Food and Agriculture Organization of the United Nations

BLACK SOILS INTERNATIONAL NETWORK

The Query for High Fertility of Black Soils and Grand Challenges in China

Zhongjun Jia (贾仲君)

Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences

February 6th, 2024

Webinar series SUSTAINABLE MANAGEMENT OF BLACK SOILS

GLOBAL SOIL PARTNERSHIP

The Query for High Fertility of Black Soils and Grand Challenges in China

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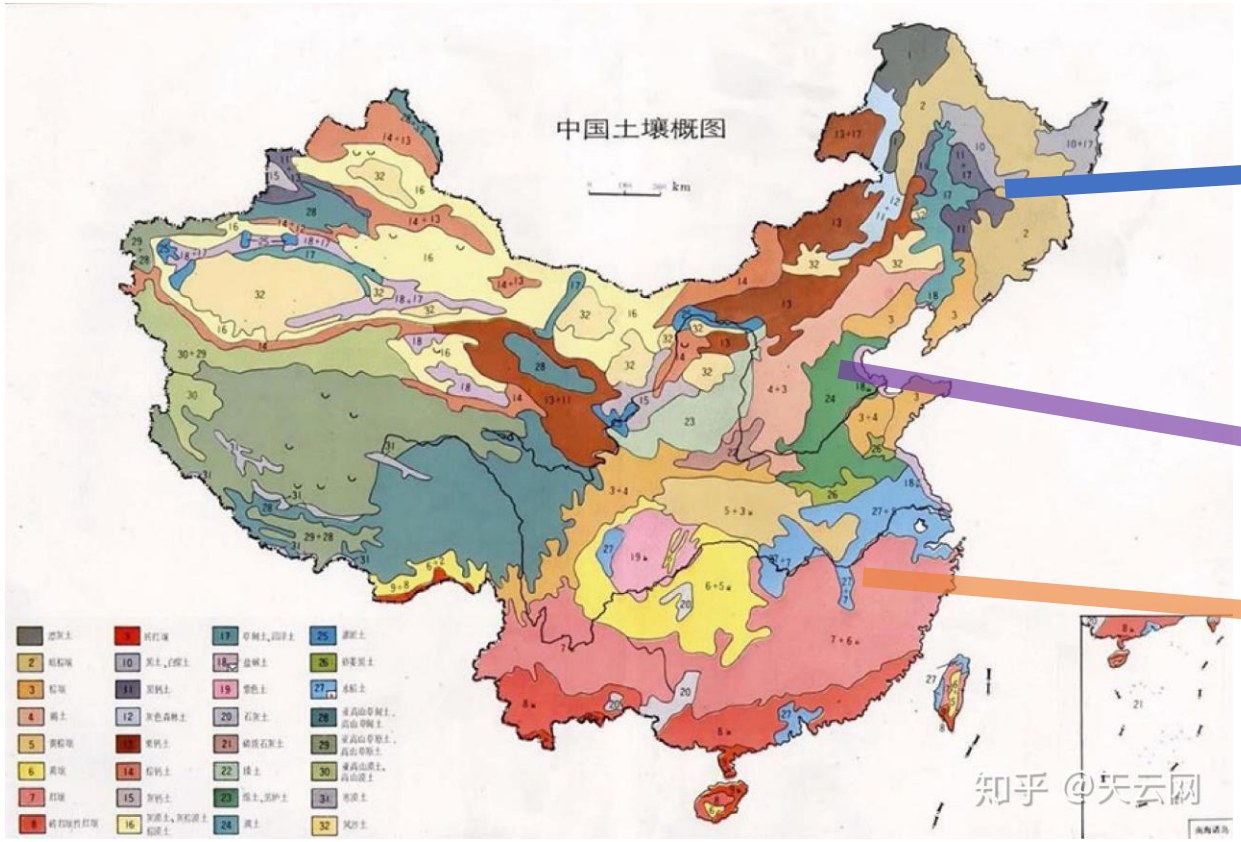
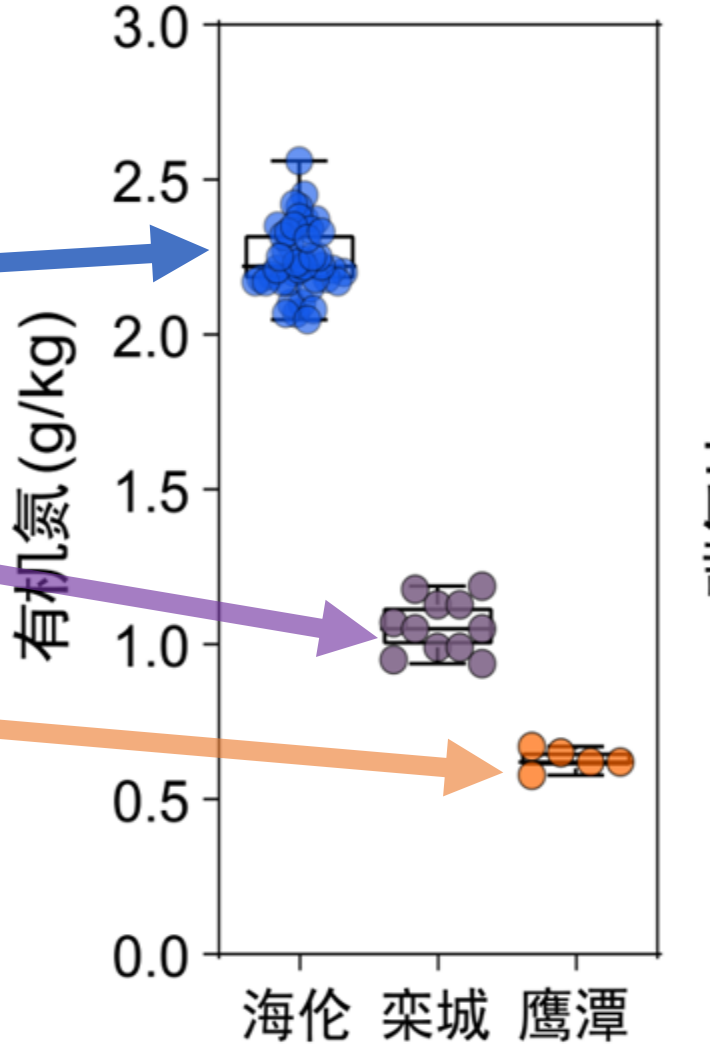
Outlines

- Origin of High Fertility?
- Mystery turnover of Soil N?
- Grand Challenges & Opportunity

Fertility: The extraordinarily high organic N in Black soil



Black Soil



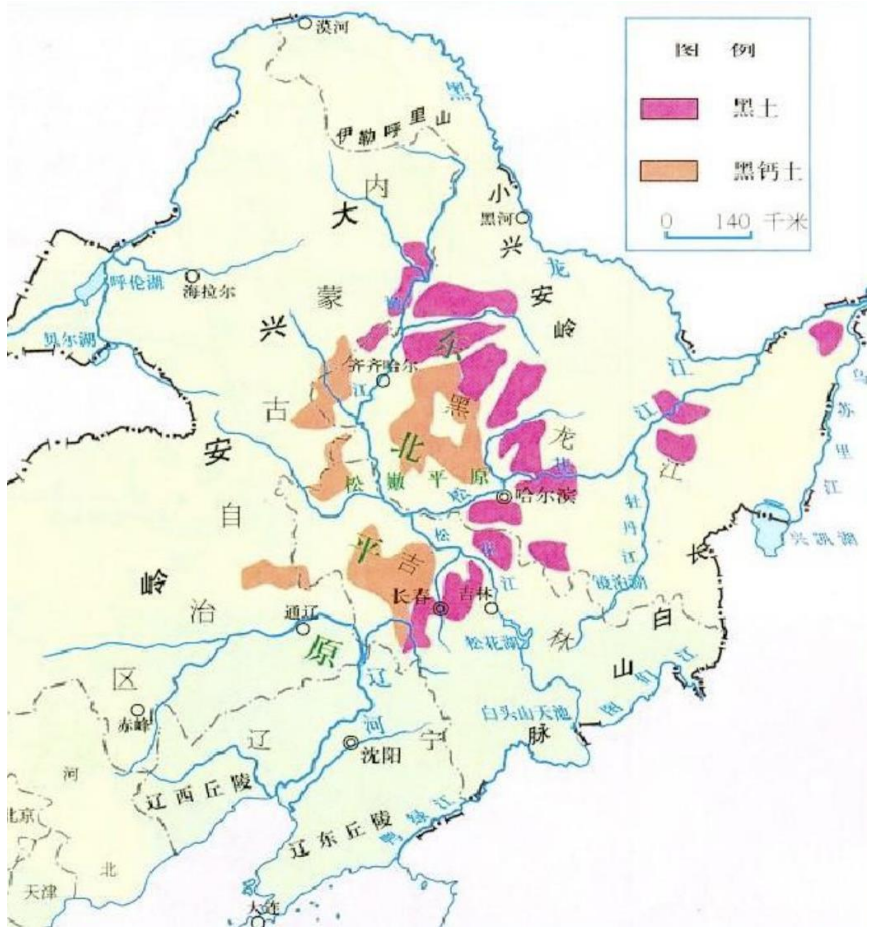
Fertility: NH_4^+ mineralized from soil organic N

