# Effect of biochar on $CH_4$ emission




Feng YZ et al., 2012, SBB.

# 2. Plastic film mulching cultivation


# Significant drought resistance effect

# Reasons for yield benefit

**Contradiction between water and temperature**

关水→低温→坐蔸

**Flooding→Low temp→ Slow growth**

放水→干旱→不长

**Drained→ Drought→ Poor growth**

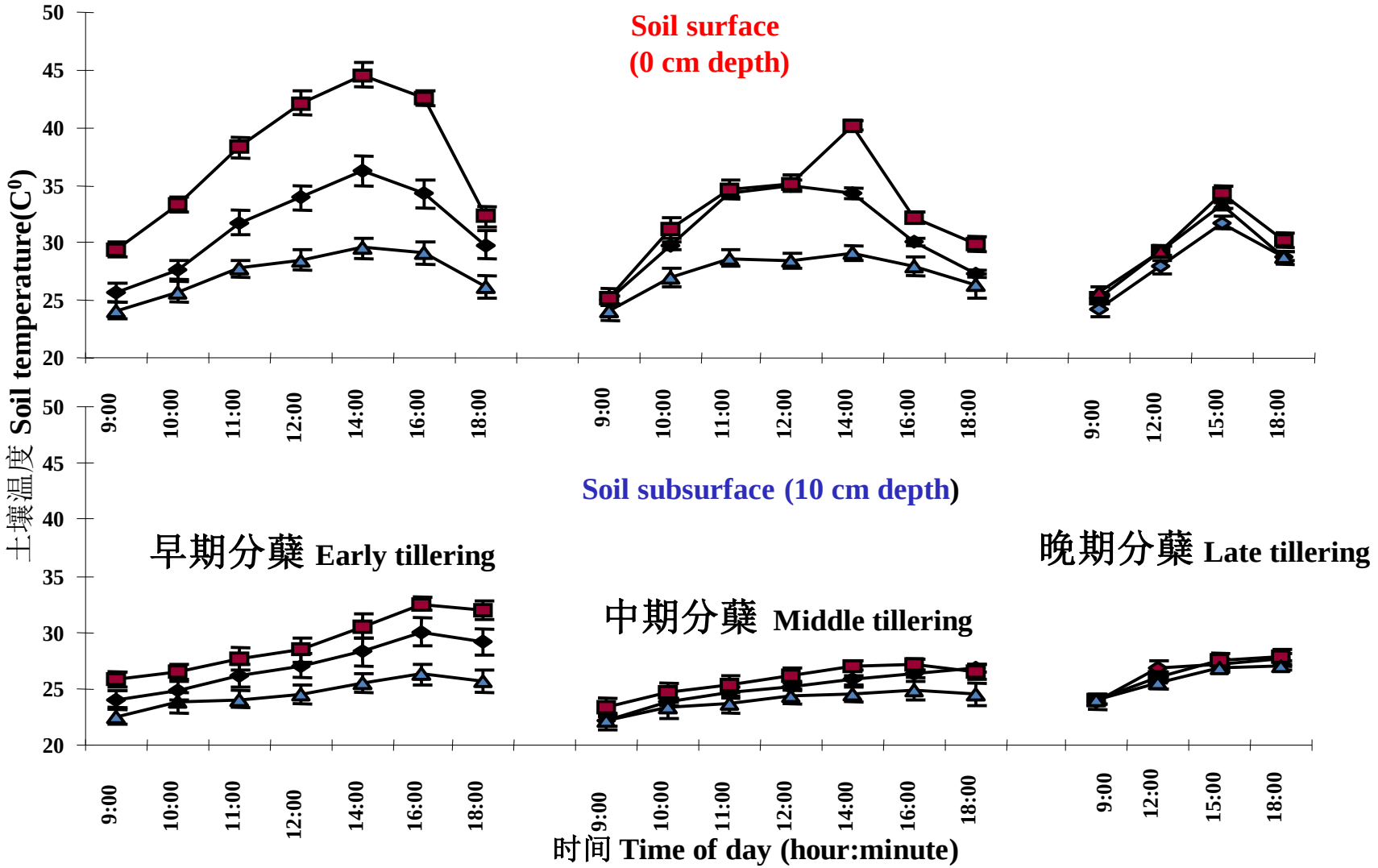
排灌方便，节水保水

**Easy drainage and irrigation; saves water**

厢沟保水，厢面增温

**Water in ditch – No drought, higher temperature in raised bed**

# Effect of plastic film mulch on soil temperature

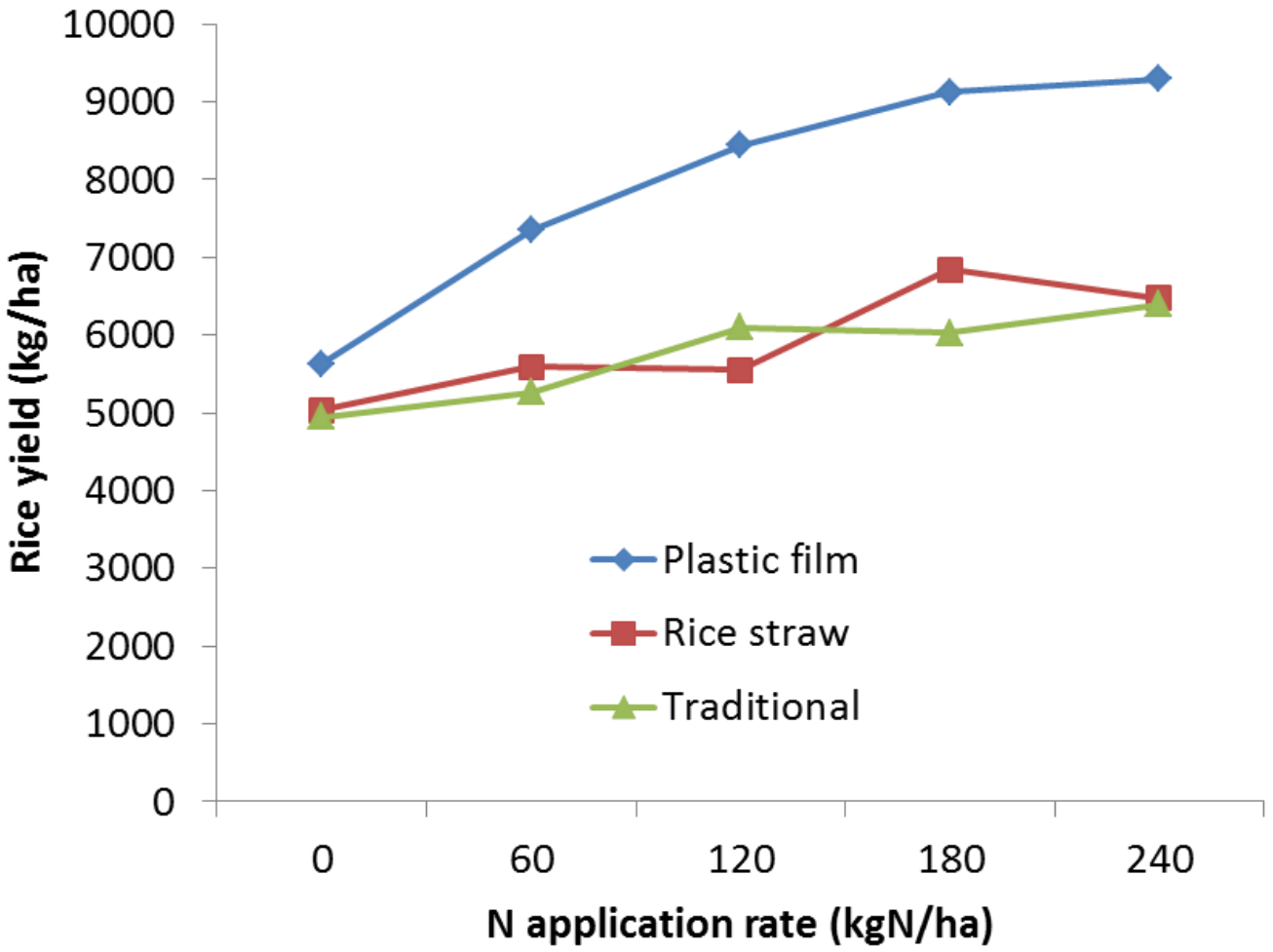



Plastic mulch

Traditional flooding

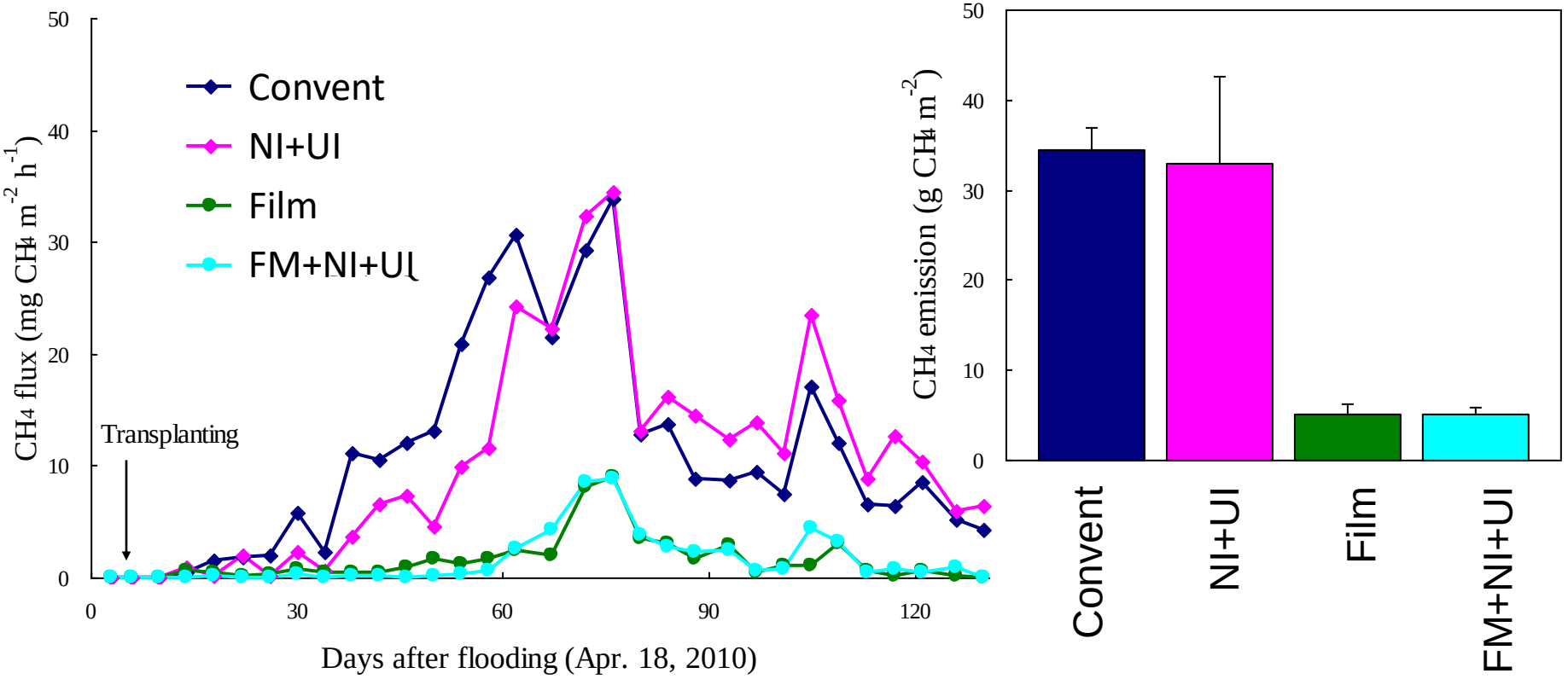
Straw mulch

