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Can we achieve carbon neutral staple food production in China?

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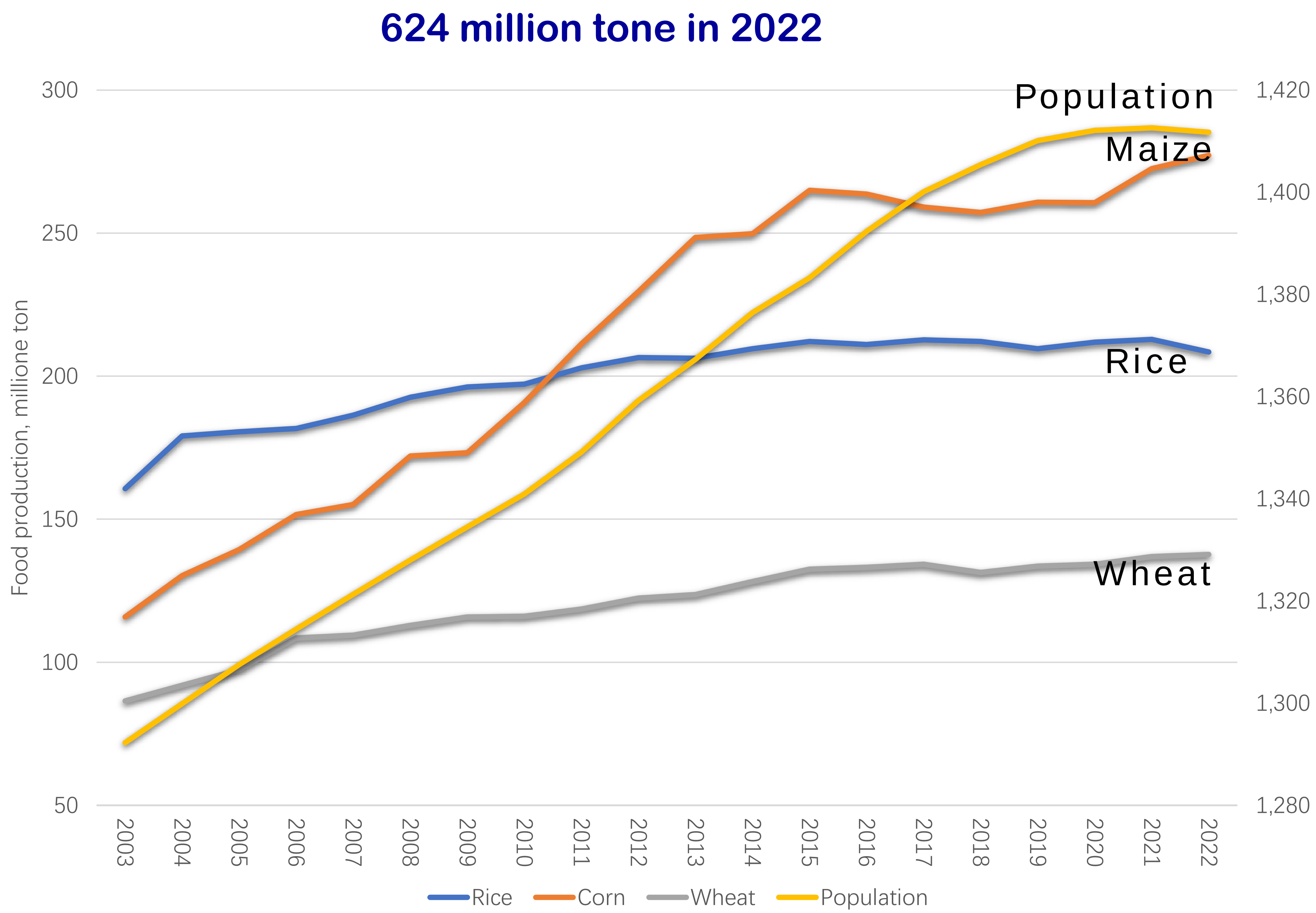
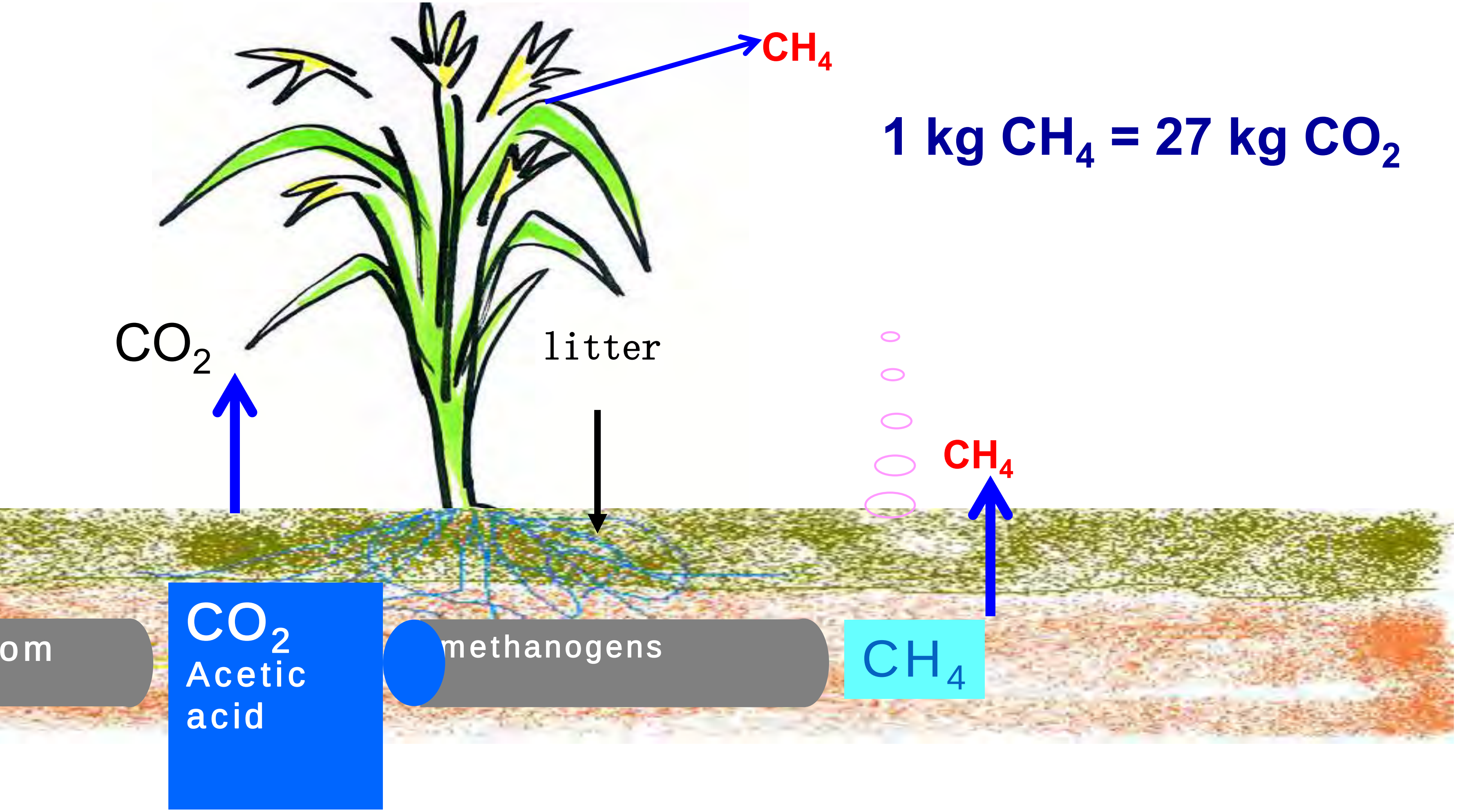
Staple food production in China



