# Nitrogen budgets in croplands of three counties with different land-use changes over the past decades

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**Abstract**

Since 1990s, dramatic land-use changes have occurred across mainland China. Large areas of cereal lands have been converted into horticultural crops because of lucrative economic benefits. Fruits and vegetables together in China have consumed more than 30% of N fertilizers. Therefore, understanding the long-term effects of land use change from cereals to orchard on N budgets in croplands at the county scale over long-term is very important for managing N in agricultural systems in China. We selected three Counties (Luochuan (LC), Mixian (MX), and Wugong (WG)) on the Loess Plateau with different land-use changes since 1990s in Shaanxi to compare the changes of N budgets in croplands at the county scales. The main crops in the three Counties were cereals (wheat and corn) before 1990s. After 1990s, the land uses in LC and MX changed dramatically; and LC and MX become the main apple and kiwifruit production county in China, respectively. The main crops in WG are still wheat and corn. It provides an ideal reference to compare the effects of land use changes on N budgets in croplands at the county scale. The N inputs and outputs, N surplus and N use efficiency (NUE, computed as N in harvested crop products divided by N inputs) at the three Counties from 1990 to 2017 were quantified. The annual N inputs and N surplus of the three Counties since 1990s were increased, and NUE decreased significantly. Compared to WG, the annual N input and N surplus of cropland of LC and MX were very high, and NUE was very low. For example, NUE in LC decreased from 64% in 1990 to 12% in 2017; and NUE in WG decreased from 55% in 1992 to 38% in 2017. To understand the fate of surplus N in cropland of LC, we also collected soil profile samples (0-6 m) from cereal lands and apple orchards in different sites of the county. The average nitrate accumulation in 0–6 m soil profiles reached 5611 kg N/ha in 2017. Approximately 67% of the total N surpluses in LC from 1990 to 2017 was accumulated in soil profile as nitrate. Land use change from cereals to orchard result in high surplus N in croplands at the county scale. The nitrate accumulation in the vadose zone is the main fate of surplus N in the intensive agricultural landscape, which should be considered an important component of the soil N budget to optimize production and environmental protection.

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# Outlines

1. Background
2. Study methods
3. Results
4. Conclusions

# 1. Background

Agricultural miracle in China since 1978:

feeding our huge population with only ~9% of global arable land.

Expensive costs:

High inputs of chemicals and other resources, e.g., consumption more than 30% of N fertilizers in the world.

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Fig 1. Changes of different agricultural products in China since 1978

# Land use change in China: cereals to horticultural crops.

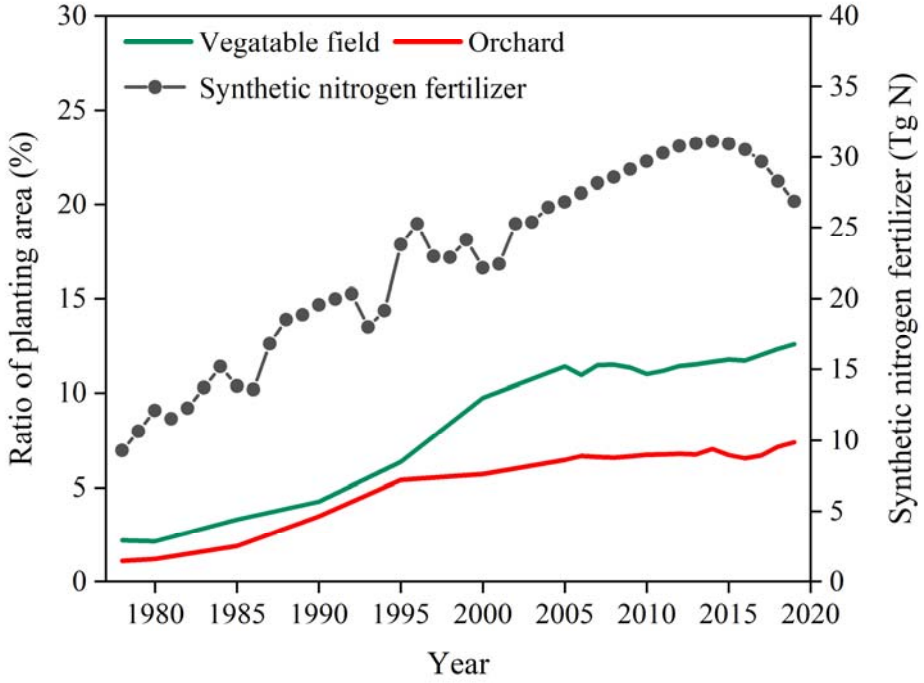
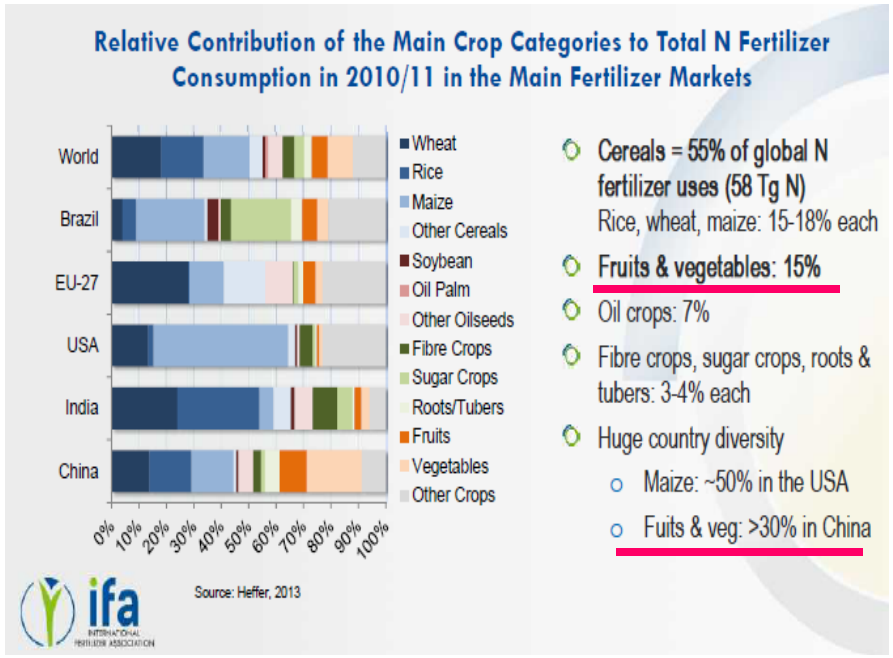



