# Assessing Alternatives for Mitigating Net Greenhouse Gas Emissions and Increasing Yields from Rice Production in China Over the Next 20 Years

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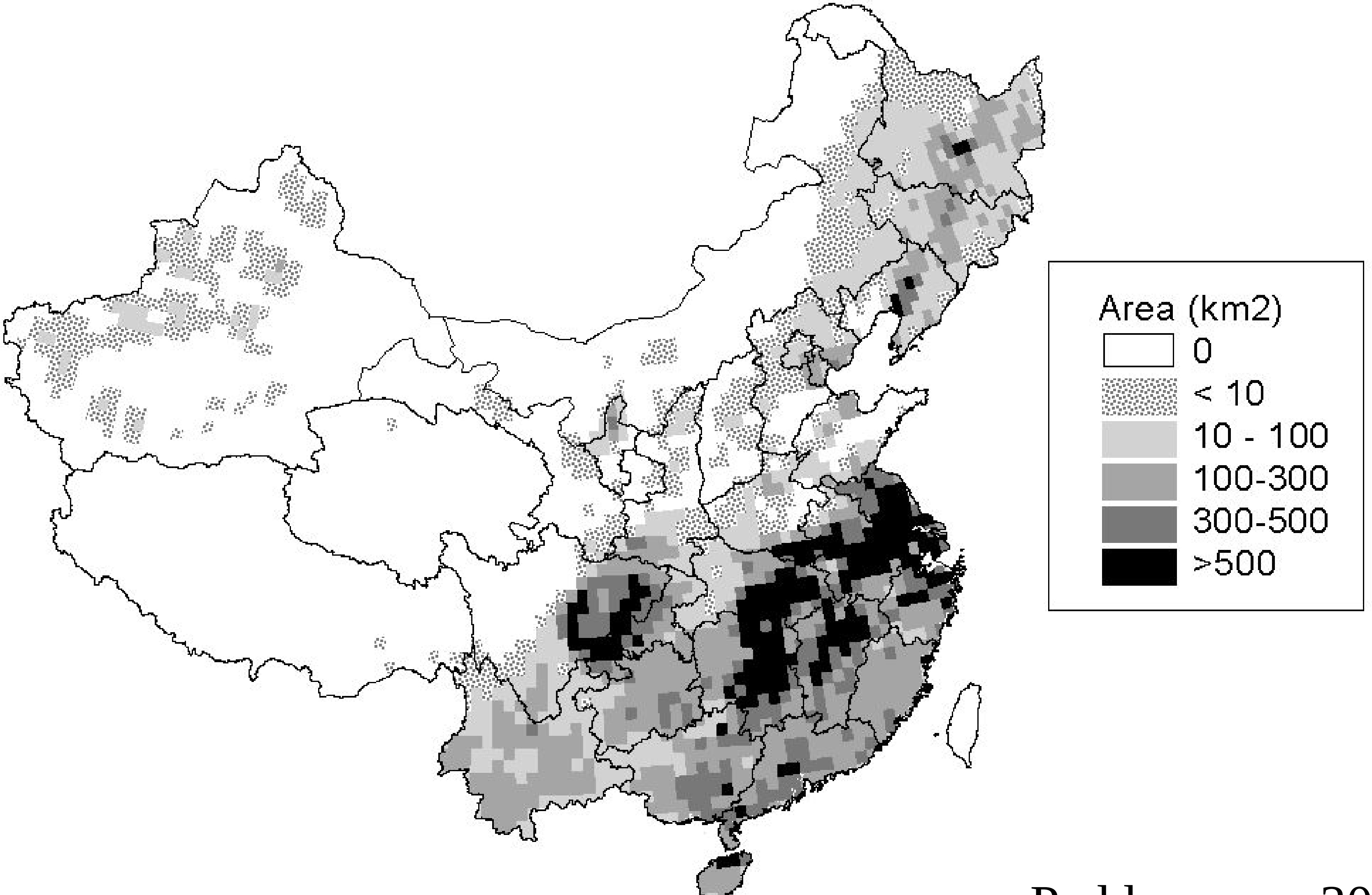
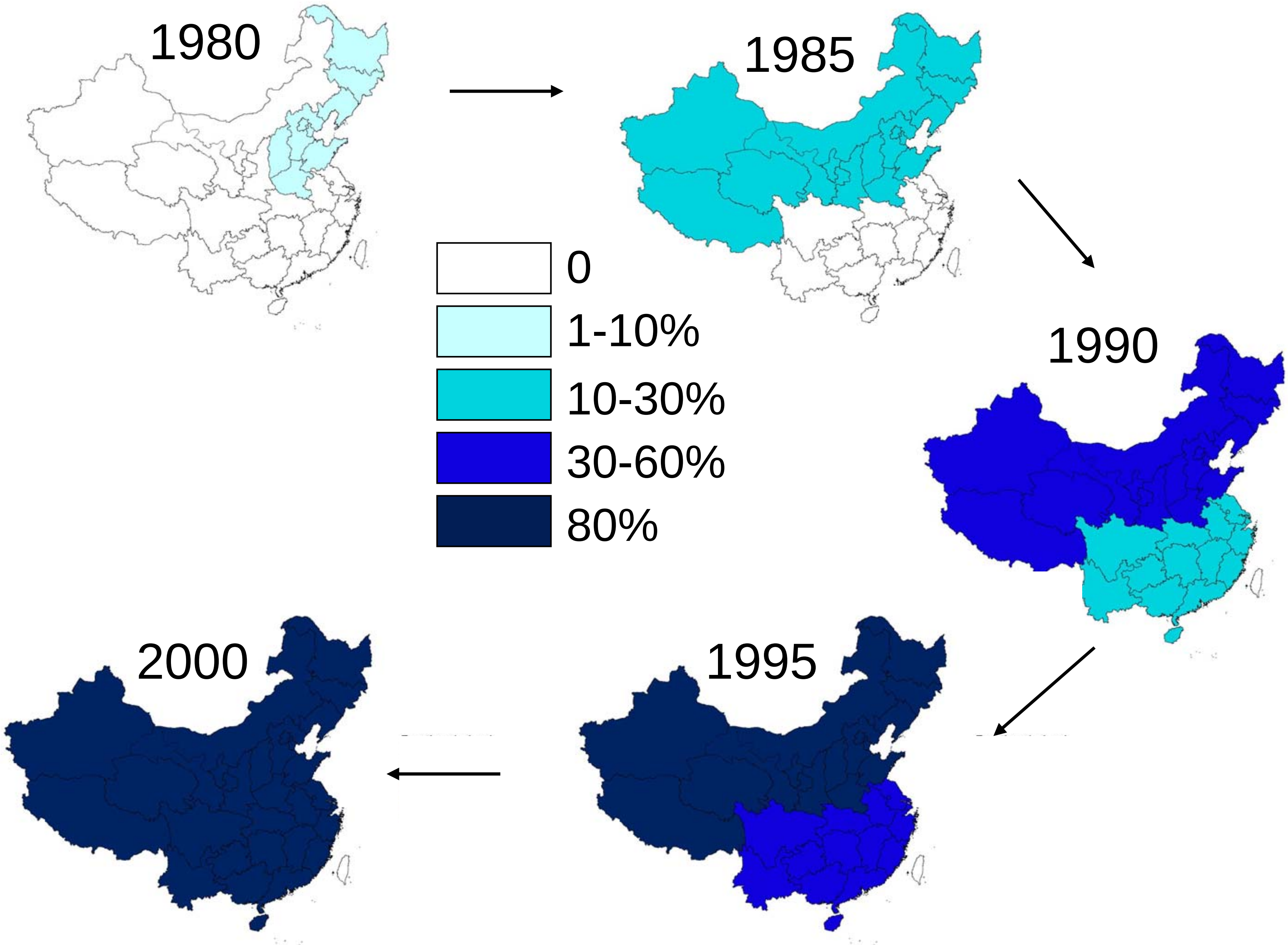
# Total rice paddy area ($km^2$ per 0.5° grid cell)




