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Nitrate leaching and soil N_2O emission and the responses to different N management options in a rainfed wheat-maize rotation system, southwest China

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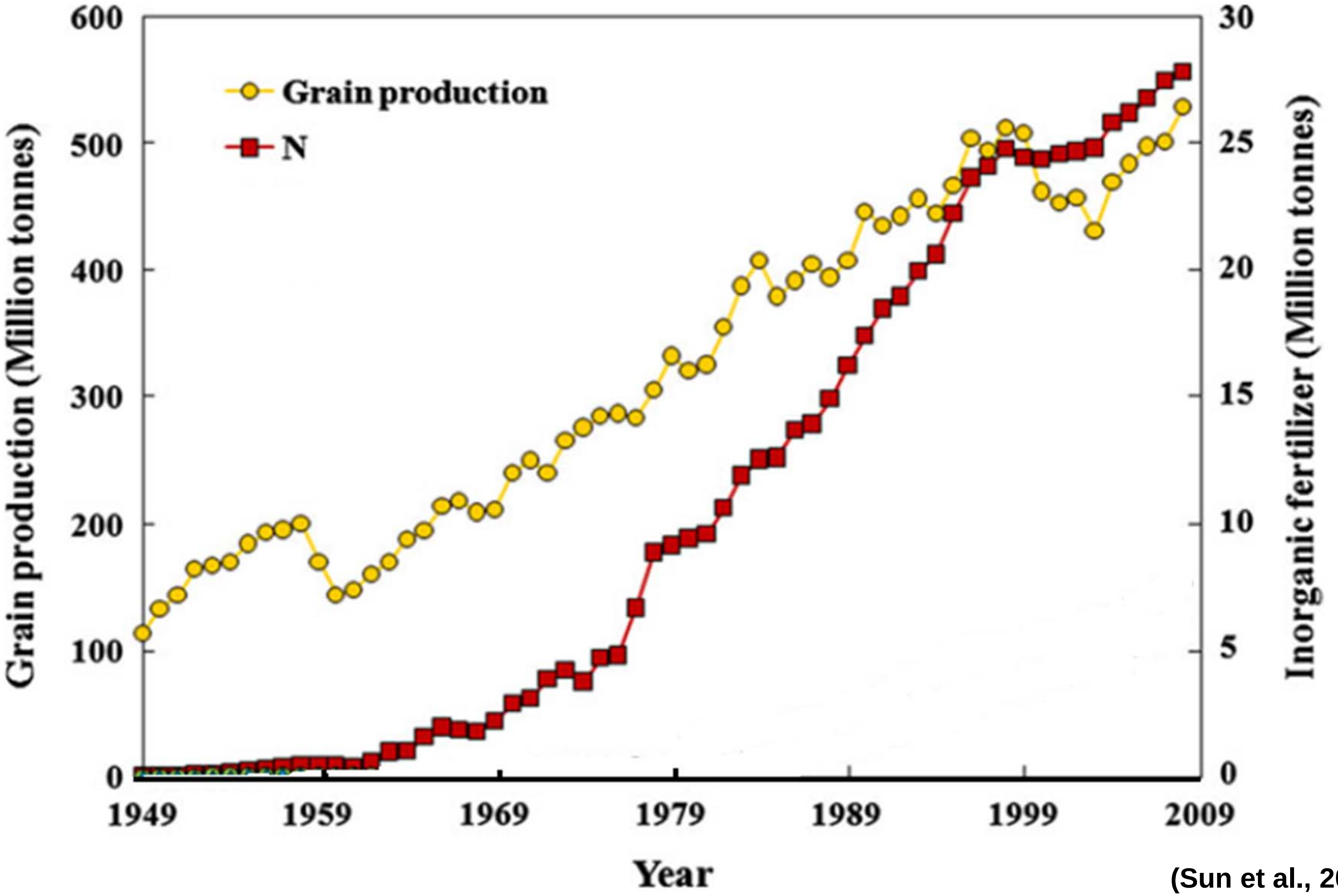
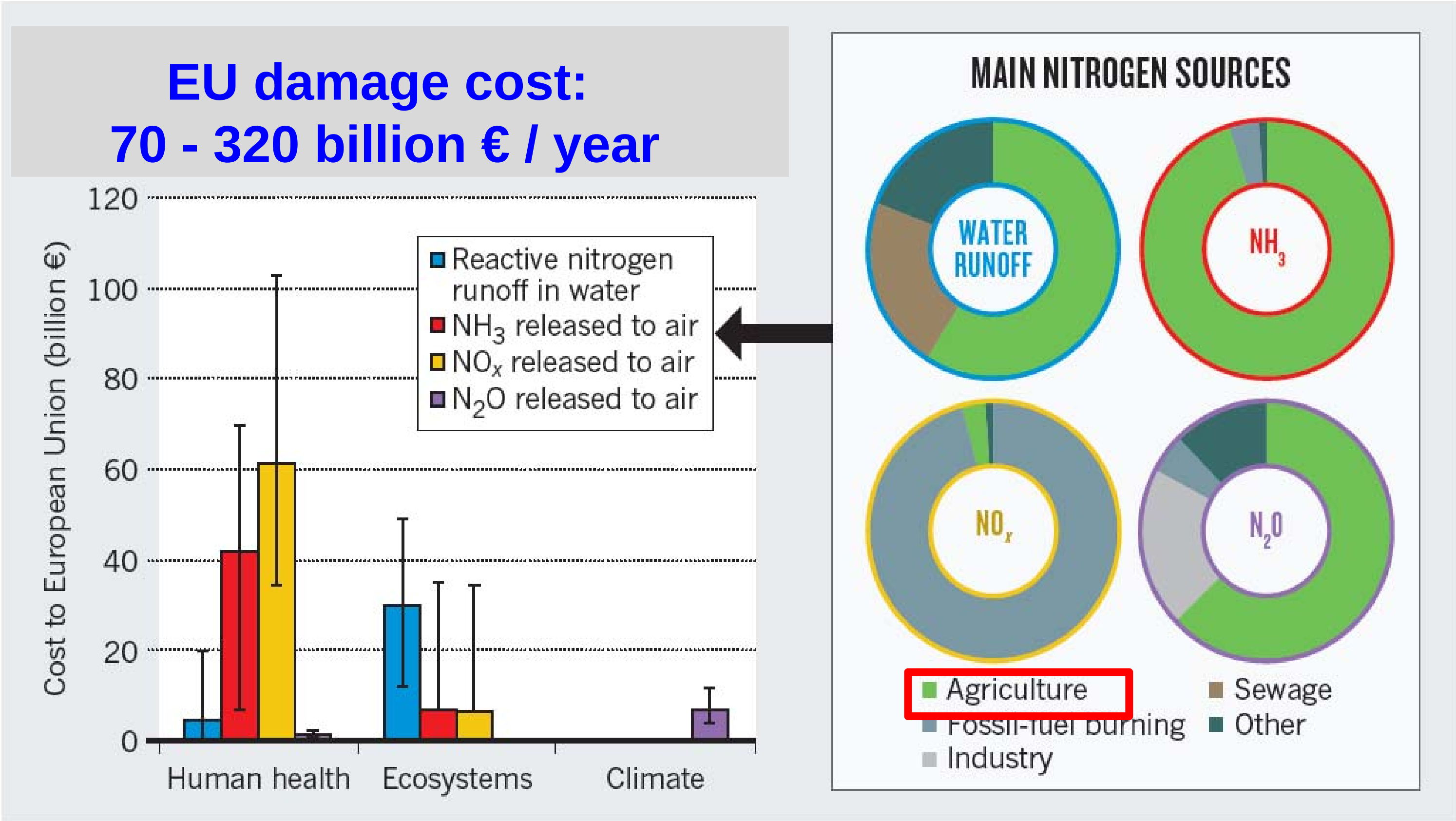
High grain production in China depends on high nitrogen input