Fig 2. Percentages of vegetable crops and orchard, and use of N fertilizers in China since 1978

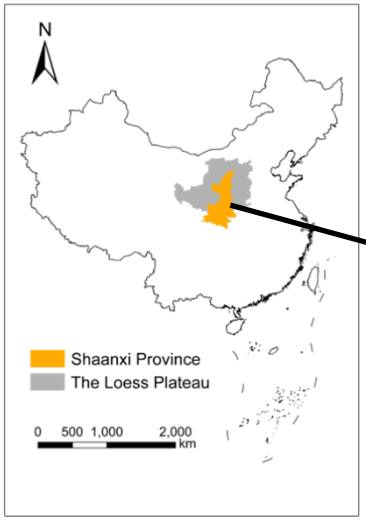


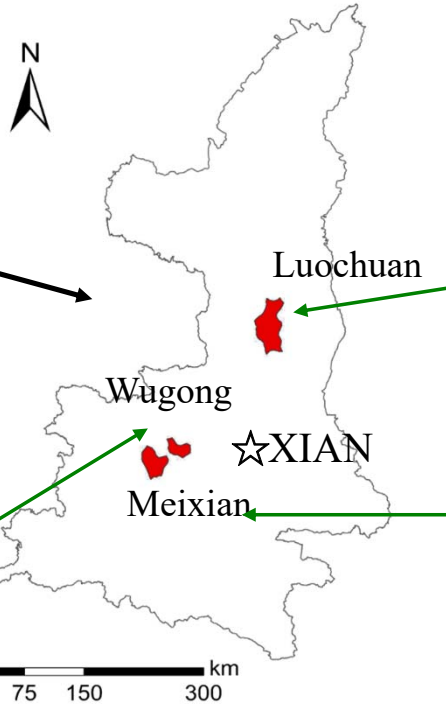

**Heffer P. 7th International Nitrogen Initiative Conference, 4-8 Dec 2016, Melbourne**

Understanding the long-term effects of this change on N budgets in croplands at the county scale is very important for managing N in agricultural systems.

# 2. Study sites & methods

Three counties with different land use changes on the Loess Plateau





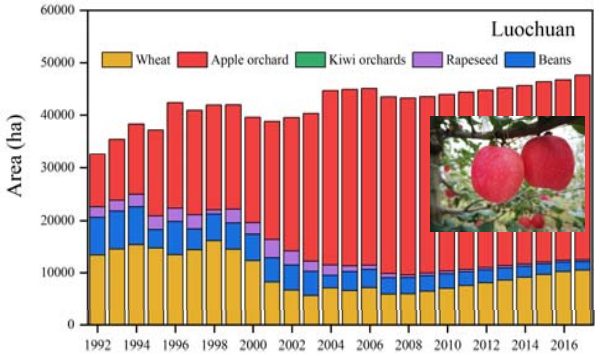
**Cereal to apple orchard (Dryland farming)**


