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中国科学院南京土壤研究所
Institute of Soil Science,
Chinese Academy of Sciences

中国科学院大学
University of Chinese Academy of Sciences

Climate change-rice-human health

Chunwu Zhu，Dongming Wang

cwzhu@issas.ac.cn

My growth and study

1999-2003, Nanjing Agricultural University, Bachelor

2003-2009, Institute of Soil Science, CAS, Master and PhD

2009-2012, National Institute for Agro-Environmental Sciences of Japan（tsukuba）, Postdoctor

2013-2017, Institute of Soil Science, CAS, Asso.Prof.

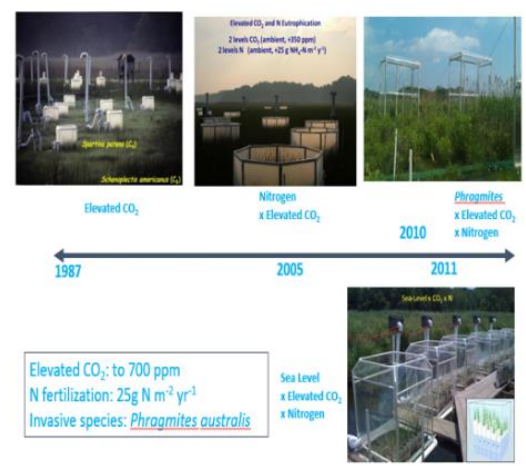
2016-2017, Environment Research Center, Smithsonian， visiting

2017- , Institute of Soil Science, CAS, Prof.

Research Field：climate change and ecosystem

Jiangdu FACE, China

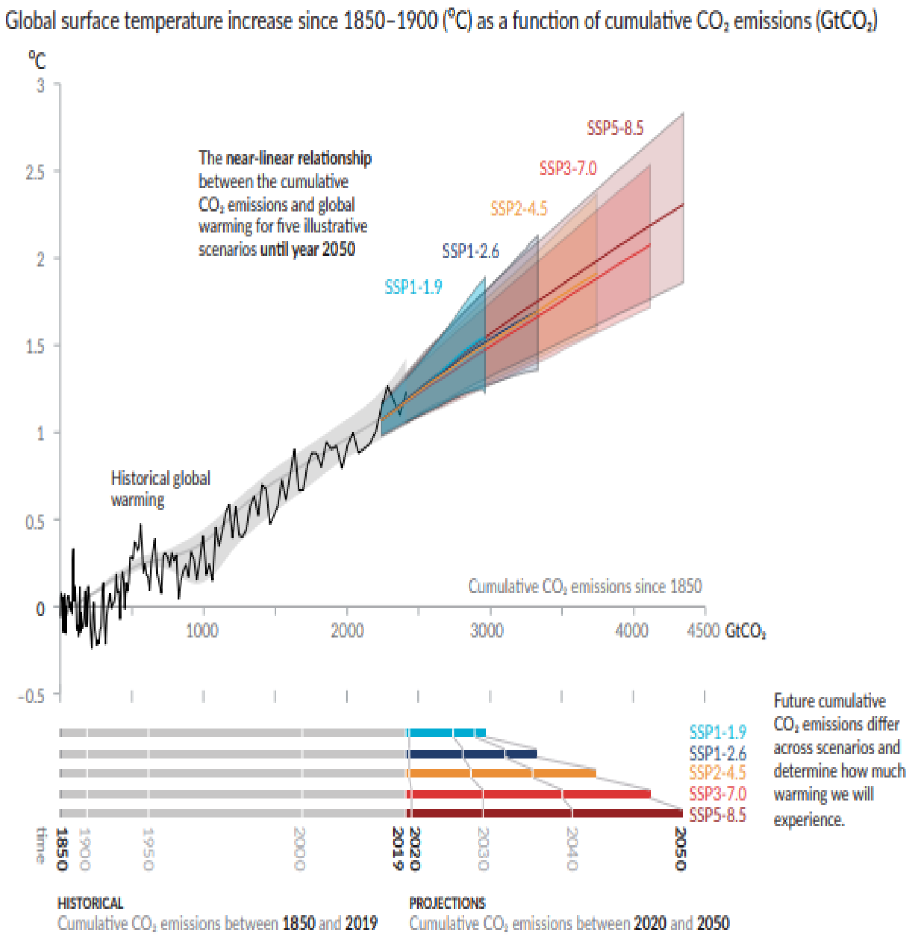
Tsukuba FACE, Japan



Wetland, Smithsonian

Climate change is happening

Rising CO_2



Rising Temperature

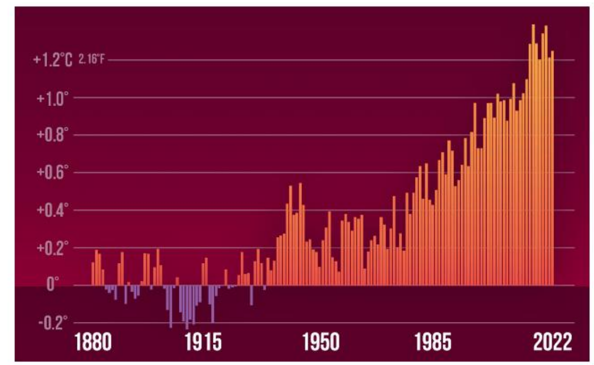
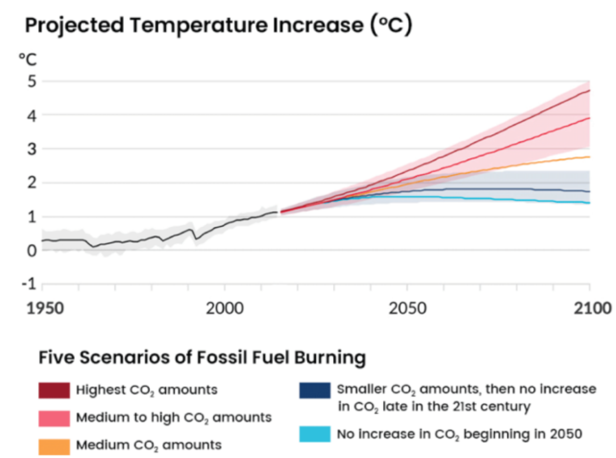