(Sun et al., 2012, AMBIO)

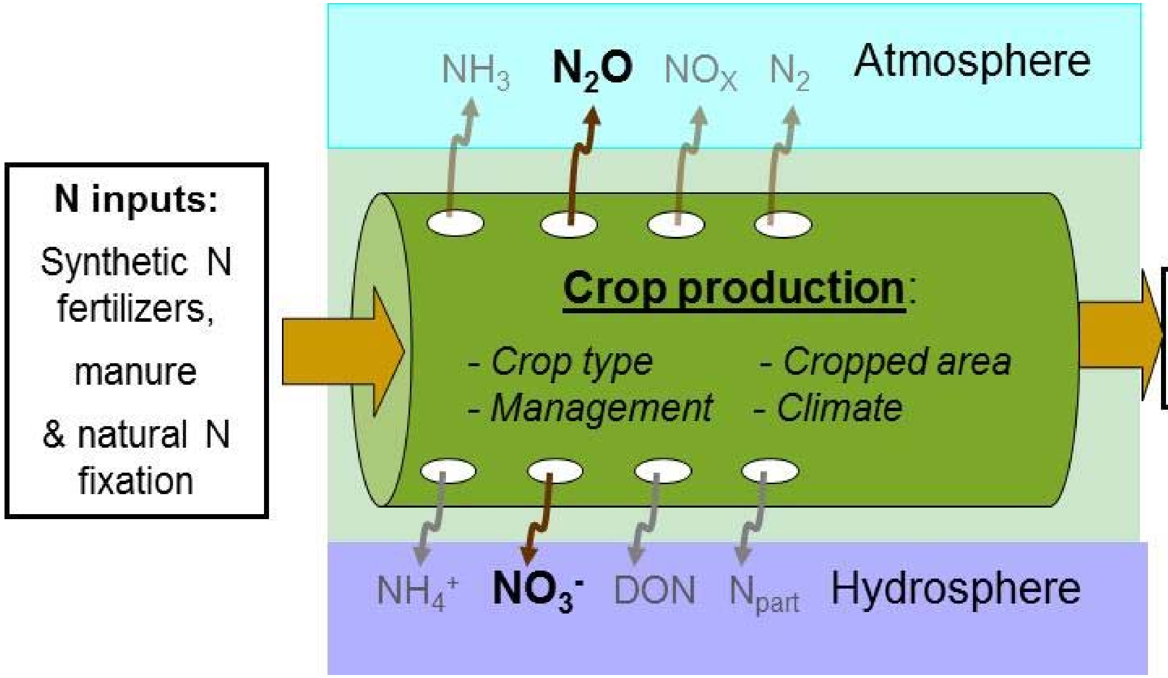
Damage costs & sources of N pollution



(Sutton et al. *Nature* 2011)

Agriculture has contributed to the major sources of N pollution and incurred substantial environmental costs

N – A very leaky element



China~ 30% (Zhang et al. 2007)

World ~47% (Galloway et al. 2002)

(Oenema et al. 2009, AGEE)

- **RQ1. How much NO_3^- leaching and N_2O emission are simultaneously lost from Chinese agricultural landscapes?**

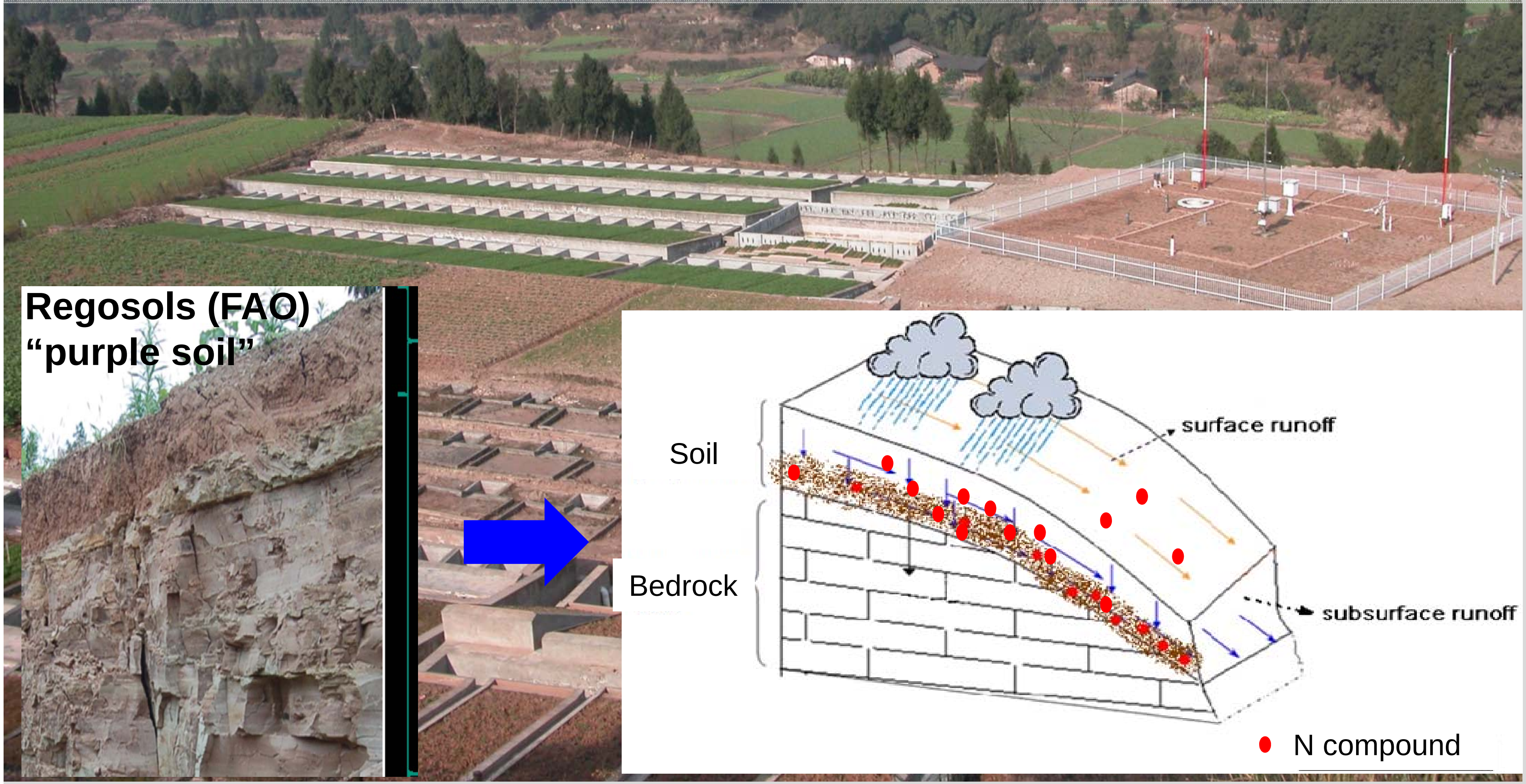
- **RQ2. Can a given N management practice simultaneously reduce NO_3^- leaching and N_2O emissions?**