Carbon and Nitrogen are the most essential block for life

Plant biomass C from CO_2 via photosynthesis

Nitrogen obtained from mineralization of SON in the form of NH4

How Black soils are formed



Difference in precipitation and temperature

Black soils with calcium
Black soil without calcium

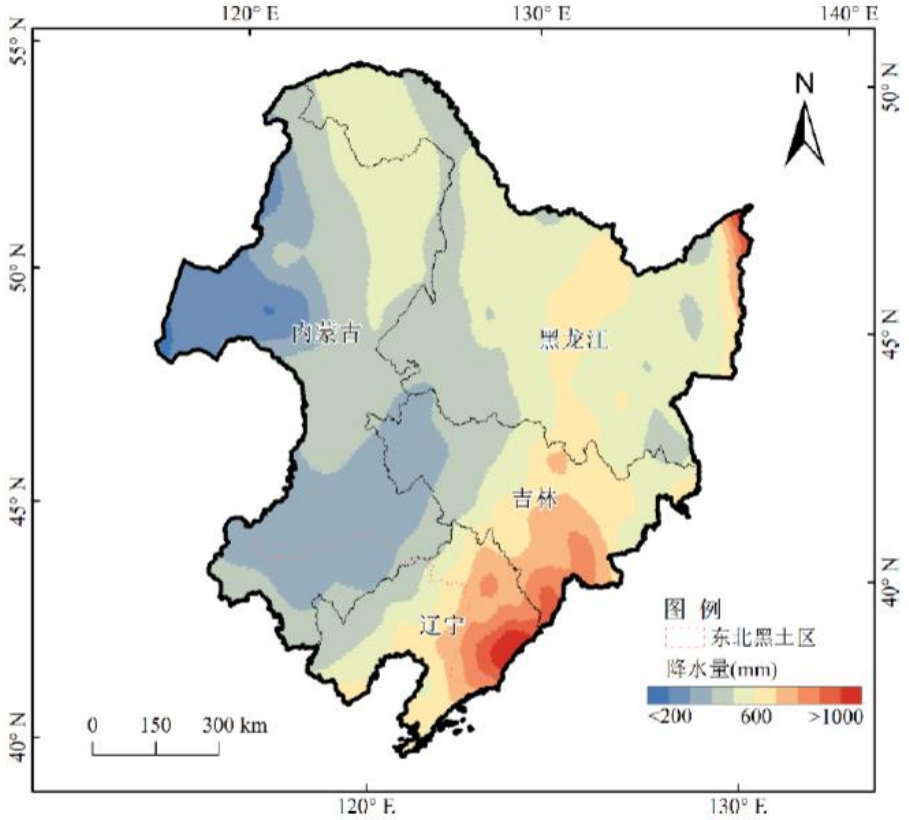
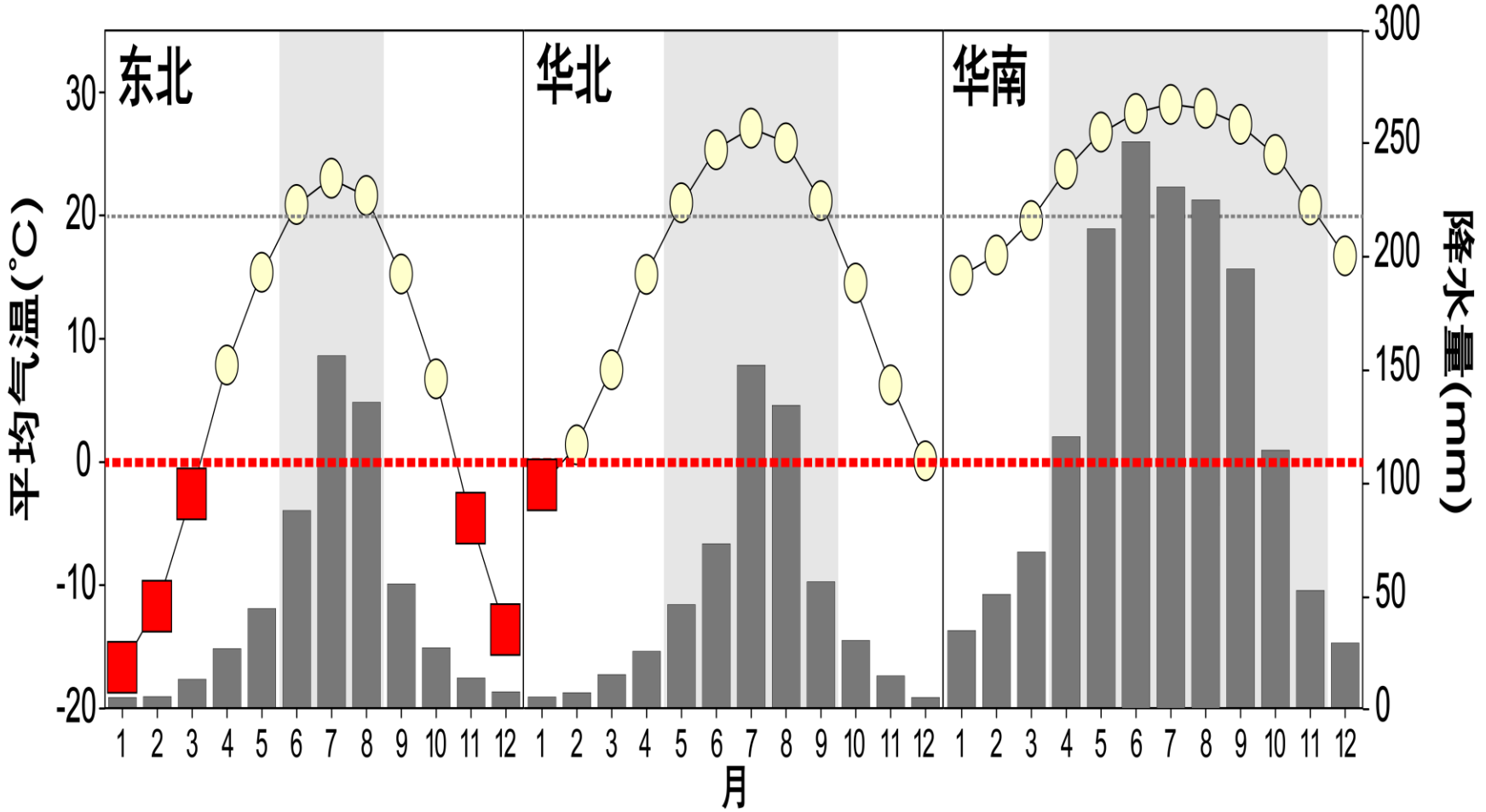


图 2-6 1981-2020 年东北地区平均年降水量分布

How soil organic N is generated and why it is high in Black soils



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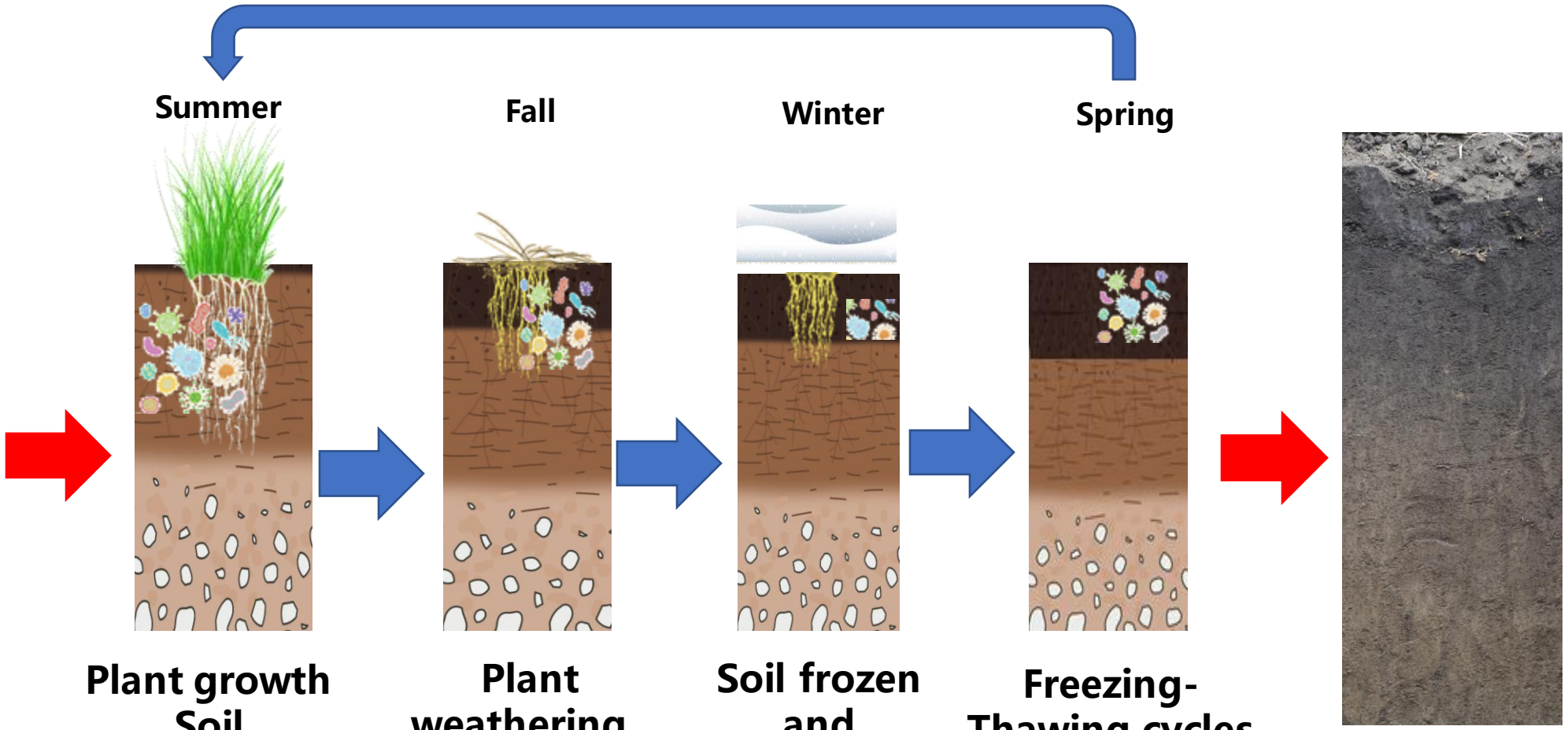

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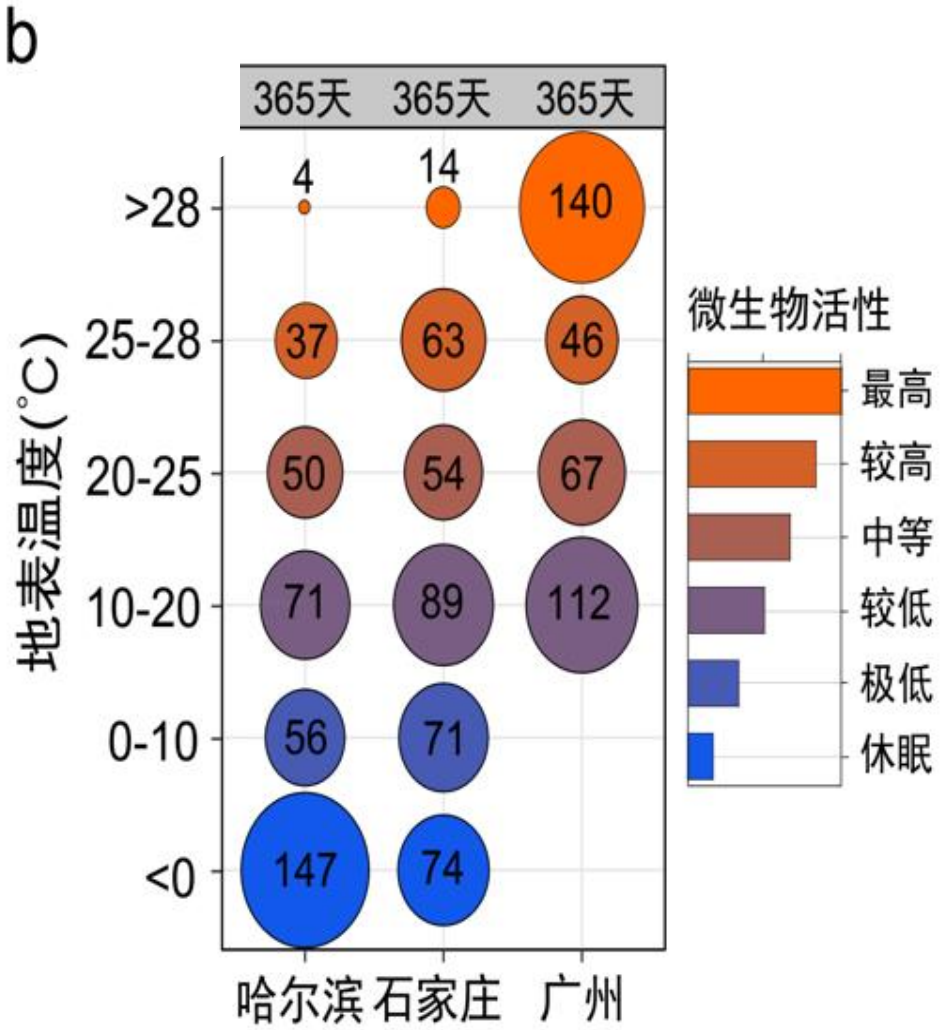
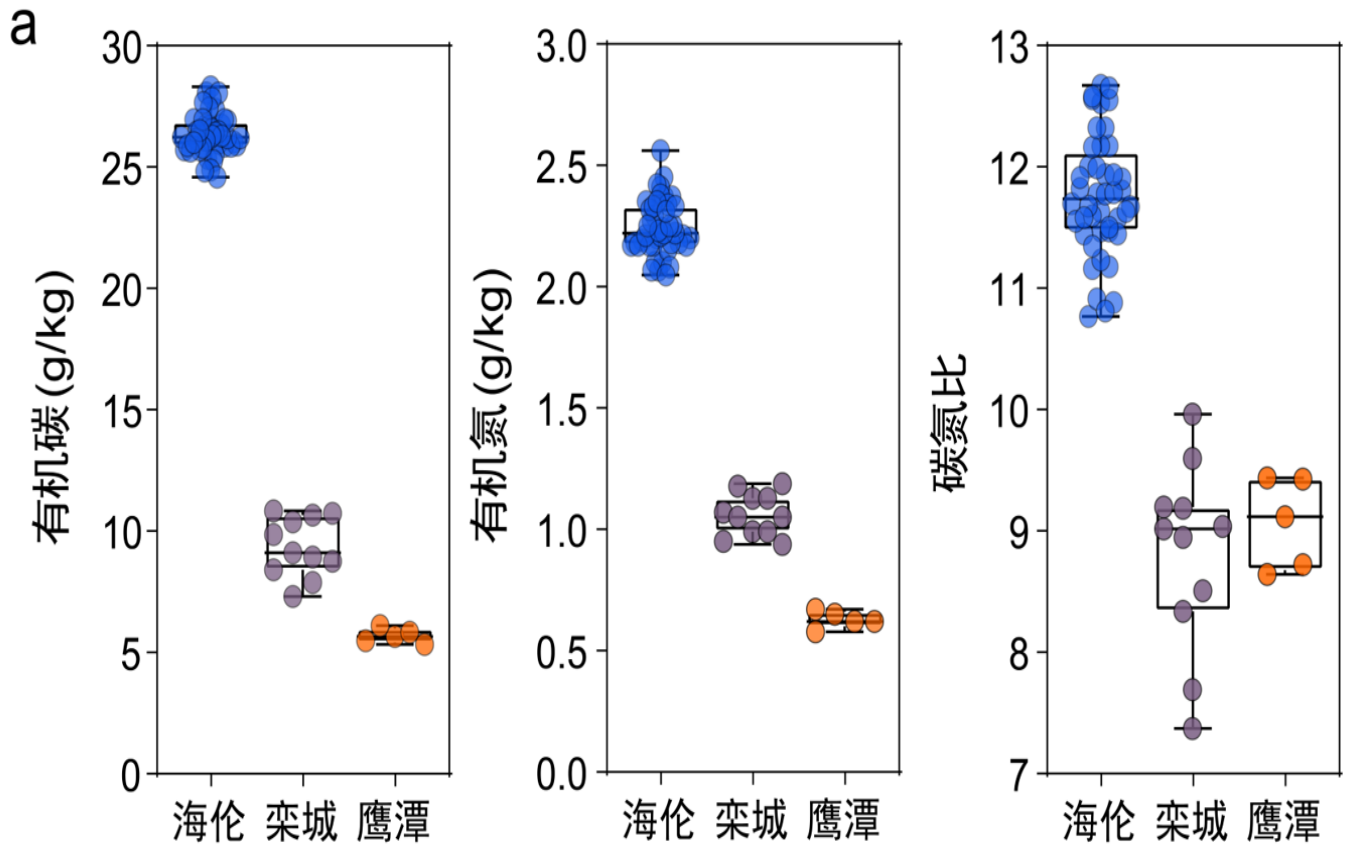
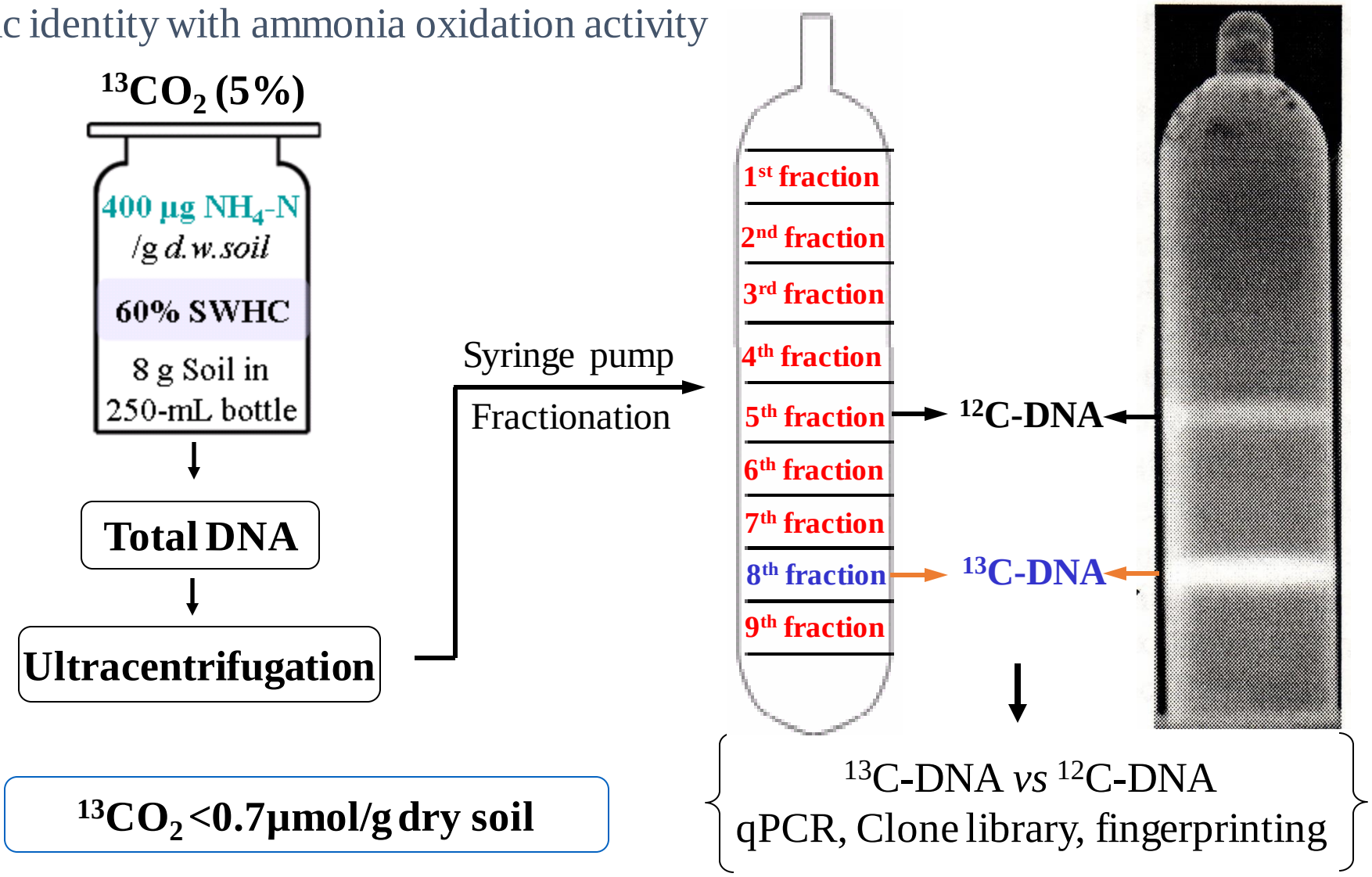