CH_4 emission from rice paddy

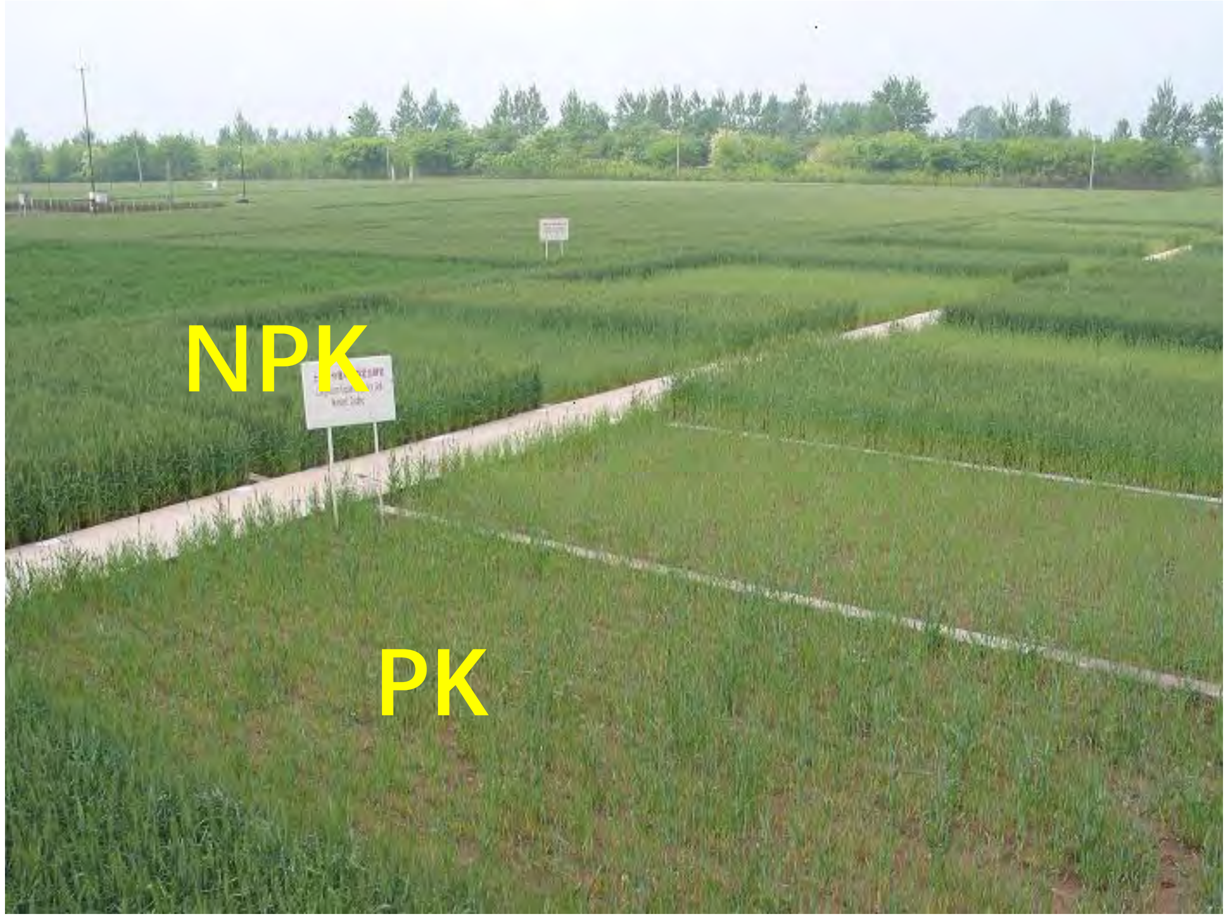
Organic input

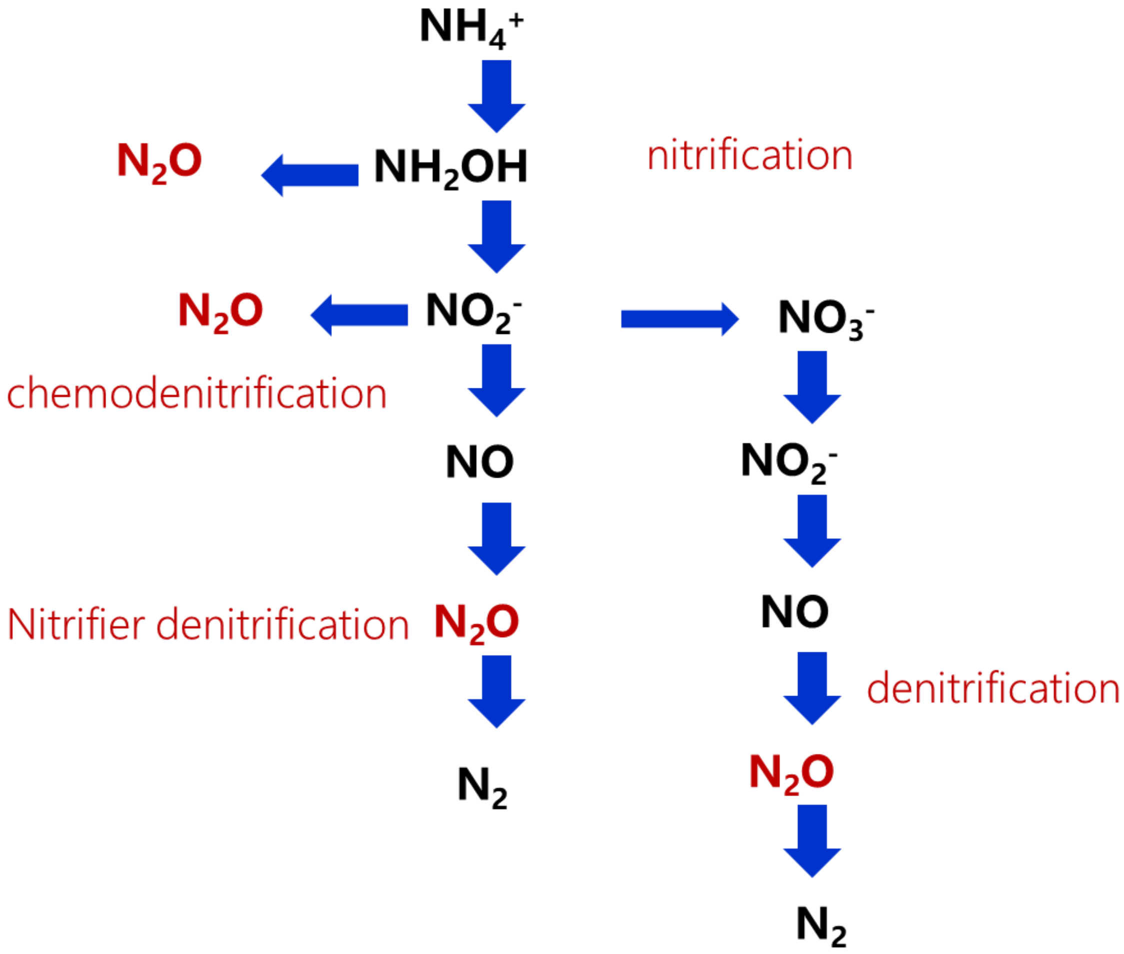
$1\ kg\ CH_4 = 27\ kg\ CO_2$



N_2O emission from nitrogen fertilizer use

$1\ kg\ CH_4 = 298\ kg\ CO_2$





CO_2 emissions from energy consumption

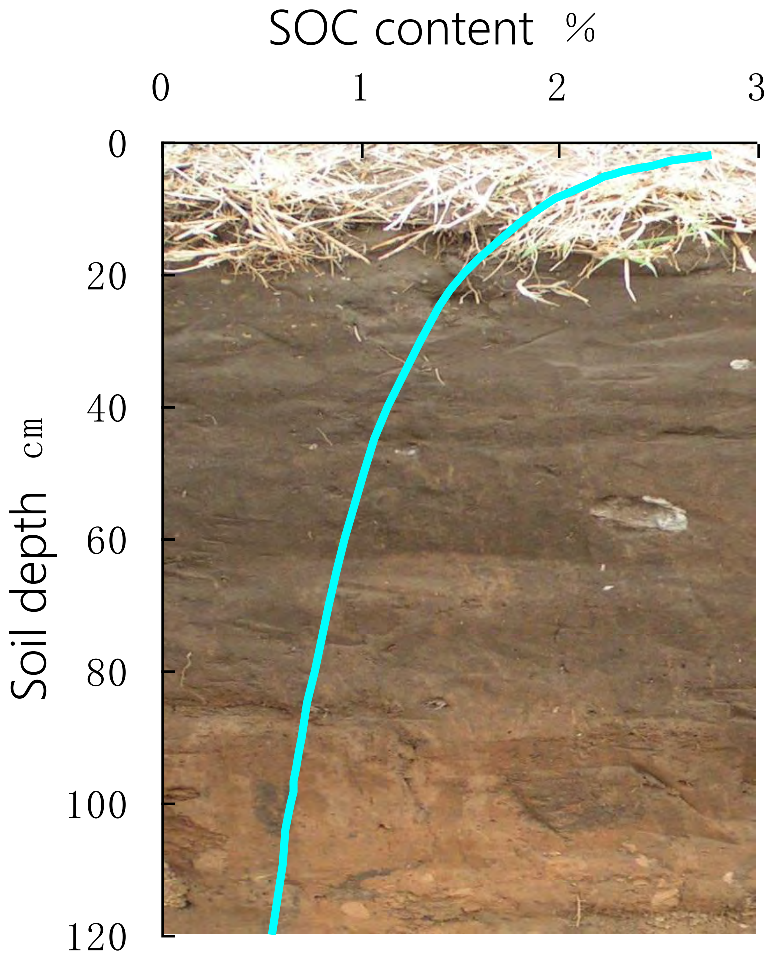
Fertilizers

Irrigation

Tillage

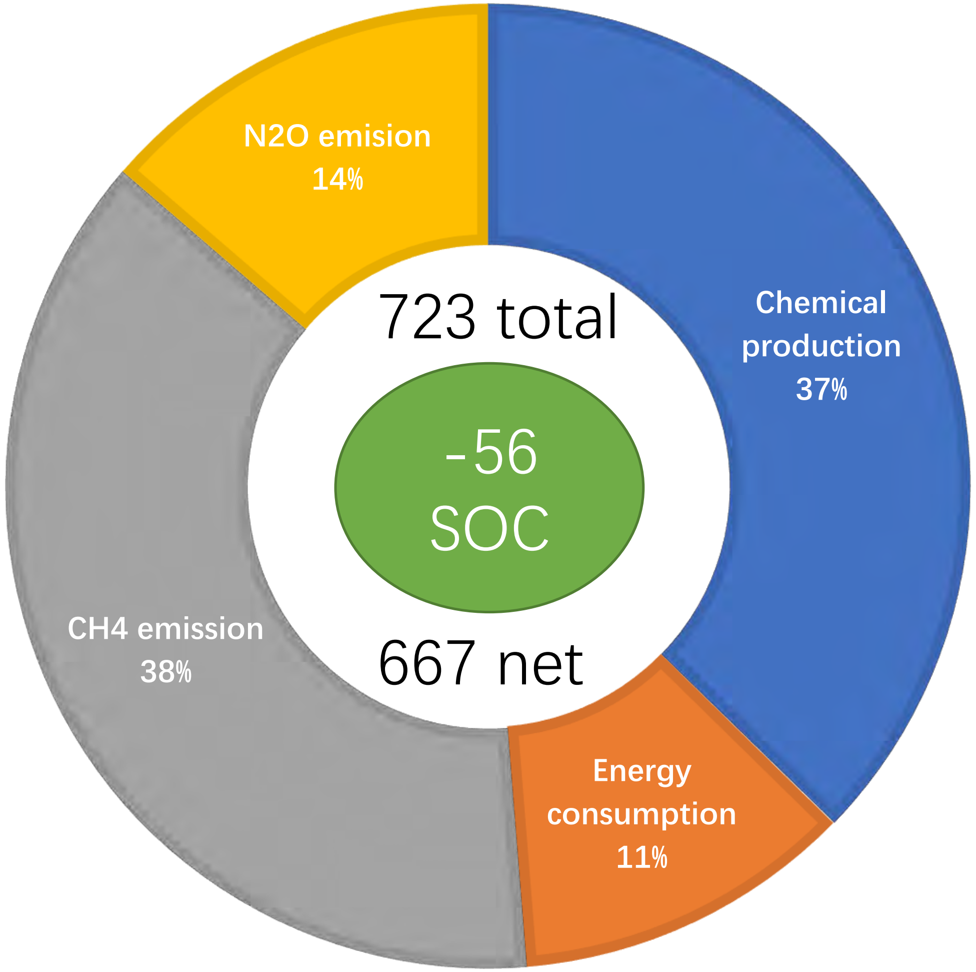
Harvesting

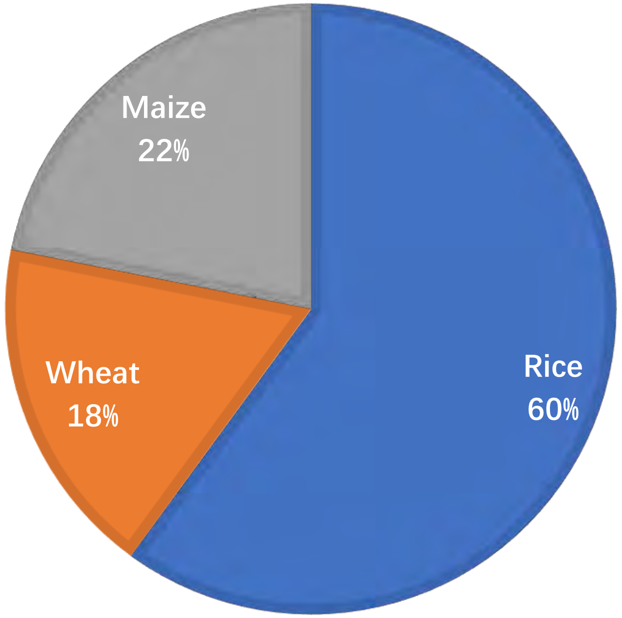
Soil carbon stock change: CO_2 source or sink