**Cereal (irrigated)**

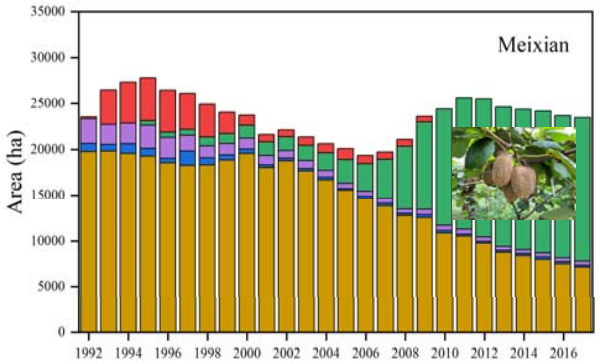

**Cereal to kiwifruit orchard (irrigated)**

# Land use changes of the three counties

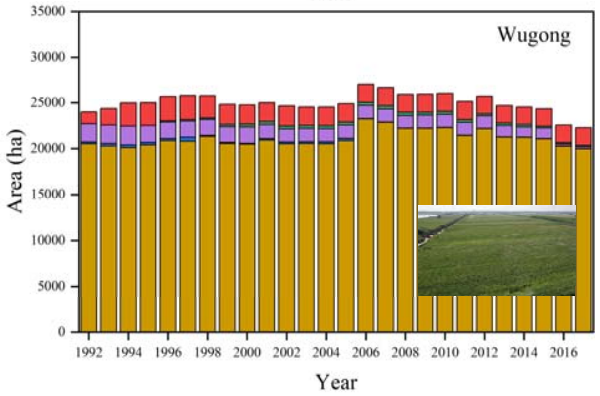
**Luochuan**




**Meixian**



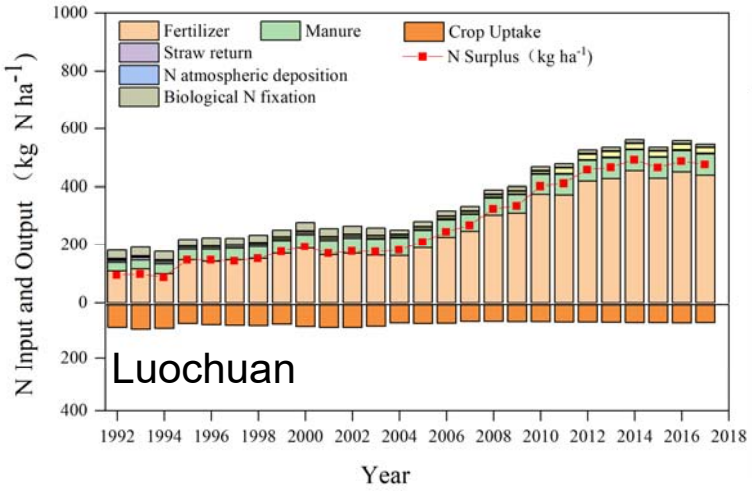

**Wugong**

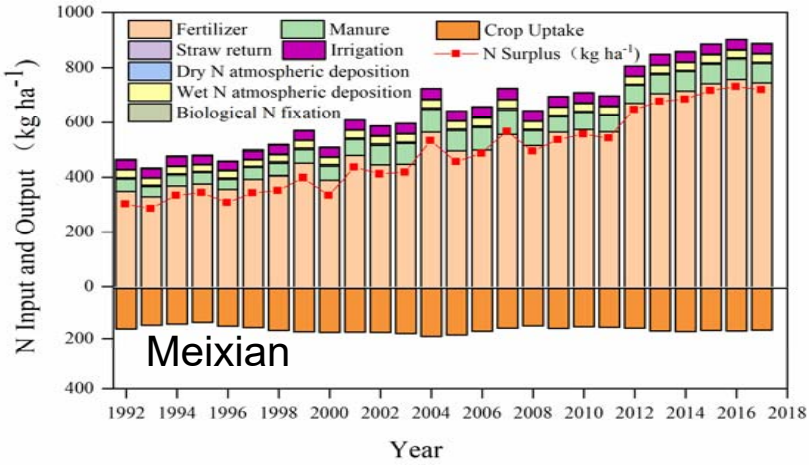



- **N budgets:**
  - **N inputs** = synthetic fertilizers + manures+ atmospheric deposition + biological fixation+ straw return
  - **N outputs** = harvested by crops + pruning of fruit trees.
  - **N surplus** = N inputs – N outputs
- **Determined the nitrate in soil profiles**