Figure 1. *Global Average Temperature Anomalies, departure from 1881-1910.*

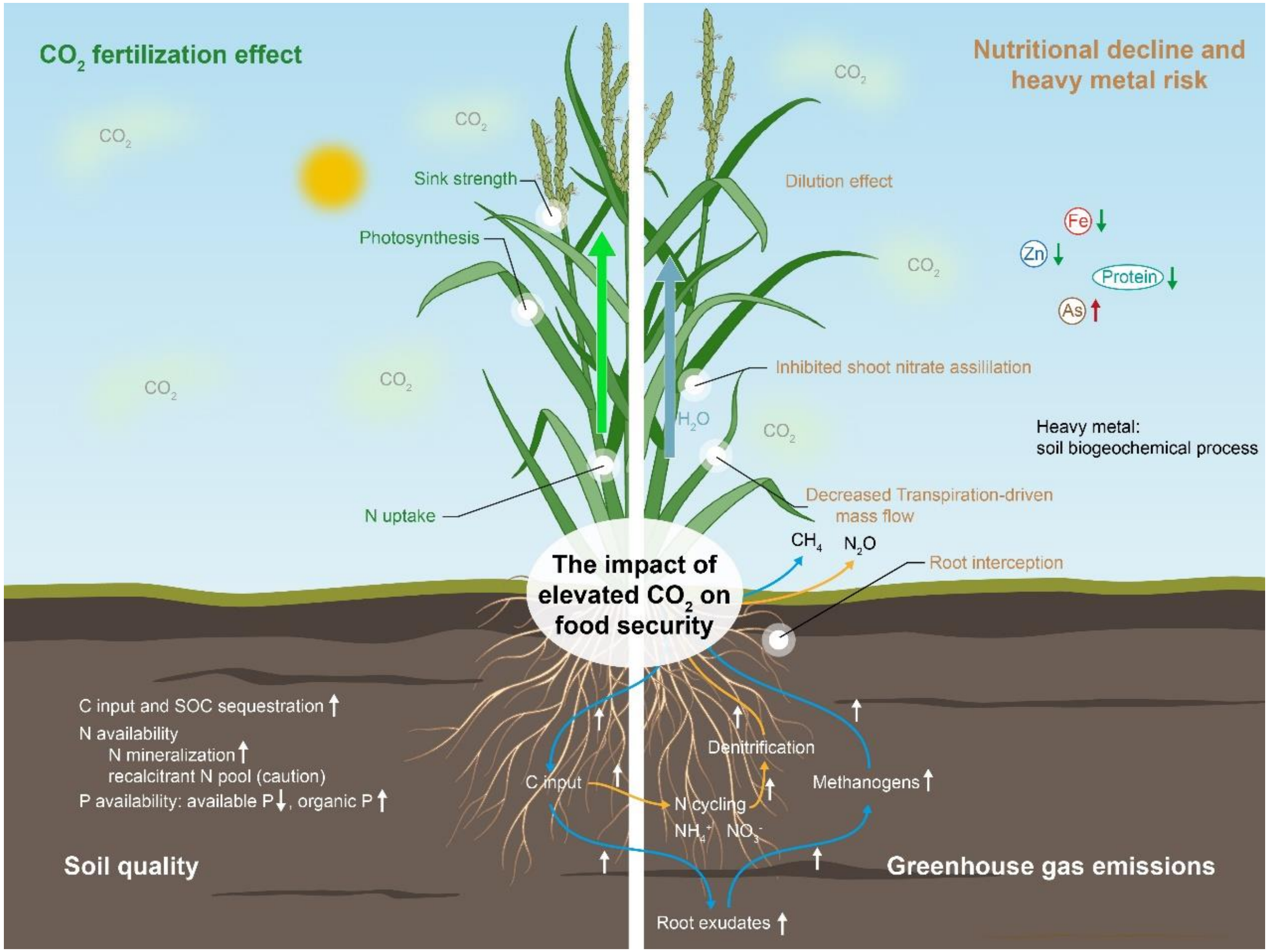
The last decade (2011-2020) was the warmest on record



CO_2 is projected to reach 500-1000 ppm; Global average temperature will rise.

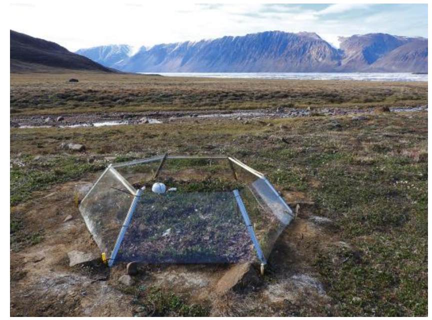
IPCC,2021,WorldBank 2024; UN climate change 2024

Climate change will impact whole agricultural system

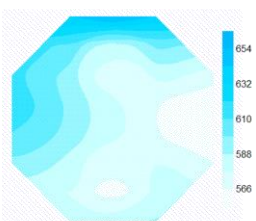


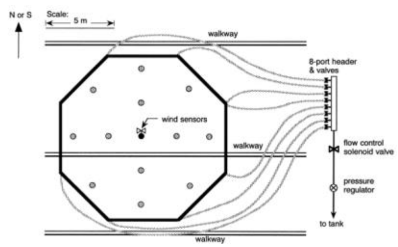
- Crop productivity
- Nutrition
- Heavy metal risk
- Soil quality
- GHG emissions