Study region

Sichuan province:
7% of national cropland
10% of national production

Yanting Agro-Ecological Station of Purple Soil (CAS)

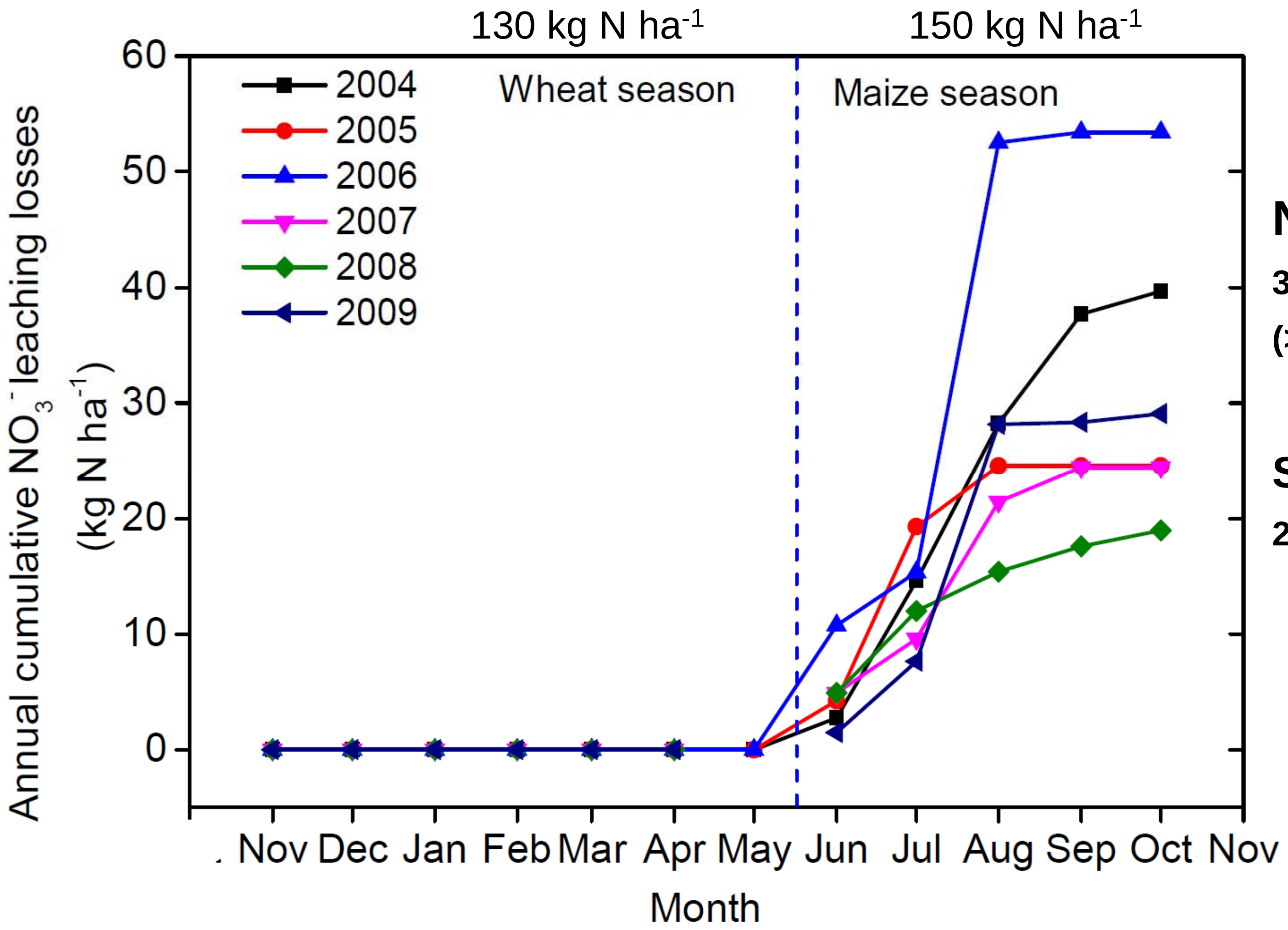
- Hilly landscape
- Rainfed agriculture
- Winter wheat-summer maize rotation (on sloping cropland)
- Subtropical climate – pronounced seasonality of precipitation (mean=826mm)