# 3. Results

## 3.1 N budgets in croplands of the county scale:



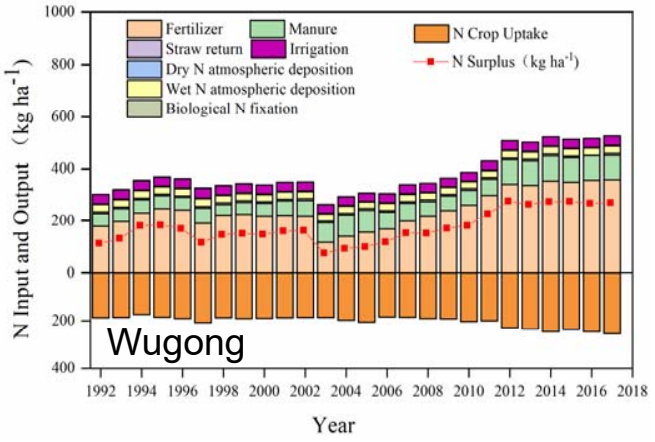




Fig 4. N budgets in croplands of three counties from 1992 to 2018

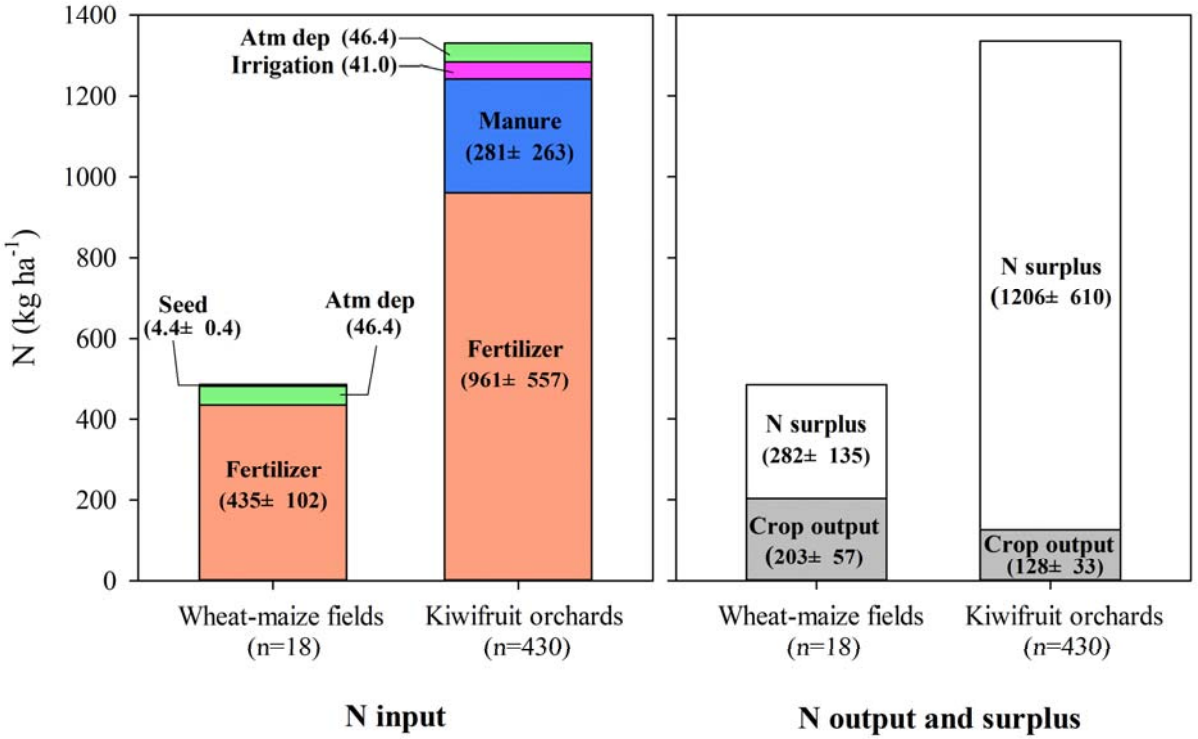
Wang Shimiao, unpublished

**N surplus (kgN/ha)**

>600 >  >400 >>  ~200

Results

# N budgets at the field scale in *Meixian*:




**N surplus (kgN/ha):**

**Kiwi-orchards = 4.2 × cereal lands**

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Figure 5 N budgets in kiwifruit orchards and cereal land of *Meixian*

# 3.2 Nitrogen use efficiency

**NUE =**

**N outputs / N inputs**

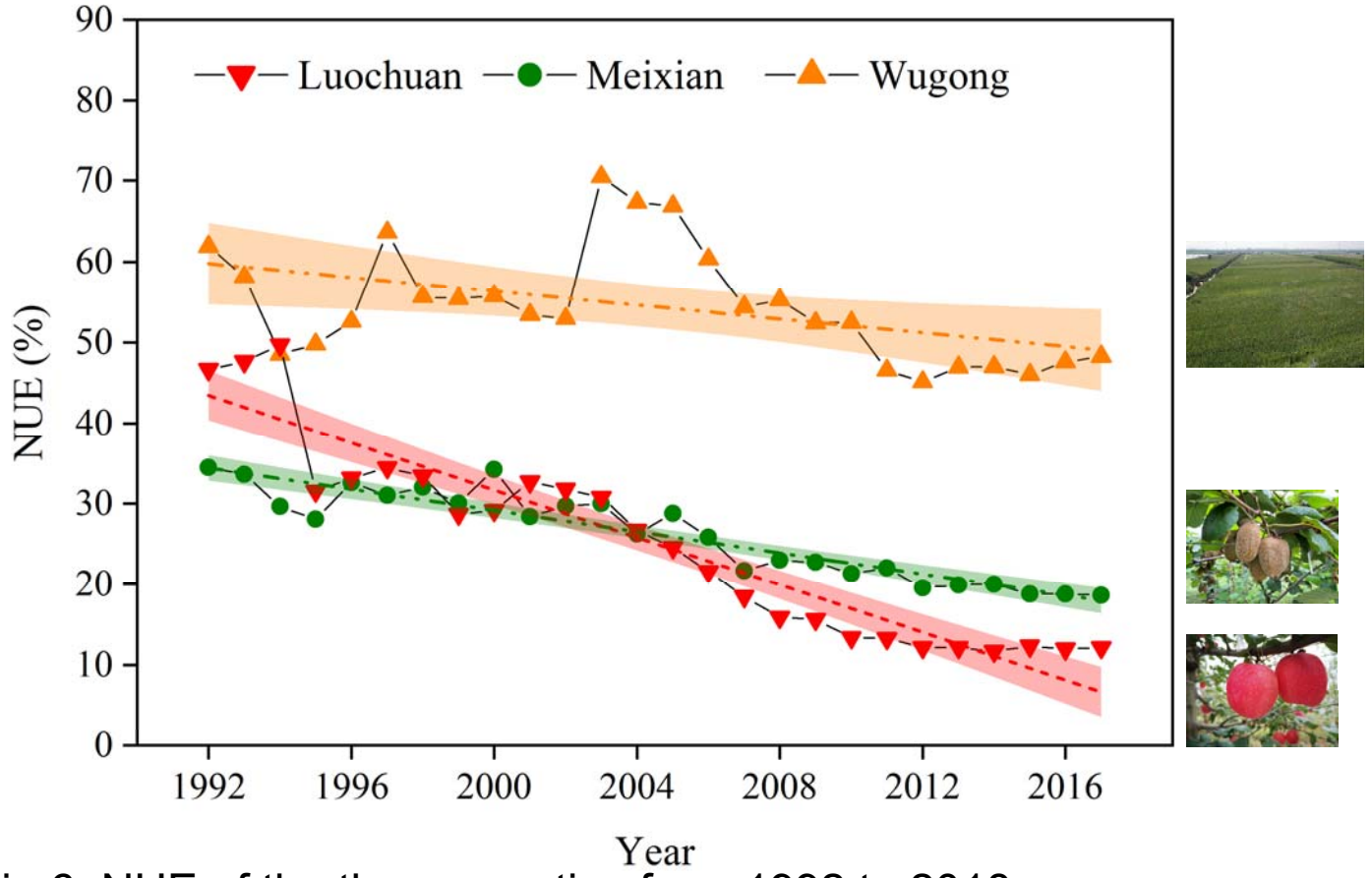
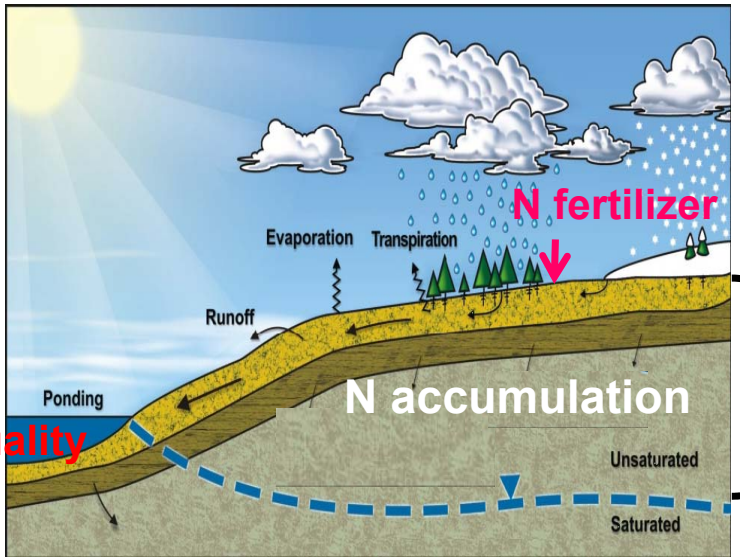