How to stimulate elevated CO_2 and temperture



FACE

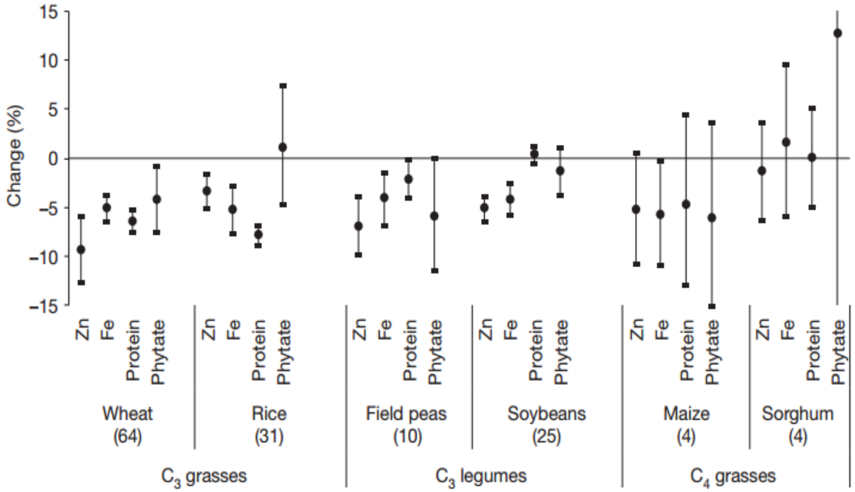




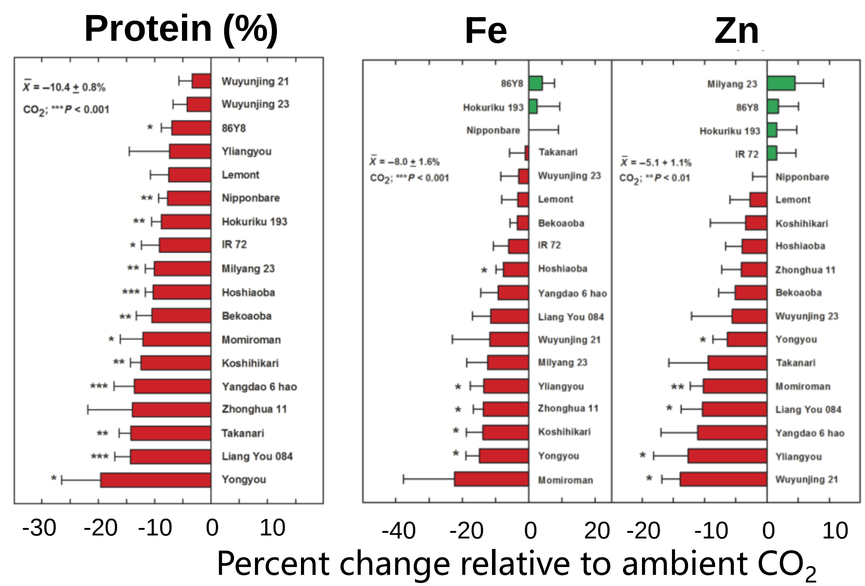
- FACE: Free air CO2 enrichment
- T-FACE: warming and FACE
- Work in field for ecology level

Elevated CO_2 increases global "hidden hugger"

➢ Global crop nutritional quality declines.