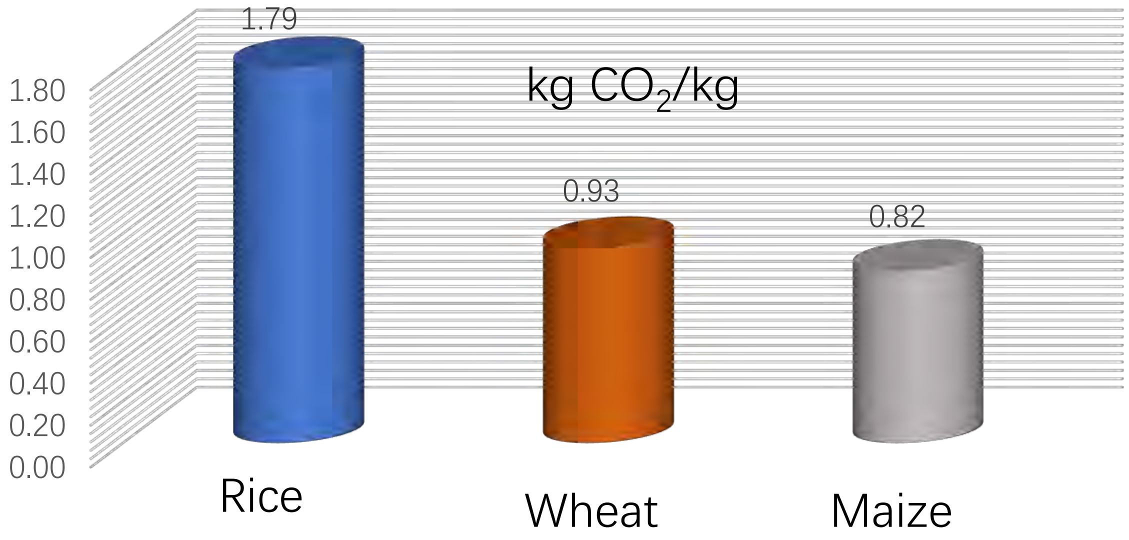


GHG emissions from staple crop production

667 Tg CO_2-eq as of 2018, ~5% of nation total GHG

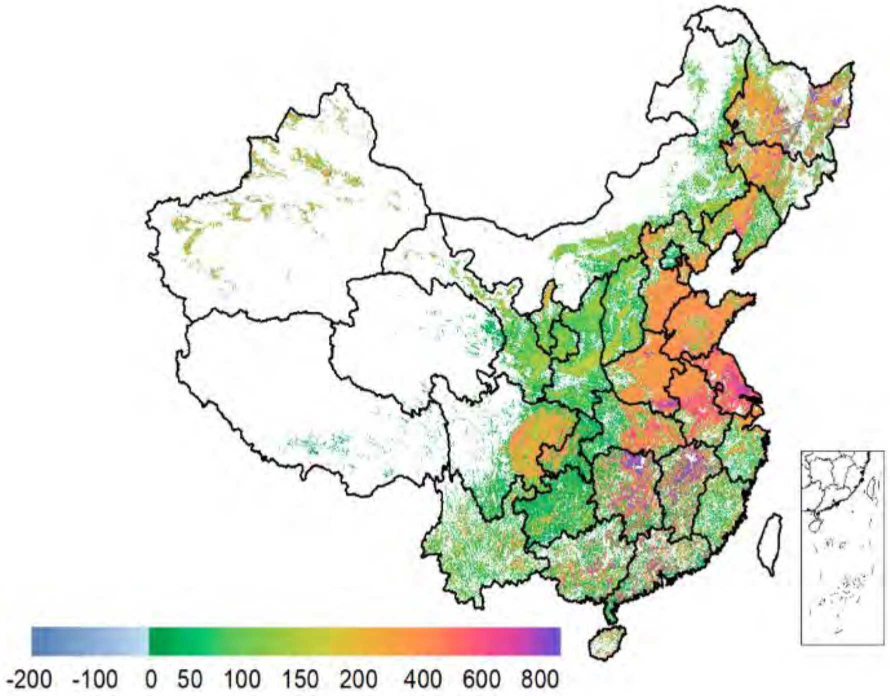






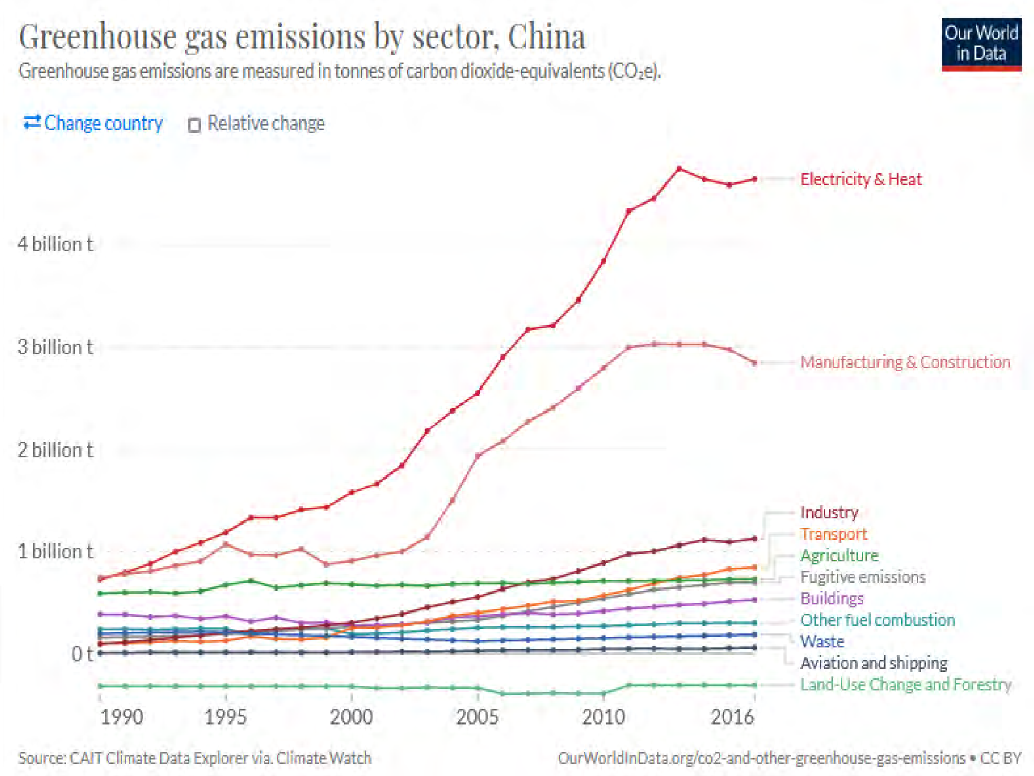
Spatial and temporal variation in emission

Spatial distribution of agricultural emission



Xia et al., 2023, Nature Food

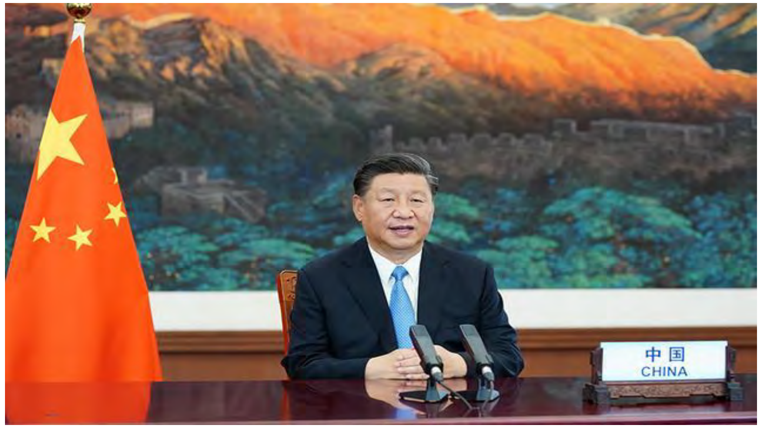
Time trend of emissions



Mitigation options

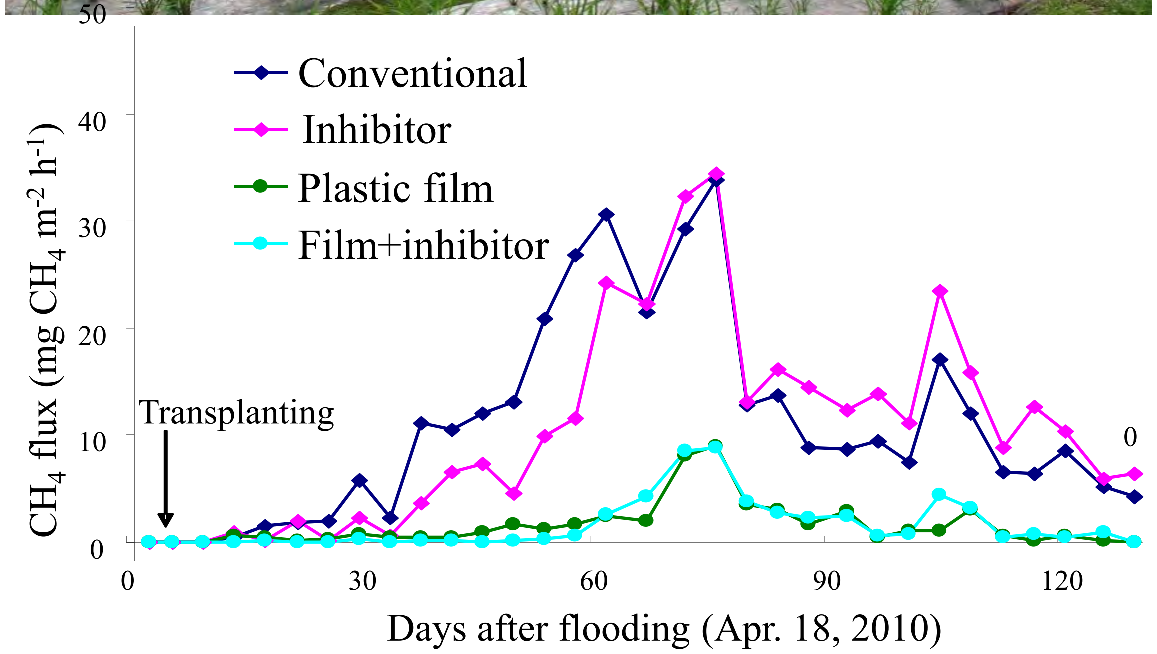
2020.9.22，the 75th United Nations General Assembly