Stable isotope probing of life and death of microbiota in soil

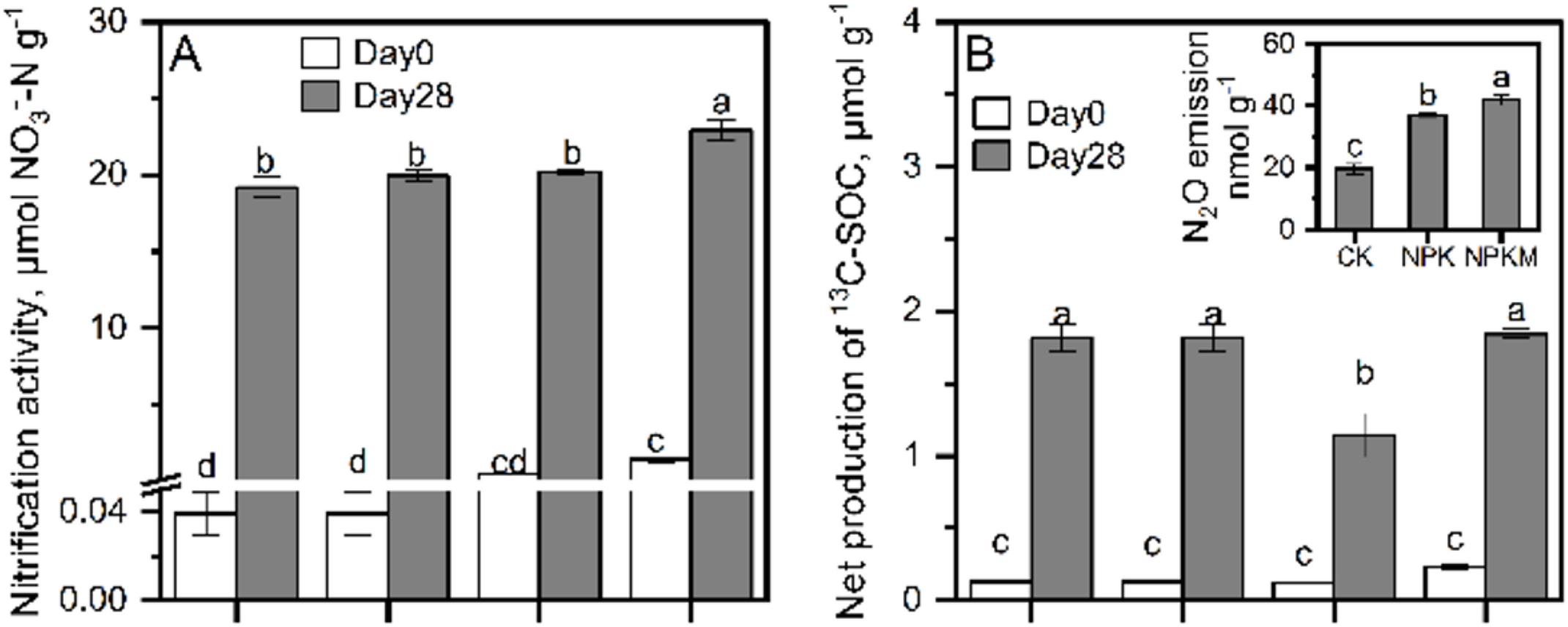
Link taxonomic identity with ammonia oxidation activity



Jia & Conrad, 2009. Environ. Microbiol.**11**:1658

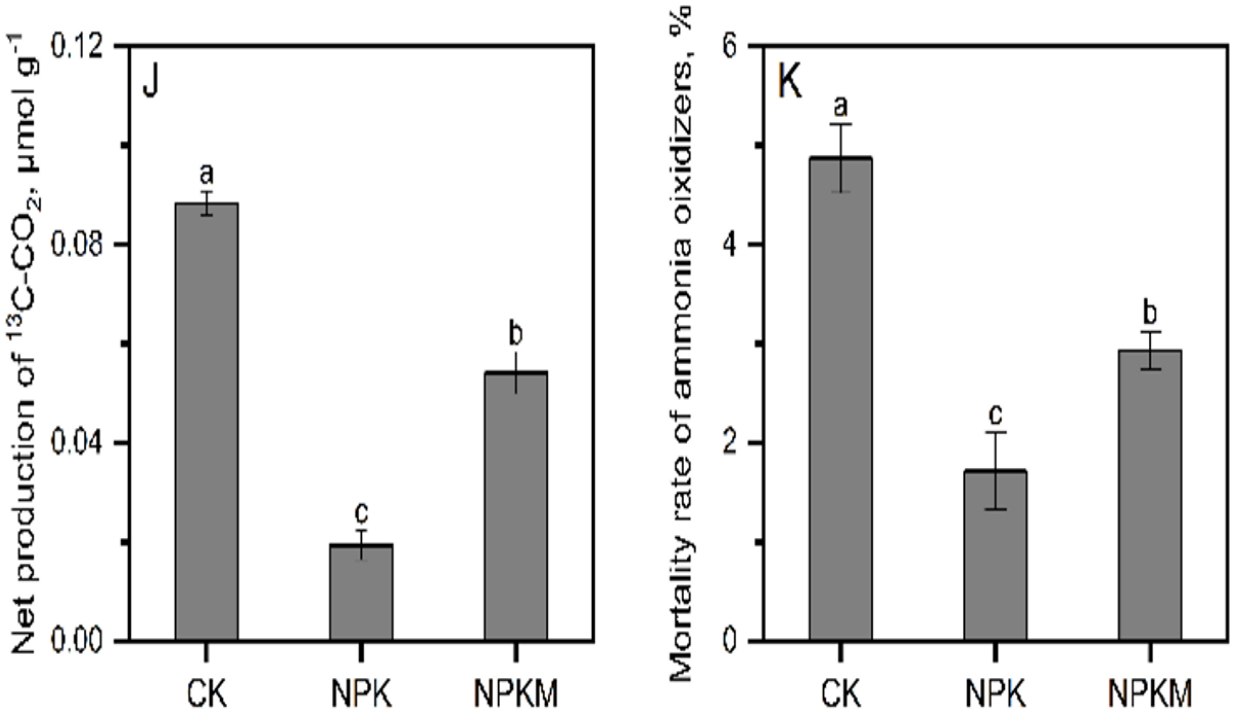
Life and death of ammonia oxidizers and its contribution to SOC