# Rice yield with different mulching materials and N rate

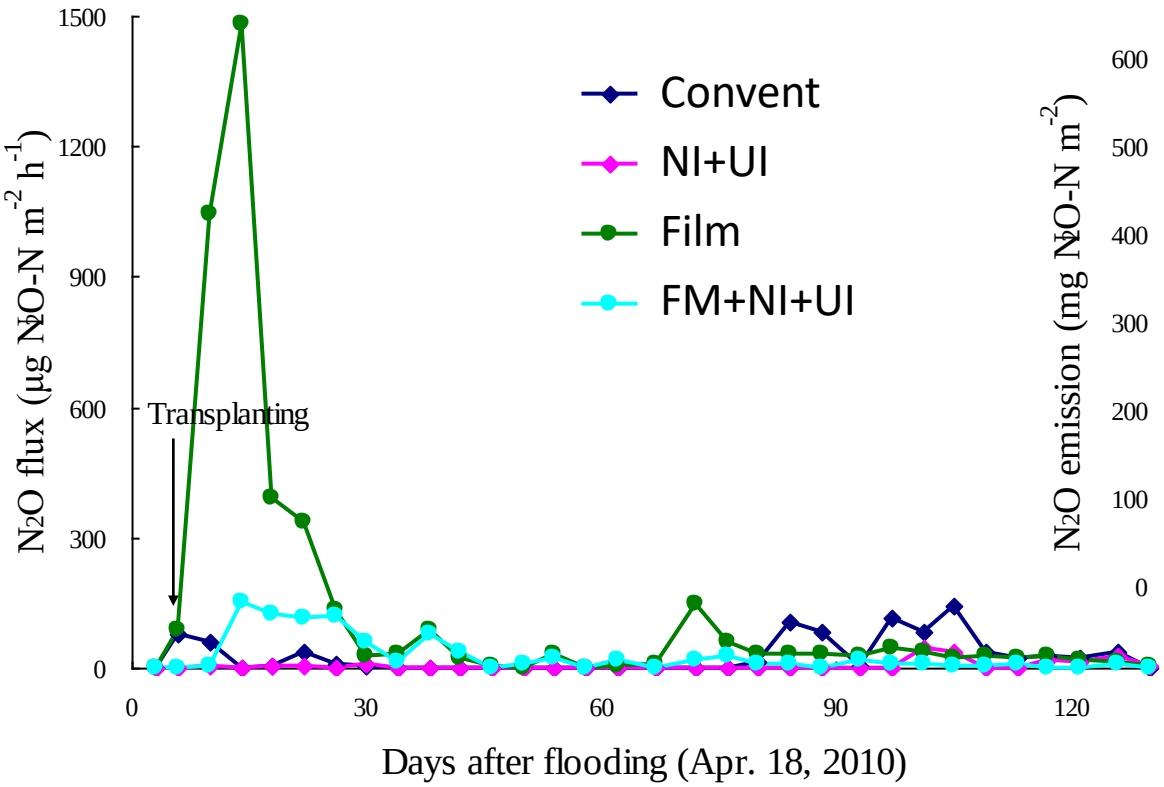


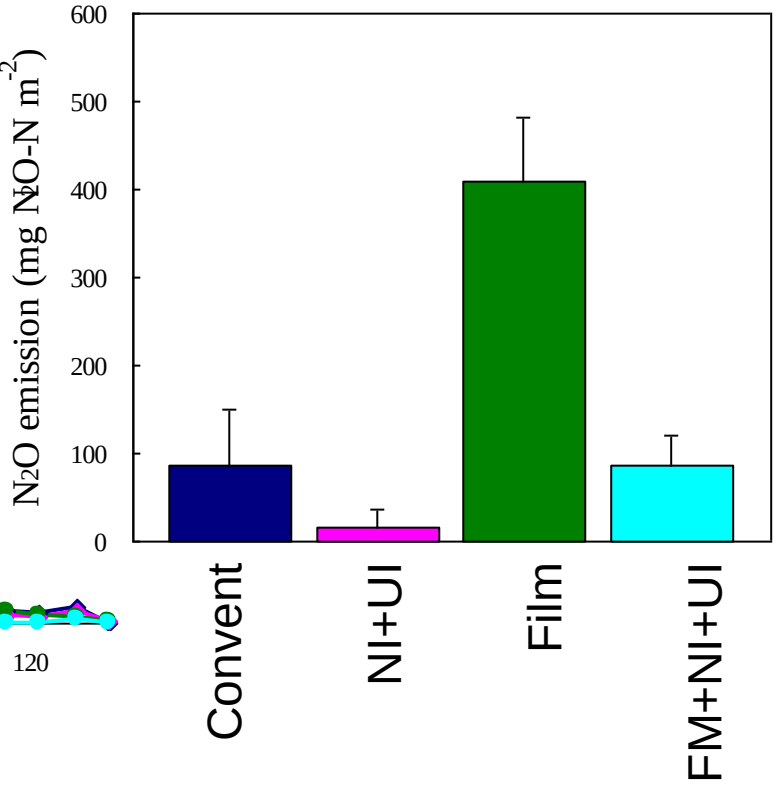
# 四川资阳：栽培方式与脲酶/硝化抑制剂施用。

# $CH_4$ emissions



# $N_2O$ emissions

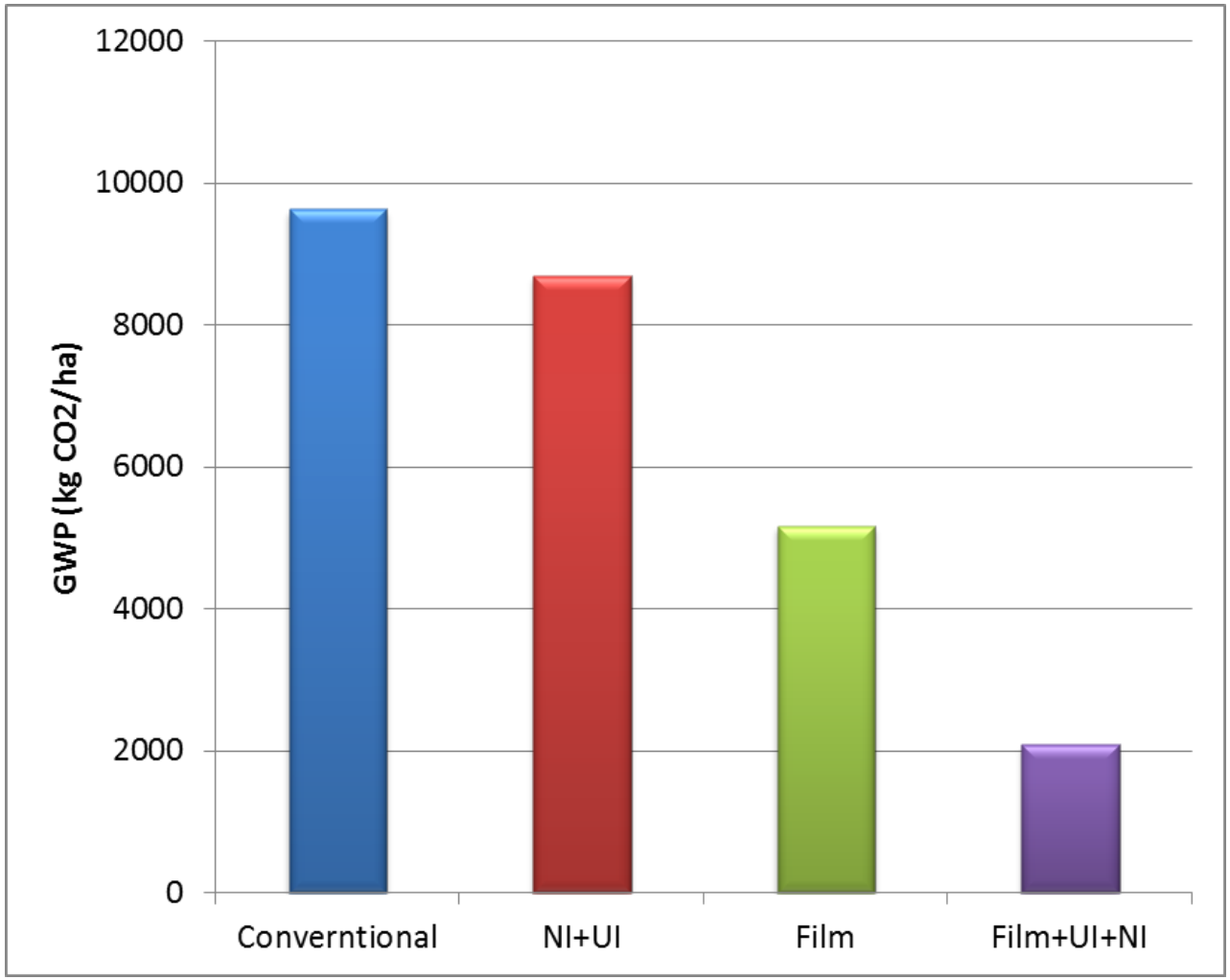



Compared to conventional, FM enhanced $N_2O$ emission by 3.77-fold.

Application of DCD/HQ reduced $N_2O$ emission by 79-81%.

# Integrated GWP



**More durable plastic film is easier to remove and prevent the plastic pollution effectively!**

# Incentives

## Economic analysis, yuan/ha

| Items | Conventional | Film mulching |
|---|---|---|
| Fertilizer input | 1620 | 1188 |
| Pesticide input | 525 | 300 |
| Film cost | 0 | 750 |
| Labor cost | 6000 | 3300 |
| Yield benefit | 6750 | 9000 |