Paddy area ~ 300,000 $km^2$

Rice sown area ~ 470,000 $km^2$

# Rice Paddies with mid-season drainage (estimated)

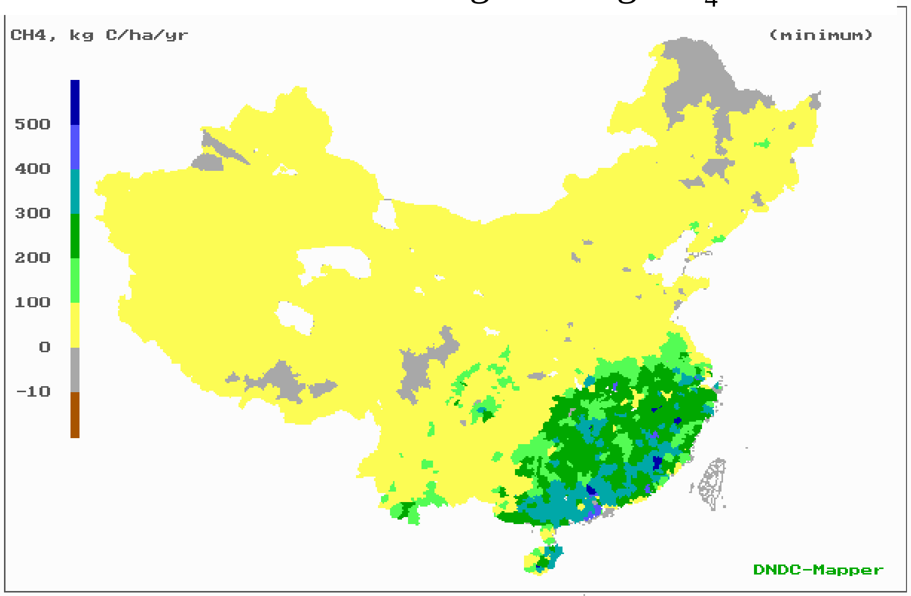



Qingmu Chen, Chinese Acad. Agric. Sci., pers. comm.

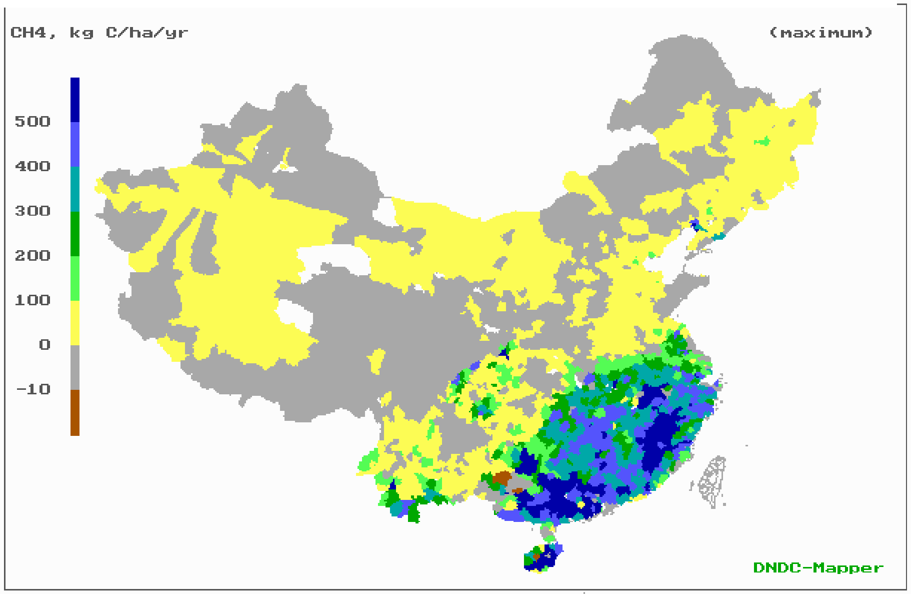
Shen ZR et al. (1998) pp1-267 in *Strategies Against Water Crisis in Chinese Agriculture*, Ag. Sci. & Tech. Press, Beijing.

A former study indicated $CH_4$ emission from rice agriculture in China was reduced by 5 Tg $CH_4$ due to midseason drainage applied from 1980-2000

Midseason drainage: 6.4 Tg $CH_4$




Continuous flooding:12 Tg $CH_4$



## Questions:

Can net GHG emissions from rice paddies in China be reduced even further?

- $CH_4$ is typically sole focus for rice systems, but $N_2O$ and SOC effects can be significant

How do mitigation options ‘rank’ with further consideration of crop yield and water resources effects?