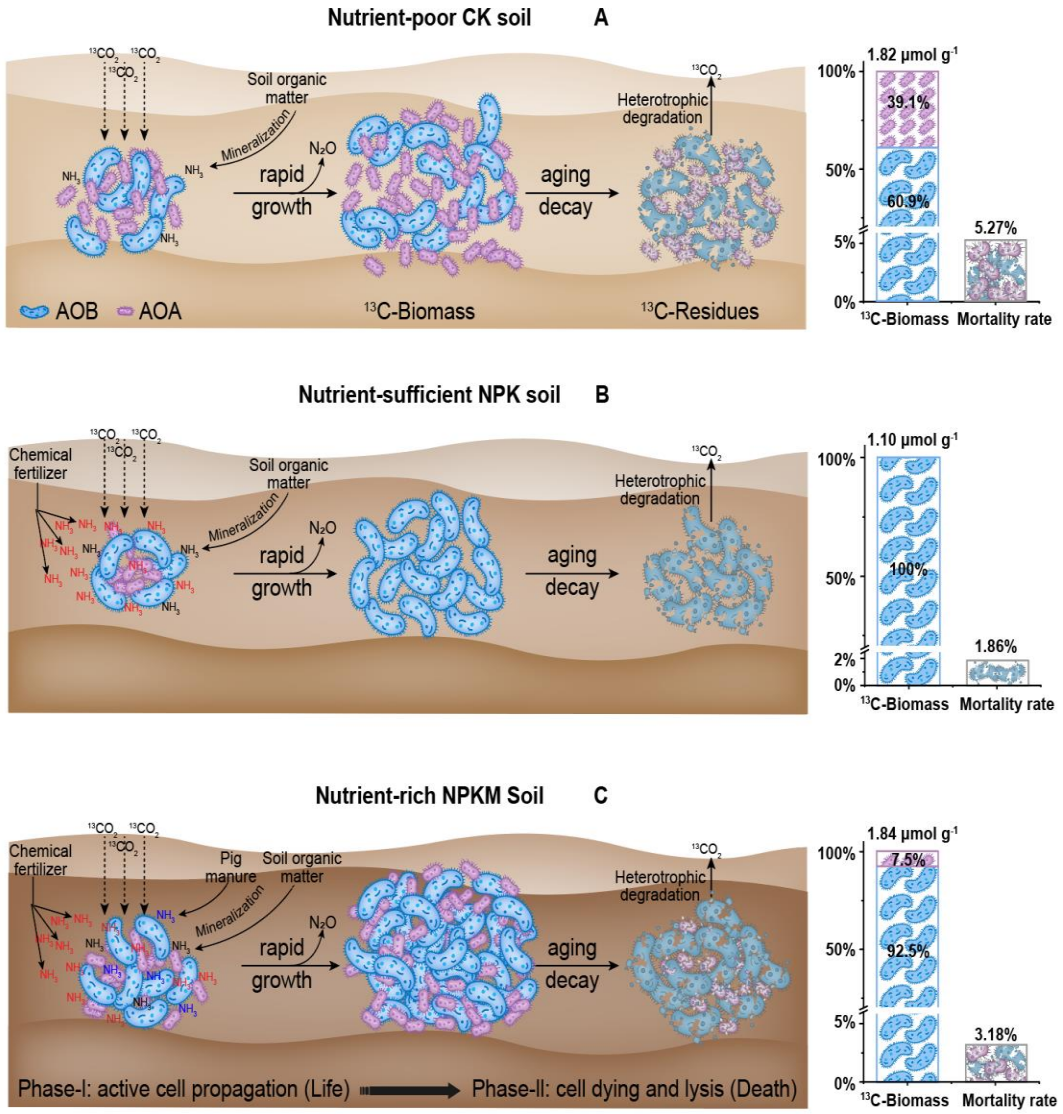
Phase-I: Active cell division of CO_2-fixing ammonia oxidizers in



Huang and Jia et al. 2023 under review

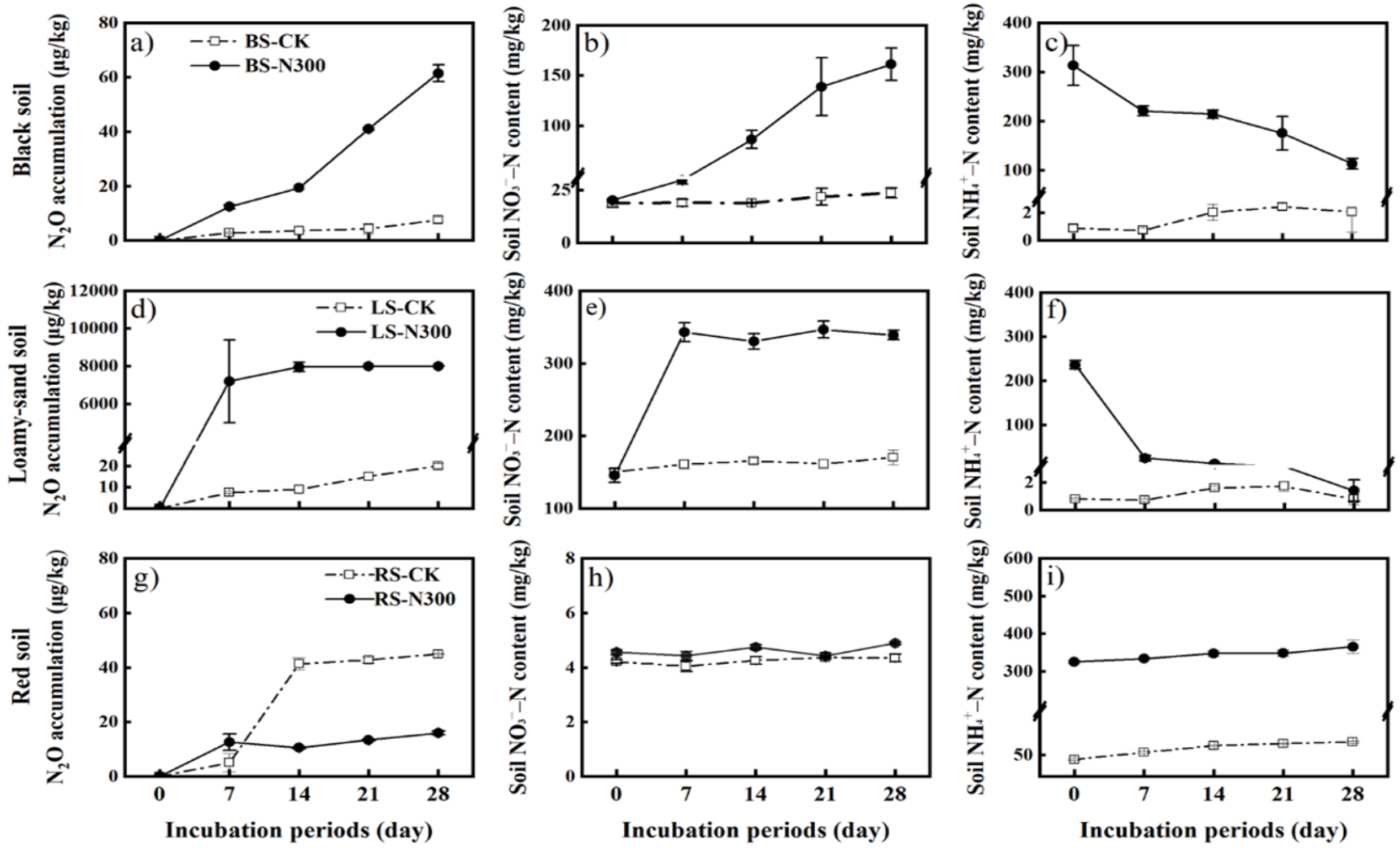
Life and death of ammonia oxidizers and its contribution to SOC





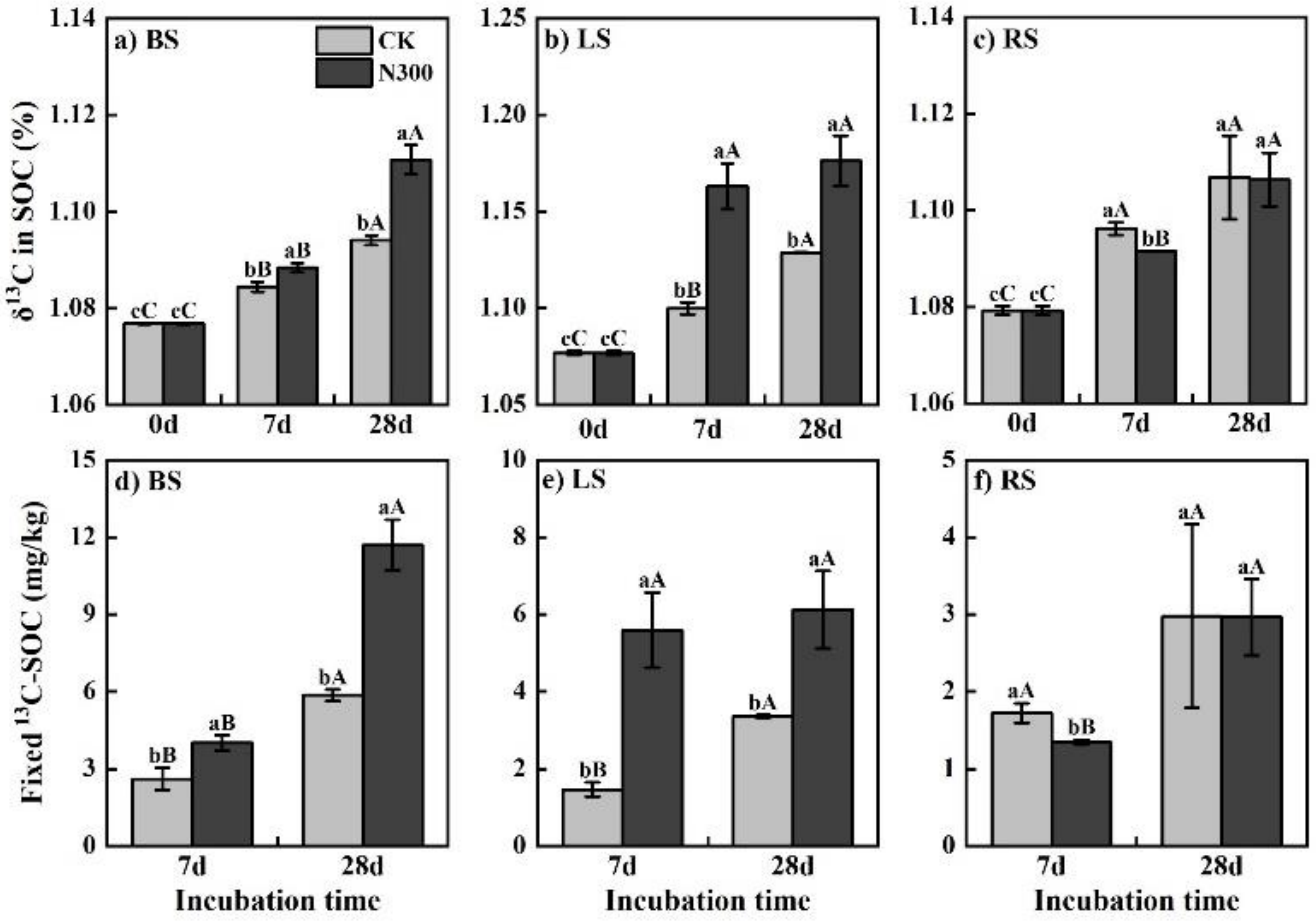
Huang and Jia et al. 2023 under review

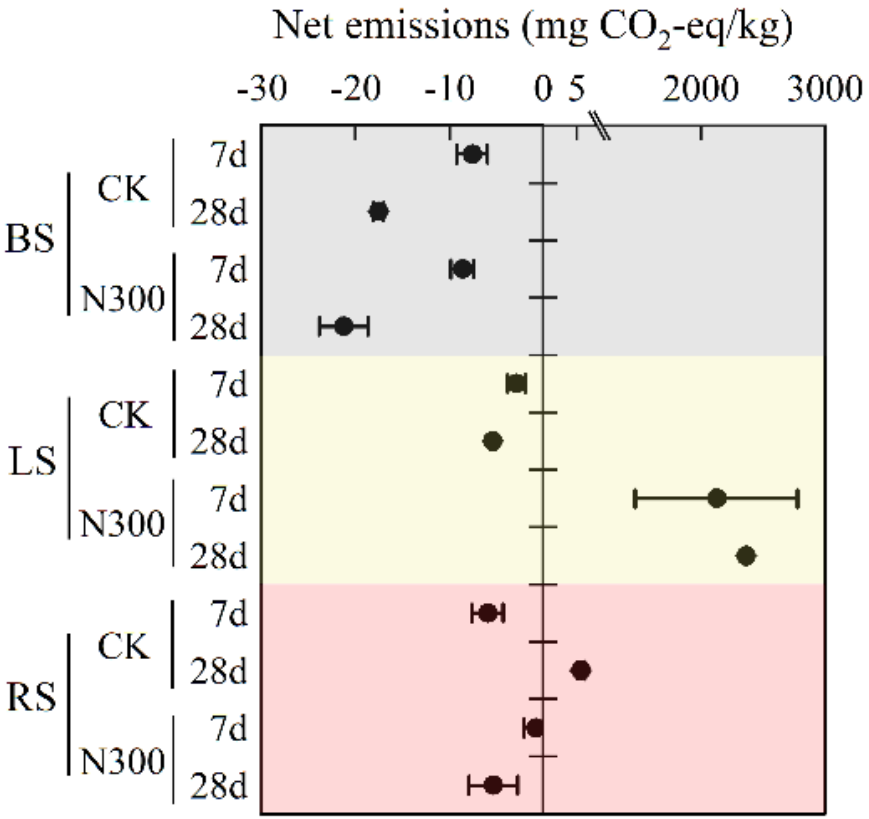
Black Soils work like slow-releasing fertilizers



Xia and Jia et al. 2023 under review

Black Soils are born to be carbon-neutral and climate-friendly.