Fig 6. NUE of the three counties from 1992 to 2018

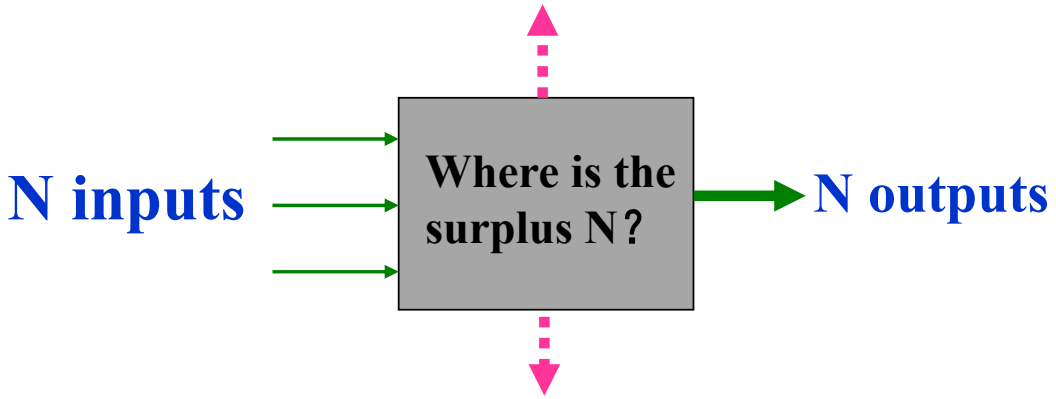
# 3.3 where is the surplus N?