Peak emission before 2030
Carbon neutrality before 2060

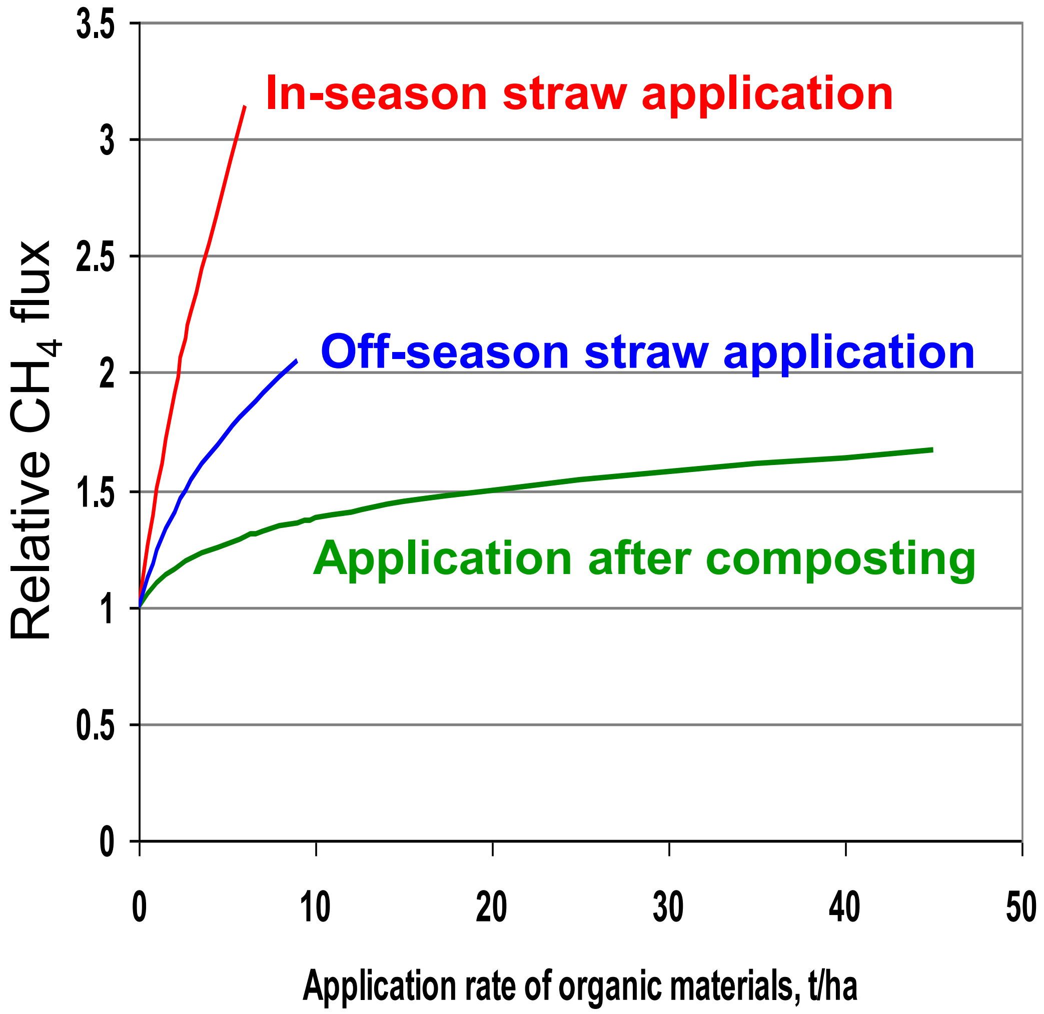


- **CH_4 emission from rice paddy**
  - **water management**
  - **residue management**
  - **Others**
- **N_2O emission from fertilizer use**
  - **Optimized N application**
  - **Enhanced efficiency N fertilizers**
- **Soil carbon sequestration**
  - **Crop residue returning**
  - **Increase plant biomass**