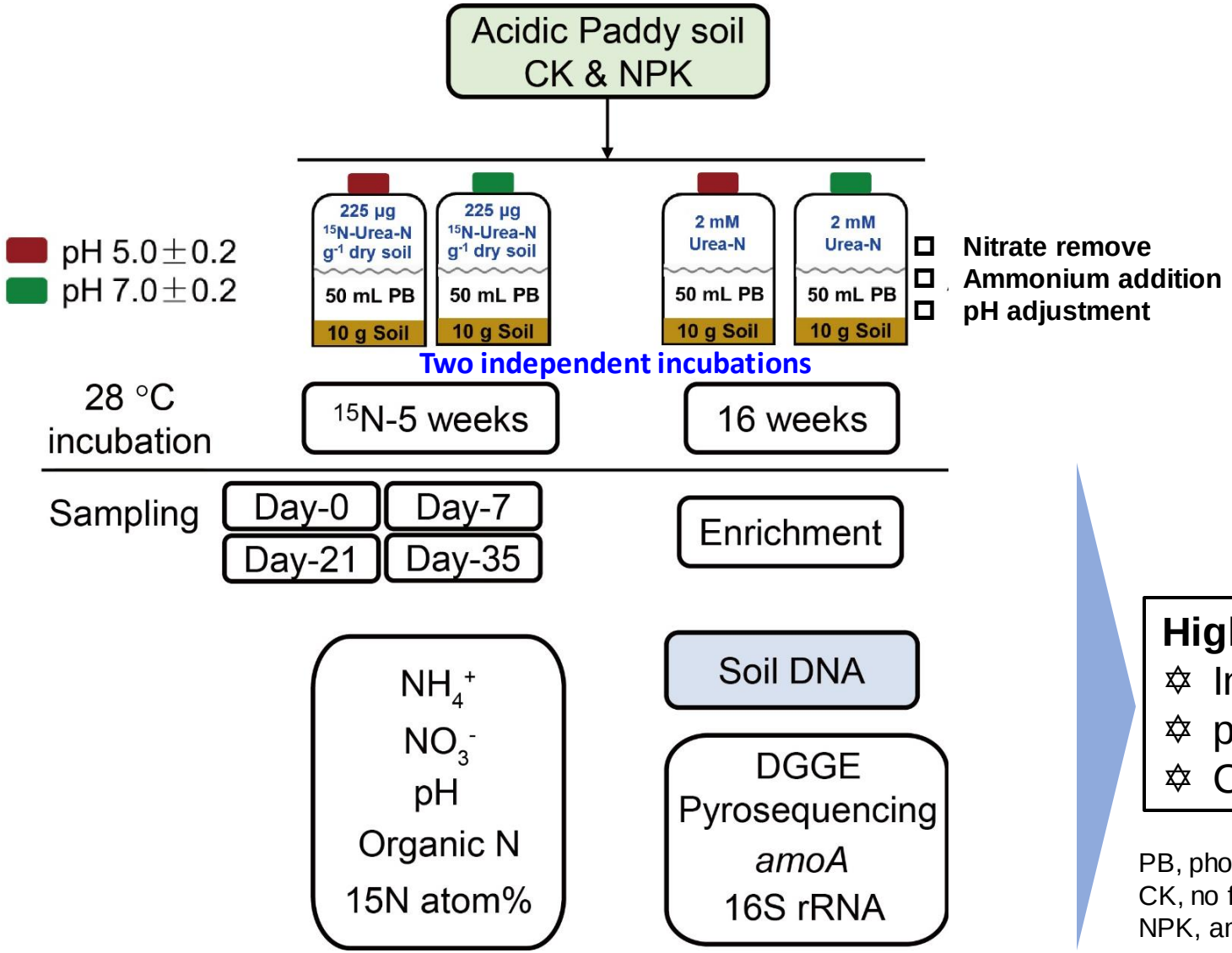




Outlines

- Origin of High Fertility?
- **Mystery turnover of Soil N?**
- Grand Challenges & Opportunity

Soil organic generation and mineralization



Highlights:

- ✡ Inorganic N assimilation and microbes
- ✡ pH 5.0 vs. pH 7.0
- ✡ CK vs. NPK

PB, phosphate buffer
CK, no fertilization
NPK, amended with chemical fertilizers for 26 years

Microbial relay and soil N-cycling

Remarkable microbial anabolisms of exogenous N can promote N mineralization and nitrification processes in acidic paddy soils

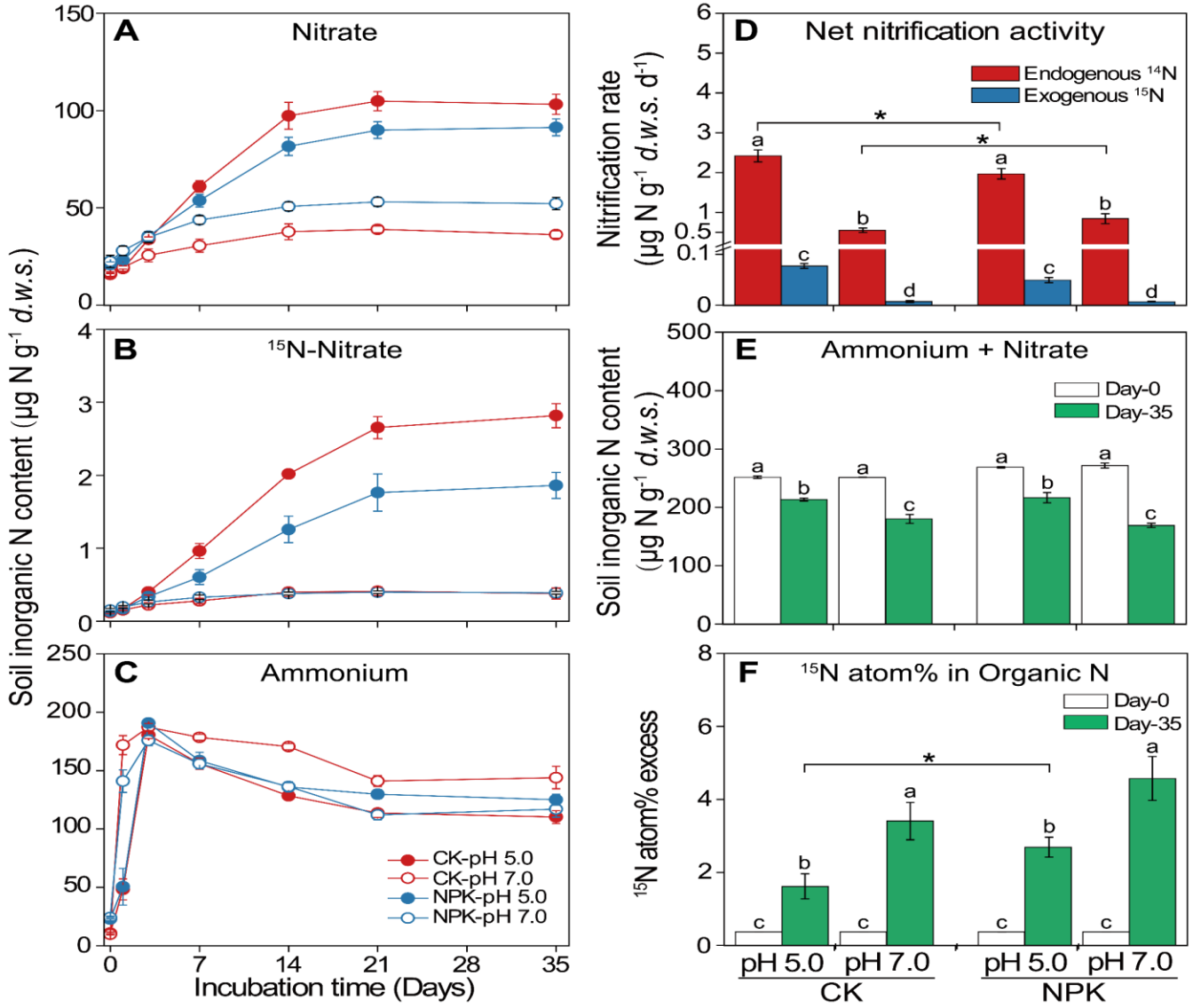


Fig. 1. Soil inorganic nitrogen dynamics in acidic (pH 5.0) or in neutral (pH 7.0) microcosms of CK (no fertilization) and NPK (amended with chemical fertilizers) soils over the 35-day incubation period. (*A-C*) Changes in nitrate, ^{15}N-nitrate and ammonium concentrations over the incubation. (*D*) Net nitrification rates for endogenous ^{15}N and exogenous ^{14}N over the incubation. (*E*) Soil inorganic N concentrations before and after the incubation. (*F*) The ^{15}N atom% excess of organic N before and after the incubation. Error bars indicate the standard deviation. Different letters above the columns in CK or NPK soils indicate a significant difference (Tukey's test, $P < 0.05$). Symbol '*' indicates the significant difference between two treatments (*t*-test, $P < 0.05$).

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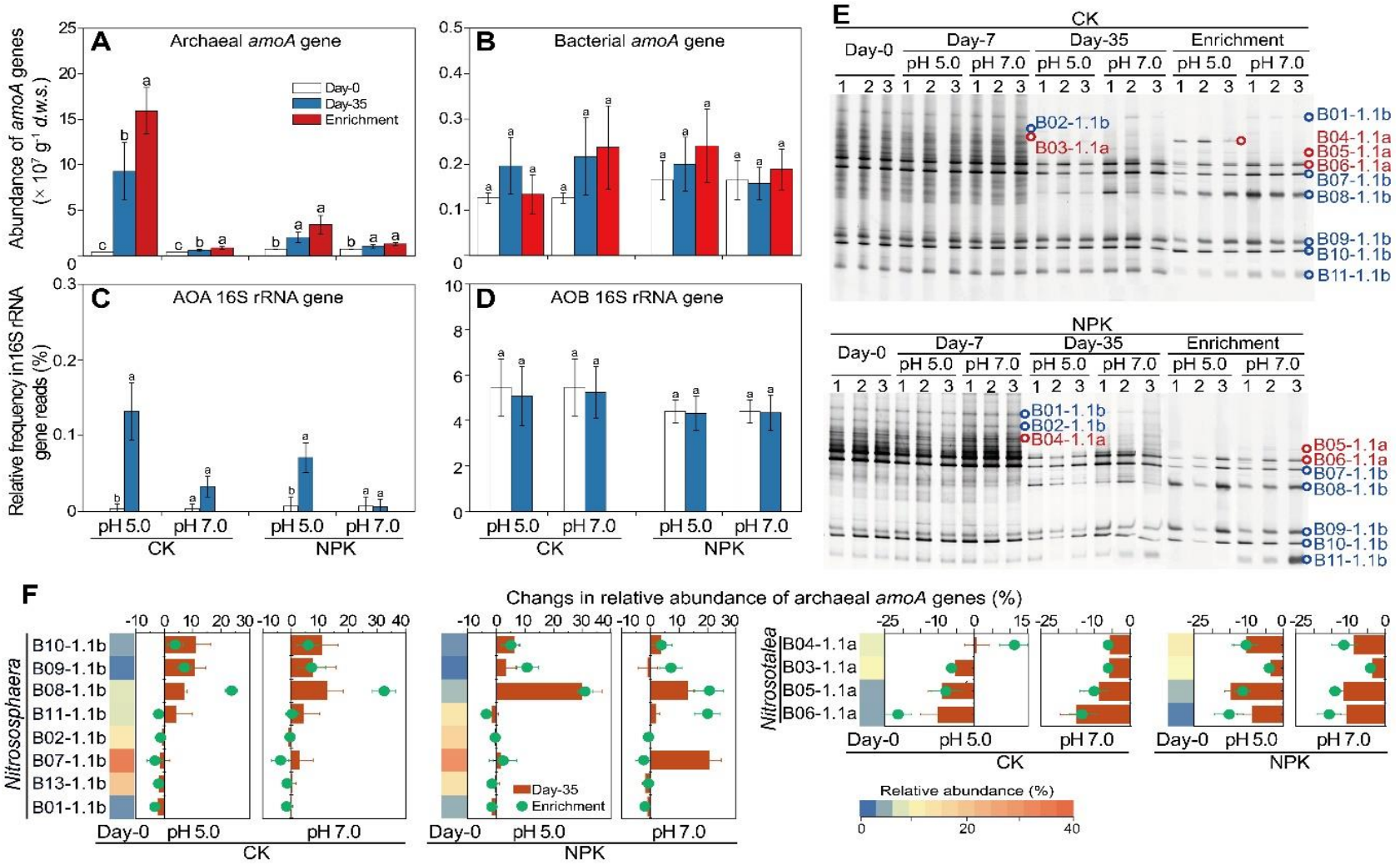