**Methane production driven by anaerobic conditions and available C:**

$$H_2 + C \longrightarrow CH_4$$

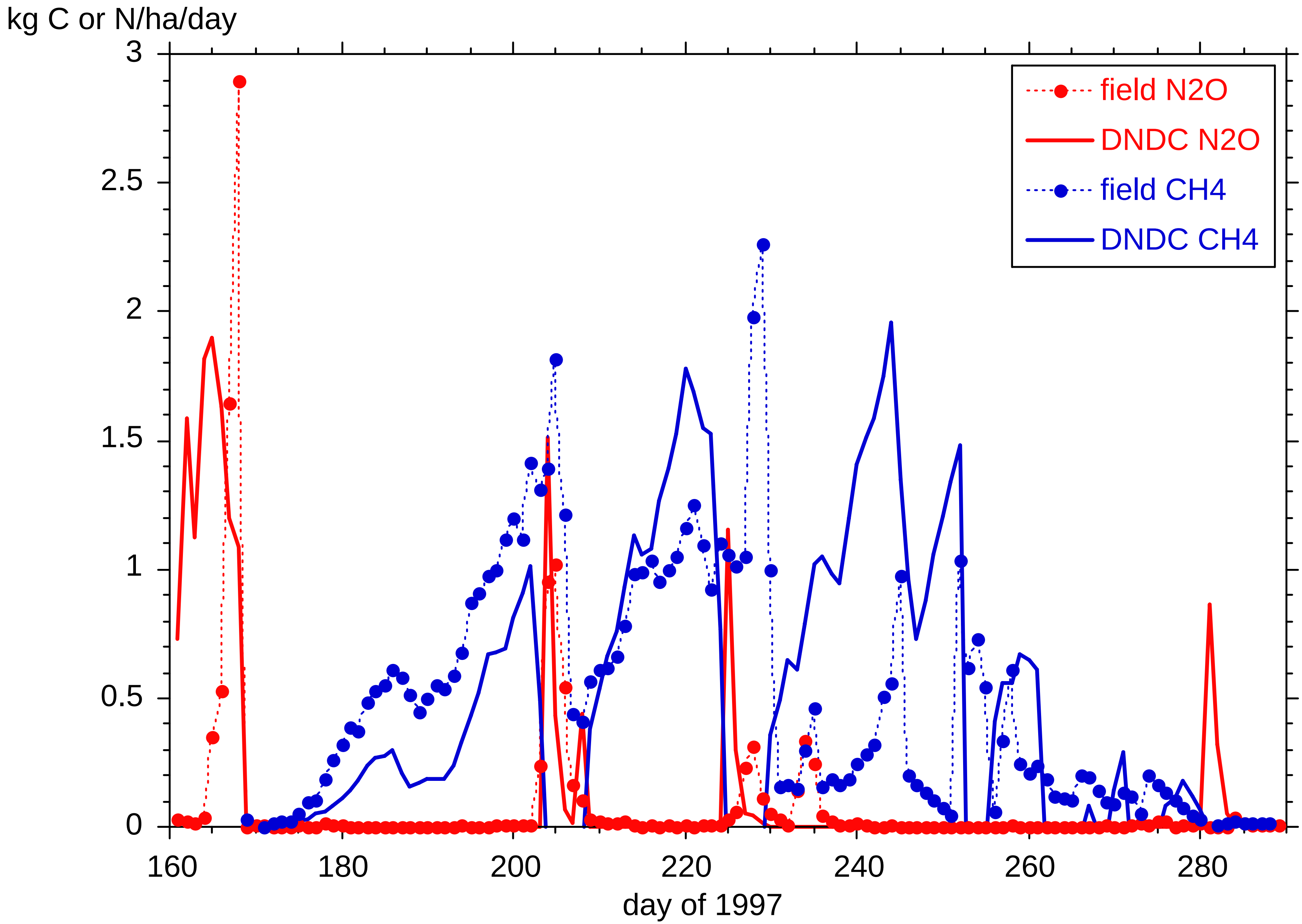
## **The principles for $CH_4$ mitigation**:

1. Increase soil Eh by introducing oxidents (e.g., $O_2$, nitrate, $Mn_4^+$, $Fe_3^+$, sulfate etc.) into the $CH_4$ -production systems;

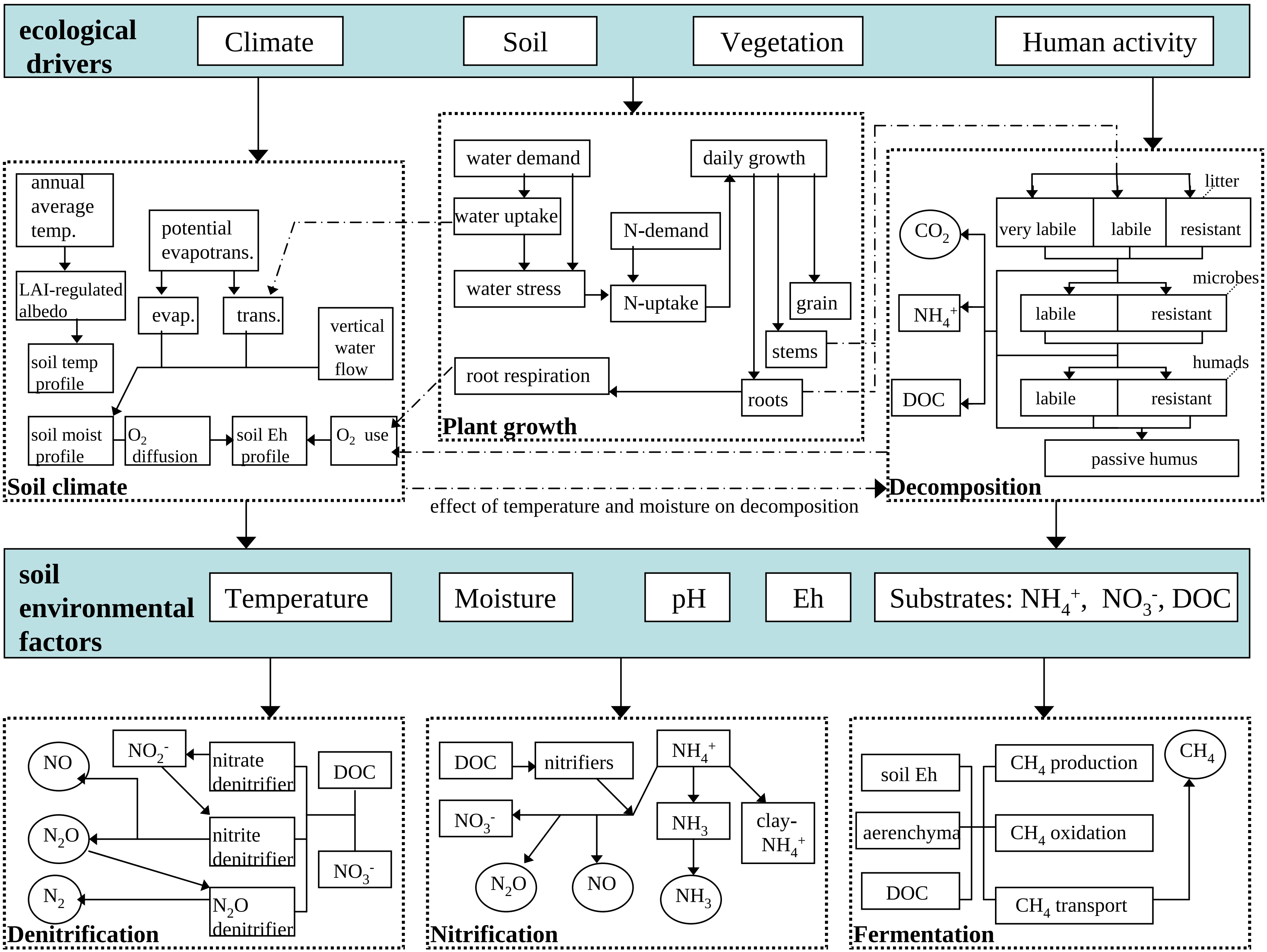
2. Decrease availability of DOC.

Note: Any change in the two factors will also affect SOC dynamics and $N_2O$ emissions.