Water management to reduce CH_4 emission

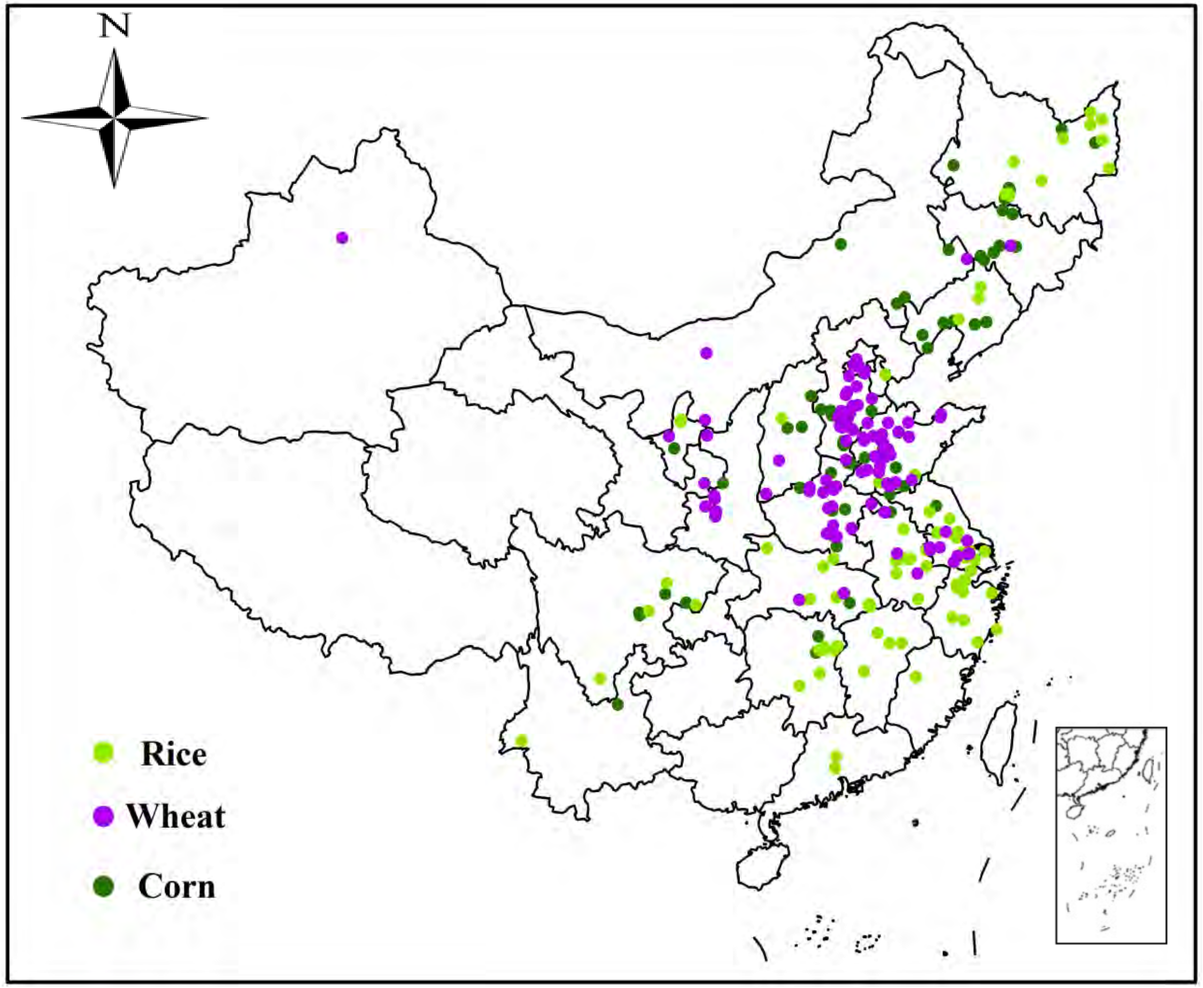


Crop residue management to reduce CH_4 emission

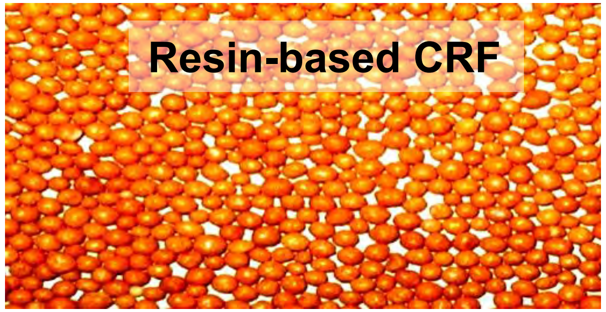


Yan et al., 2005, GCB

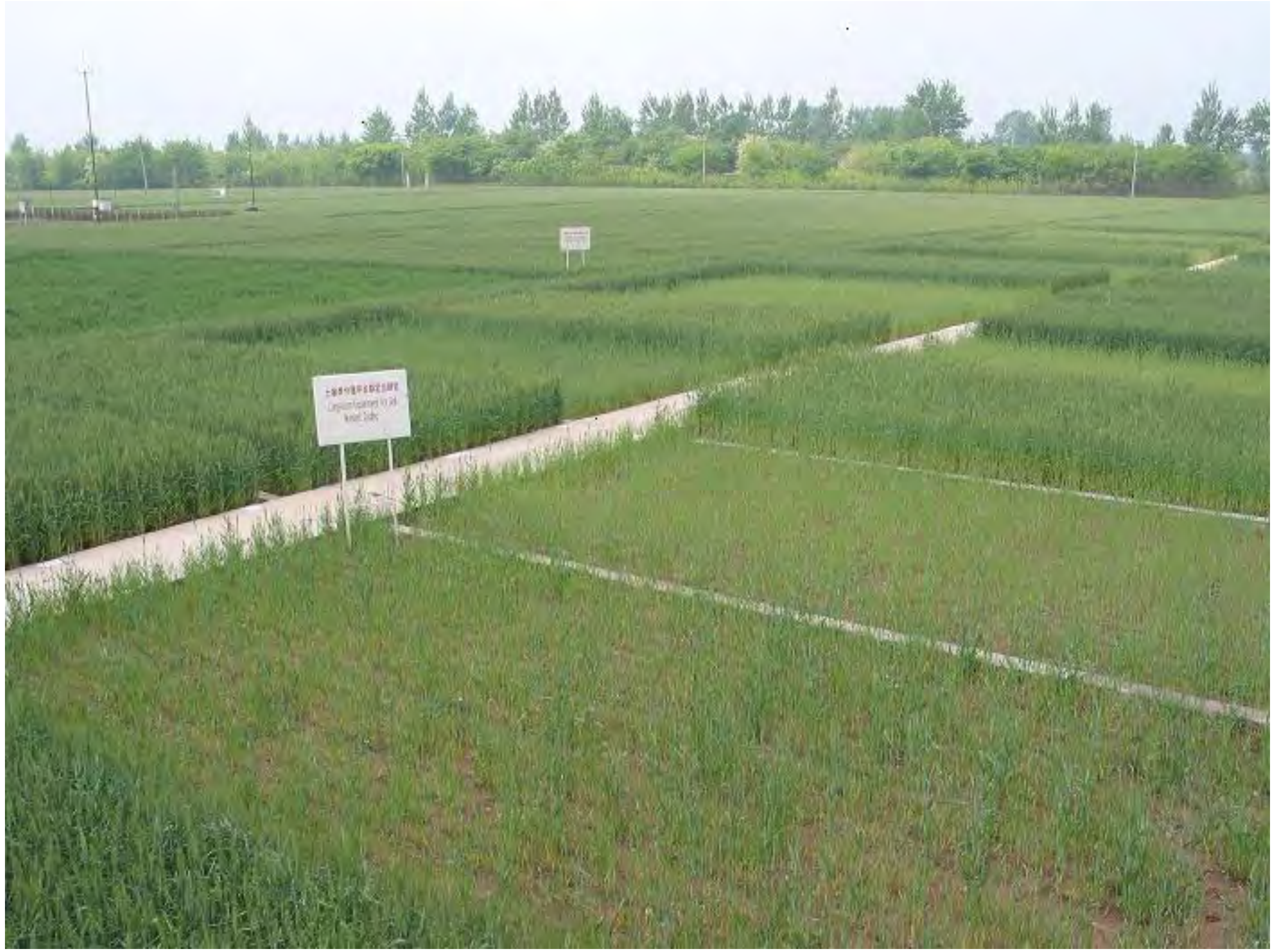
N_2O mitigation options

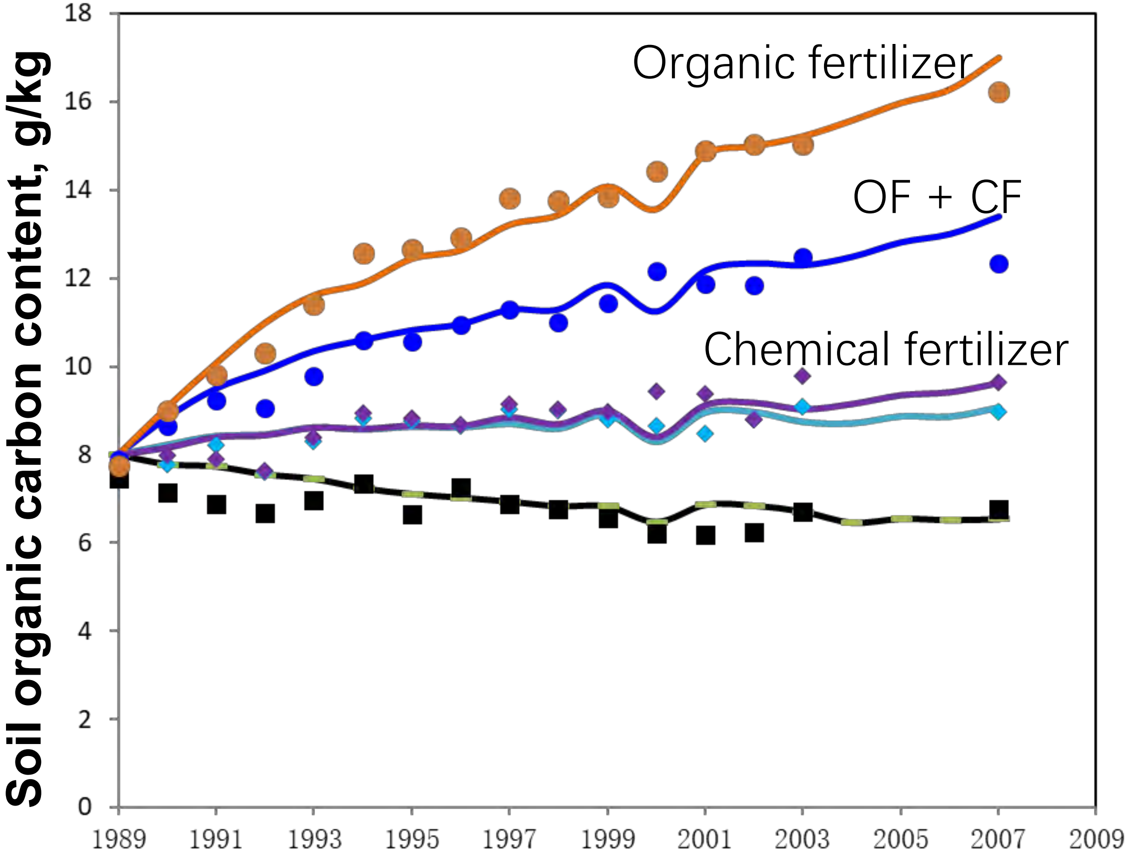


- **Optimized N application**
  - Increasing N splitting frequency
  - Applying N deep placement
  - Reducing N rate under soil N test
- **Enhanced efficiency N fertilizers**
  - Controlled-release N fertilizer (CRF)
  - Nitrification inhibitor (NI)
  - Urease inhibitor (UI)



SOC sequestration in croplands

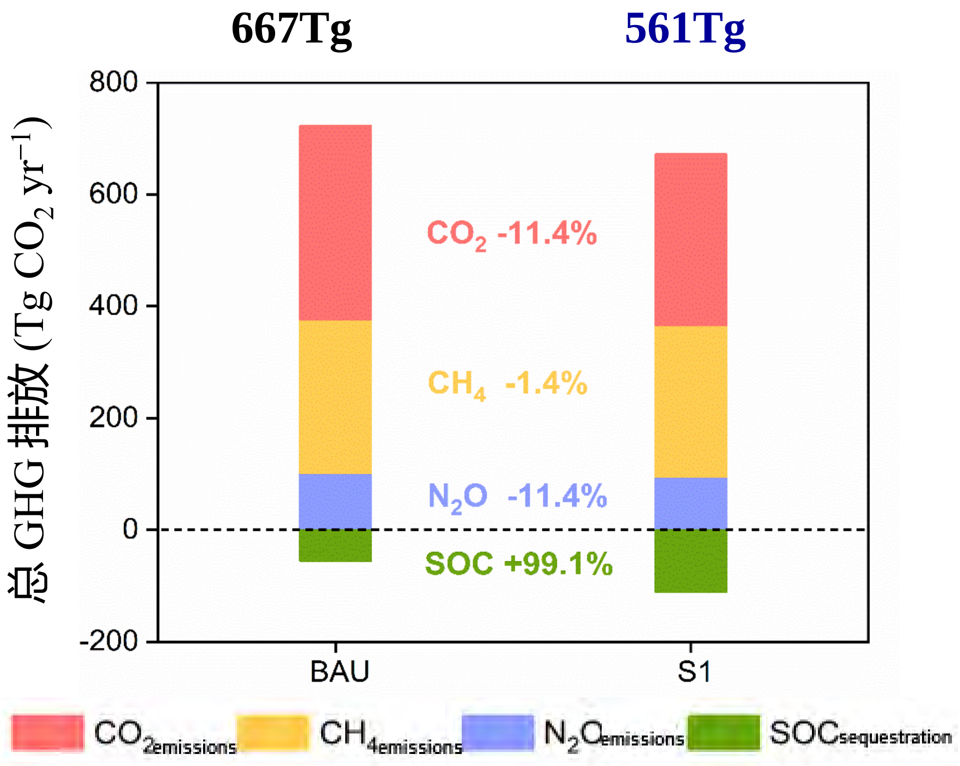


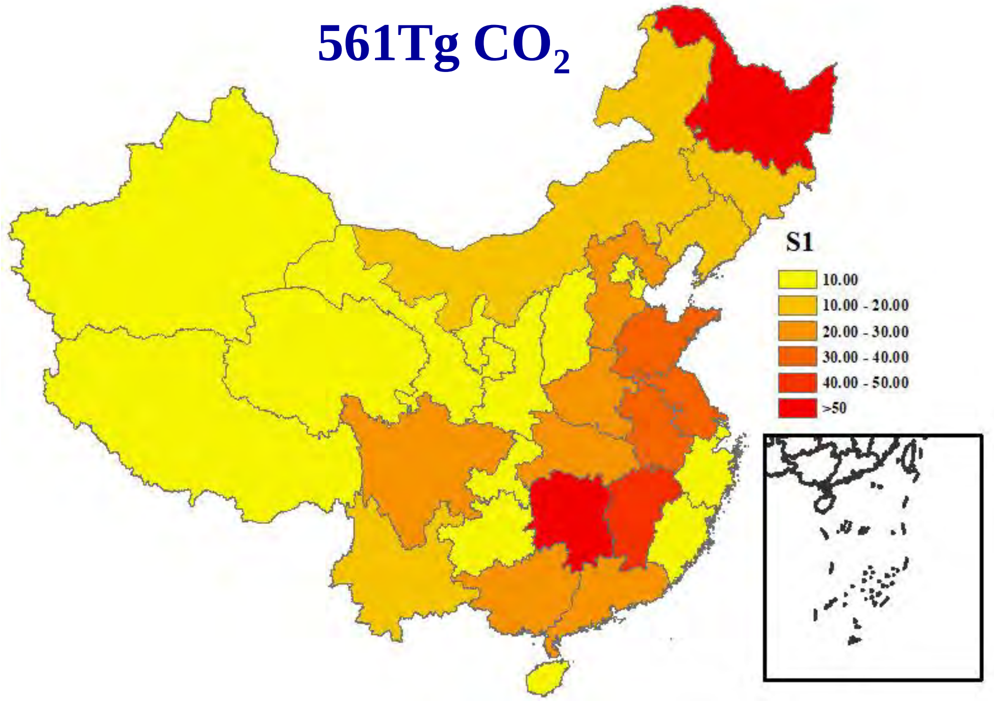


Conventional mitigation options (S1)

- **+SOC**： crop residue return (44% to 82%)
- **-CH_4** ： Intermittent irrigation
- **Optimal N use**： N rate -15% （-N_2O and -CO_2)