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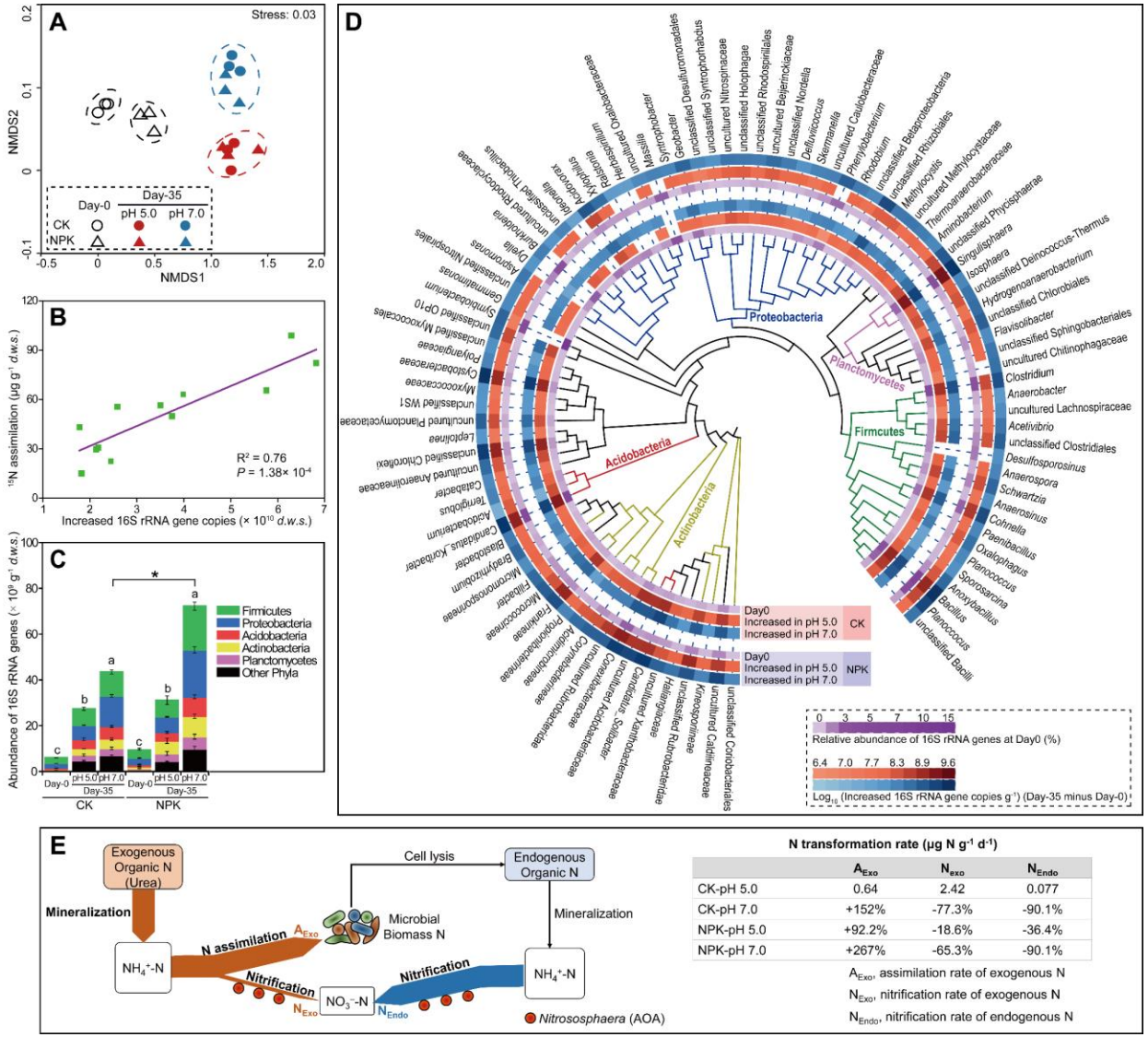


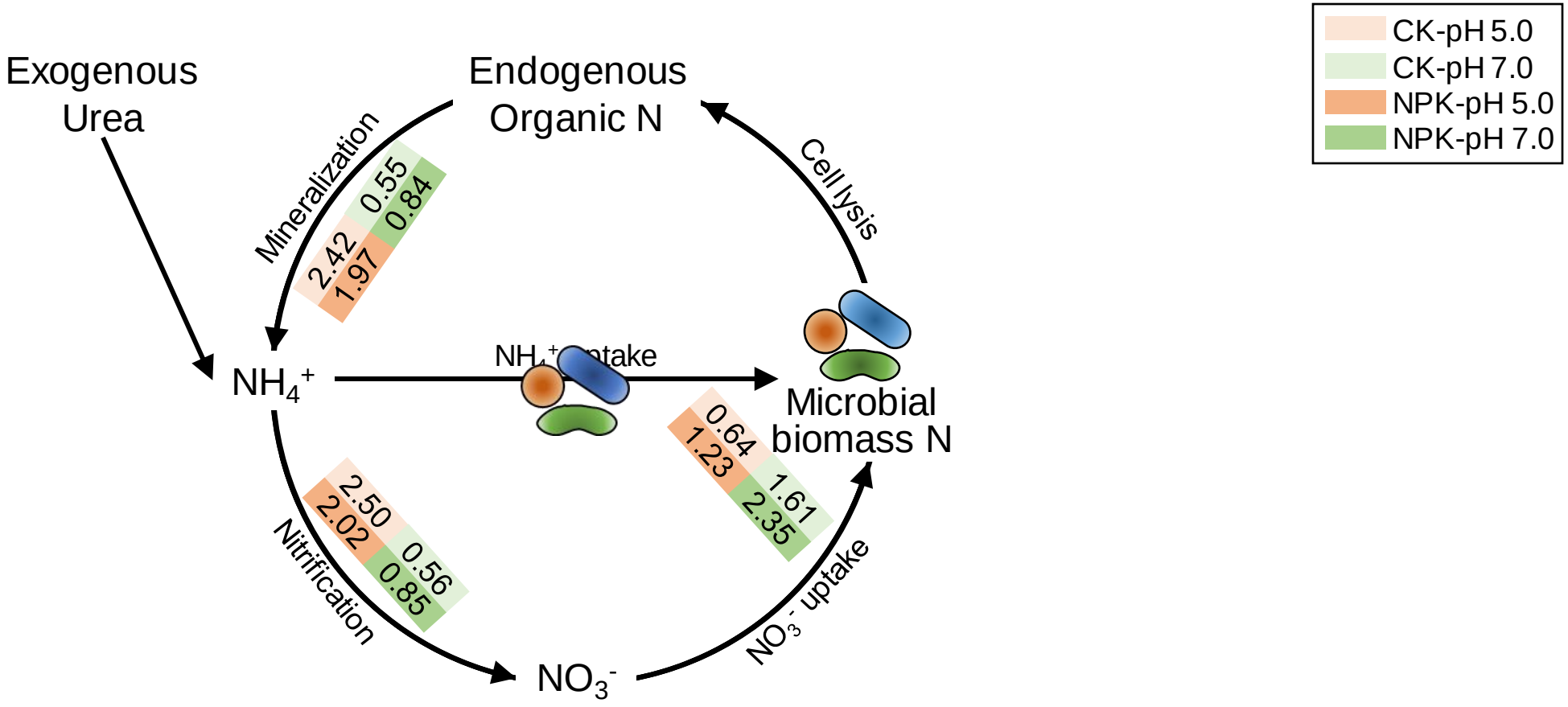
N transformation rate (μg N g^{-1} d^{-1})

	A_{Exo}	N_{exo}	N_{Endo}
CK-pH 5.0	0.64	2.42	0.077
CK-pH 7.0	+152%	-77.3%	-90.1%
NPK-pH 5.0	+92.2%	-18.6%	-36.4%
NPK-pH 7.0	+267%	-65.3%	-90.1%

A_{Exo}, assimilation rate of exogenous N
N_{Exo}, nitrification rate of exogenous N
N_{Endo}, nitrification rate of endogenous N

Microbial relay and soil N-cycling

N transformation process (mg N kg^{-1} d^{-1})



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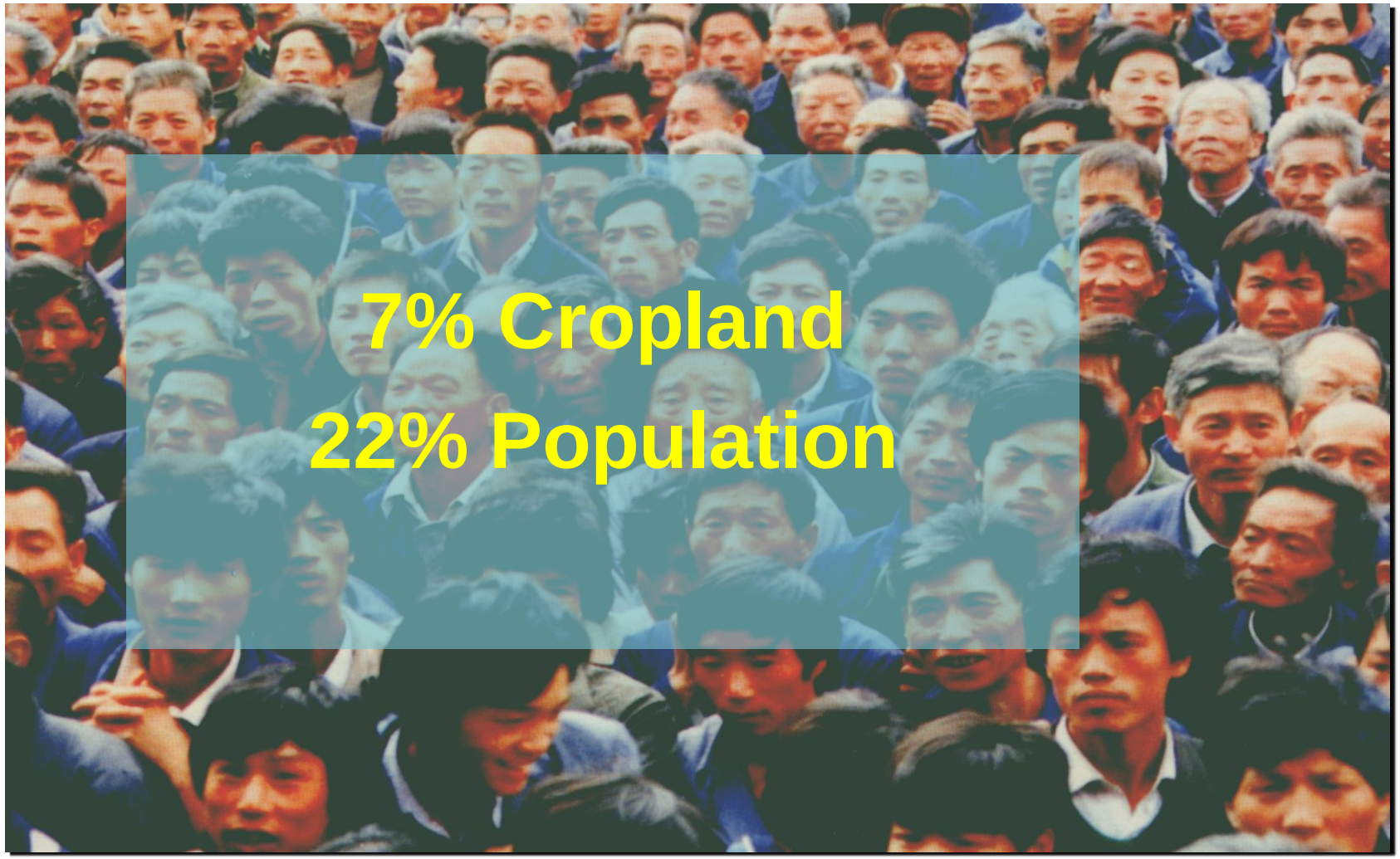
- Mystery turnover of Soil N?
- **Grand Challenges and Opportunity**