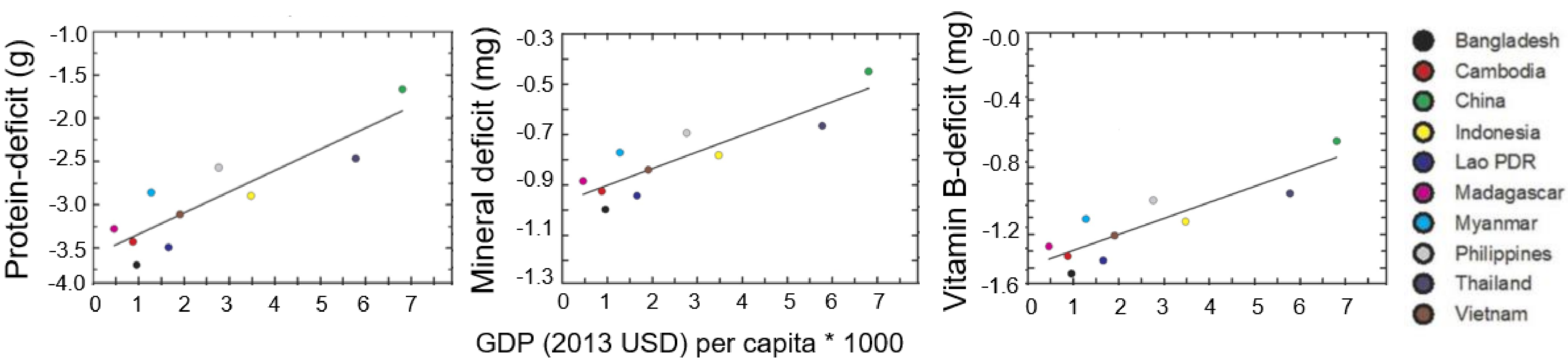


wheat, rice, soybean, maize, sorghum
Global meta analysis



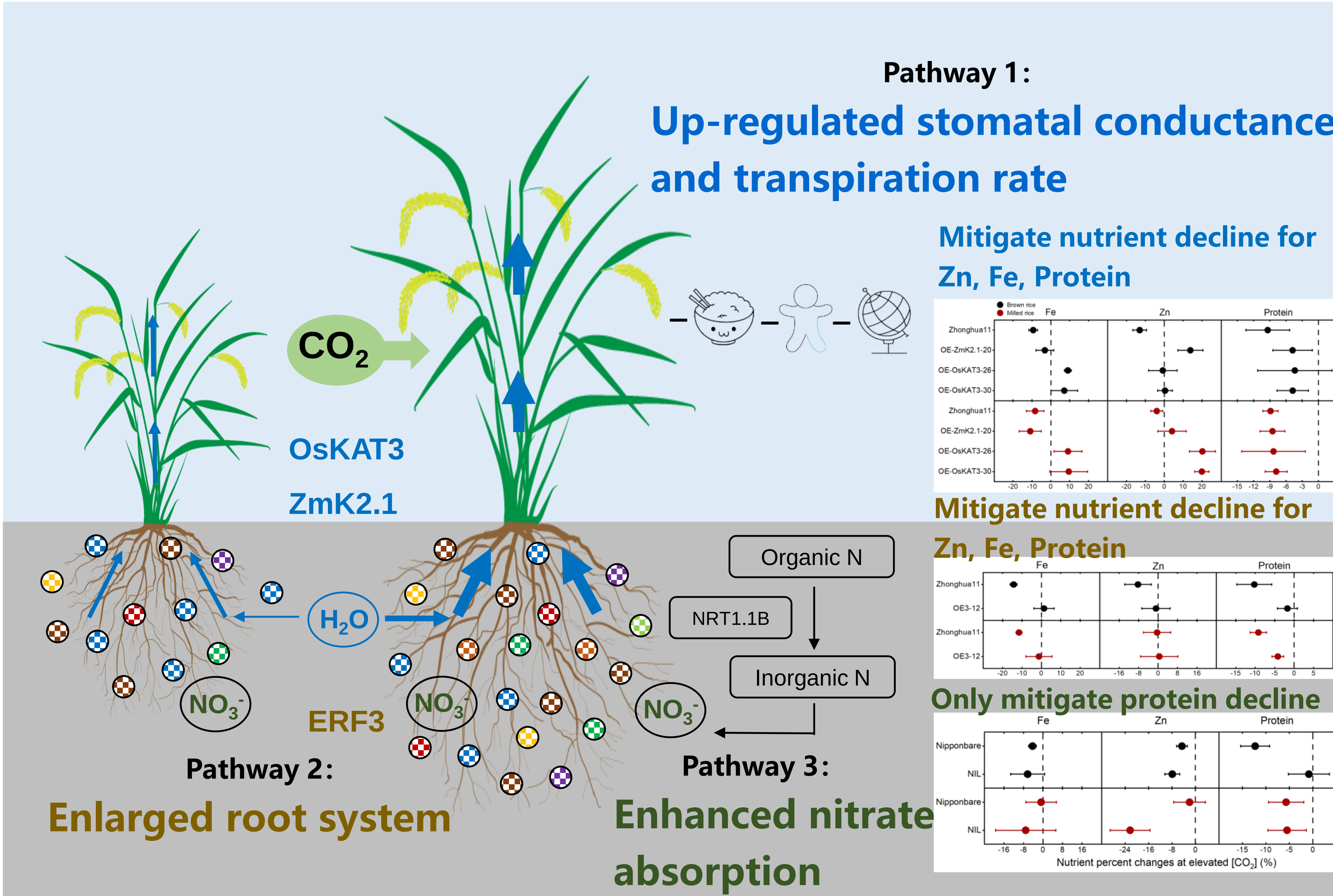
China and Japan FACE

➢ Posing risks for the health of 600 million people.

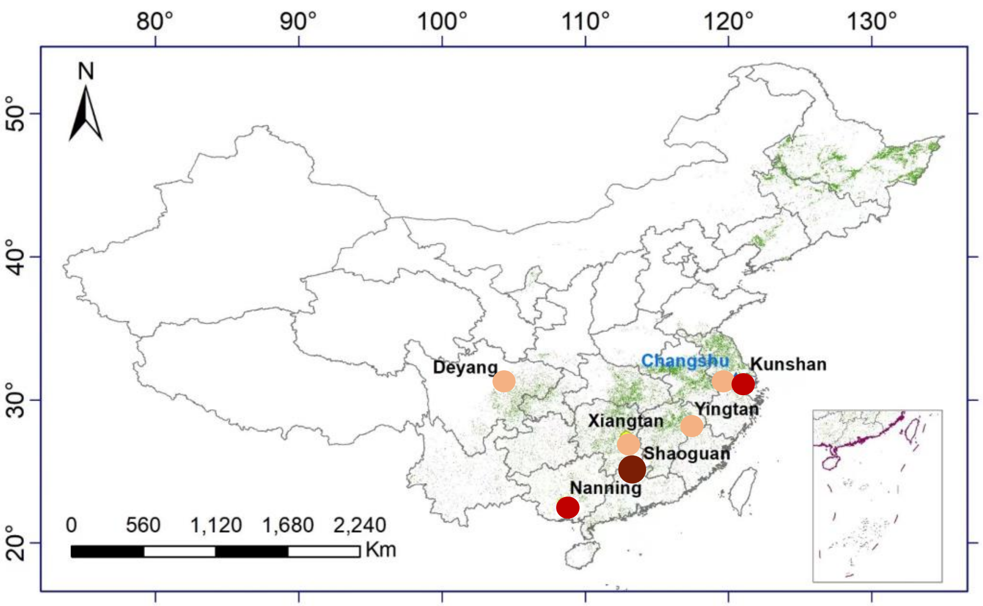


Myers et al, Nature, 2014, 2019; Zhu et al, Science Advances, 2018

Nutritional integrity also benefits from these actions.

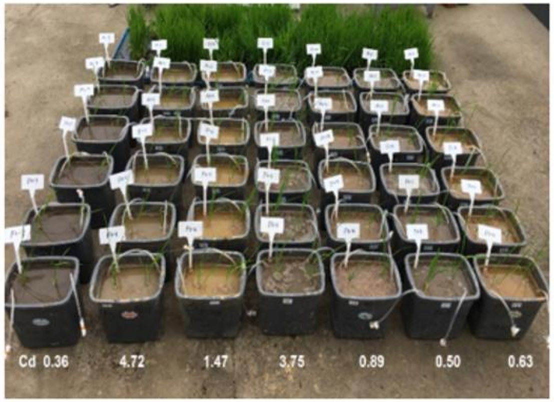


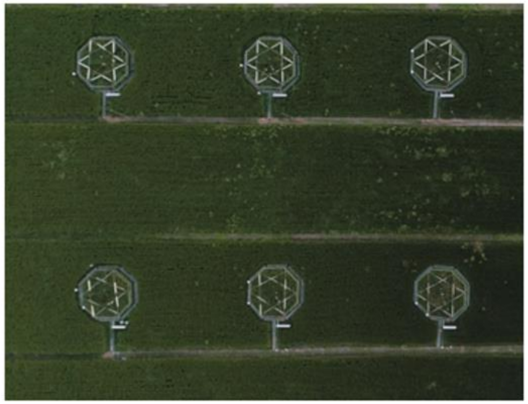
Will elevated CO_2 affects Cd (Cadmium) accumulation?