Provincial reduction 2~43%
Unable to achieve carbon neutral



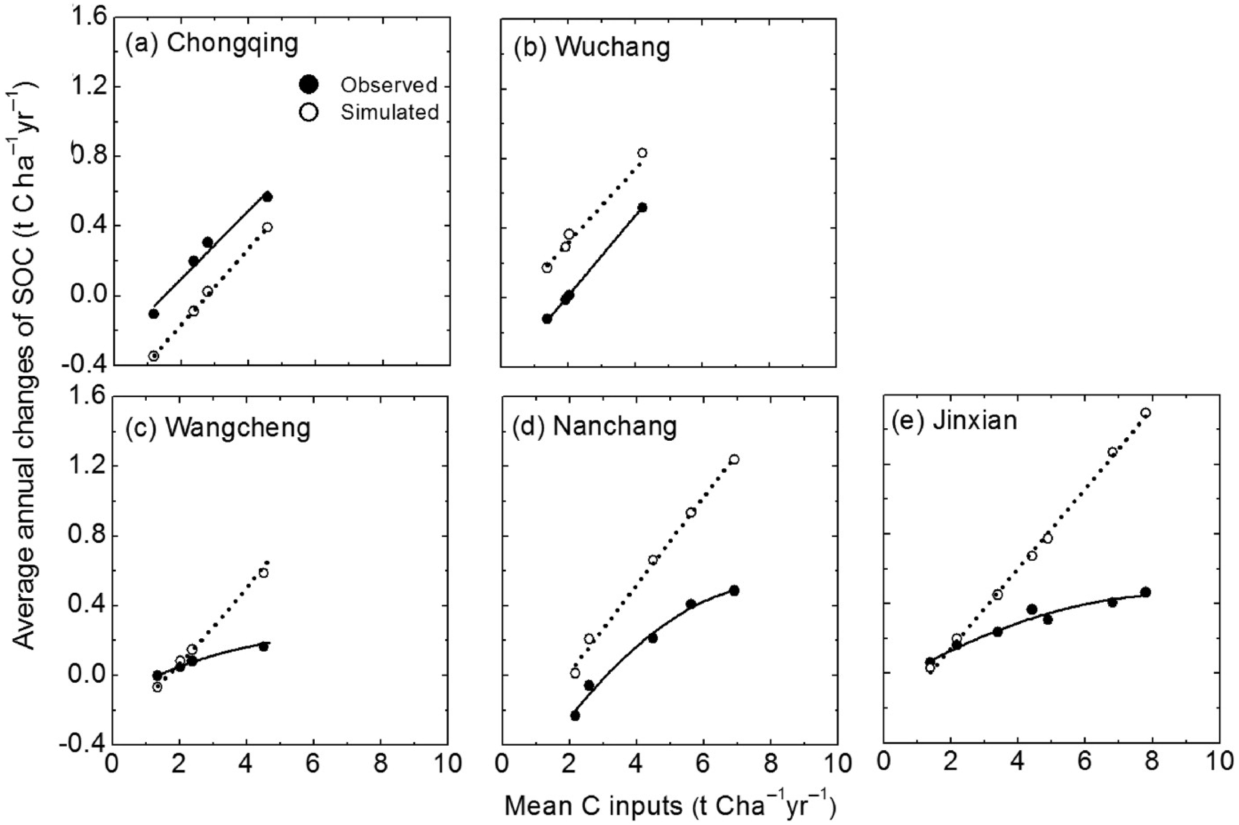


Xia et al., 2023, Nature Food

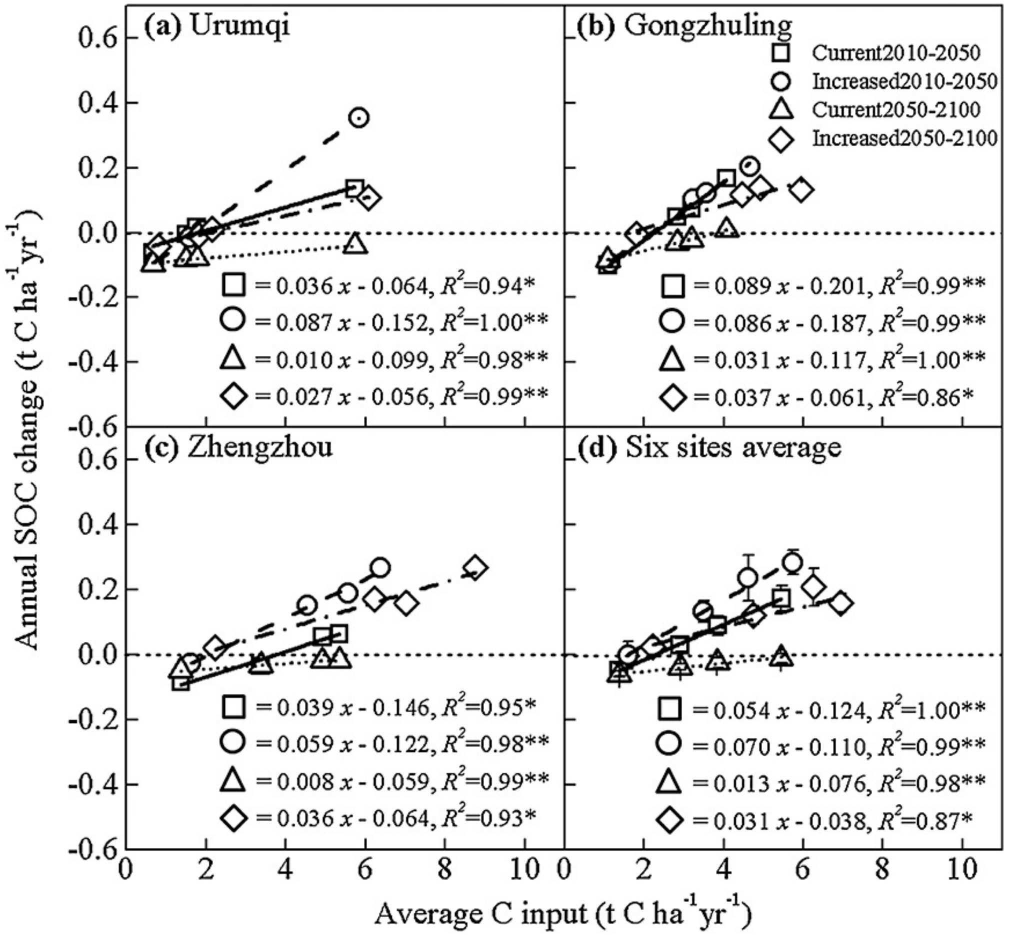
Low SOC sequestration efficient under straw application

Paddy field：3-10%

Upland field：1-9%

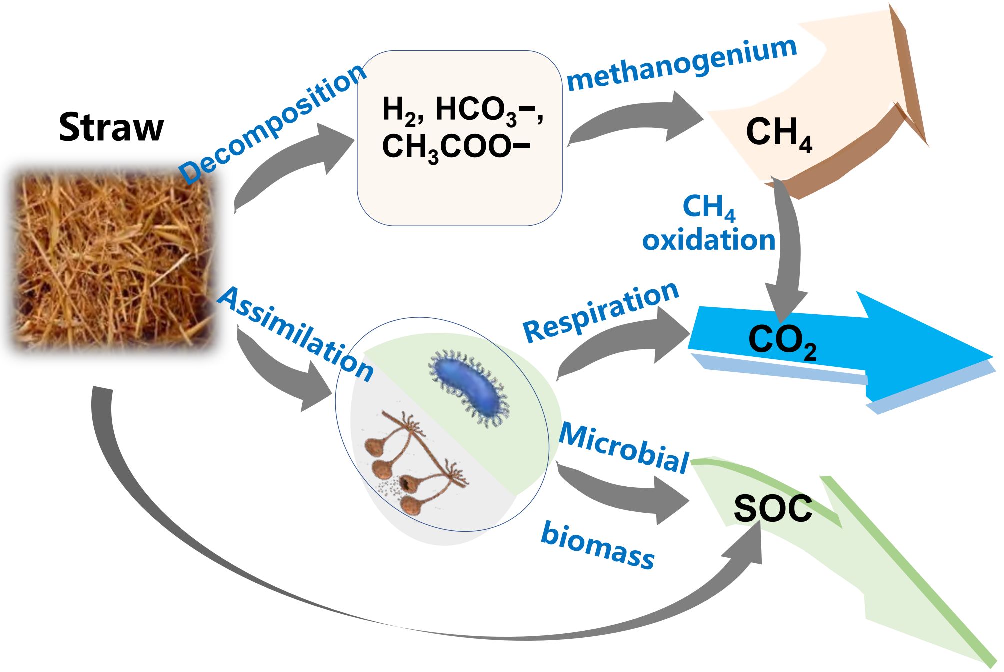


Jiang et al., 2012, SSPN



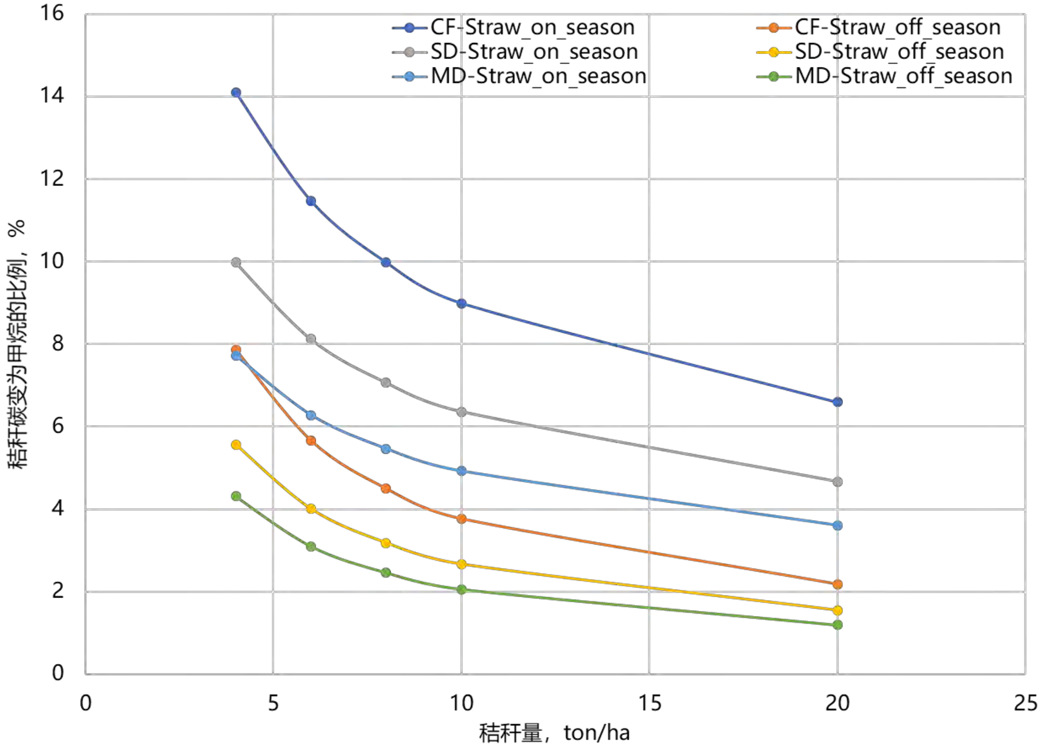
Jiang et al., 2014, GBC

Trade-off between SOC and CH_4 emissions in paddy



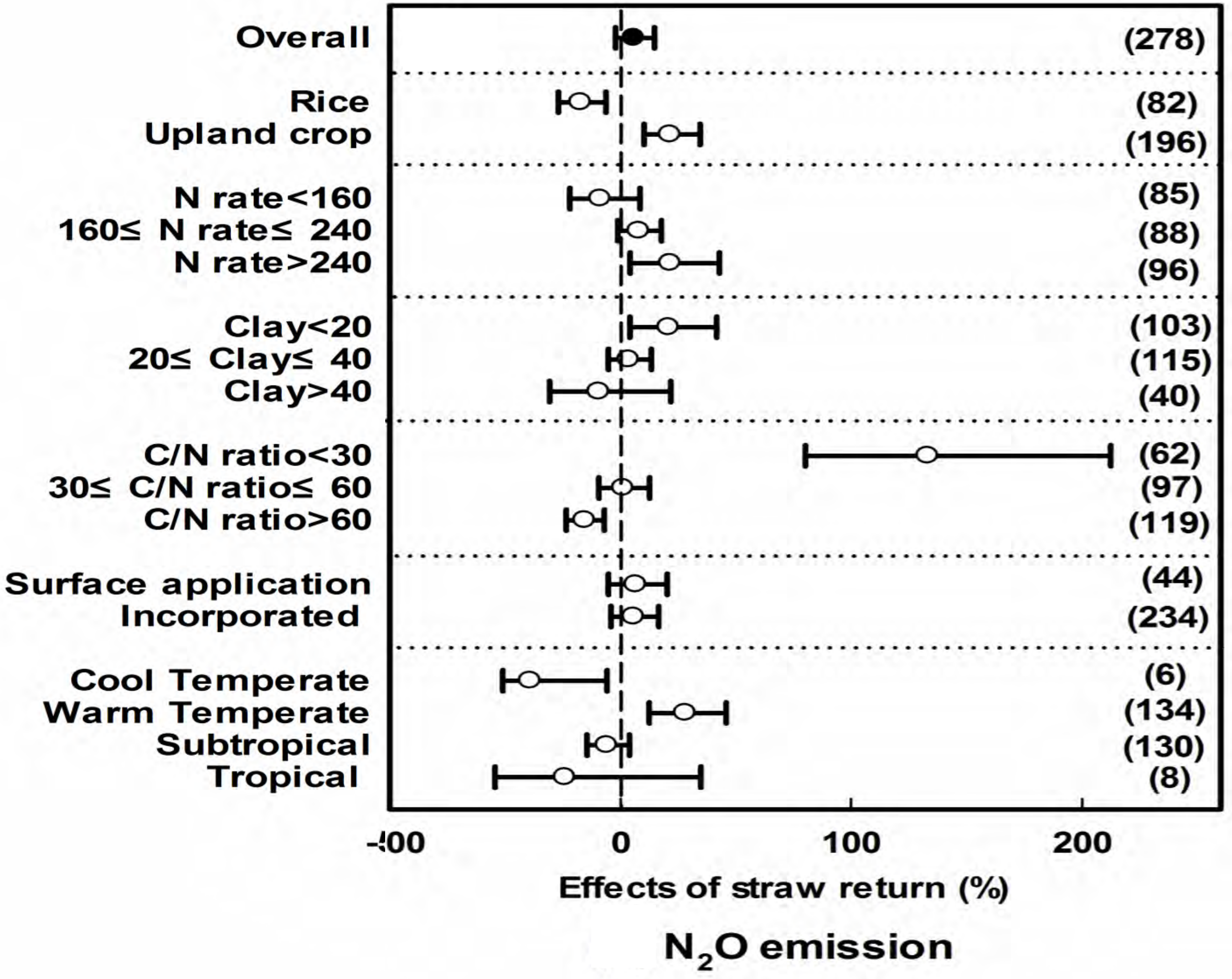
Proportion of straw C ends in CH_4

3-11%



- 1 kg CH_4=27 kg CO_2 in GWP
- Straw-induced CH_4 emission (kg CO_2-e) = 9.8 times SOC increase (CO_2-e)