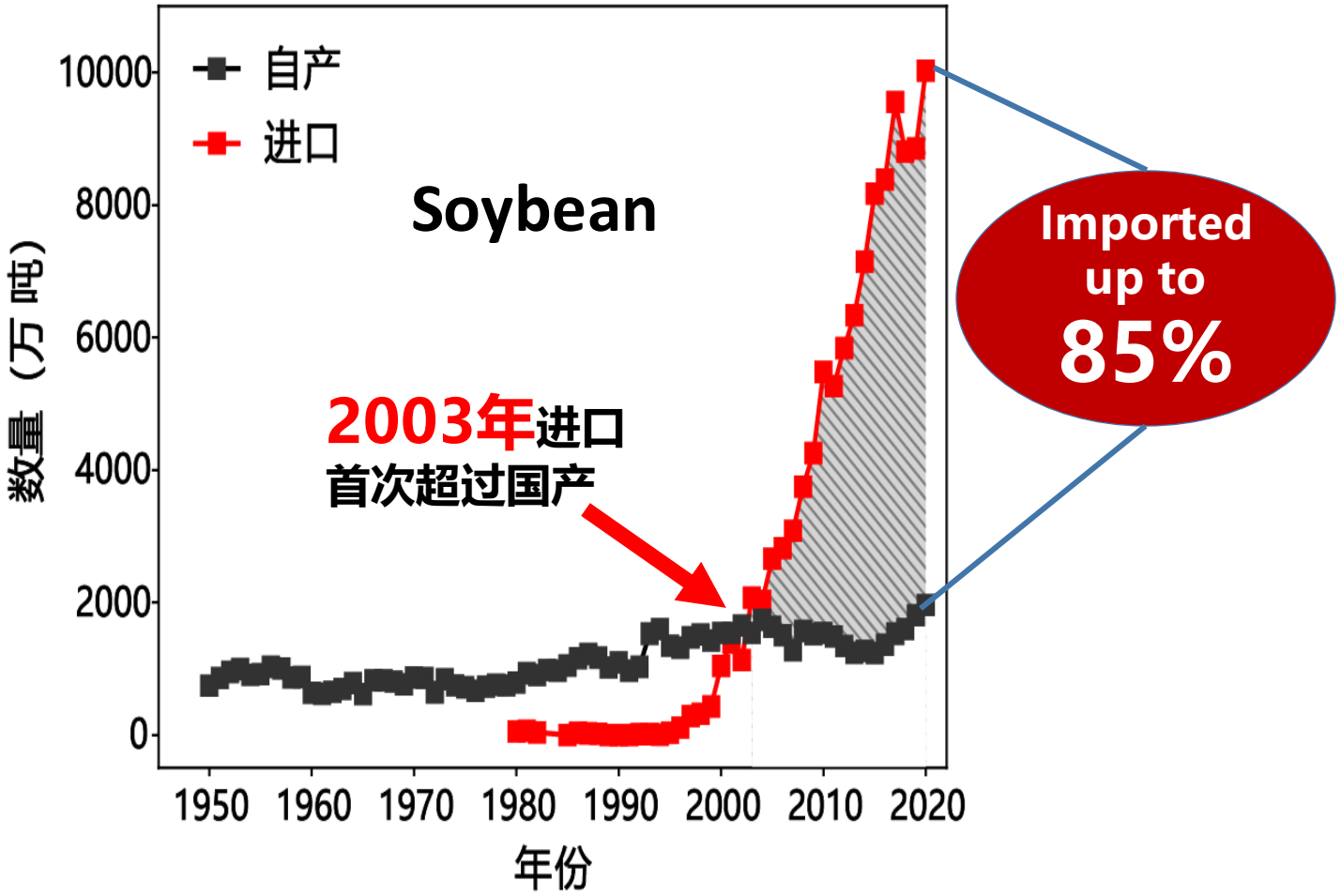
Grand Challenge: Food security is the 1st issue in China



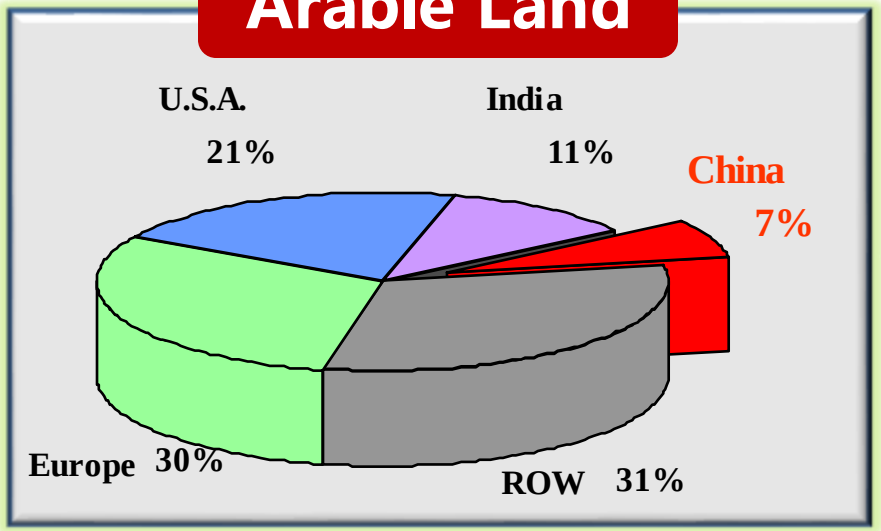
In coming 30 years, crop yield per unit must increase annually by 1% to meet food demand for increasing population.

Global Significance: food in China is always a global concern

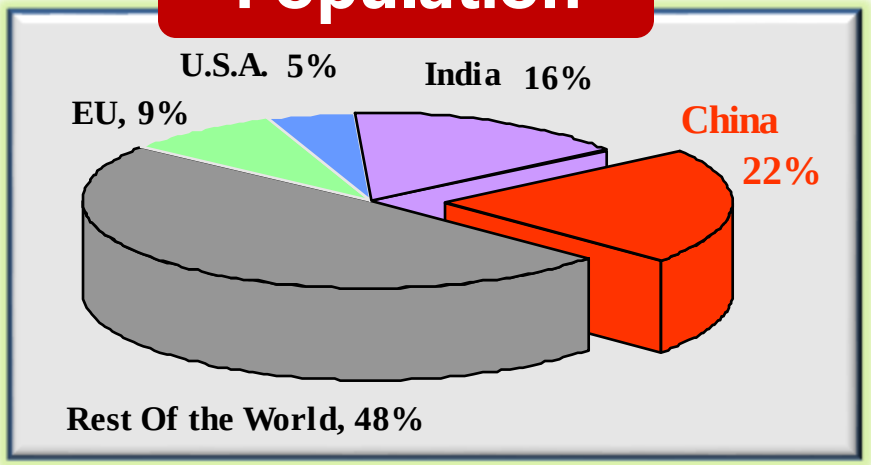
- In 2020, China imported soybean up to 40 billion US dollars
- It ranks as the 6th largest single product imported oversea.



Arable Land



Population

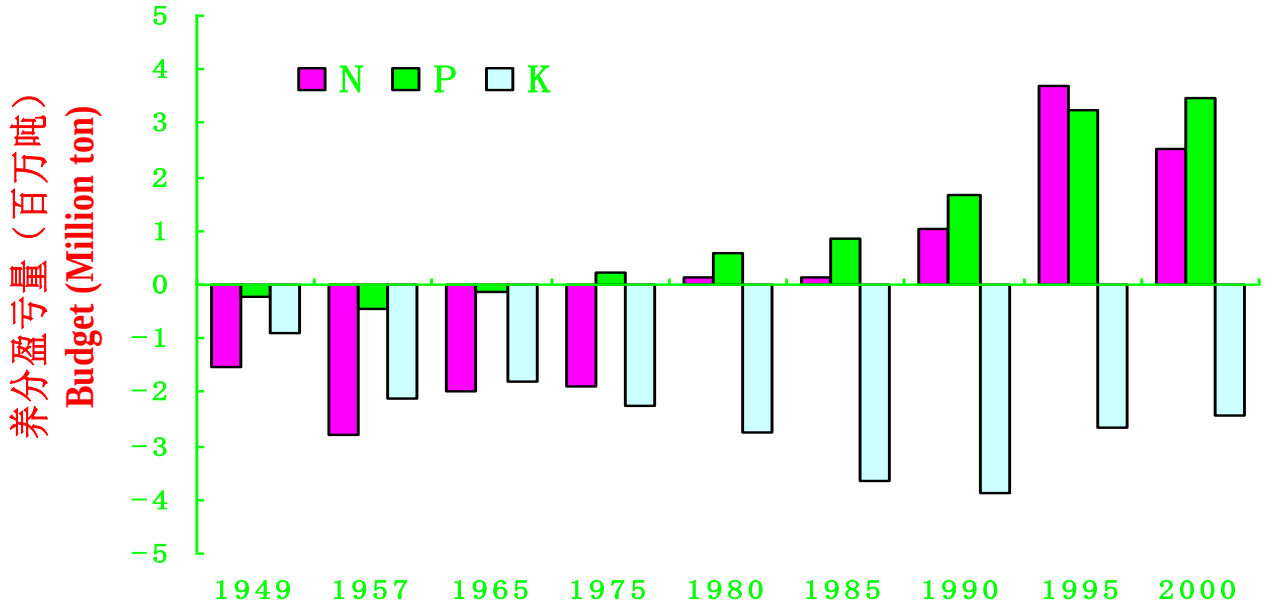


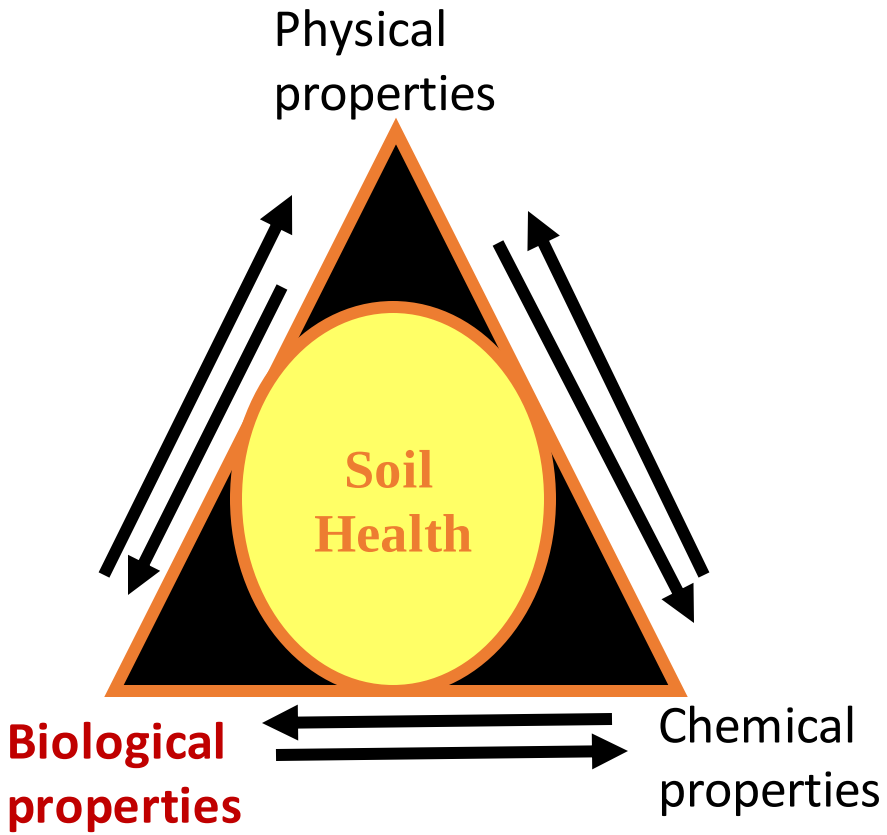
Black soils are a "ballast stone" of food security in China

- Black soil area produces 1/4 grain yield and 1/3 commodity grain of China
- Black soil area produces 18% rice, 34% maize and 44% soybean of China
- However, the intensified input of chemical fertilizers facilitates soil degradation