| Net economic benefit | 630 | 6582 |

# Climate-smart, environmentally friendly

- 4 Savings: irrigation, fertilizer, pesticide, labor
- 2 Early: transplant, harvest
- 2 Increase: yield, profit
- 1 Decrease: GHG

## Economic analysis, yuan/ha

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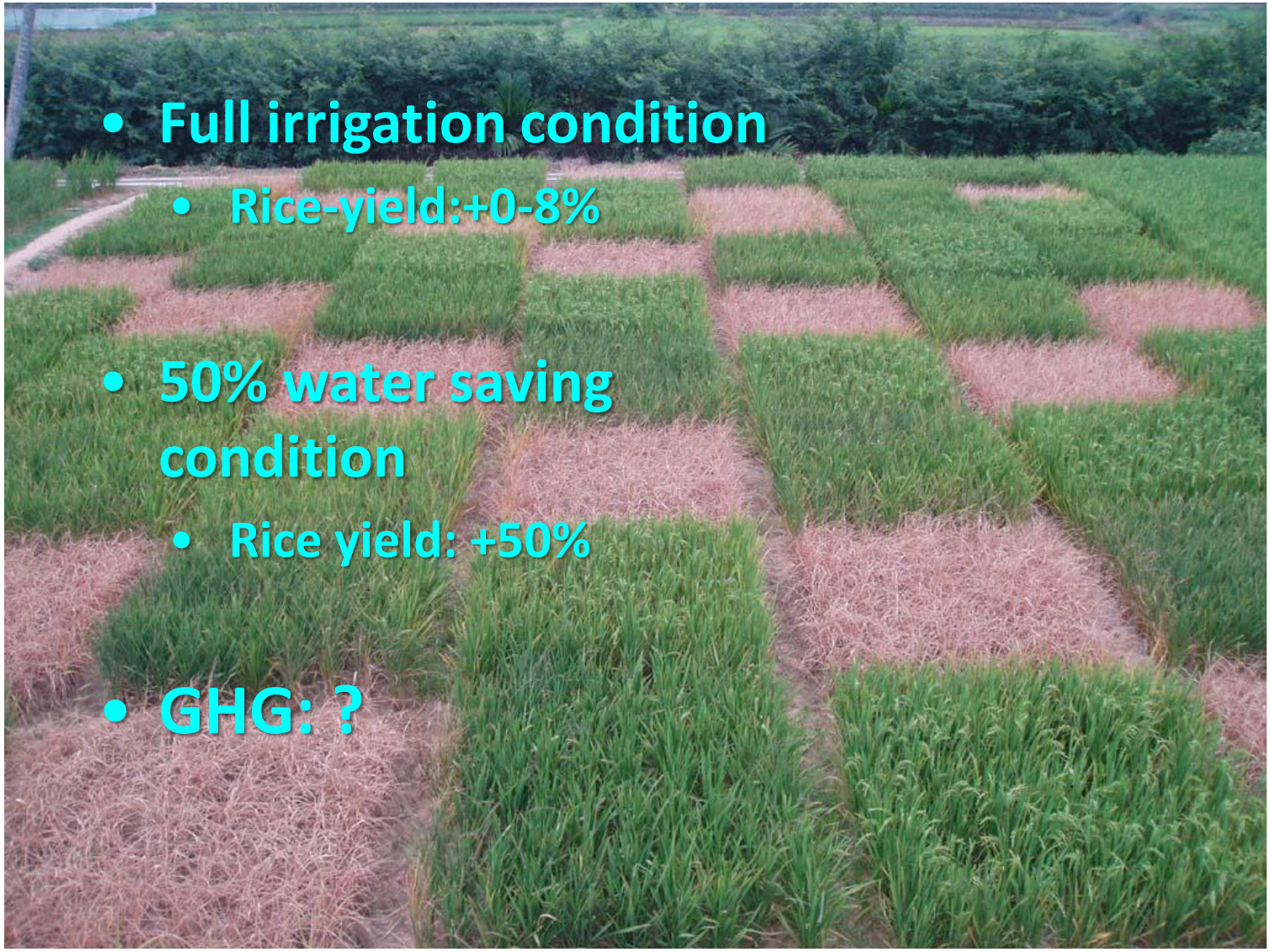
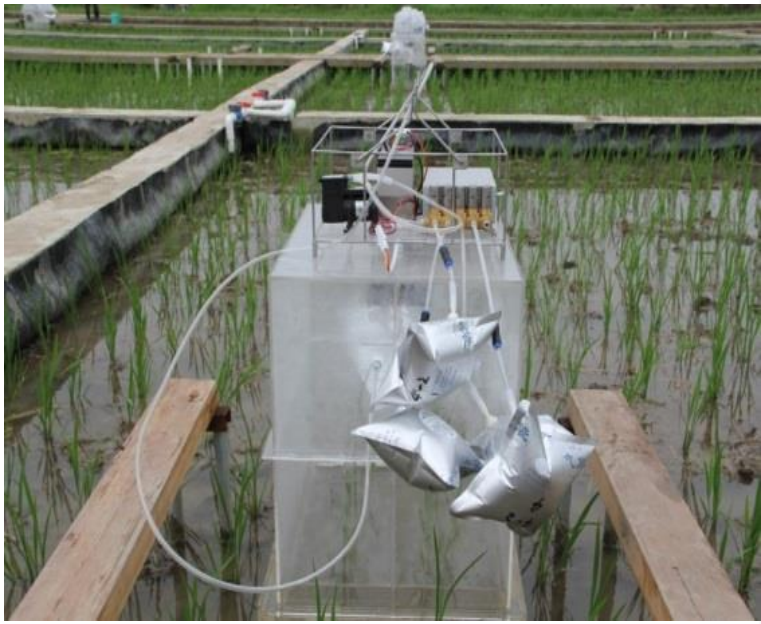
# 3. Drought-resistant rice variety



# Drought-resistant rice variety



- Rice varieties:
  - Drought-resistant (D/r) variety
  - Traditional variety
- Irrigation amount :
  - Normal irrigation (100% irrigation, IR100%)
  - 70% of normal irrigation (70% irrigation, IR70%)
  - 30% of normal irrigation (30% irrigation, IR30%)