# Observed and modeled $CH_4$ and $N_2O$ fluxes from paddy with mid-season drainings, Jiangsu Province, China, 1997 (field data from Zheng et al. 1999)



# The DNDC Model



# *A regional prediction for China from 2000-2020:*

**Baseline management scenario:**

-Crop yield increases at rate of 1% per year

(matching IFPRI projections)

-Rice area remains fixed over time

(IFPRI projects decline, with regional variation)

-Crop residue incorporation increases from 15% to 50% in 2000-2010; rice straw is amended at rate 1000 kg C/ha at early season; no animal manure is applied

-Urea and ammonium bicarbonate are used at rate 140 kg N/ha per crop season

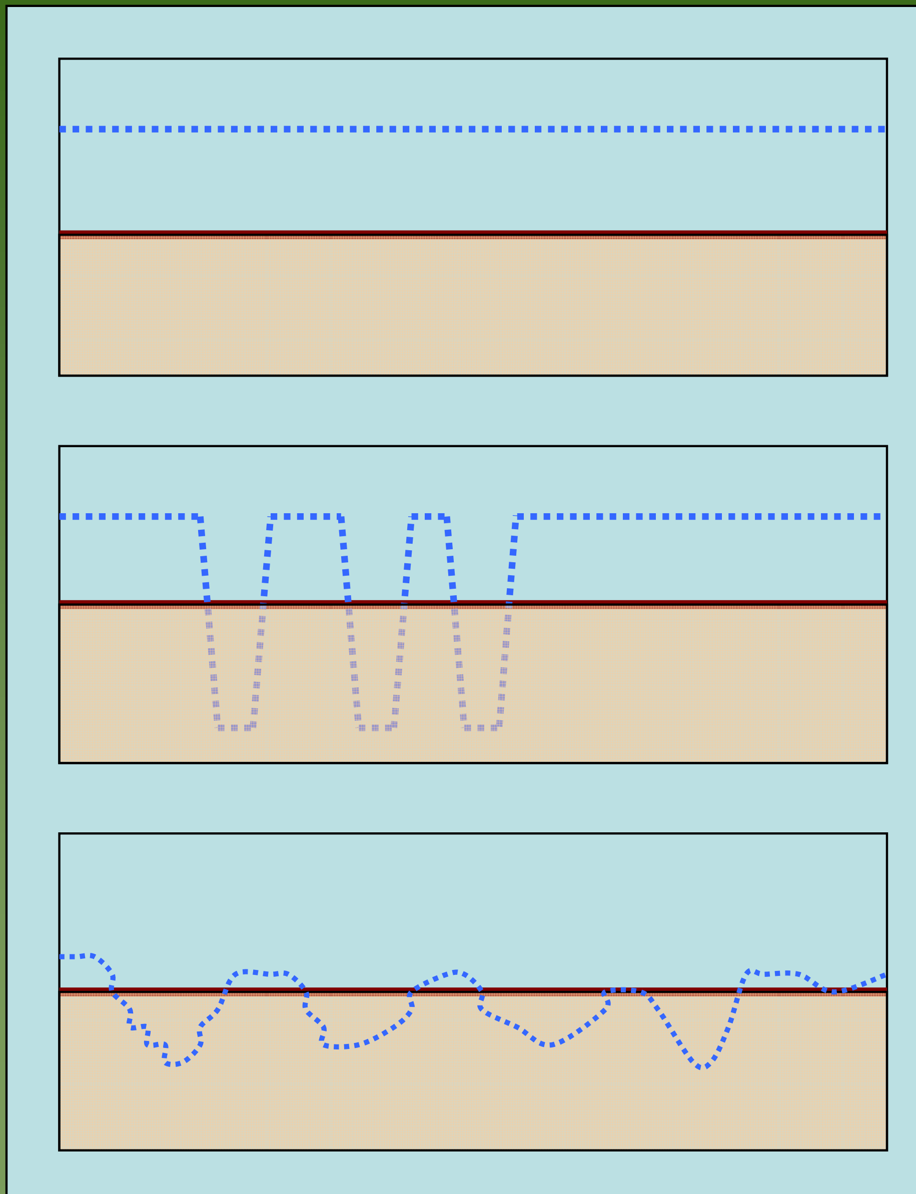
-80% rice paddies are under midseason drainage

# Water Management Evolution for Rice Paddies in China

- 1980: continuous flooding

1980-2000: midseason drainage

2000 -: Marginal flooding



***Biogeochemical Implications:***

- Improve soil aeration;
- Stimulate root/shoot development;
- Increase soil mineralization.

***Consequences:***

- Increase crop yield;
- Decrease water consumption;
- Alter GHG emissions.

## *A regional prediction for China from 2000-2020:*

**Alternative management scenario:**

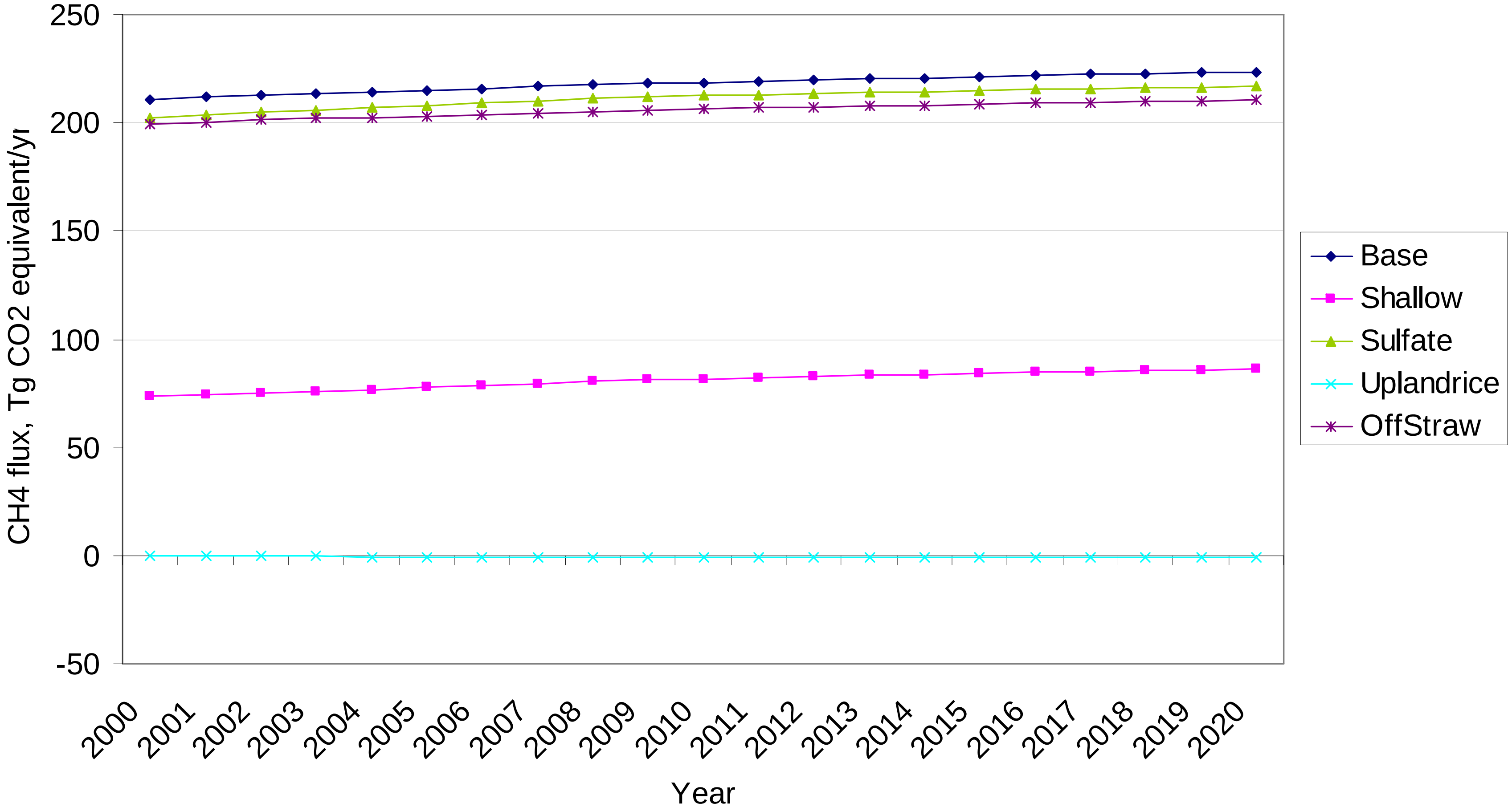
1. Marginal flooding
2. Upland rice
3. Off-season rice straw amendment
4. Ammonium sulfate
5. Fertilizer with slow-release rate