Unbalance of nutrient inputs

-- Surplus of N,P, deficiency of K

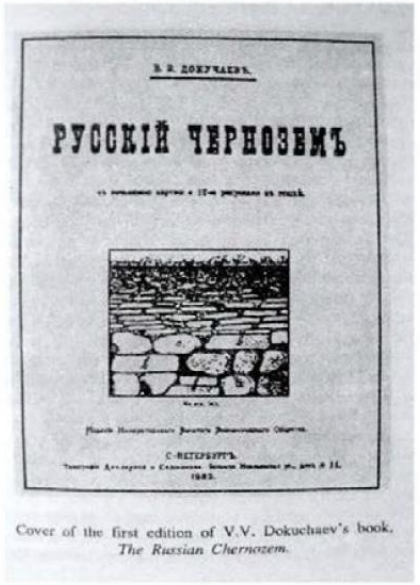




Priority-1: How to put soil health in the context of pedogenesis

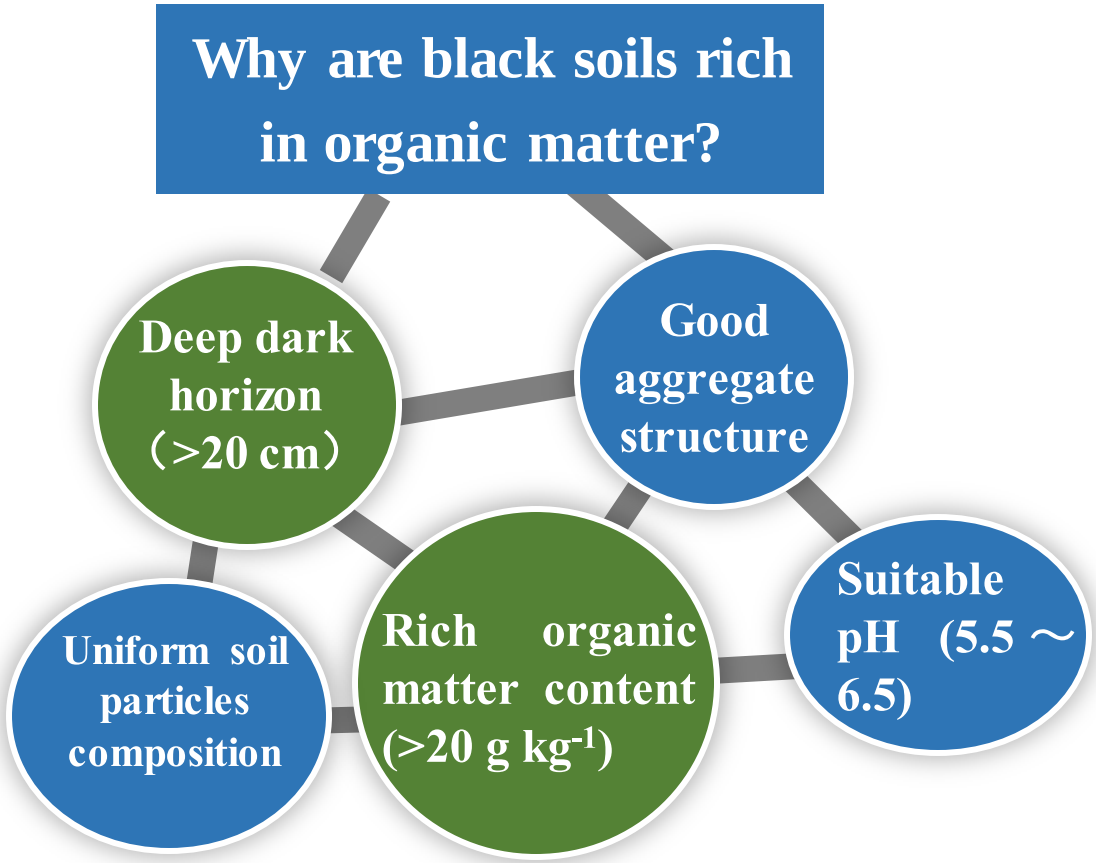
- The concept of black soil formation is the founding father of soil science
- But, how to date soil health and how to decipher the role of inherent soil properties

照片 1　B.B.道库恰耶夫
（1846 ~ 1903）
Photo 1　V.V.Dokuchaev
（1846 – 1903）



Cover of the first edition of V.V. Dokuchaev's book, *The Russian Chernozem*.

照片 2　《俄罗斯黑钙土》封面（1883）
Photo 2　Cover of 《Russian Chernozem》(1883)



张佳宝. 2023. 土壤内稳性地力与农业可持续发展. Pedosphere. 33: 3-5

Opportunity-2: Soil heath design to counteract land degradation

Intensive farming

① Output > Input
② Chemical-dominated inputs
③ Heavy soil disturbance
④ No surface cover
⑤ Mono-cropping
⑥ Soil compaction

Soil degradation

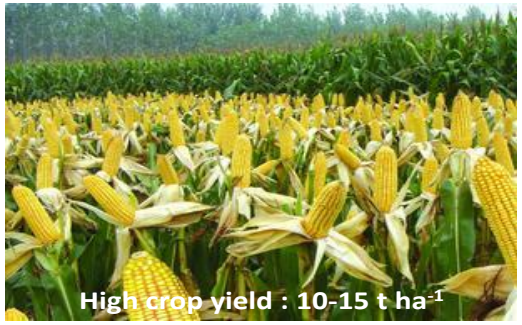
- SOM decomposition
- Unbalanced nutrients
- Poor tilth
- Low water & nutrient holding capacity
- Reduced biodiversity

Soil erosion

- Water erosion
- Wind erosion

Soil Health Design

- Dark horizon thinning
- Soil impoverishing
- Soil hardening

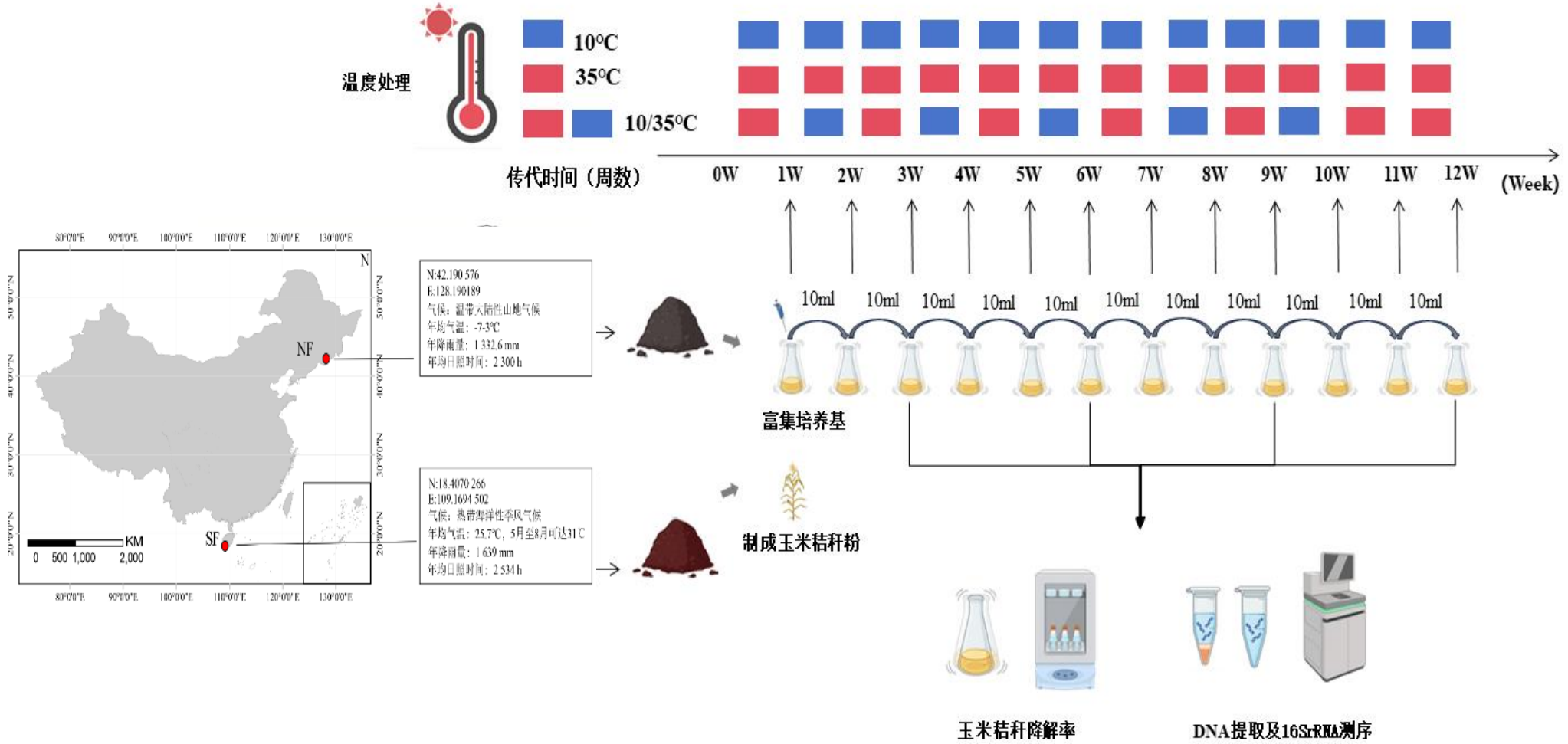

High crop yield : 10-15 t ha^{-1}


Intensive tillage: 20-35 cm


Residue burning leads to bare surface


Water erosion: 12-35 t ha^{-1} yr^{-1}

Is there cold-loving straw decomposer?



"Created with BioRender.com."

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Thank you !

Zhongjun Jia (贾仲君)

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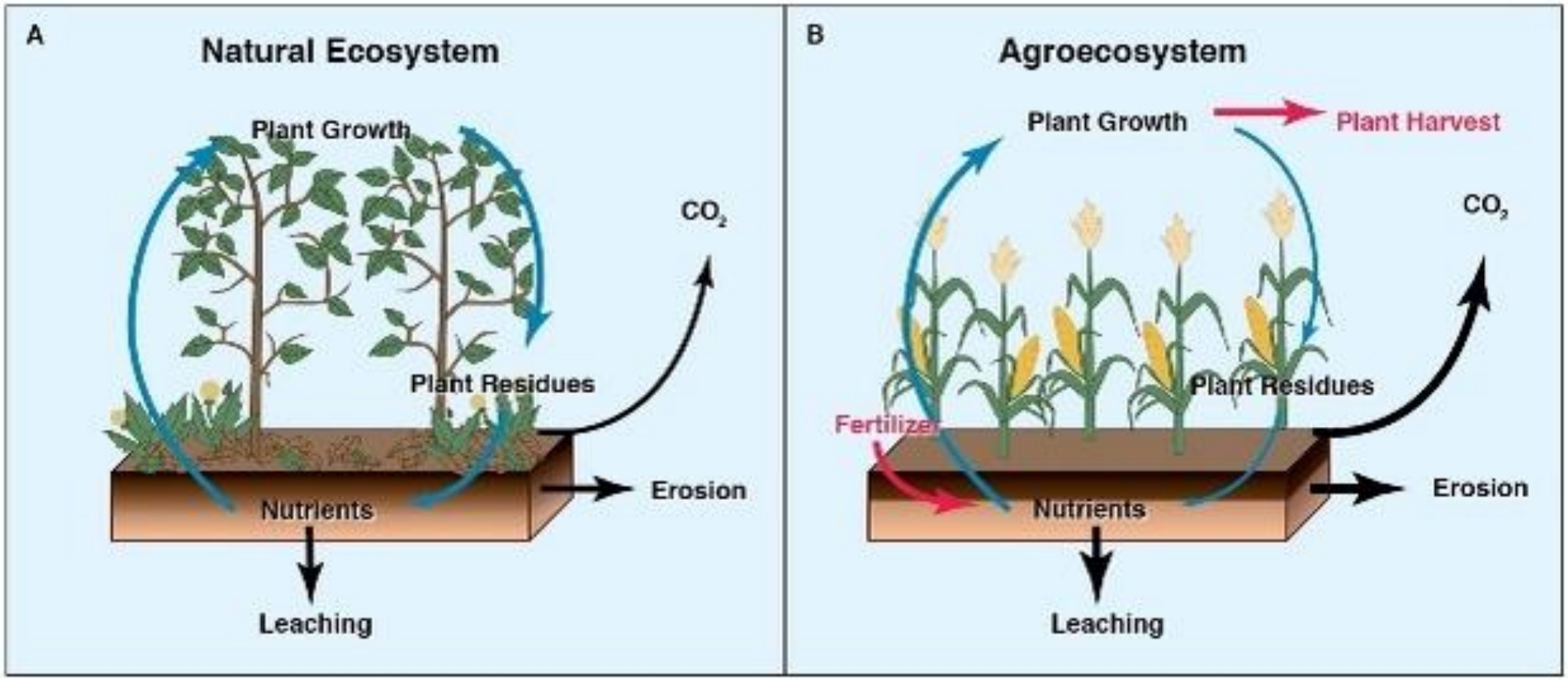
Nitrogen removed and chemical fertilizer required in Agriculture



Bernhard, A. The Nitrogen Cycle: Processes, Players, and Human Impact. *Nature Education Knowledge* 2, 12 (2010).