Soils

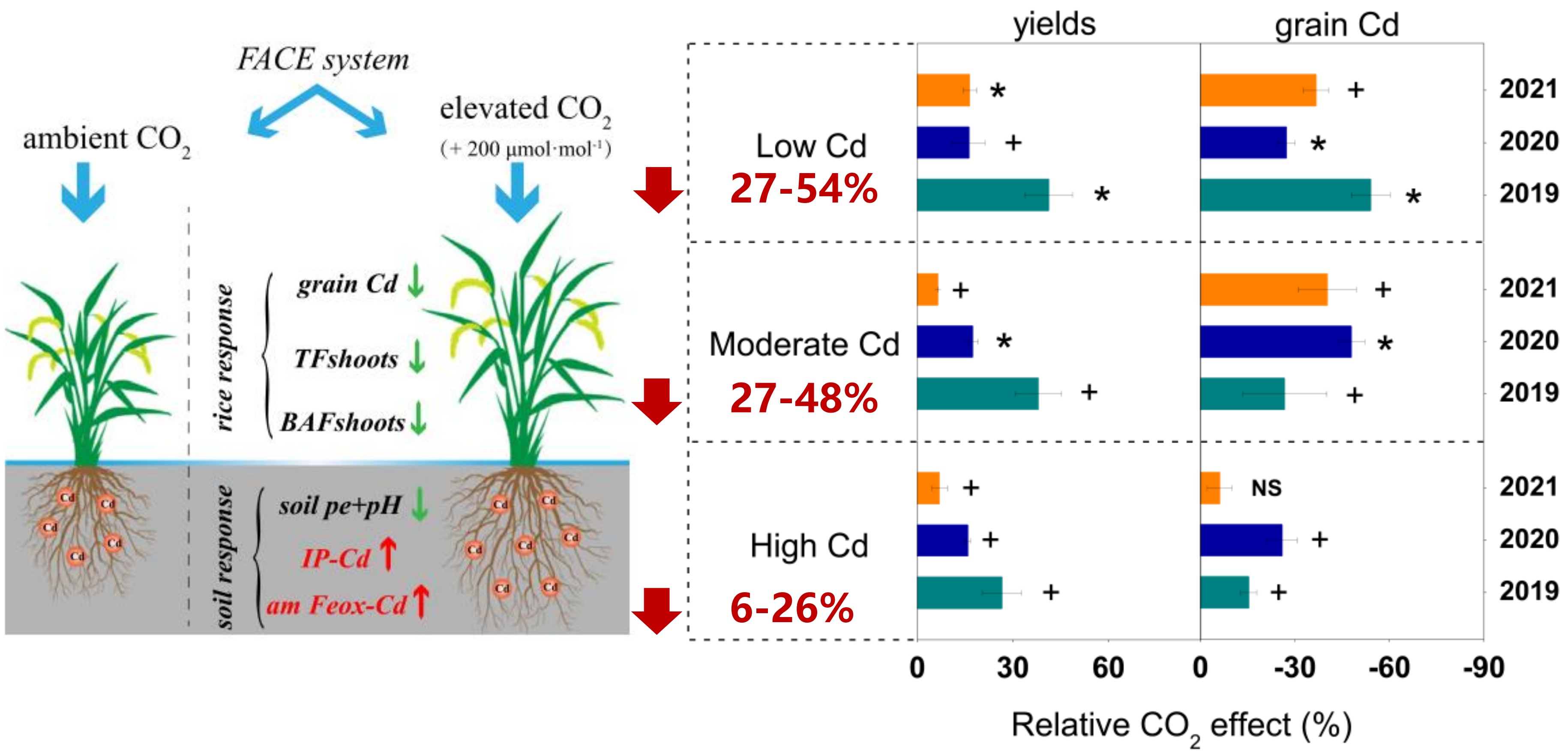
- Low Cd
- Moderate Cd
- High Cd





FACE study-multiple in situ Cd contaminated soils in South China

Elevated CO_2 declines Cd bioaccumulation

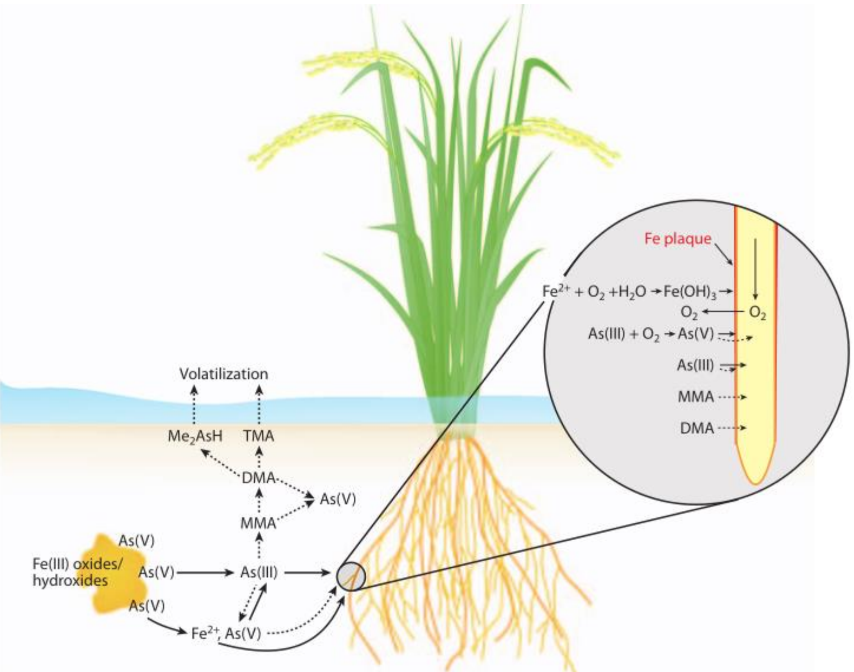


Three-year experiment: eCO_2 lowered Cd concentration:

- **The availability of Cd decreased in soils**
- **Increases Cd retention in Fe plaque of root**
- **Decreases Cd transfer from root to grain.**

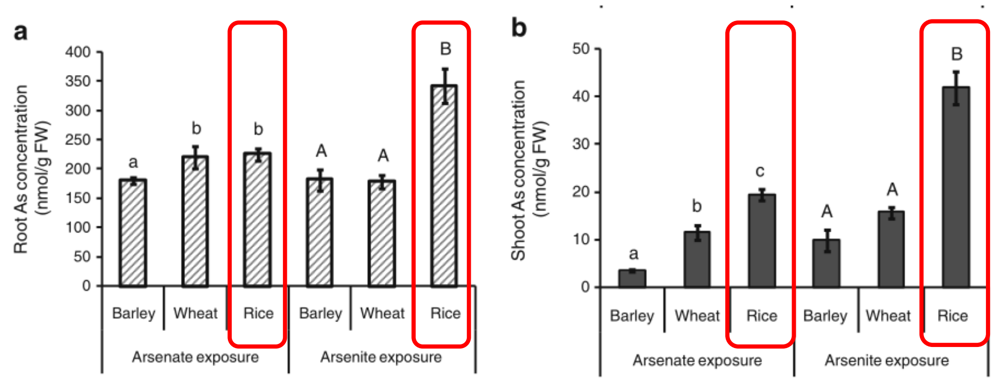
Climate change and arsenic bioaccumulation?

Soil

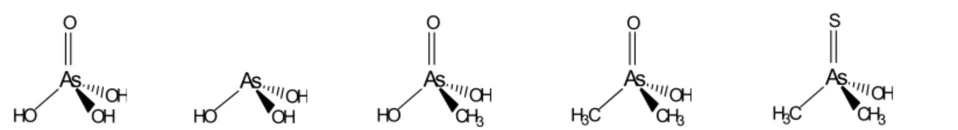


Arsenic mobilization and transformation in flooded paddy soil and interactions in the rice rhizosphere.

Crop



Rice is efficient at As accumulation, thus posing a potential health risk to humans

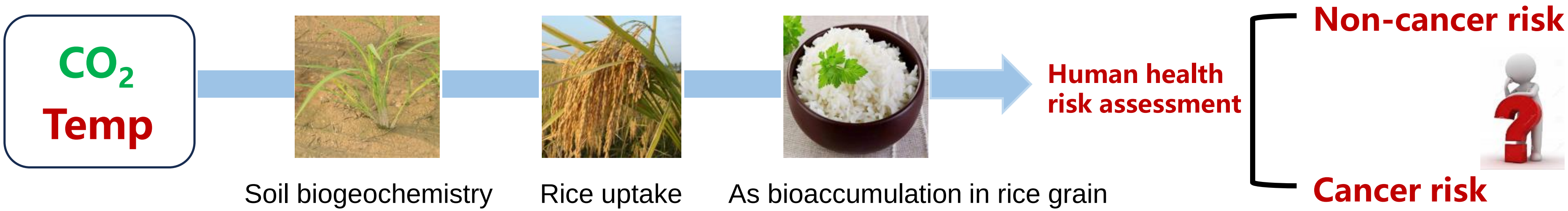


Arsenate | Arsenite | Monomethylarsenate (MMA) | Dimethylarsenate (DMA) | Dimethylmonothioarsenate (DMMTA)

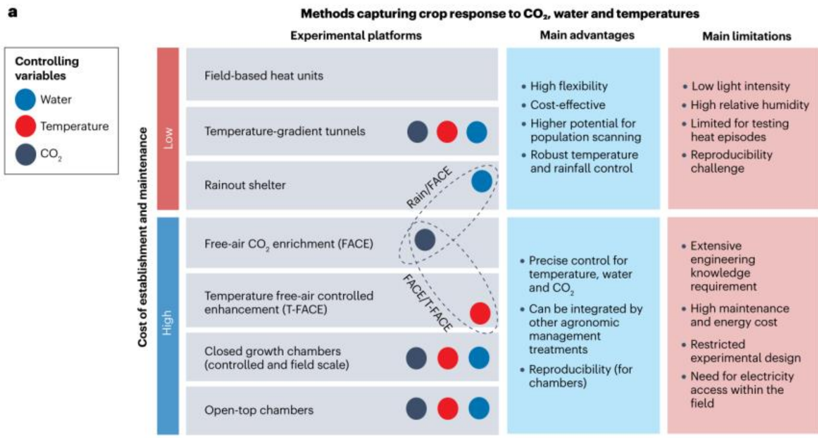
Chemical species of As commonly found in rice

Zhao et al., Molecular plant, 2022; Su et al., Plant soil, 2010; Zhao et al., Annu. Rev. Plant Biol, 2010

Climate change may influence arsenic uptake



Method – FACE (free-air CO_2 enrichment)