Large free-drain field lysimeters (area: 4m × 8m)

- Multi-year field measurements
- Multi-factorial experiments

NO_3^- leaching loss



NO_3^- leaching:

32.8 (19.0-53.4) kg N ha^{-1}

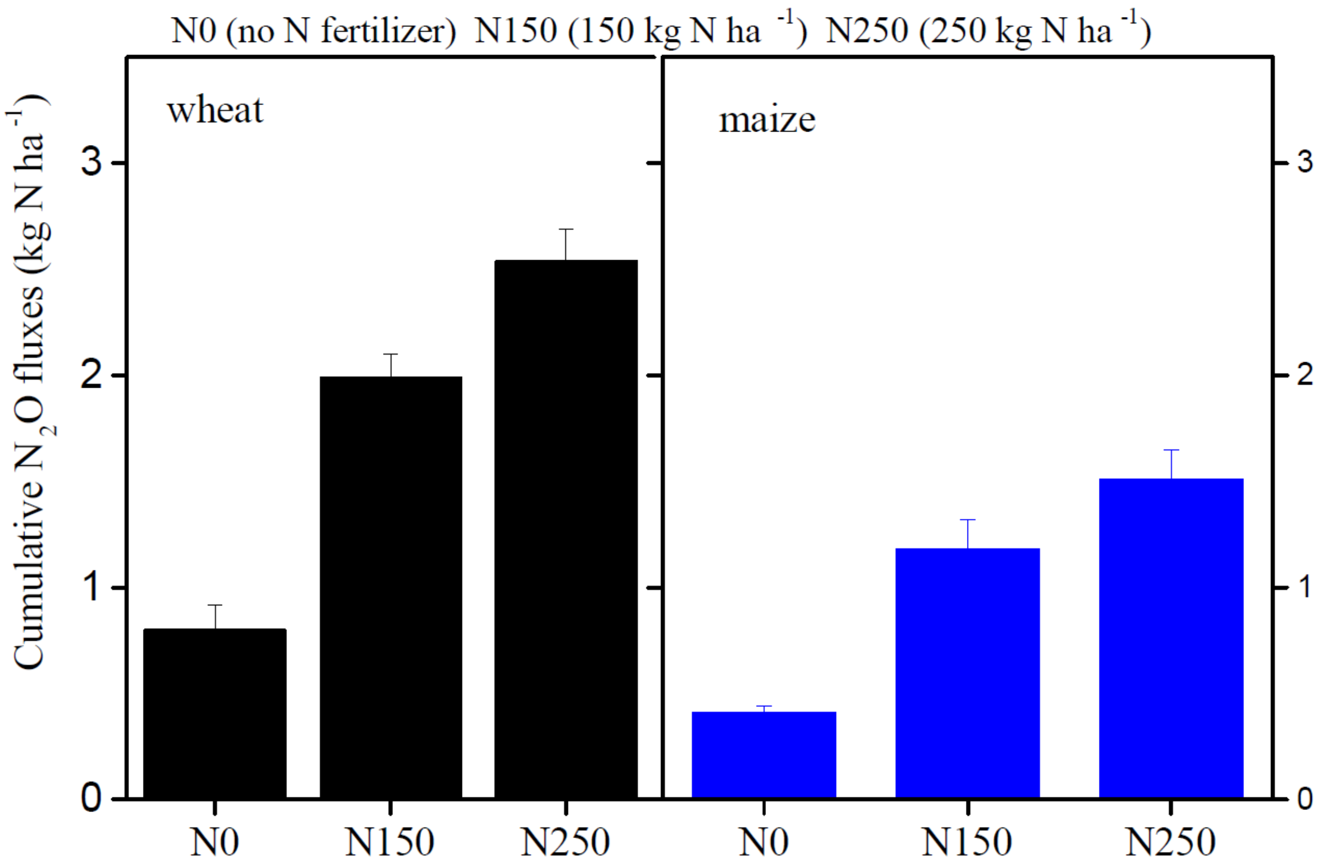
(>20% of applied N)

Surface runoff:

2.6 (0.7-8.5) kg N ha^{-1}

(Zhou et al., 2012 *Environ. Pollut.*)