## *A regional prediction for China from 2000-2020:*

-For each management scenario, DNDC simulated crop growth, soil water dynamics, and soil C and N biogeochemistry for each of 11 rice-rotated farming systems in 2,473 counties at daily time step for 21 years from 2000-2020;

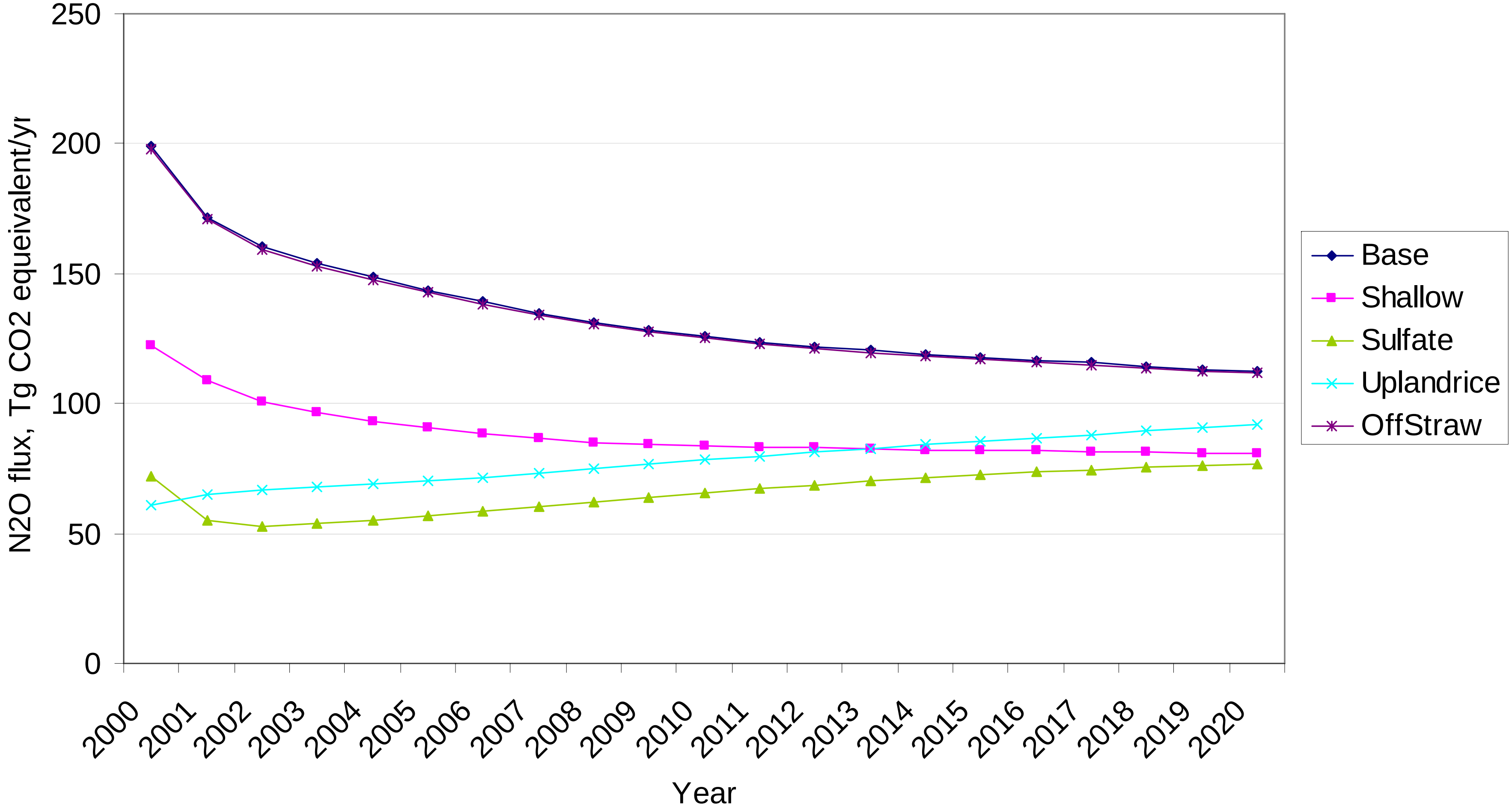
-Crop yield, water consumption, and GHG fluxes from each farming system were summed up to get a county total. The county totals were further integrated to obtain watershed or national inventories.

# DNDC-Predicted Total Emissions of $CH_4$ from Rice Yields in China in 2000-2020: Baseline v. Alternative Management Scenarios