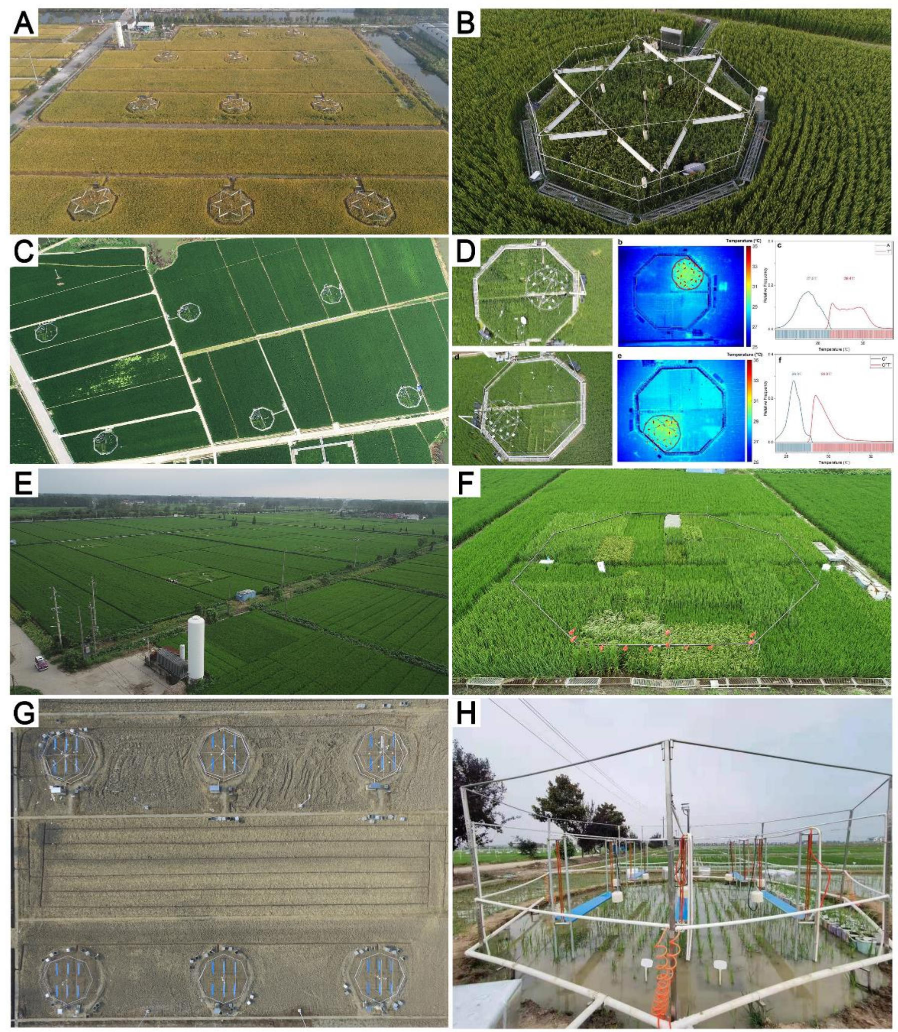
Our study covers 10 years (2014-2023)

FACE 1

FACE 2

FACE 3

FACE 4



Four FACE platforms:

FACE 1: Changshu   FACE 2: Nanjing

FACE 3: Yangzhou   FACE 4: Danyang

Four climate conditions:

1. Ambient

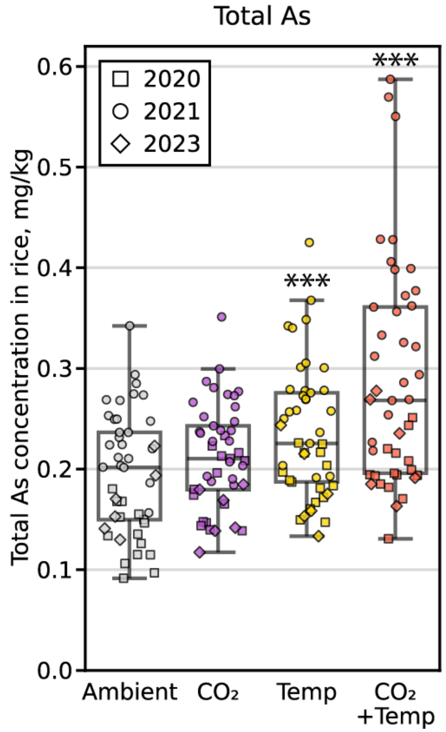
2. CO_2: +200 ppm

3. Temp: +2℃

4. CO_2+Temp: +200 ppm + 2℃

T-FACE study: Climate change increases total arsenic concentrations in rice grain

Cultivar	Subgroup
Changyou 5	Japonica (hybrid rice)
Chuanyou 6203	Indica (hybrid rice)
Cliangyou 810	Indica (hybrid rice)
Cliangyouhuazhan	Indica (hybrid rice)
Cliangyouyuehesimiao	Indica (hybrid rice)
Ningliangyou 1	Indica (hybrid rice)
Ningxianggeng 9	Japonica (conventional rice)
Quanyou 123	Indica (hybrid rice)
Shenliangyou 3206	Indica (hybrid rice)
Taoyouxiangzhan	Indica (hybrid rice)
Tianyouhuazhan	Indica (hybrid rice)
Xiangliangyou 143	Indica (hybrid rice)
Yongyou 7850	Indica (hybrid rice)