- Uptake by plant
- accumulation in vadose zone
- Loss to atmosphere and aquifer




Water quality

vadose zone




- Loss to aquifer?
- Accumulation in vadose zone

Results

# The soils in the Loess Plateau have very deep vadose zone.

◆**Deep borehole method**

# Two types: irrigated *vs* dryland



**Cereal to apple orchard (Dryland farming)**

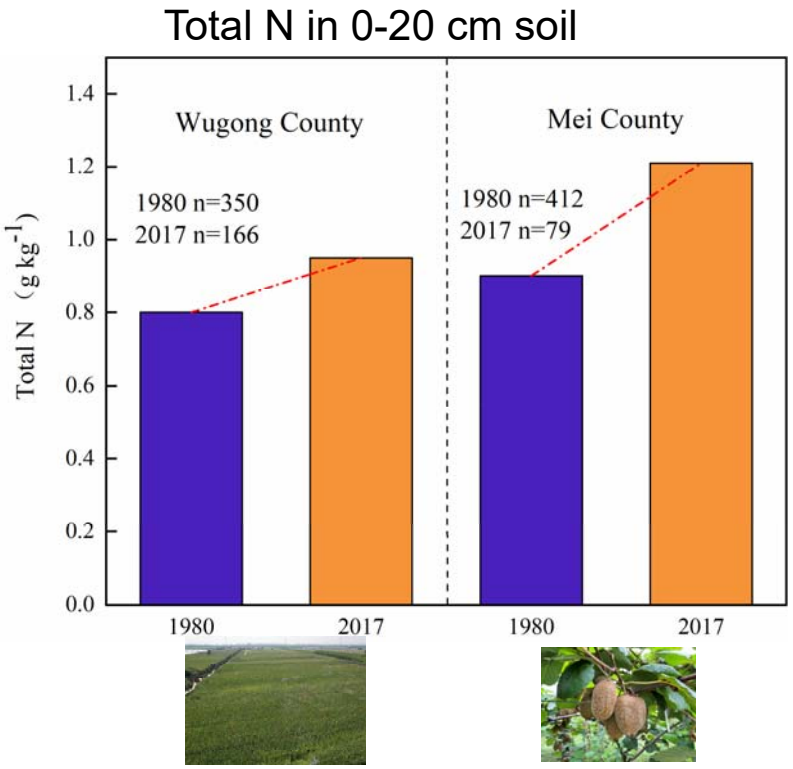

**Cereal (irrigated)**


**Cereal to kiwifruit orchard (irrigated)**

Results

# (1)Fates of surplus N in *Meixian* and *Wugong* Counties

## (Irrigated ~300 mm + rainfall ~630 mm)



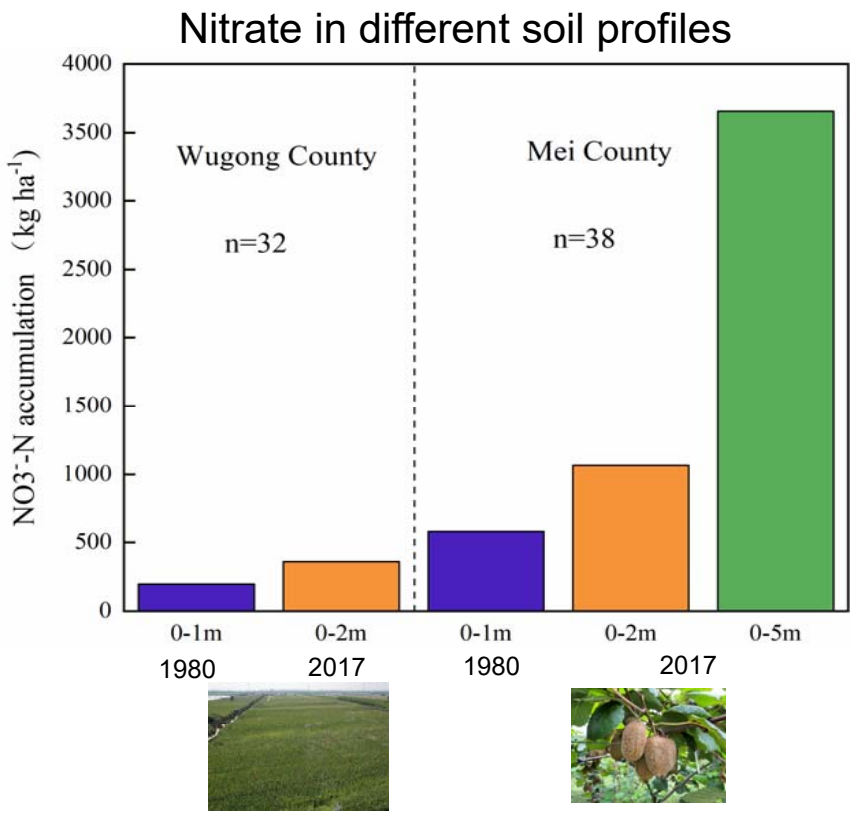
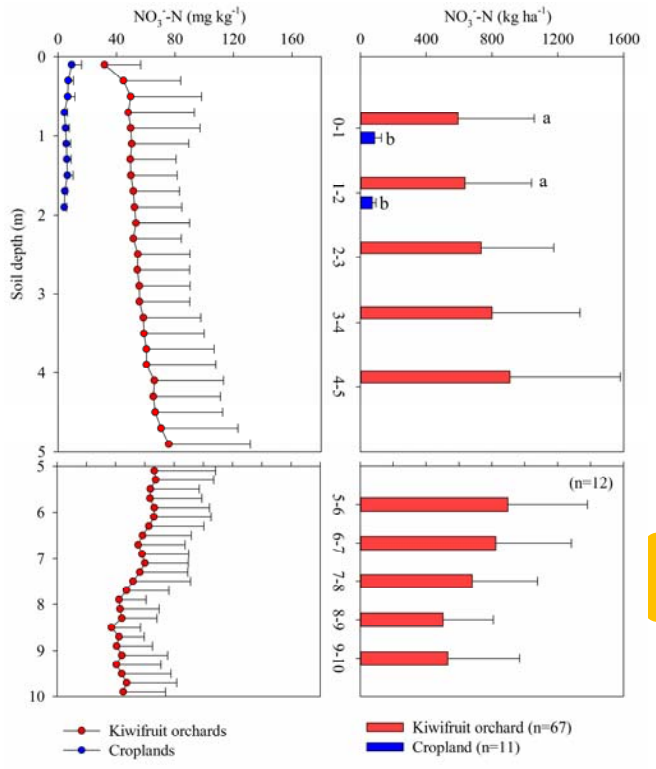




Fig7 Changes of total N and nitrate in soil profiles of *Wugong* and *Meixian* between 1980s and 2017

# High nitrate accumulation in soil profiles (0-10m)




**∑= 7113 kgN/ha**

Fig. 8 Concentration and accumulation of $NO_3^-$-N in 0-10 m soil profiles in cereal land and kiwi-orchards in *Meixian*