# Yield depends on rainfall

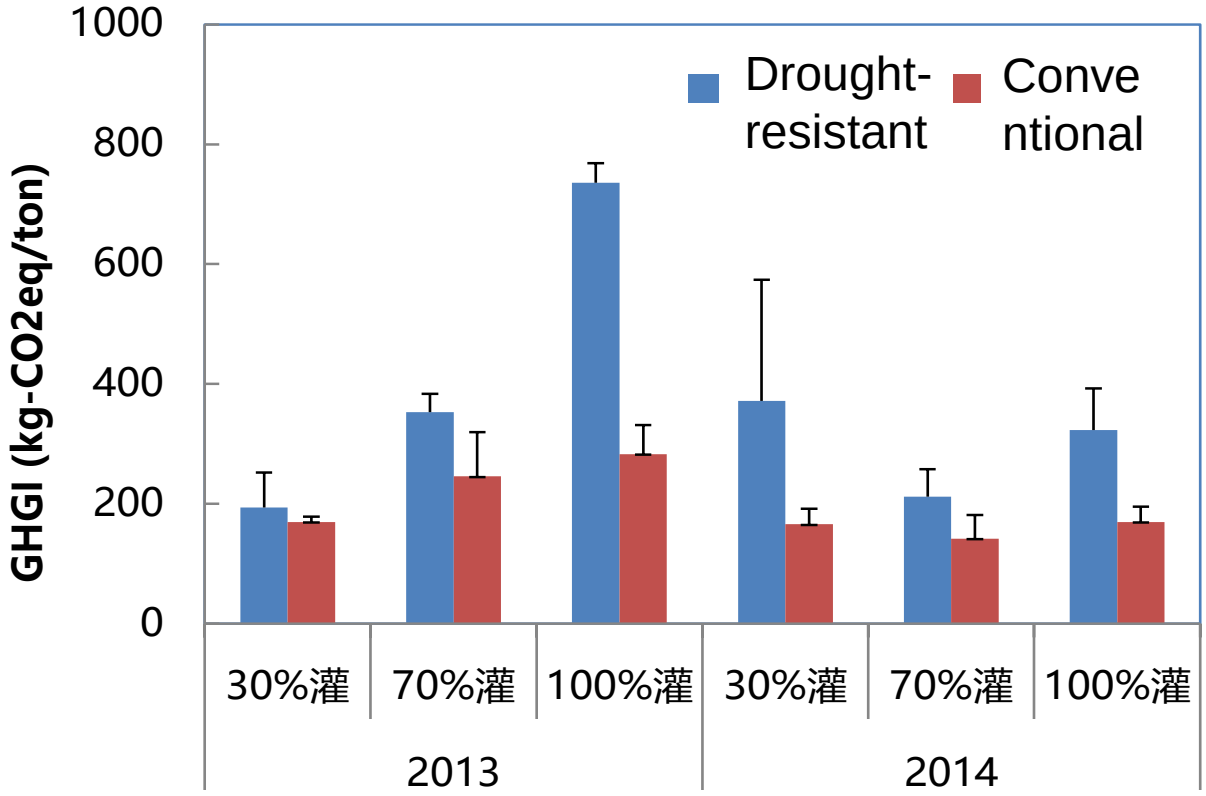
Rainfall and irrigation

| Year | Treatment | Rainfall in jun-sep（mm） | Irrigation（mm） | Actual water use（mm） |
|---|---|---|---|---|
| 2013 | 30%灌 | 272 | 184 | 455 |
| | 70%灌 | 272 | 428 | 700 |
| | 100%灌 | 272 | 612 | 884 |
| 2014 | 30%灌 | 763 | 35 | 798 |
| | 70%灌 | 763 | 82 | 844 |
| | 100%灌 | 763 | 117 | 879 |

Rice yield

| Year | Treatment | Yield ( t/ha ) | |
|---|---|---|---|
| | | Drought-resistant | Conventional |
| 2013 | 30%灌 | 8.2±0.4 | 7.9±0.0 |
| | 70%灌 | 8.6±0.3 | 8.3±0.2 |
| | 100%灌 | 8.7±0.1 | 8.8±0.1 |
| 2014 | 30%灌 | 9.3±0.1 | 9.8±0.1 |
| | 70%灌 | 9.3±0.1 | 10.0±0.2 |
| | 100%灌 | 9.4±0.1 | 10.1±0.2 |

# Yield-scaled emission

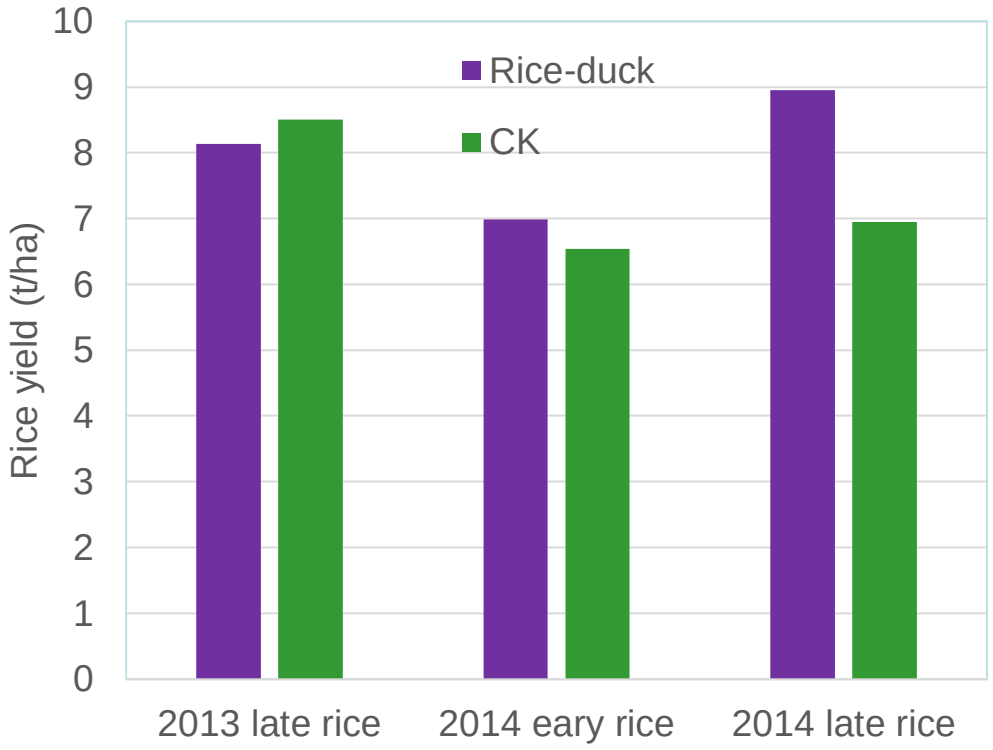


# 4. Rice-duck system

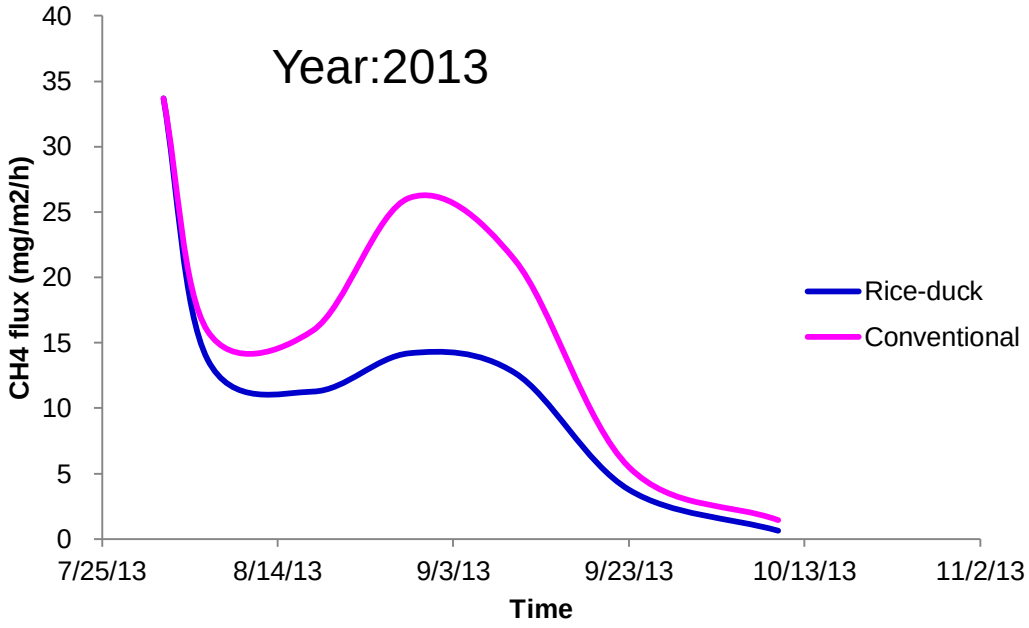
A rising rice cultivation system in south China

Incentives:

- Improving economic income
- Saving pesticide …

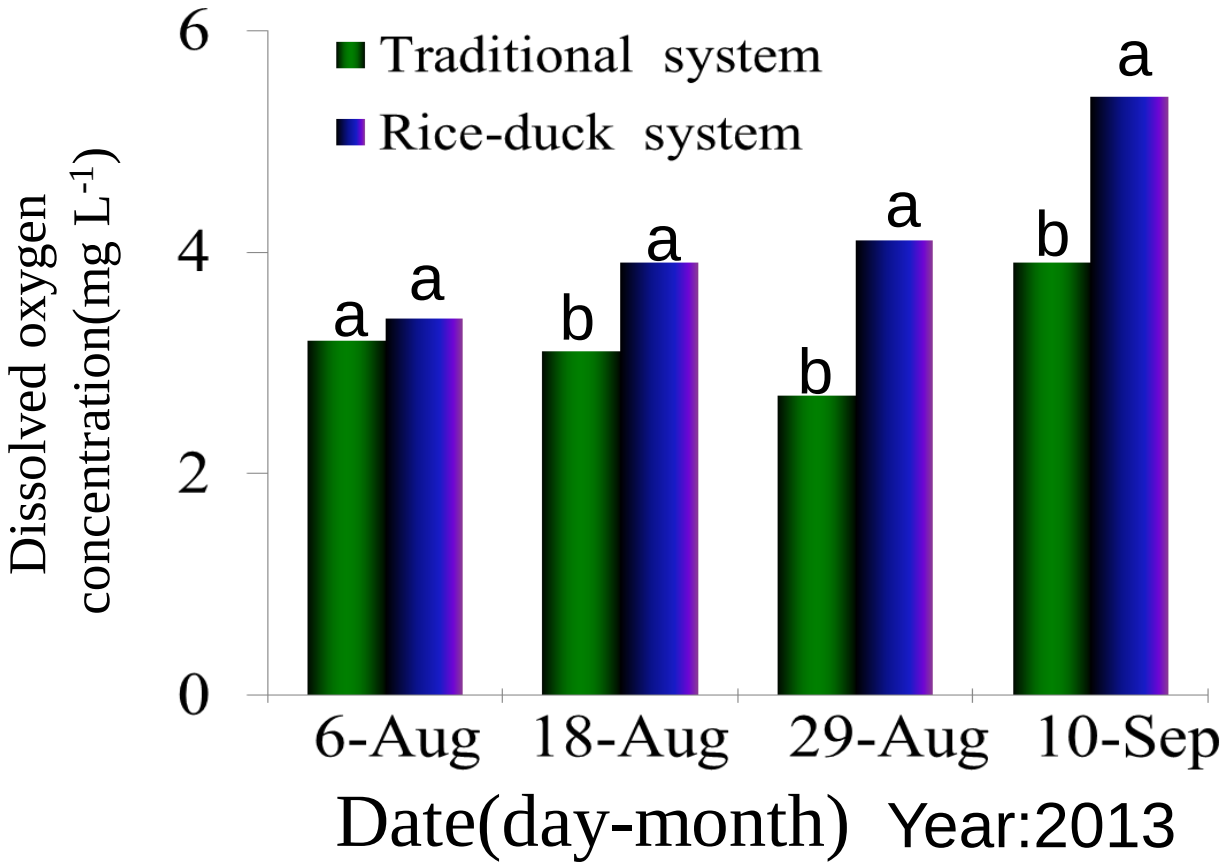

10
9
8
7
6
5
4
3
2
1
0
Rice yield (t/ha)
Rice-duck
CK
2013 late rice
2014 eary rice
2014 late rice

# CH4 emission from rice-duck system

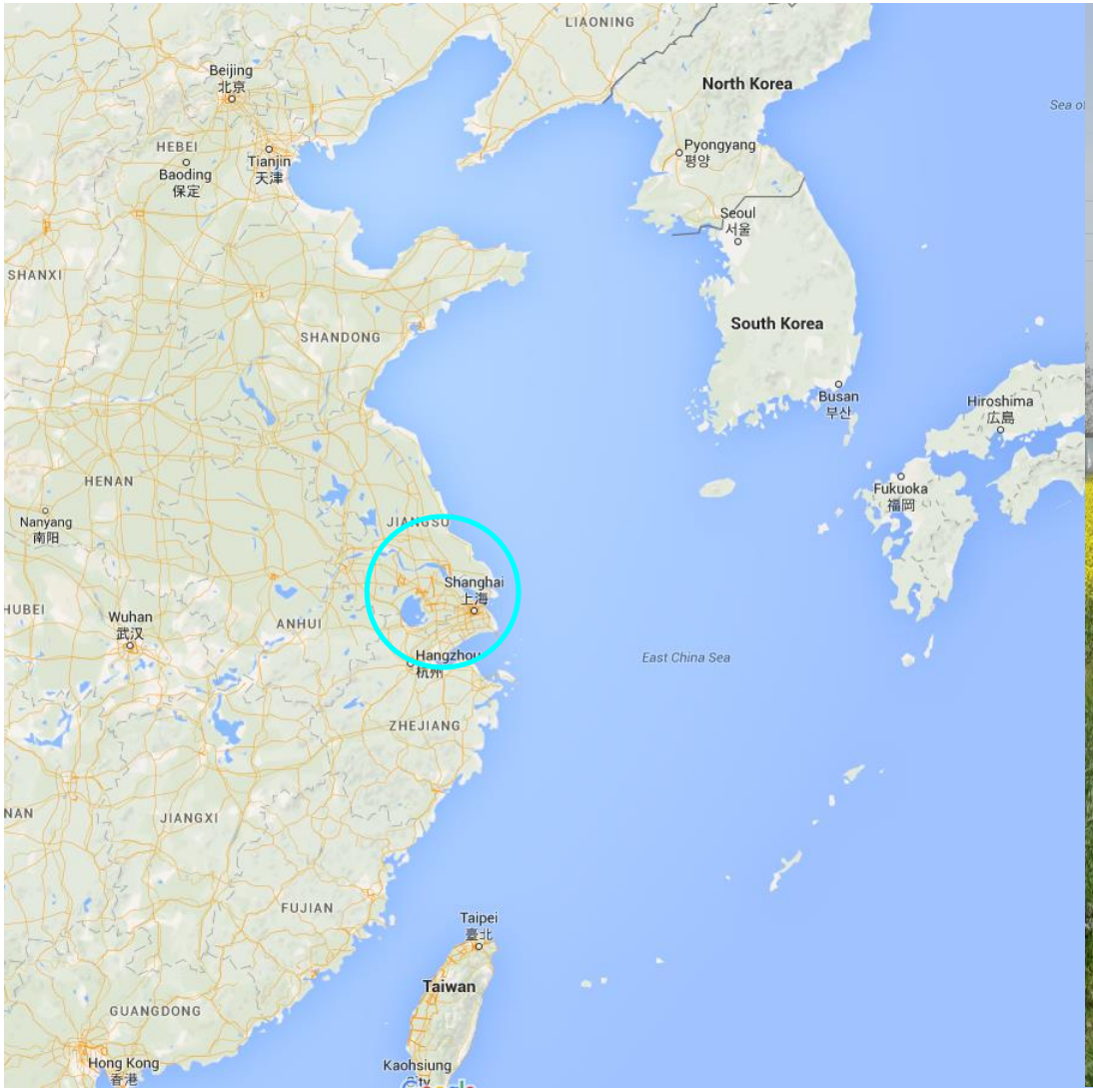



| Year | Season | Treatment | Total CH4 (g/m2) | Yield scaled emission(g/kg) | Emission reduction (%) |
|---|---|---|---|---|---|
| 2013 | Late rice | Rice-duck | 22.7 | 27.9 | 17.2 |
| | | CK | 30.2 | 33.7 | |
| 2014 | Early rice | Rice-duck | 27.37 | 35.93 | 15.9 |
| | | CK | 32.5 | 42.742 | |
| | Late rice | Rice-duck | 26.36 | 29.46 | 35.8 |
| | | CK | 31.91 | 45.91 | |