Seasonal N_2O fluxes

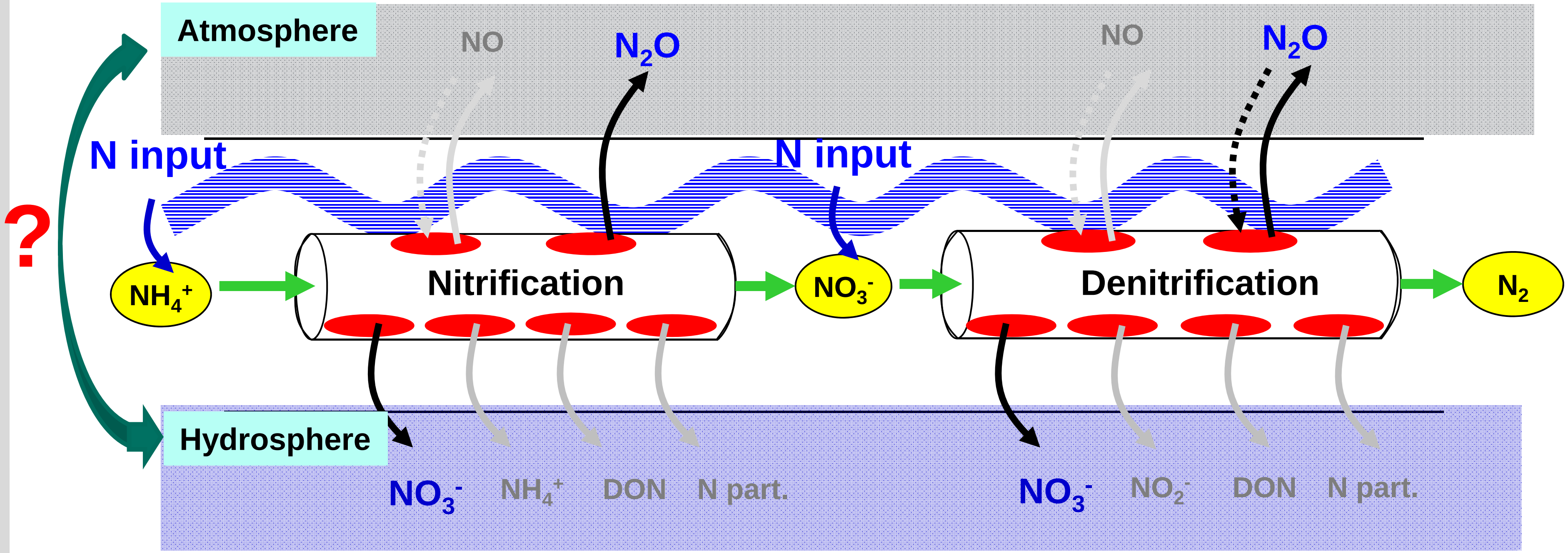


(Zhou et al., 2013 *Plant Soil*)

- **Direct N_2O emission factors (EF_d):**
  - the fraction of N fertilizer input released as N_2O
  - wheat: 0.74% (0.25-1.06%); maize: 0.48% (0.12- 0.72%)
  - wheat (dry & cold) > maize (warmer & wetter)

Conceptual model of N_2O emission

The "holes in the pipe" model (modified by Davidson et al 1993, 2000)