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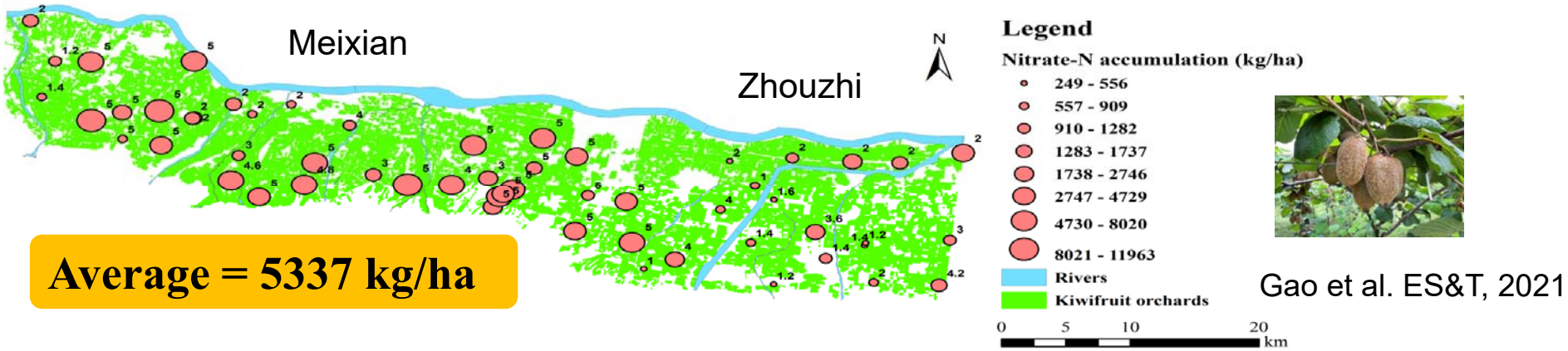
# Nitrate accumulation in soil profiles of kiwifruit belt (0-5m, n=57)




**Average = 5337 kg/ha**



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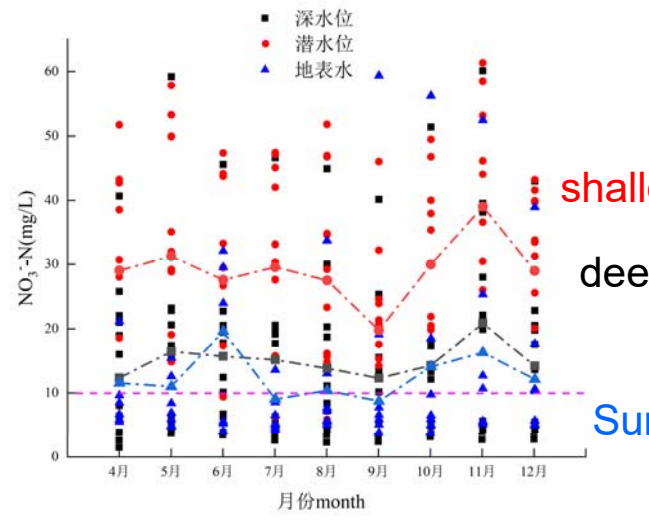
Fig 9 Nitrate accumulation in soil profiles of kiwifruit belt (0-5 m)




shallow groundwater

deep groundwater

Surface water

Fig 10 Nitrate in surface and groundwater of kiwifruit belt (mgN/L)

Total N loss to aquifer?

# (2)Fates of surplus N in *Luochuan* County

## (Dryland farming, rainfall ~600 mm)

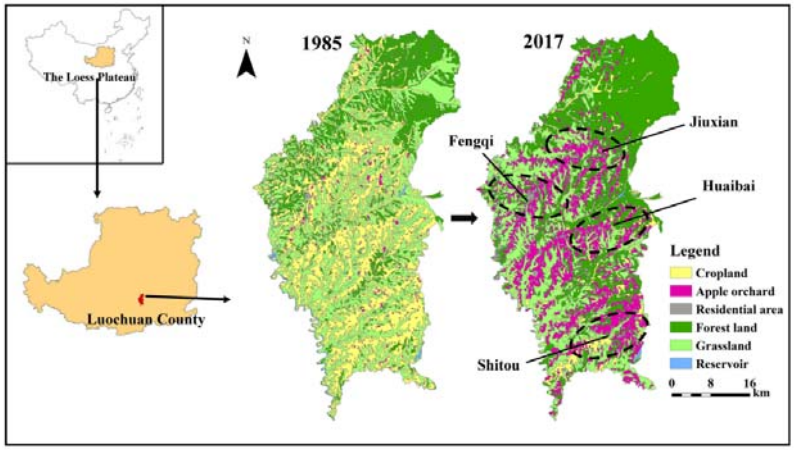



Fig 11 Land use change in 1985 and 2017 and soil sampling sites at Luochuan County

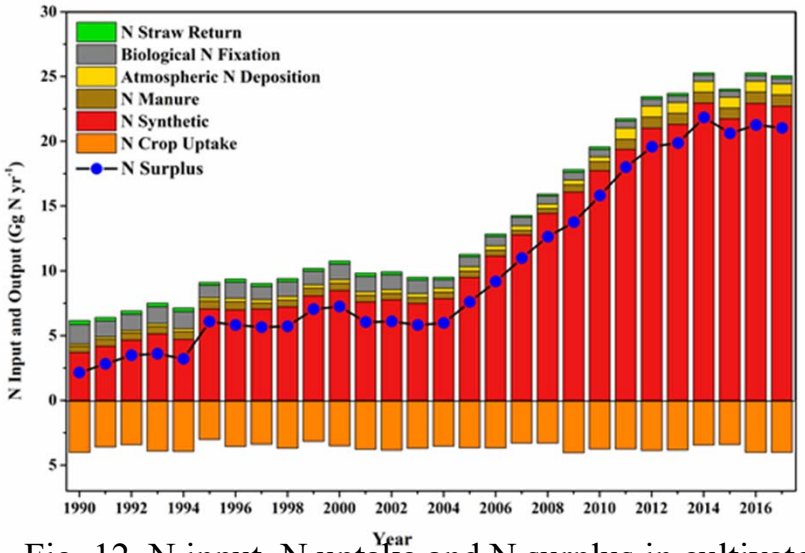



Fig. 12. N input, N uptake and N surplus in cultivated land in Luochuan County from 1990 to 2017. (Unit: Gg=$10^9$ g).