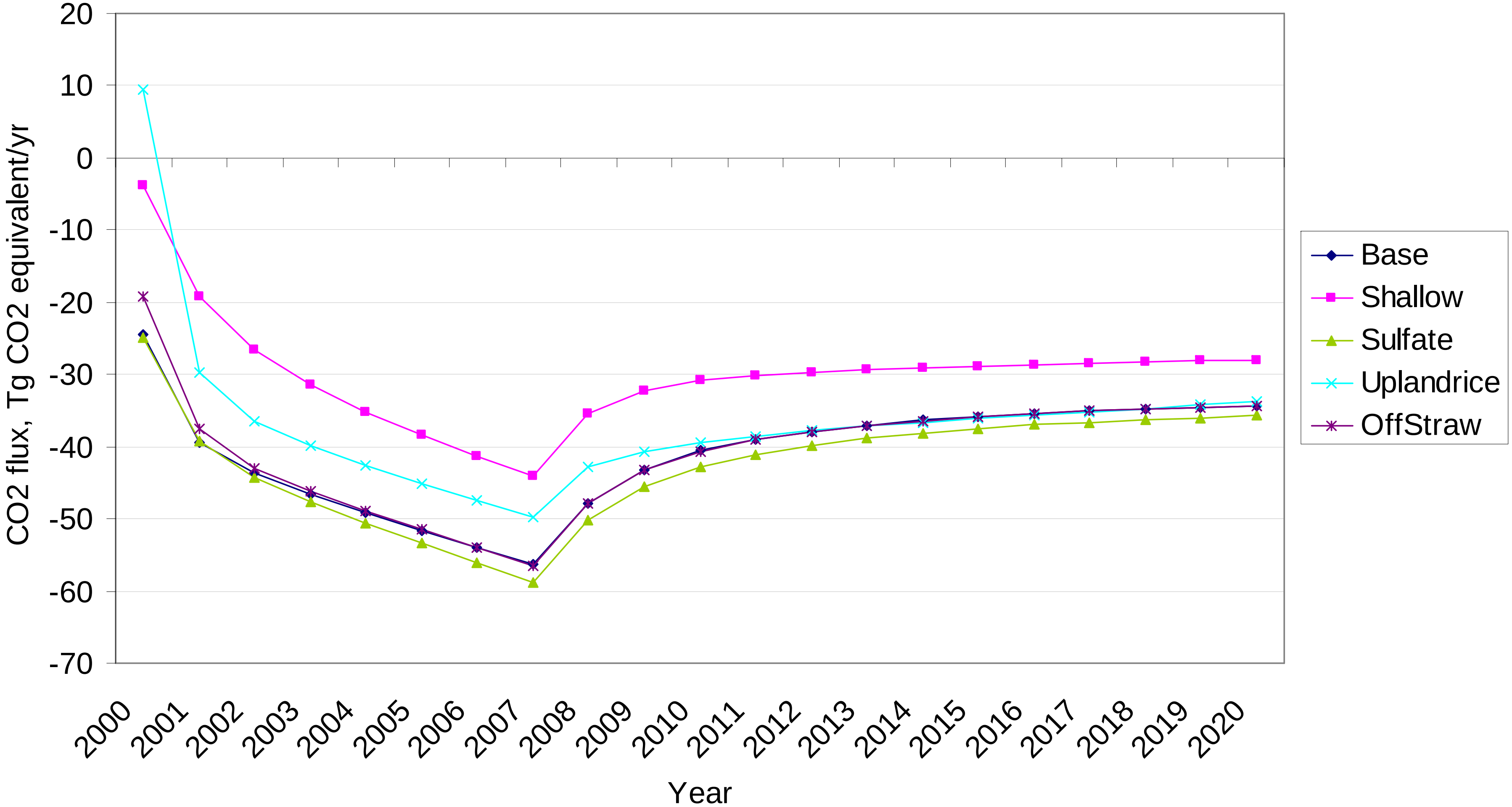

Rice area remains constant in these runs

# DNDC-Predicted Total Emissions of $N_2O$ from Rice Yields in China in 2000-2020: Baseline v. Alternative Management Scenarios