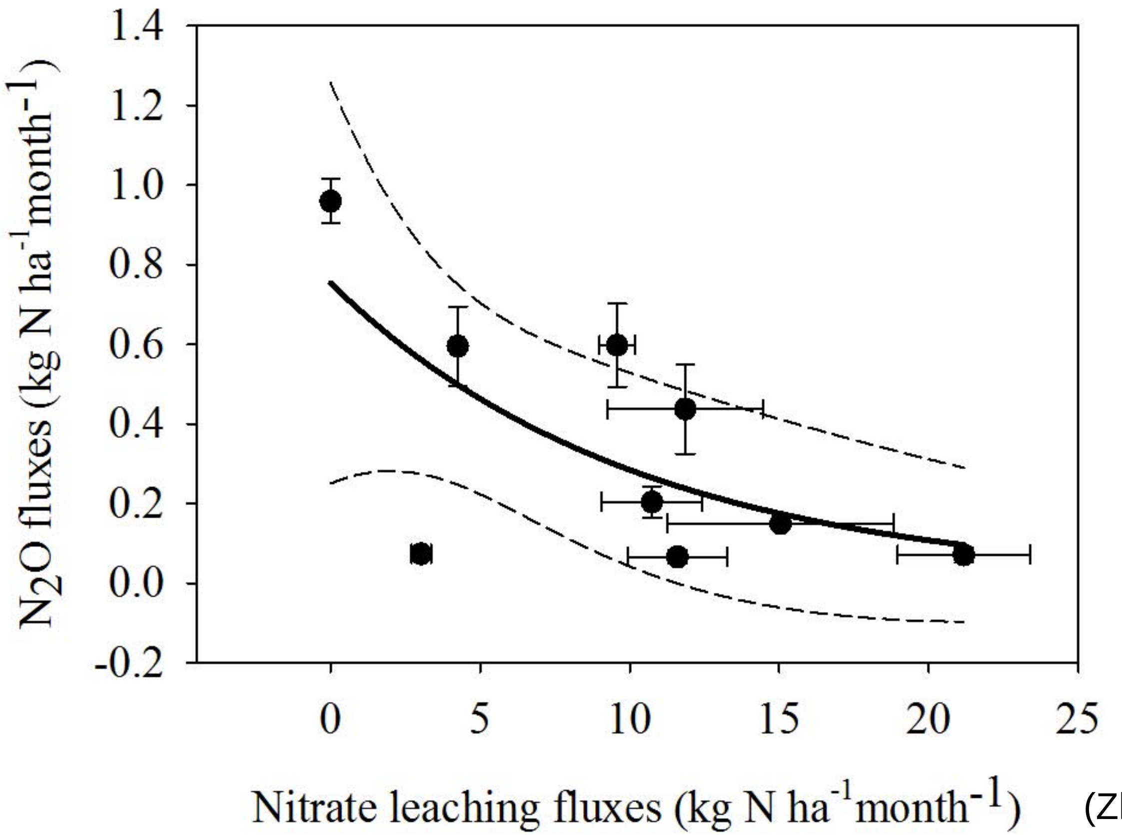


Soil N_2O emission =

Mass flow through the pipes & size of the holes

Hydrological N losses through the holes (e.g. **NO_3^- leaching**)

NO_3^- leaching and N_2O emission is interrelated

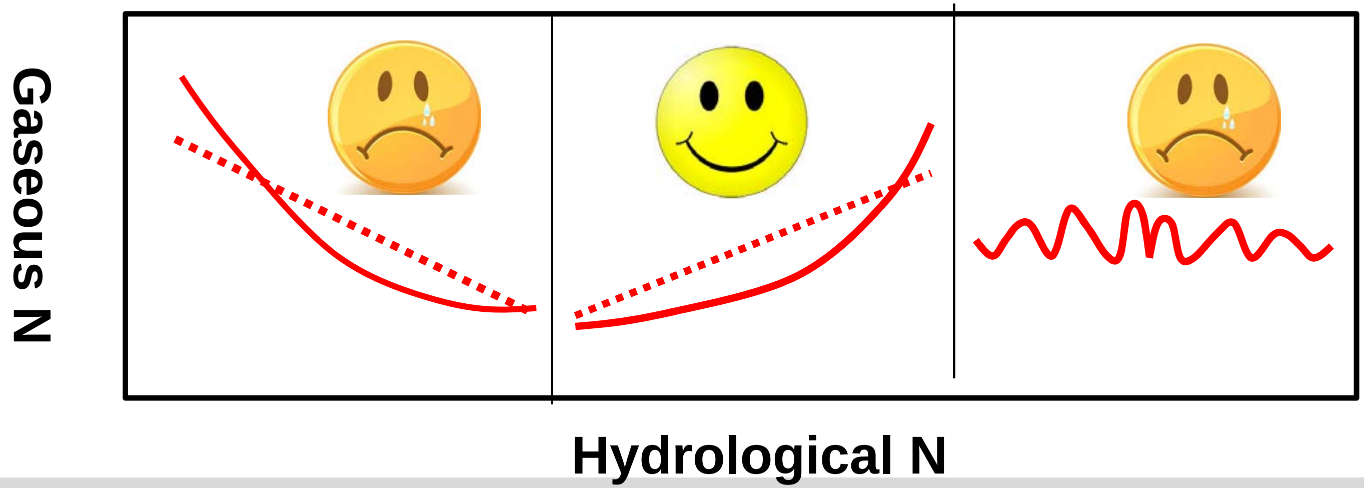


(Zhou et al., 2013 *Plant Soil*)

- **Pollution swapping, i.e. high NO_3^- leaching loss while low N_2O emissions and vice versa**
- **Indirect N_2O emission due to NO_3^- leaching: 0.26 kg N ha^{-1} (= 16% of direct N_2O emissions)**