Effects of straw on N_2O emissions



(1) Rice field: -17%

MBN +38.4%

DOC +15.4%

Denitrification($N_2O \rightarrow N_2$)

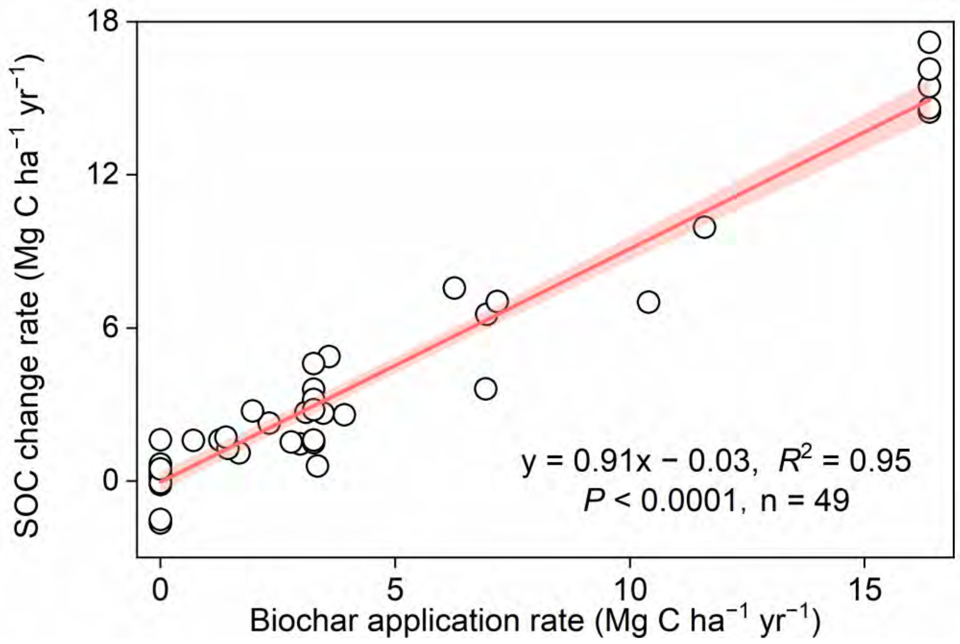
(2) Upland field: +22%

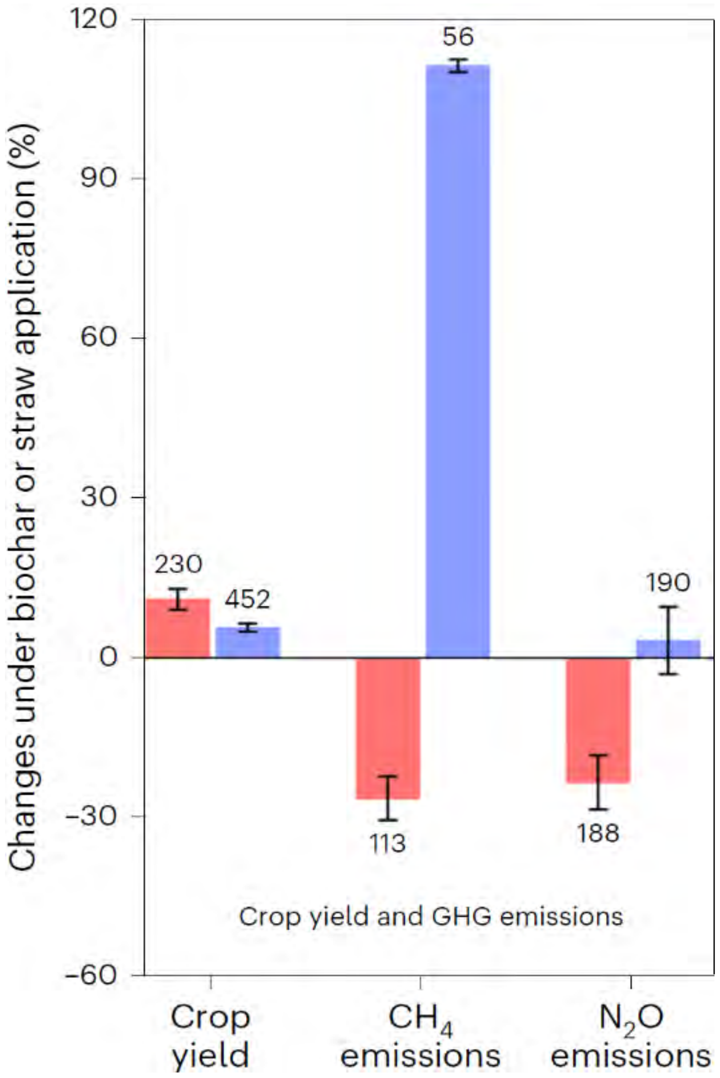
SWC +14%

DOC +24.2%

Xia et al., 2018, GCB

Effect of biochar application



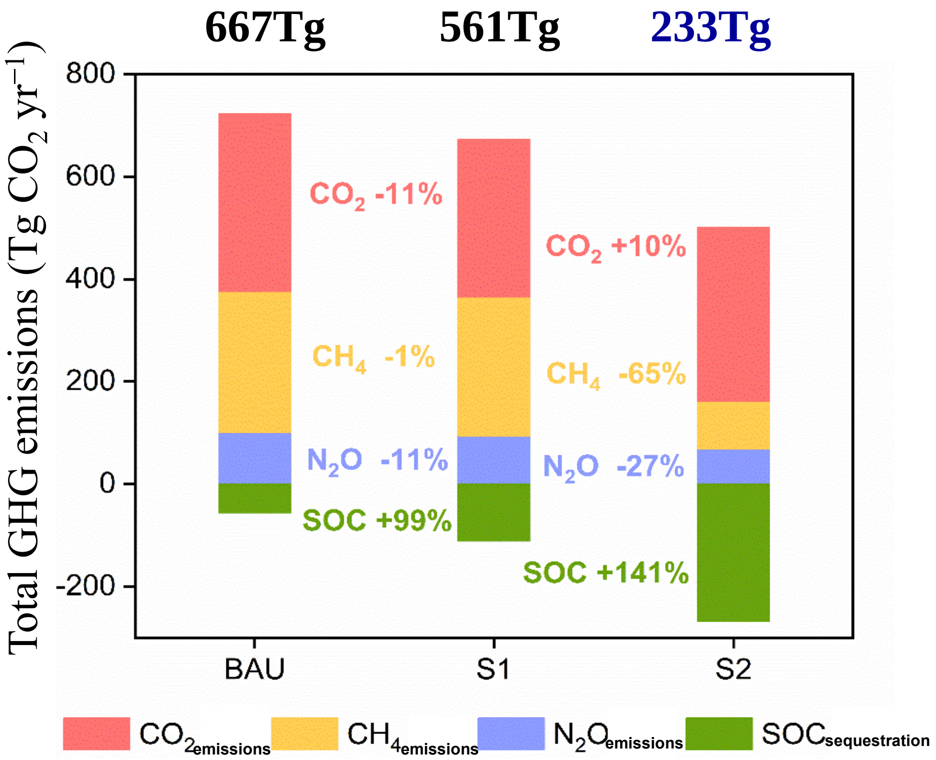


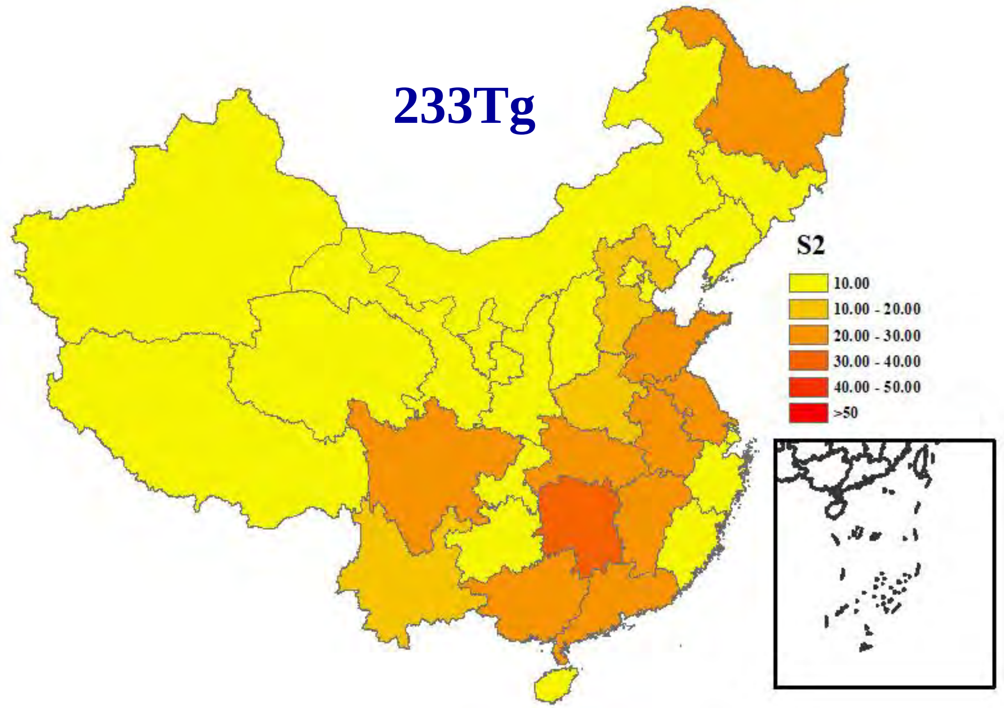
Xia et al., 2023, Nature Food

Conventional options + Biochar (S2)

- **+SOC**: Biochar application (use 82% straw)
- **-CH_4**: Intermittent irrigation, biochar
- **Optimal N use**: N rate -15% (-N_2O and -CO_2)