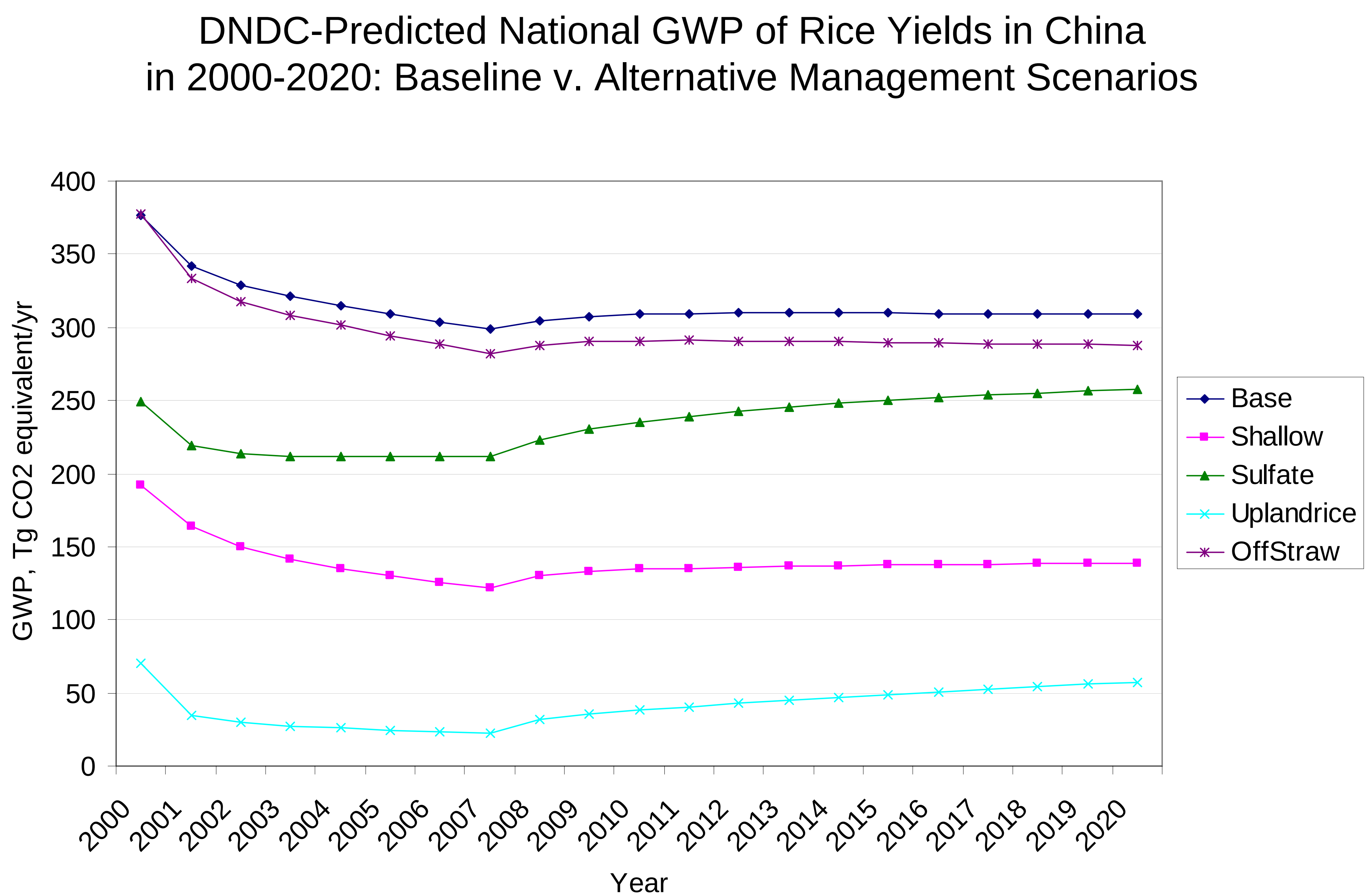



Rice area remains constant in these runs

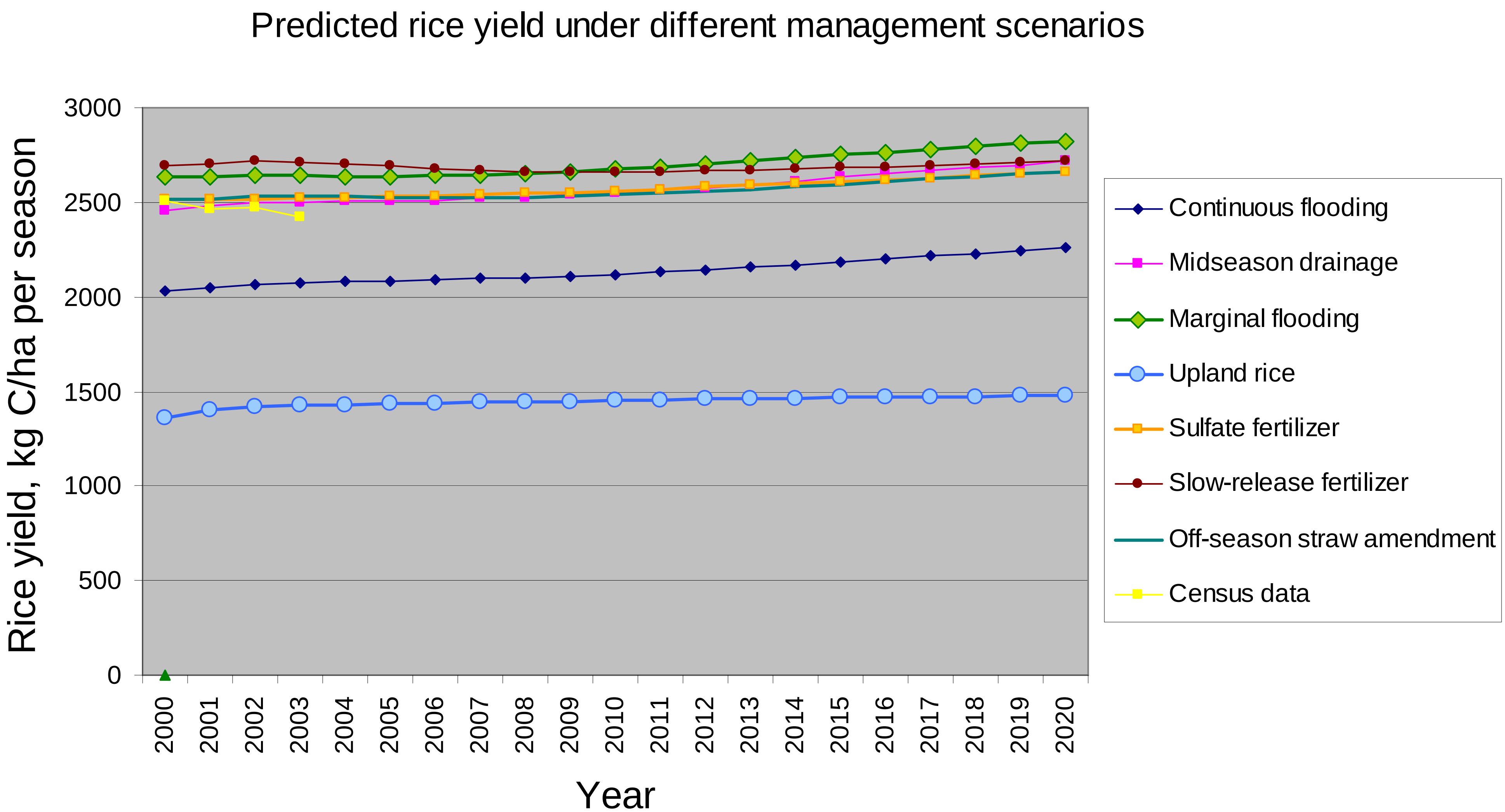
DNDC-Predicted Total Emissions of $CO_2$ from Rice Yields in China in 2000-2020: Baseline v. Alternative Management Scenarios