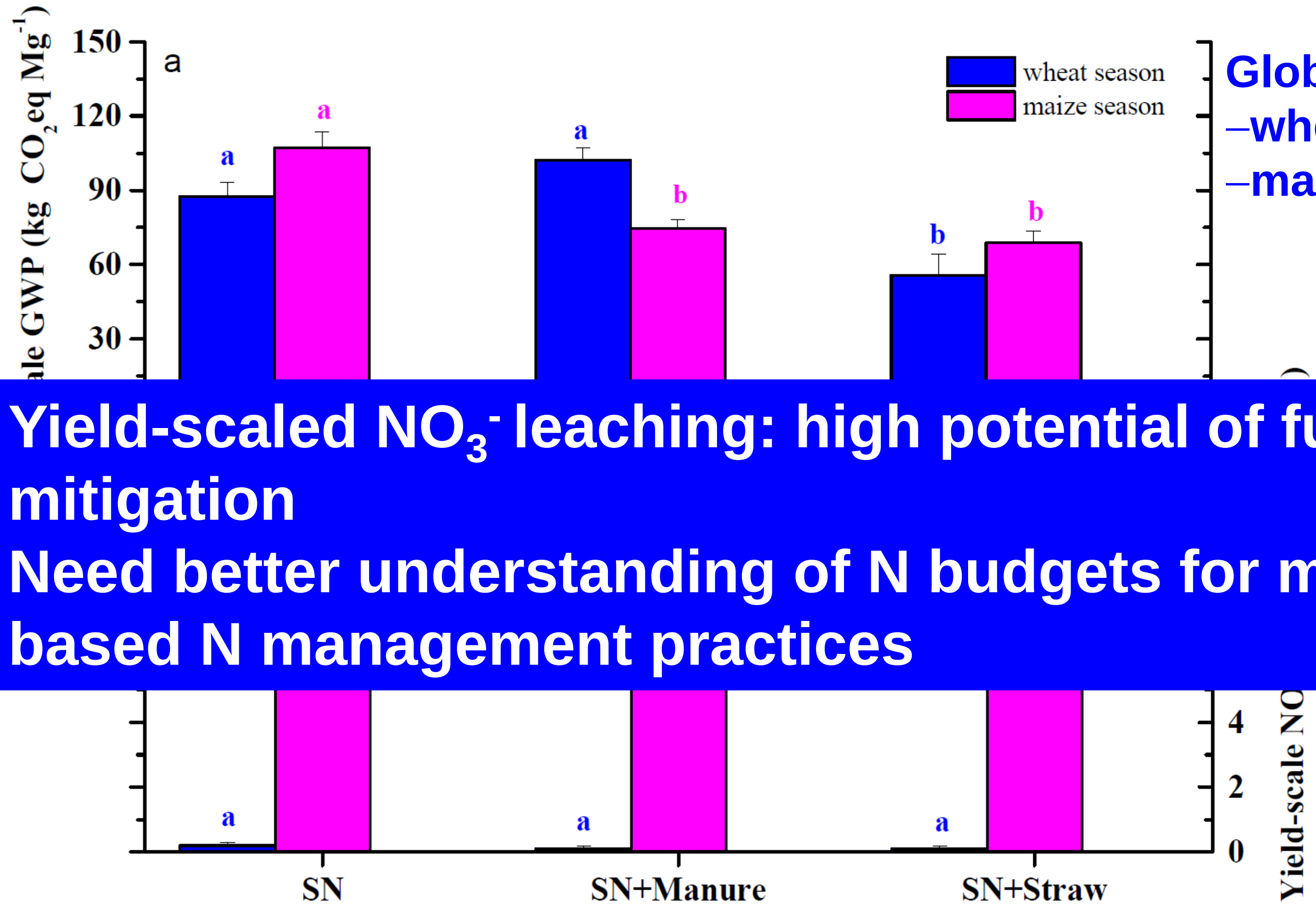
Key messages

- First time to demonstrate trade-offs between NO_3^- leaching and soil N_2O emissions
- It may be not possible to simultaneously reduce NO_3^- leaching and N_2O emissions
- Interrelationship between NO_3^- leaching and N_2O emission needs to be carefully considered



Is reduction of N application rate enough to mitigate NO_3^- leaching and N_2O emission?

- **Recommended N fertilizer application: 280-300 kg N $ha^{-1}yr^{-1}$**
- **Three different fertilizer treatments (280 kg N $ha^{-1}yr^{-1}$) plus control**
  - *100% **s**ynthetic **N** fertilizer (**SN**)*
  - *60% **s**ynthetic **N** fertilizer + 40% pig **manure** (**SN + Manure**)*
  - *60% **s**ynthetic **N** fertilizer + 40% crop **straw** (**SN + Straw**)*
- **Fertilizer applied at planting**
- **One-year measurements**
- **Yield-scaled metric applied (kg N ha^{-1} *vs.* kg N Mg^{-1} grain)**



Global mean value
–wheat:166
–maize:185

- **Yield-scaled NO_3^- leaching: high potential of further mitigation**
- **Need better understanding of N budgets for manure-based N management practices**

(Zhou et al., 2014 *Ecosystems*)

Not only amount of fertilizer but also fertilizer type matters

Conclusions

- NO_3^- leaching dominates the nitrogen loss (>20% of applied N fertilizer)
- Region-specific direct N_2O emission factors < IPCC default value
- First time to demonstrate trade-offs between NO_3^- leaching and soil N_2O emissions, which needs to be considered for proposing N management practices
- Incorporations of manure decreased yield-scaled NO_3^- leaching and soil N_2O emissions
- Large free-drain field lysimeters are reliable to measure N flows, fates and budgets

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