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The evapotranspiration is higher than rainfall, results in water deficit in deeper soil profiles of the old apple orchards

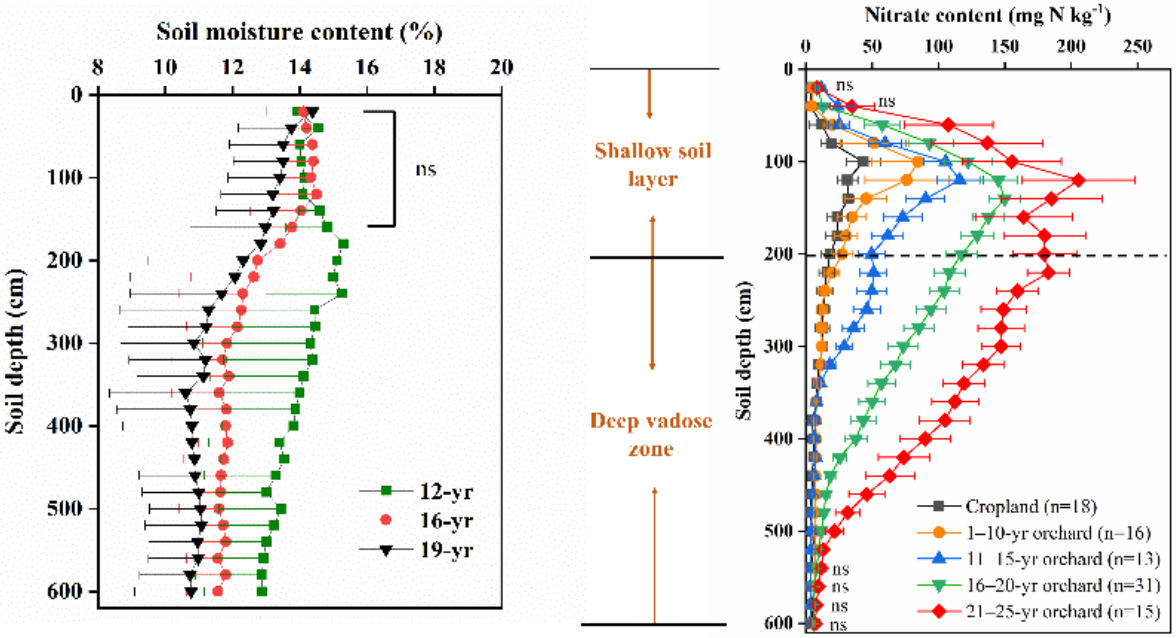


Fig. 13. Soil moisture and nitrate contents in the soil profiles of cereal lands and apple orchards of different stand ages in Luochuan County

**Nitrate accumulation in vadose zone is the main fate of surplus N (~ 2/3 of surplus N)**

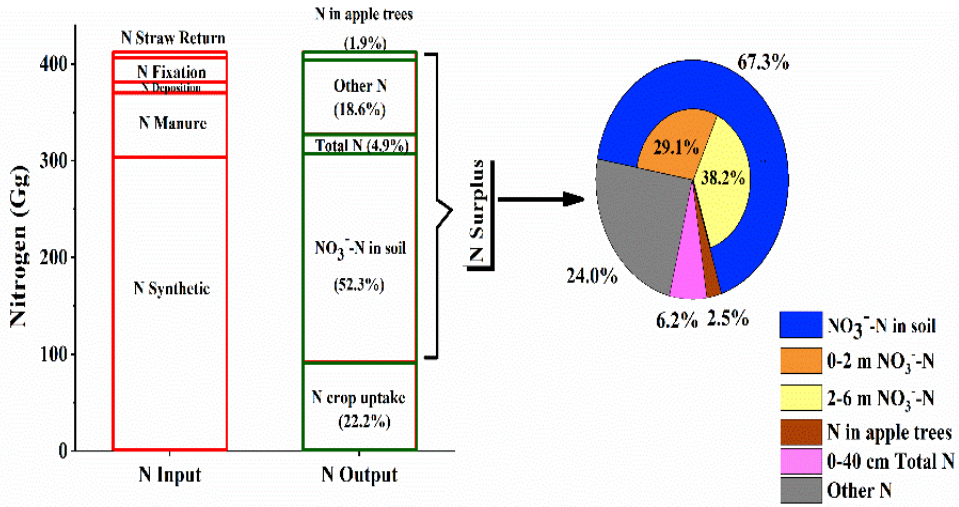


Fig. 14. Percentages (%) of the net soil nitrate storage, total N surplus and total N crop uptake out of total N input during the past 28 years in Luochuan County. Note: 0–2 m $NO_3^-$-N means nitrate accumulated in the 0–2 m soil layers; 2–6 m $NO_3^-$-N means nitrate accumulated in the 2–6 m soil layers. Total N indicates net increase of total N in the 0–40 cm soil layers. Other N means N losses through $NH_3$, $N_2$ and $N_2O$ emissions. Unit: Gg = $10^9$ g.

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# 4. Conclusions

◆Land use changes from cereal lands to orchards resulted in high N surplus (N hotspot!).

◆Nitrate accumulation in the vadose zone is the main fate of surplus N. (the missing N?)

◆Nitrogen accumulation in vadose zone is a big risk to the water quality at the intensive agricultural regions in China (Legacy N).

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## Thanks + questions?

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