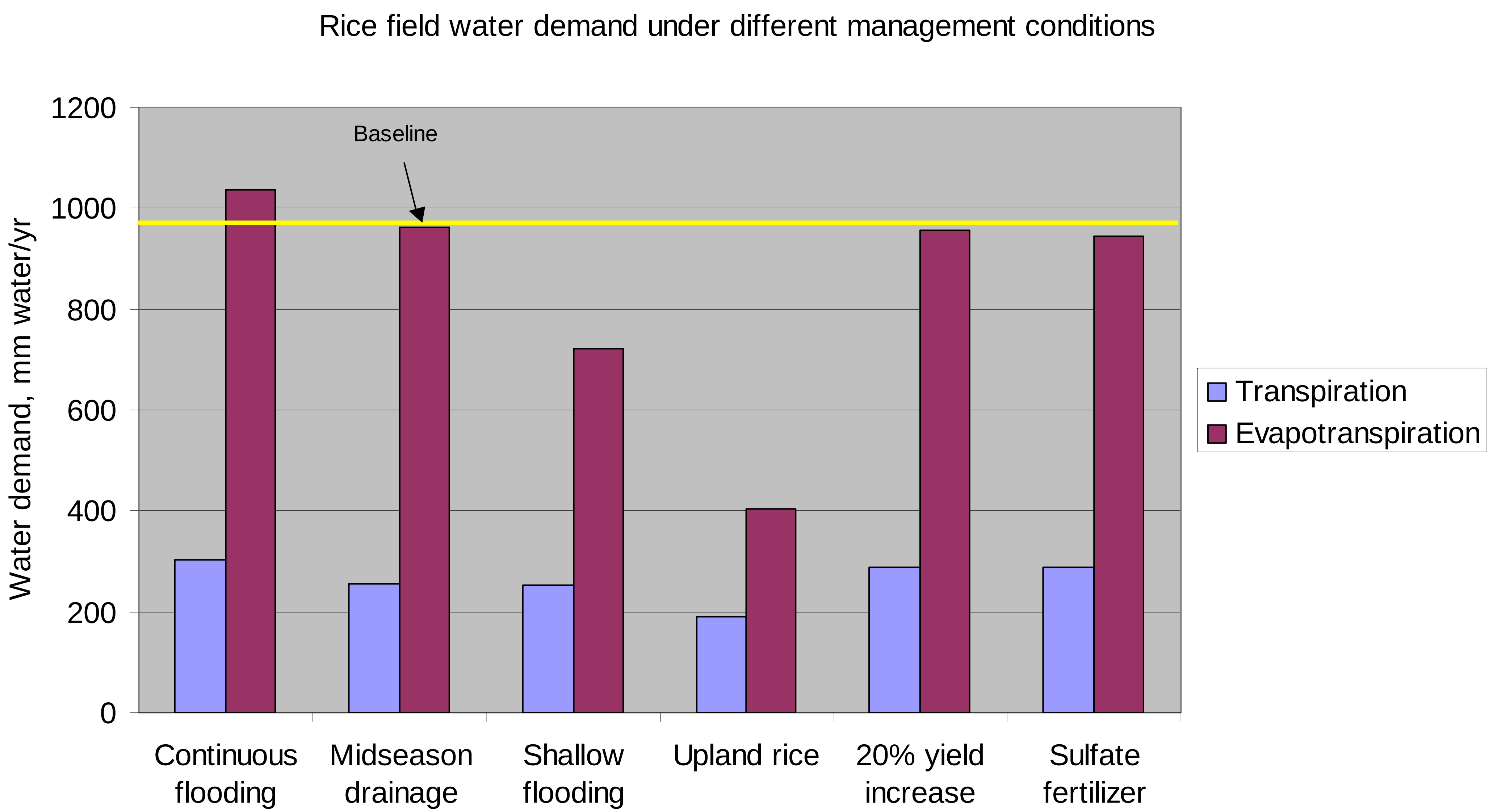

Rice area remains constant in these runs




Rice area remains constant in these runs

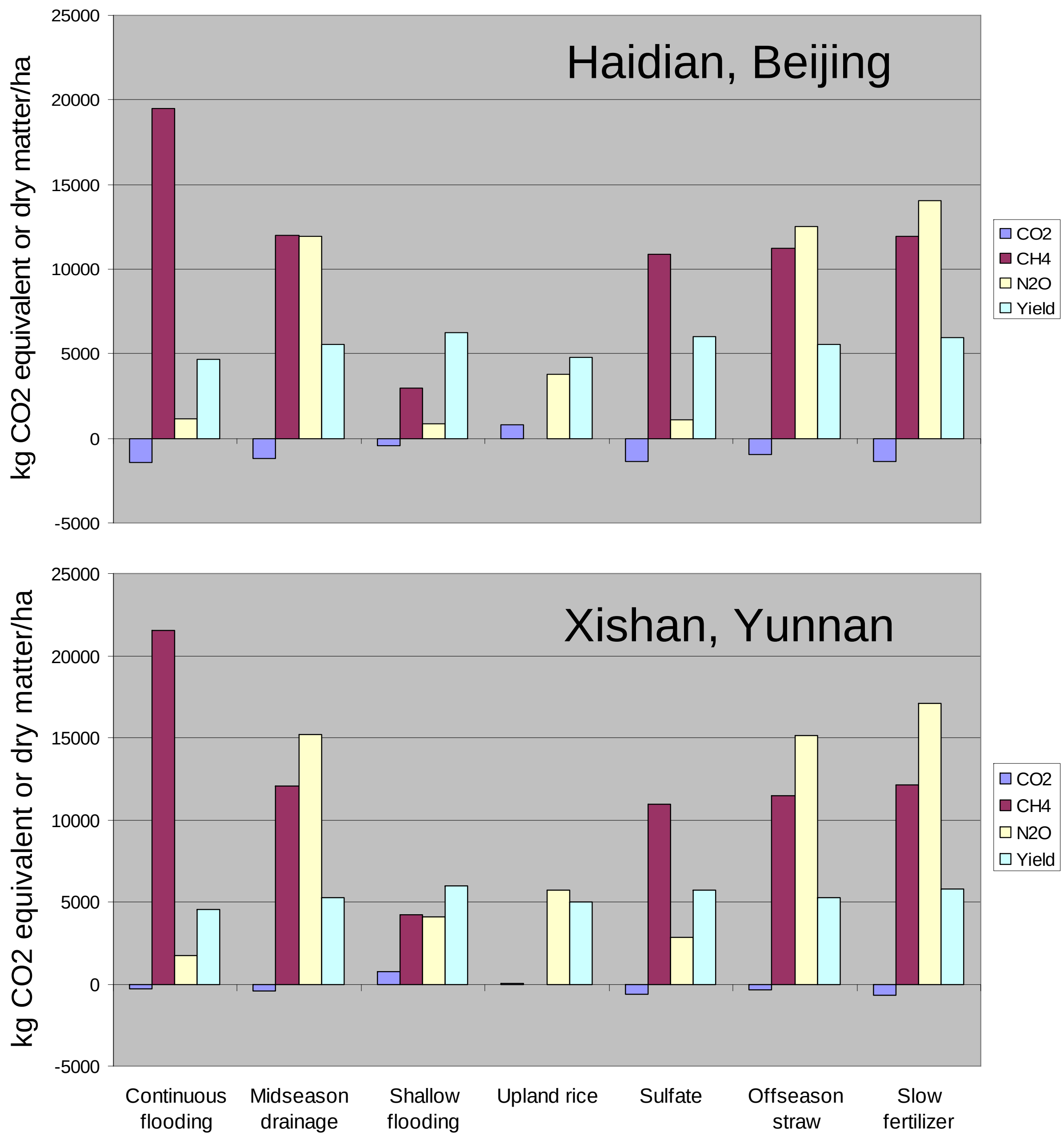


Predicted rice yield under different management scenarios
Rice yield, kg C/ha per season
3000
2500
2000
1500
1000
500
0
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
Year
Continuous flooding
Midseason drainage
Marginal flooding
Upland rice
Sulfate fertilizer
Slow-release fertilizer
Off-season straw amendment
Census data



Rice field water demand under different management conditions
Water demand, mm water/yr
1200
1000
800
600
400
200
0
Baseline
Transpiration
Evapotranspiration
Continuous flooding
Midseason drainage
Shallow flooding
Upland rice
20% yield increase
Sulfate fertilizer

# DNDC Predicts 2000 Crop Yield and GHG Emissions under Different Climate/Soil/Management Conditions at County Scale



## Discussion:

1. **Results indicate 2000 net GHG level can be further reduced by 20-80%**
2. **Based on net GWP calculations, effectiveness order of alternatives:**
    - upland rice
    - shallow flooding
    - sulfate fertilizer
    - off-season straw amendment
3. **Change in water management showed to be most effective in reducing both $CH_4$ and $N_2O$.**
4. **Shallow flooding decreased $CH_4$ by 1/2 and $N_2O$ by 1/3. Upland rice eliminated $CH_4$ and reduced $N_2O$ by 1/3. The two options slightly decreased soil C sequestration rates by <20 Tg $CO_2$ eq/yr.**
5. **Adopting ammonium sulfate slightly depressed $CH_4$ although significantly decreased $N_2O$.**
6. **Shifting straw amendment from in-season to off-season slightly decreased $CH_4$ but almost no effect on $N_2O$ or SOC.**

## Discussion (continued):

7. **Based yield predictions, alternatives can be divided into 3 groups:**
   - Slow-release fertilizer & shallow flooding *increased yield*.
   - Sulfate & off-season straw incorporation almost *no effects on yield*.
   - Continuous flooding & upland rice significantly *decreased crop yield*.
8. **Based on water use prediction:**
   - Shallow flooding & upland rice significantly reduced water consumption.
   - Alternative water management practices mainly affected surface water and soil evaporation while plant physiological demand for water (i.e., transpiration) basically remained unchanged.
   - This study adopted 1990 climate data for all simulated 21 years -- no significant inter-annual variations in water consumption observed. Effect of inter-annual yield increase on field water consumption was relatively small.