# Why $CH_4$ emission is reduced?




# 5. Technology integration

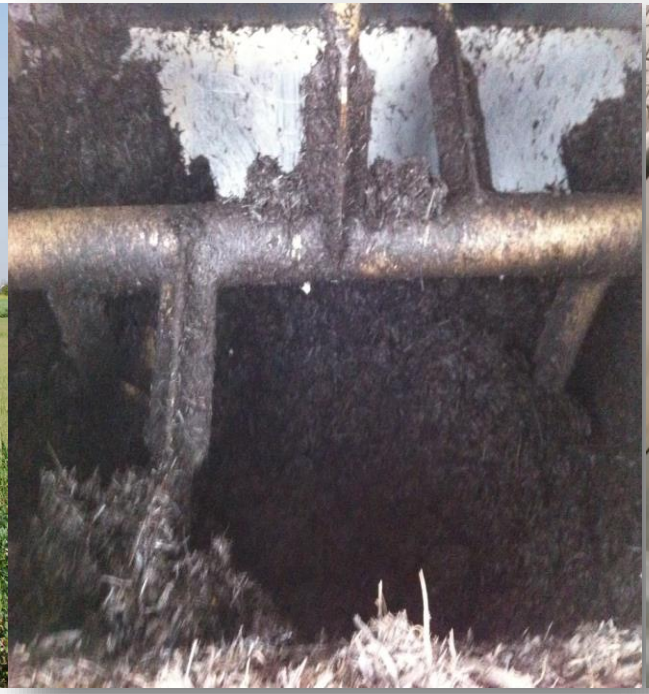


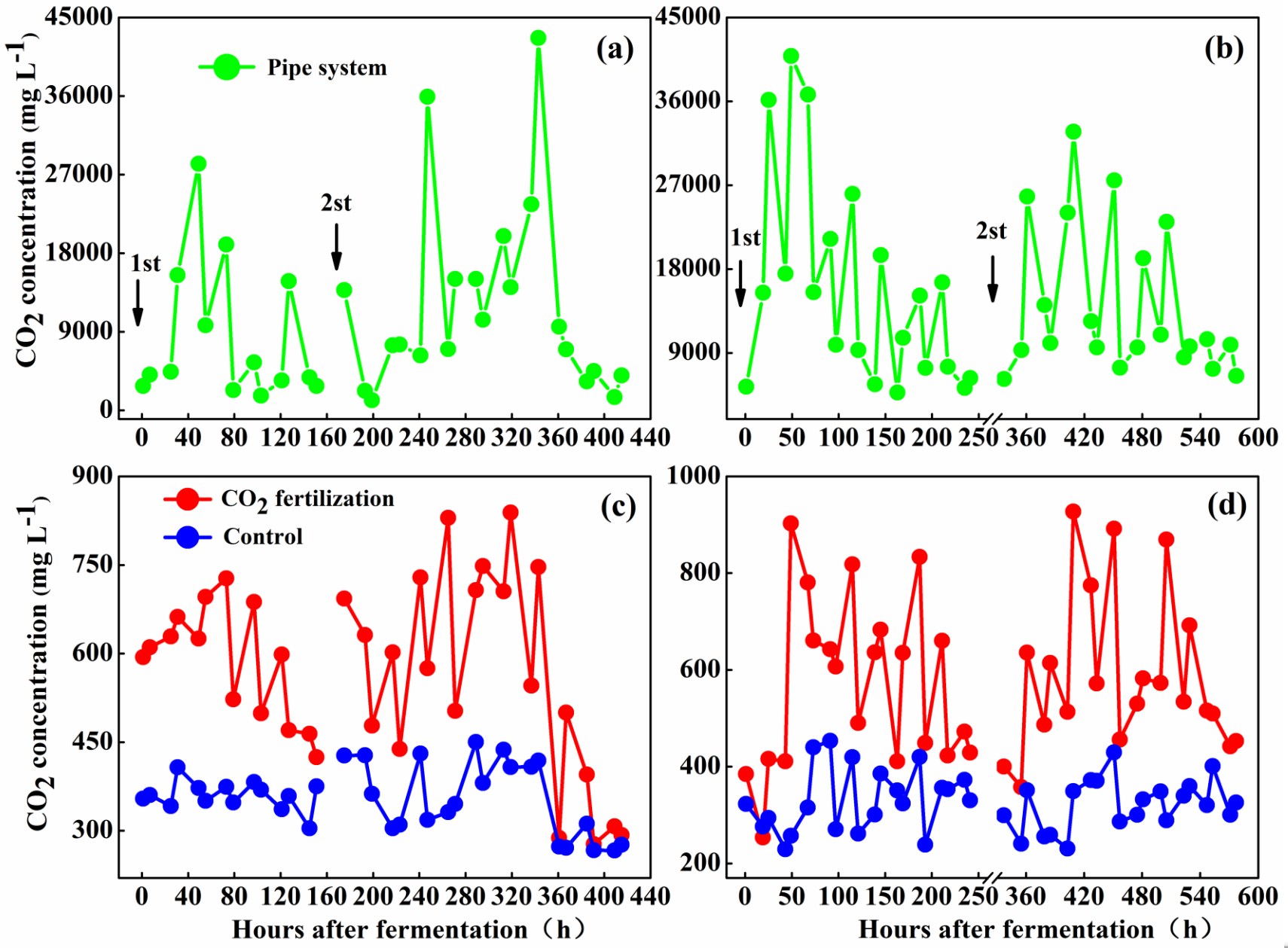

# Integration of technologies

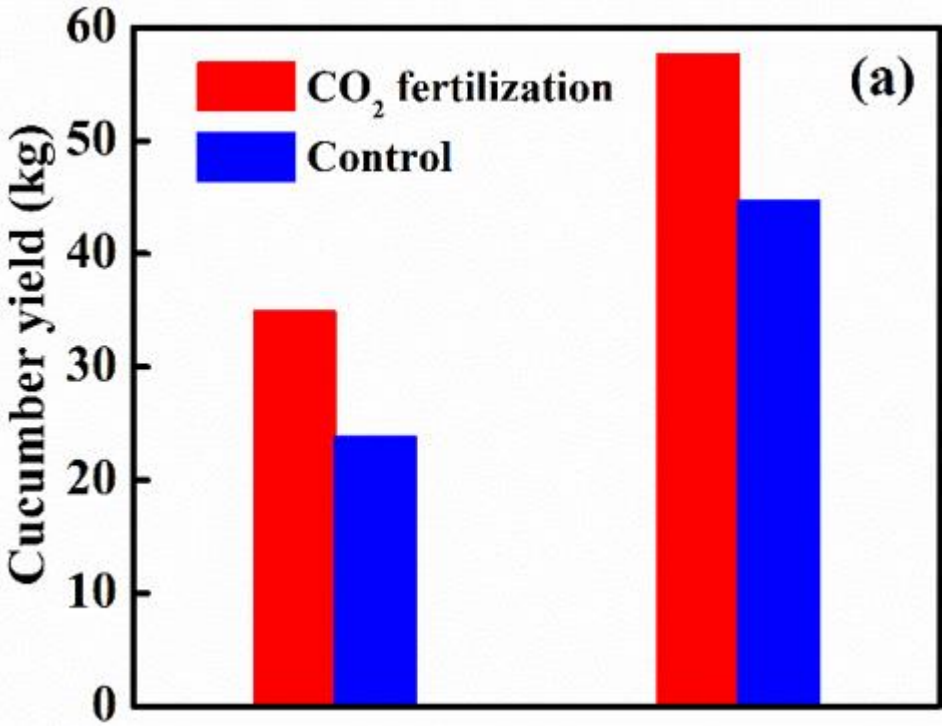
Rotation change

Aerobic residue fermentation

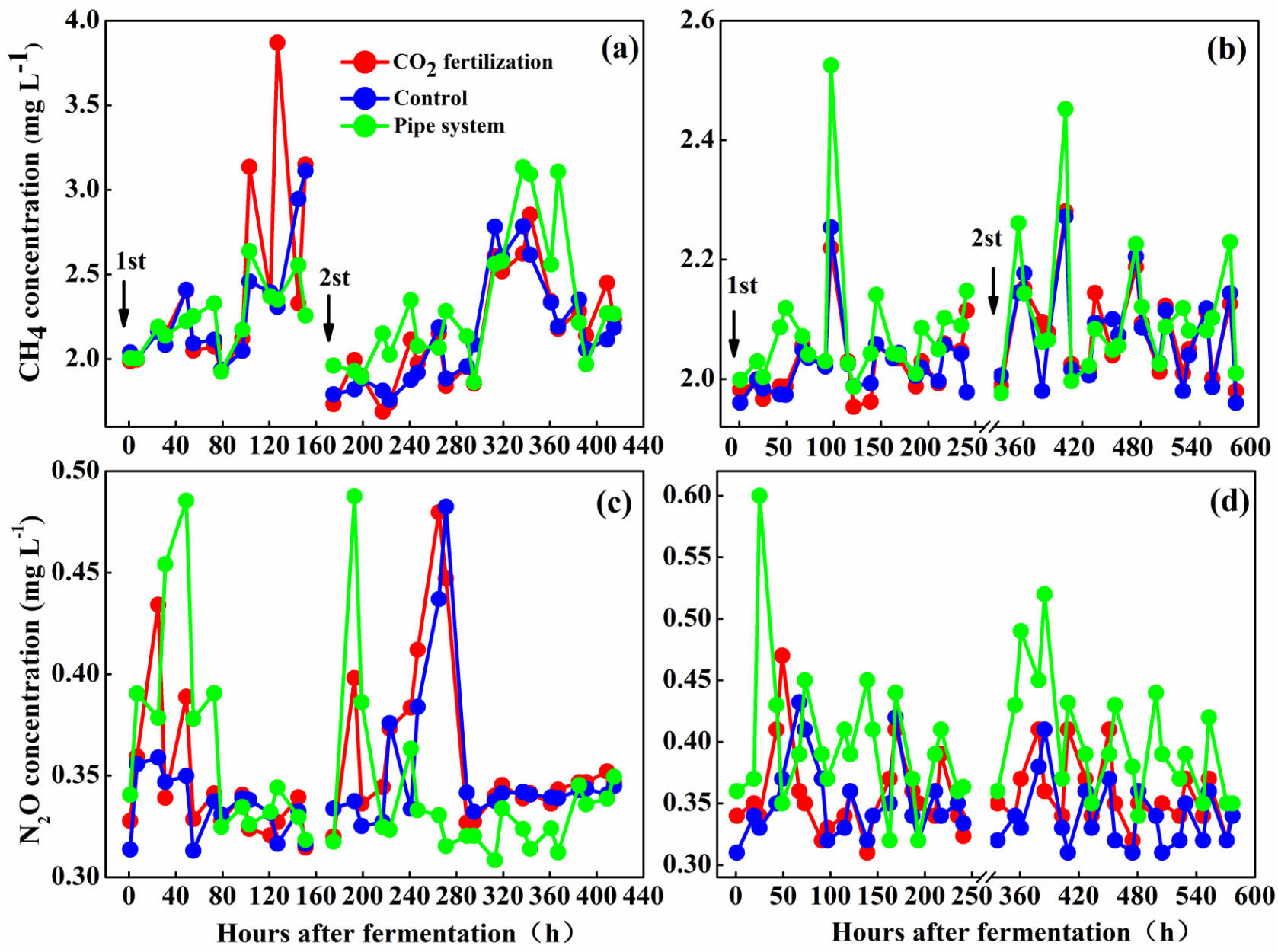
$CO_2$ utilization

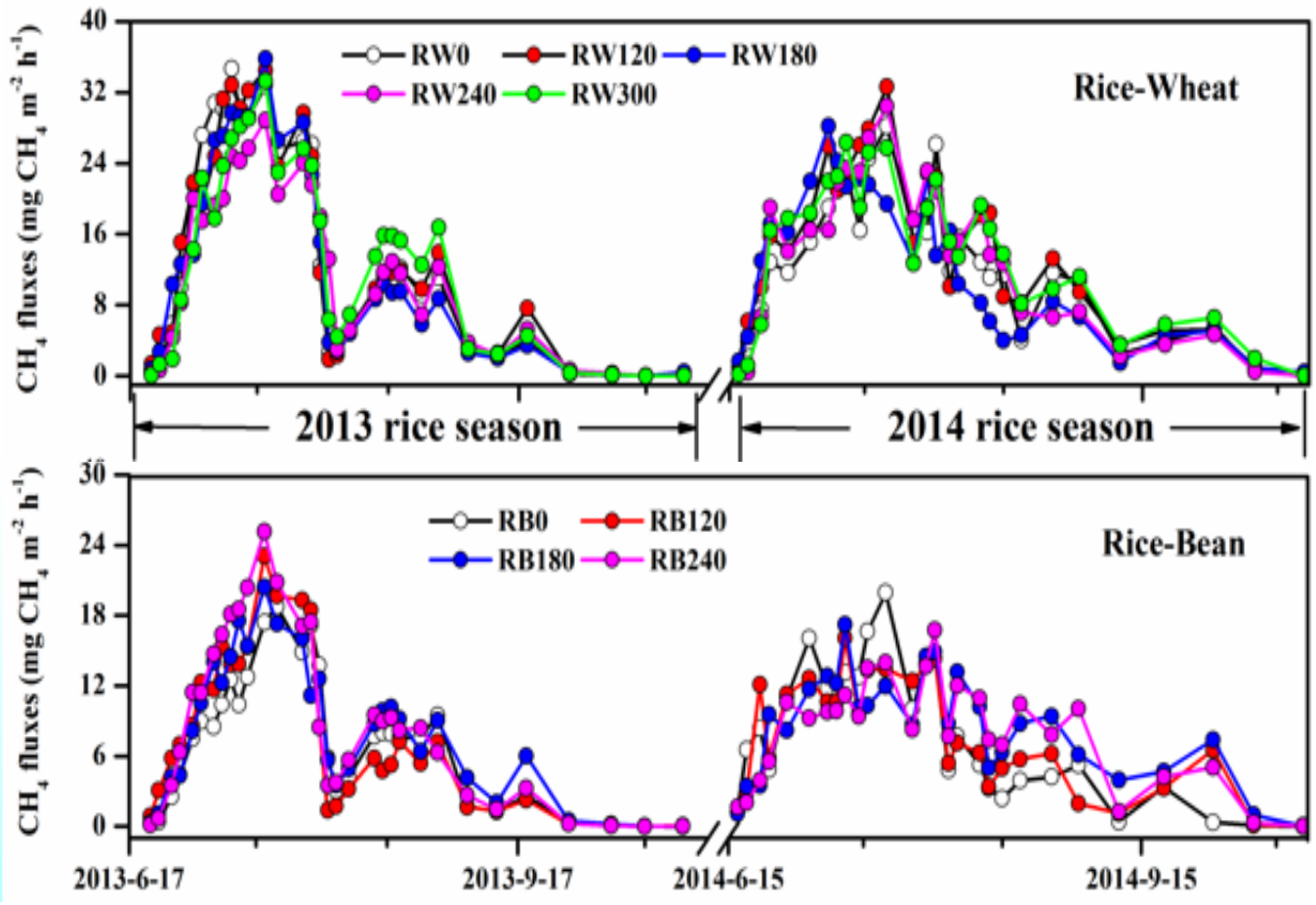



(a)
(b)
(c)
(d)
Pipe system
1st
2st
CO2 fertilization
Control
CO2 concentration (mg L-1)
Hours after fermentation（h）