Provincial reduction 40~80%
Unable to achieve carbon neutral

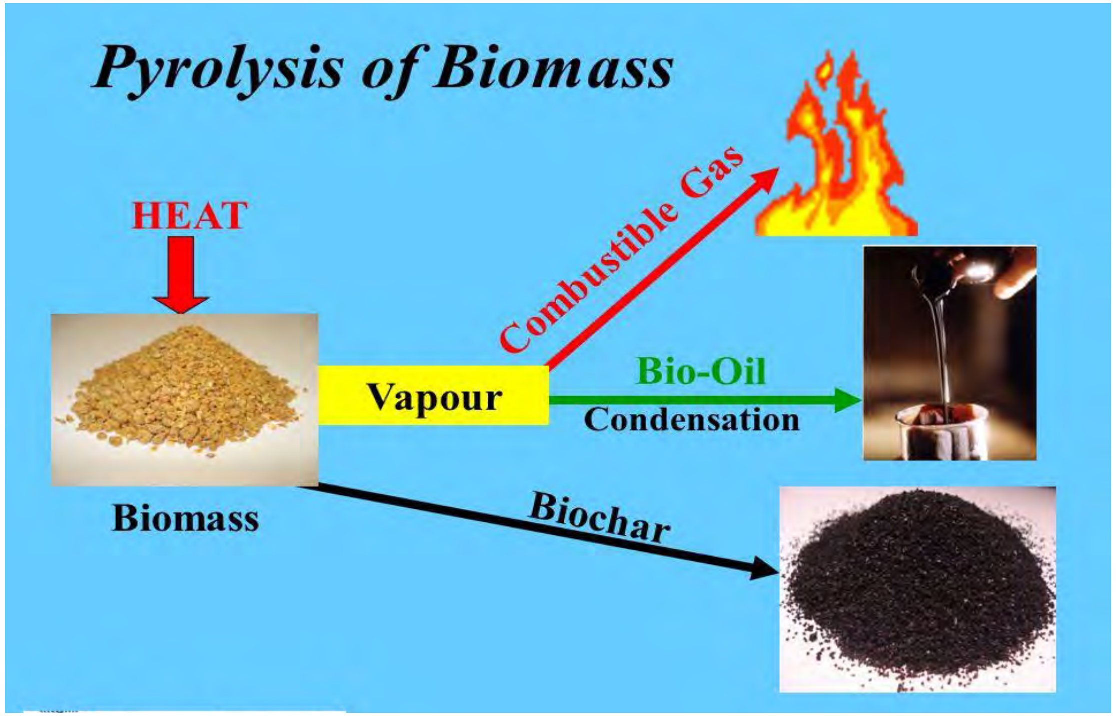




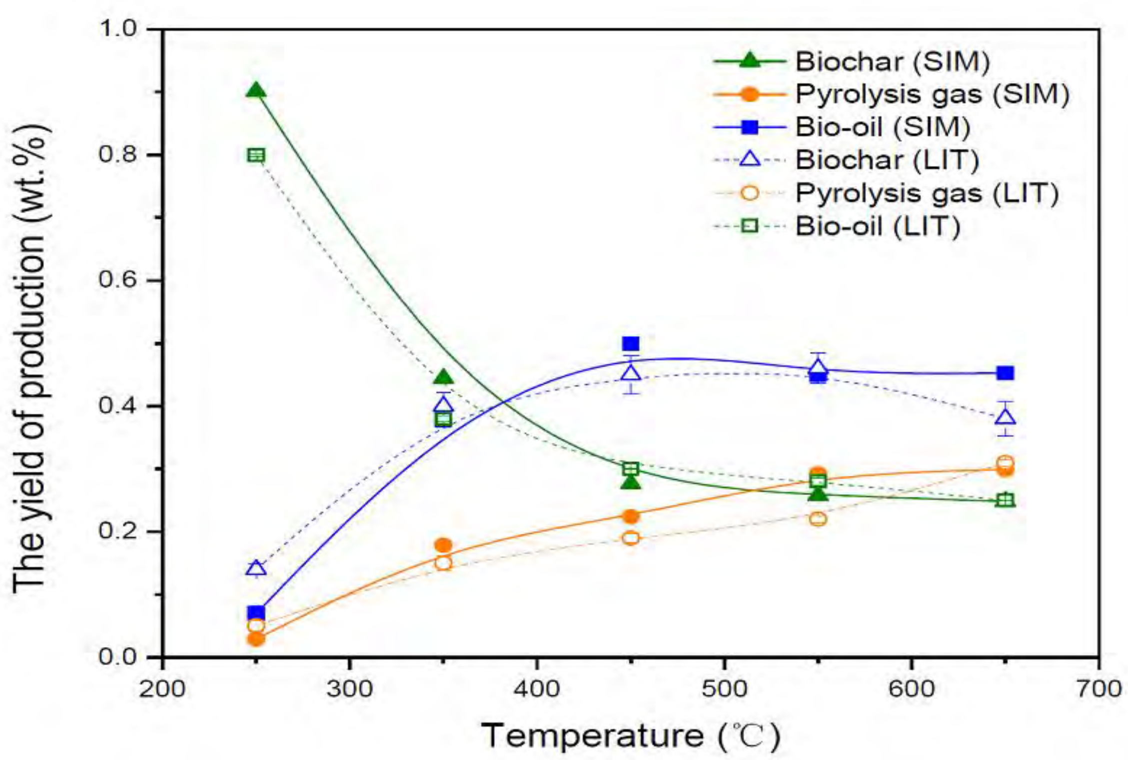
Xia et al., 2023, Nature Food

Energy substitution effect of biochar production

Using by-products (bio-oil and bio-gas) for clean energy prodution



Jouhara et al., 2017, Thermal Science and Engineering Progres



Gao et al., 2017, Energy

Energy substitution effect of biochar production

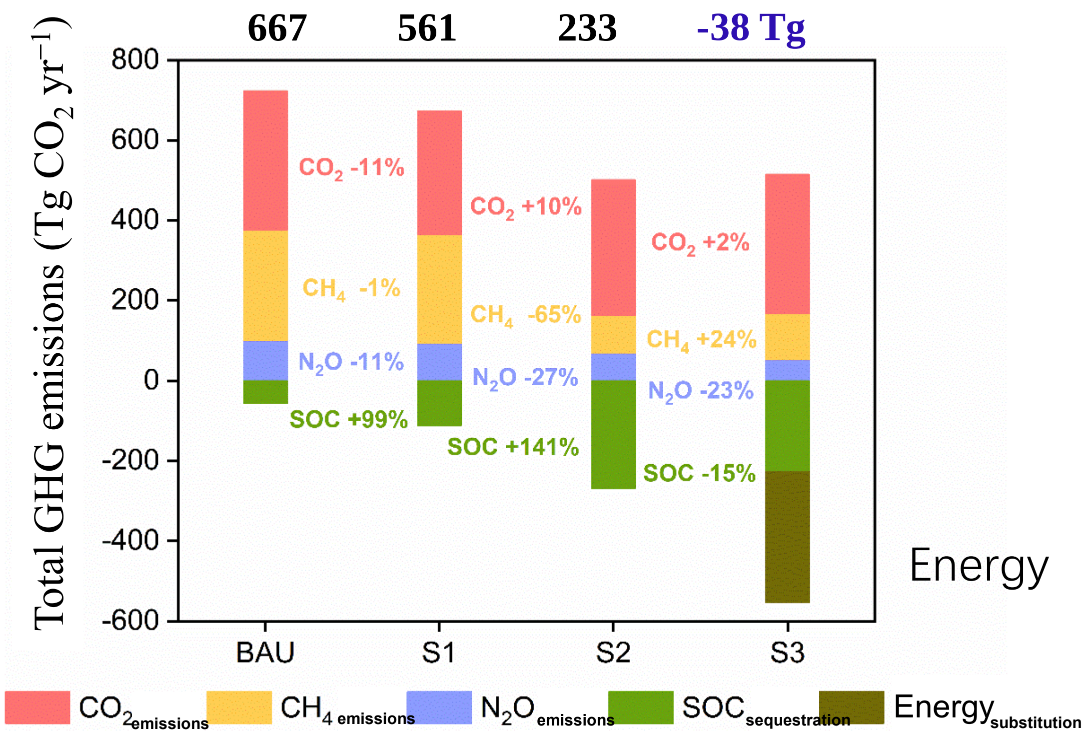
Using by-products (bio-oil and bio-gas) for clean energy prodution

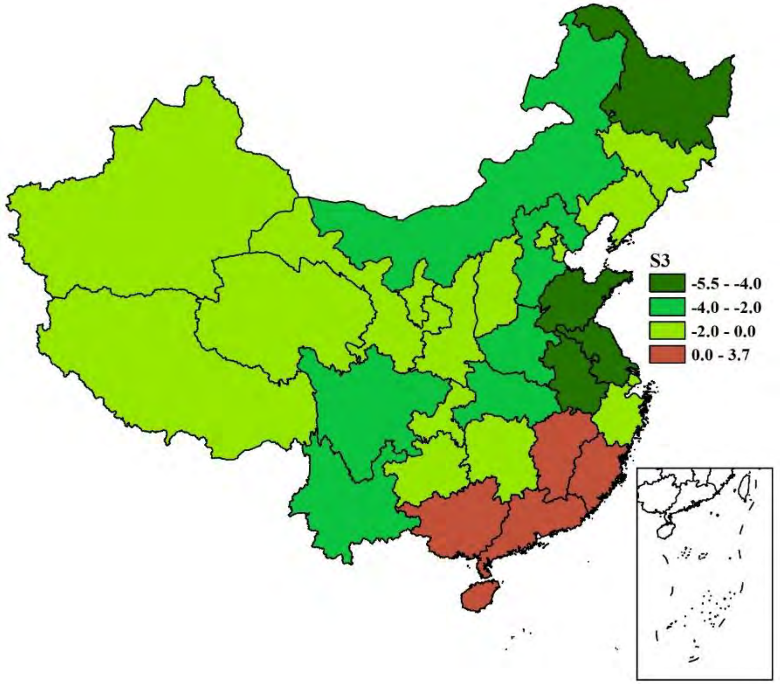
https://bioenergy-concept.com/pyrolysis/

Conventional options + Biochar + Energy substitution (S3)

- **+SOC**： Biochar application (use 72% straw)
- **Energy substitution**: -CO_2
- **-CH_4**： Intermittent irrigation, biochar
- **Optimal N use**： N rate -15% （-N_2O and -CO_2)

Provincial reduction 95~118%
Achieved carbon neutral





Xia et al., 2023, Nature Food

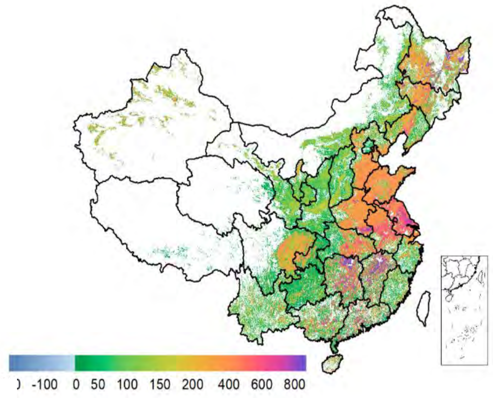
Summary

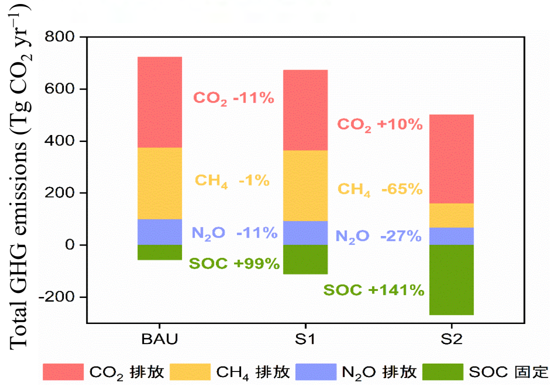
- **Staple crop production is an important and steady sector of GHG emissions, with CH_4 from rice paddy the dominant source.**

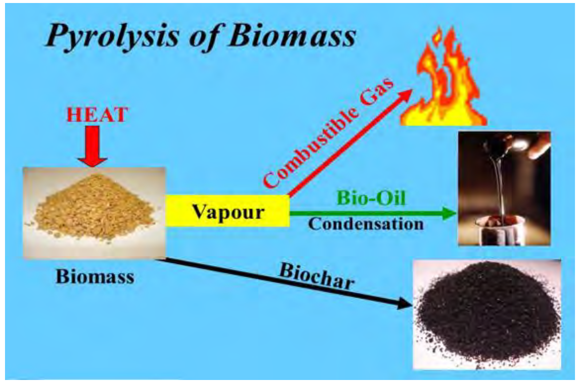
- **Conventional mitigation options can largely reduce GHG emissions, but not sufficient to achieve carbon neutrality, due to the trade-off relationship between GHG emissions and SOC sequestration resulting from crop straw return.**

- **Straw-derived biochar application coupled with energy capture has the potential to achieve carbon neutrality for staple food production in China.**

- **Constrains include: technology to capture and store energy, market mechanisms to adopt low carbon practices in agriculture, MRV methodologies.**








Thank you