45000
36000
27000
18000
9000
0
900
750
600
450
300
1000
800
400
200
0 40 80 120 160 200 240 280 320 360 400 440
0 50 100 150 200 250 360 420 480 540 600

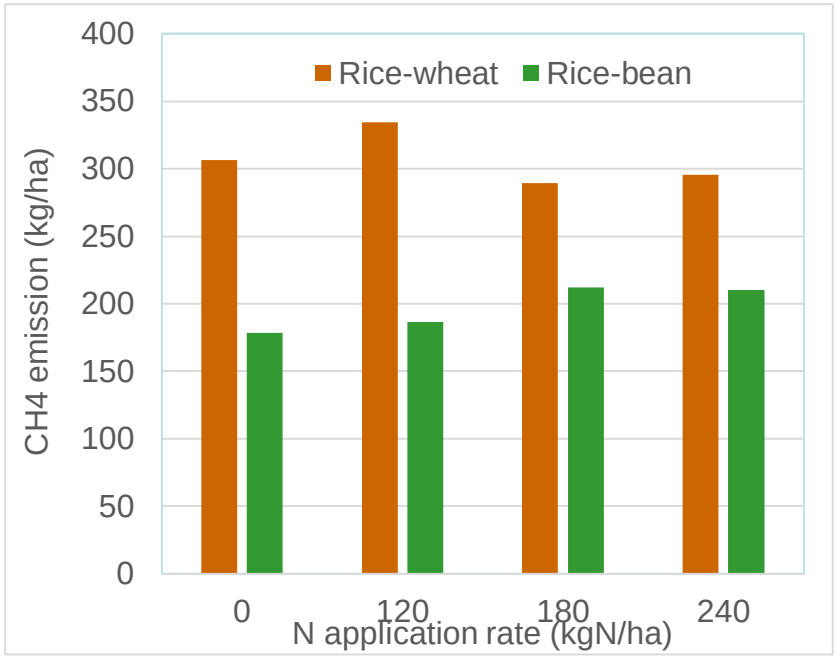

60
50
40
30
20
10
0
Cucumber yield (kg)
CO2 fertilization
Control
(a)


CO2
CK

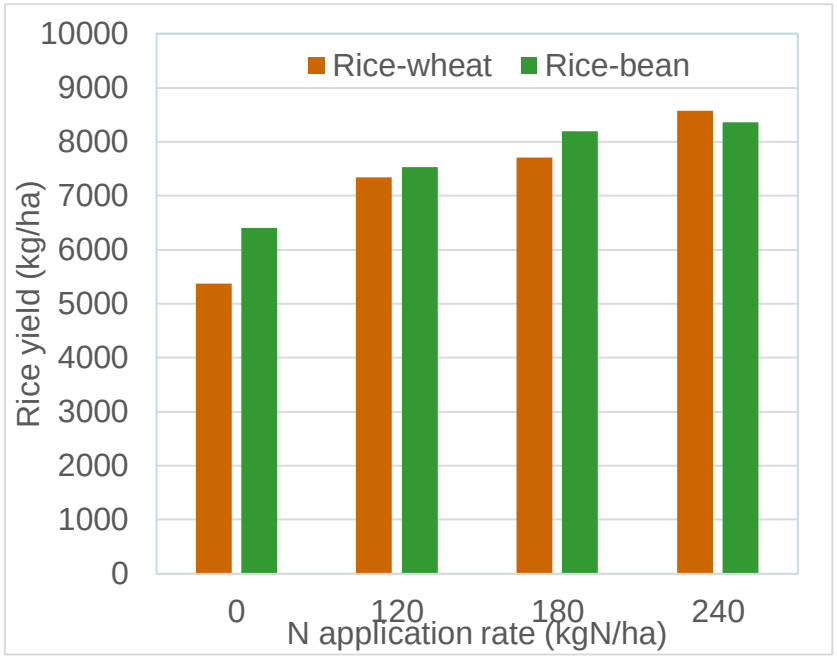

(a)
(b)
(c)
(d)
CO2 fertilization
Control
Pipe system
1st
2st
CH4 concentration (mg L-1)
N2O concentration (mg L-1)
Hours after fermentation（h）
Hours after fermentation（h）

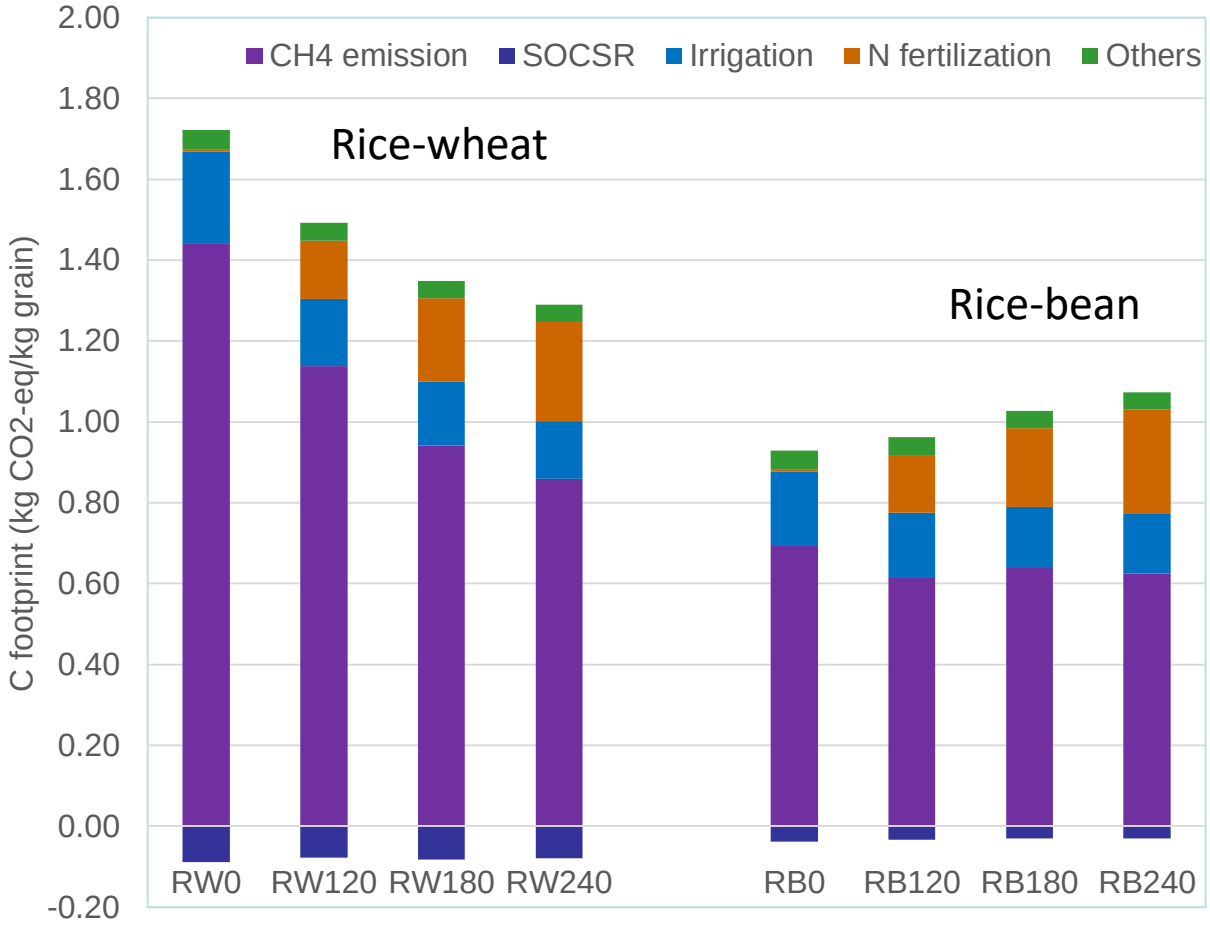

RW0
RW120
RW180
RW240
RW300
Rice-Wheat
CH4 fluxes (mg CH4 m-2 h-1)
2013 rice season
2014 rice season
RB0
RB120
RB180
RB240
Rice-Bean
2013-6-17
2013-9-17
2014-6-15
2014-9-15

## Seasonal CH4 emission




## Rice yield

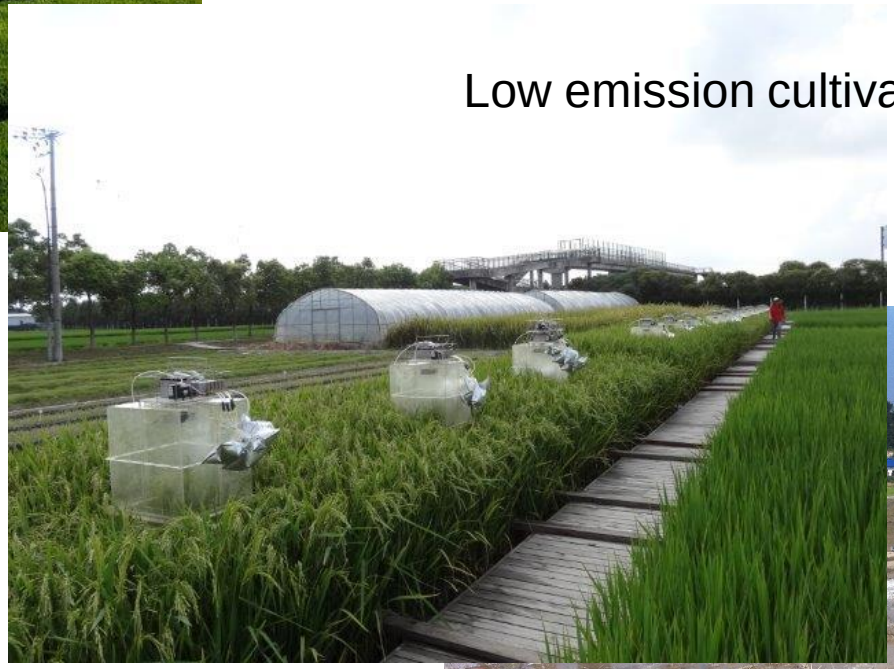



CH4 emission
SOCSR
Irrigation
N fertilization
Others
Rice-wheat
Rice-bean
C footprint (kg CO2-eq/kg grain)
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
RW0
RW120
RW180
RW240
RB0
RB120
RB180
RB240

# Other technologies

Ridged cultivation

Low emission cultivar



Inhibitors

# SUMMARY

- GHG emission from rice cultivation accounts for about 2.5% of nation total.
- Promising mitigation practice includes plastic film mulching, biochar application, crop rotation change
- Many of the mitigation options have environmental and economic synergies.

# Thank you

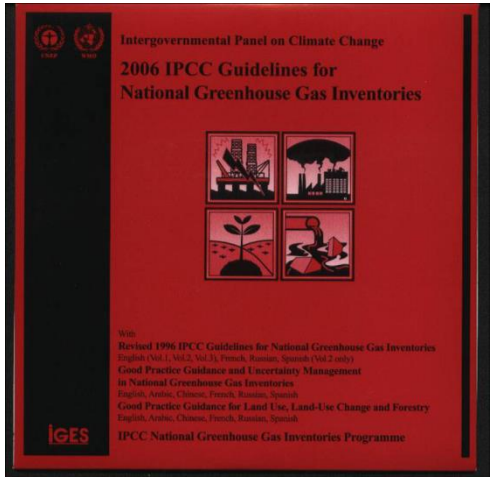
## and my collaborators:

Hua Xu (Institute of Soil Science, CAS)

Xiangfu Song (Shanghai Academy of Agricultural Sciences)

Zhiqiang Fu (Hunan Agricultural University)

# Factors affecting $CH_4$ emission




**Equation 5.1**

**$CH_4$ Emissions from Rice Cultivation**

$$\text{Emissions from Rice Cultivation (Gg/yr)} = \Sigma_{ijk} (EF_{ijk} \bullet t_{ijk} \bullet A_{ijk} \bullet 10^{-6})$$

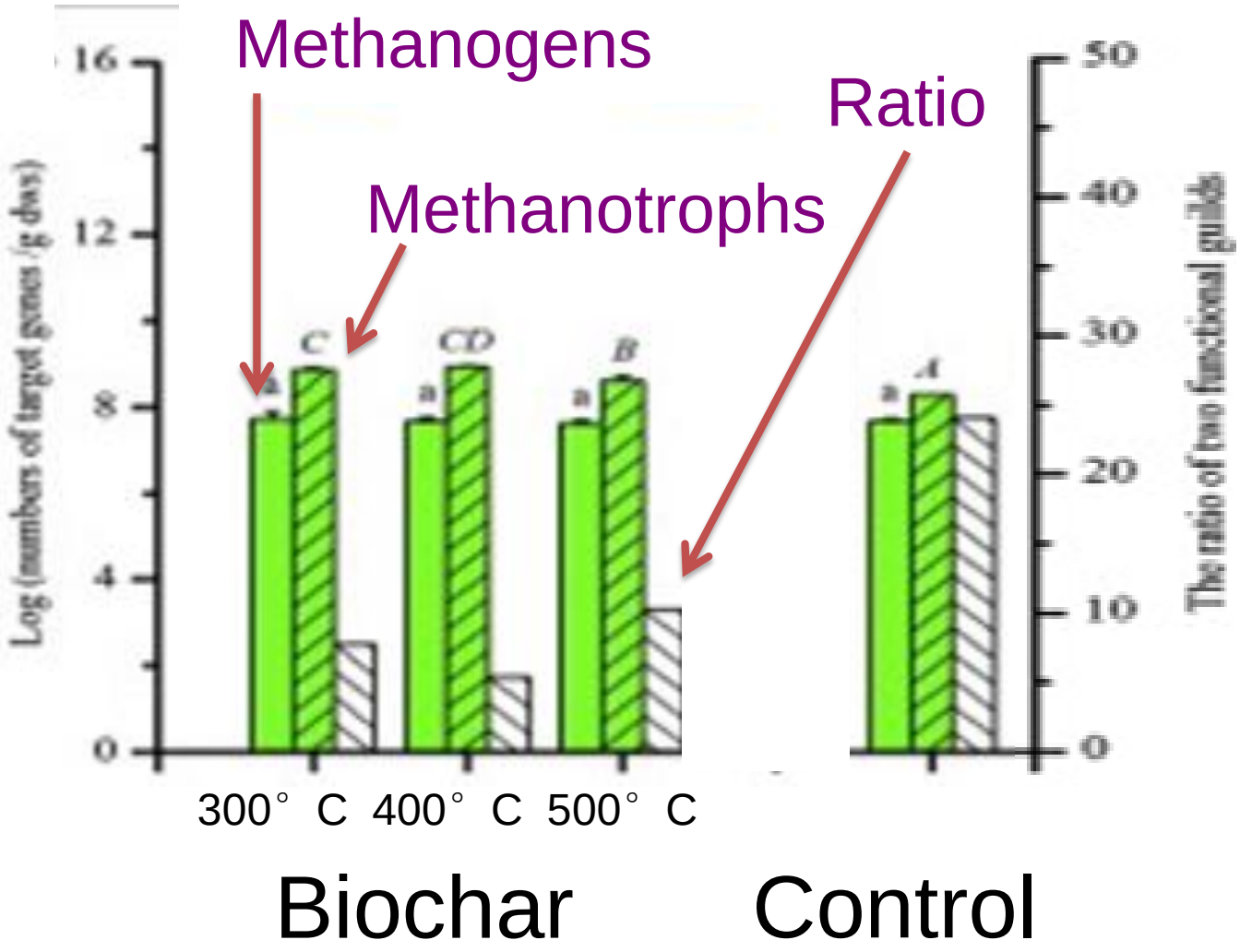
i, j, and k: different ecosystems, water regimes, organic amendments, etc.

**Equation 5.2**

**Adjusted Daily Integrated Emission Factor**

$$EFi = EFc \bullet SFw \bullet SFp \bullet SFo \bullet SFs,r$$

# Effect of biochar on $CH_4$ emission




(1) significant increase of methanotrophs

(2) decrease in methanogens/ methanotrophs

Feng YZ et al., 2012, SBB.

# 1.Residue management