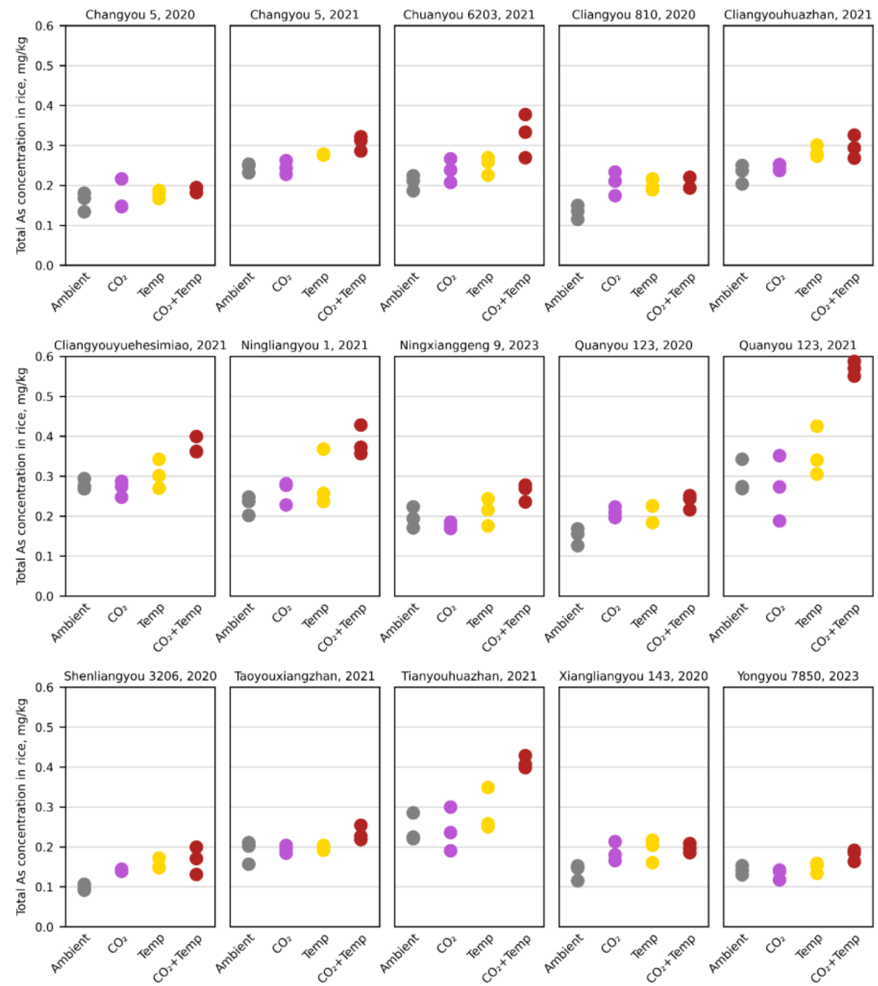
Four climate conditions:

Ambient

CO_2: +200 ppm

Temp: +2℃

CO_2+Temp: +200 ppm + 2℃



- **Temperature is an important driver**

T-FACE study: Climate change increases inorganic arsenic concentrations in rice grain

Cultivar	Subgroup
Changyou 5	Japonica (hybrid rice)
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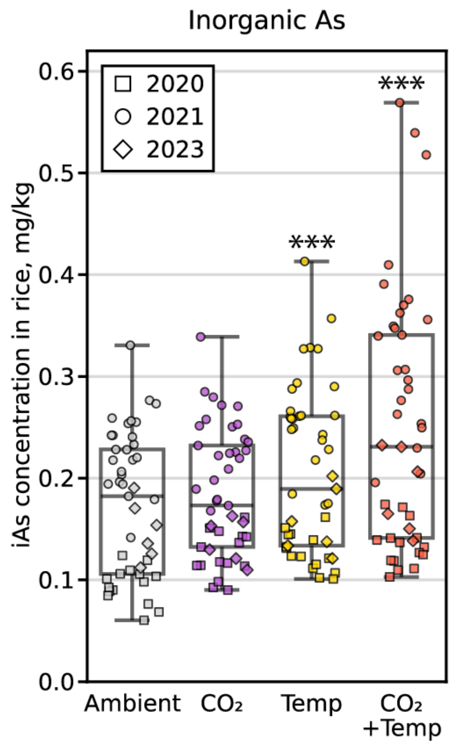


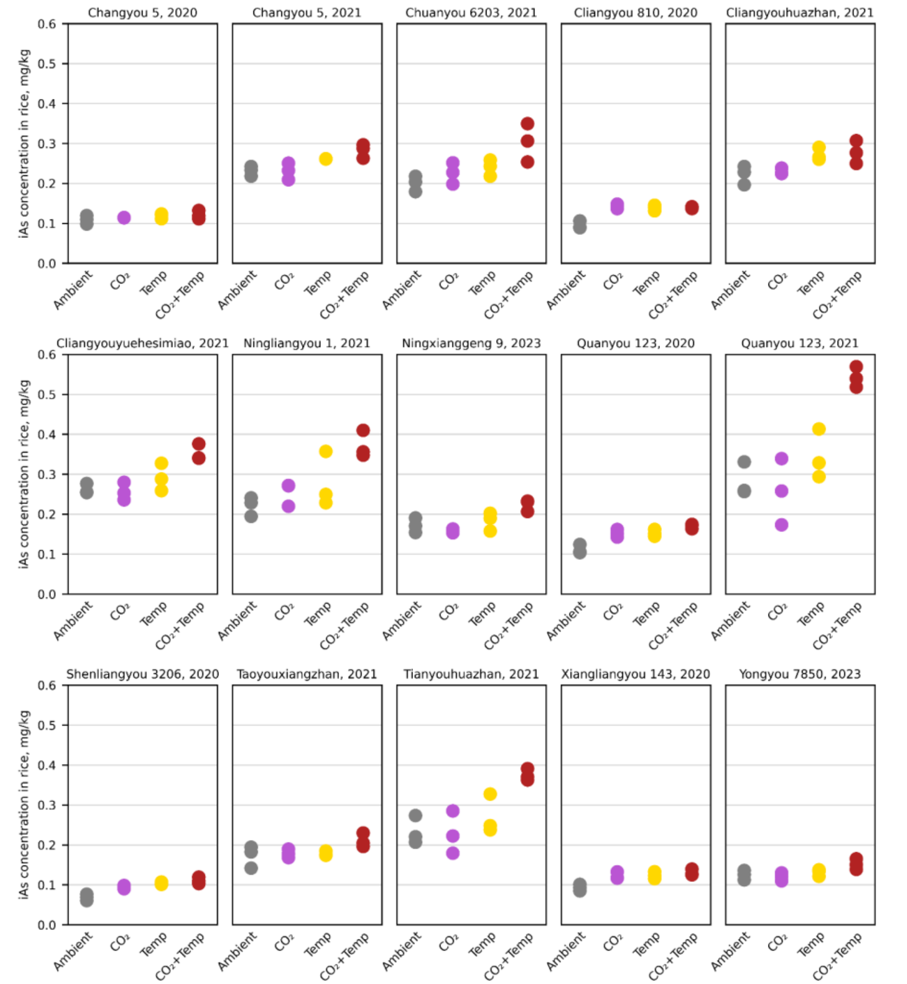
Four climate conditions:

Ambient

CO_2: +200 ppm

Temp: +2℃

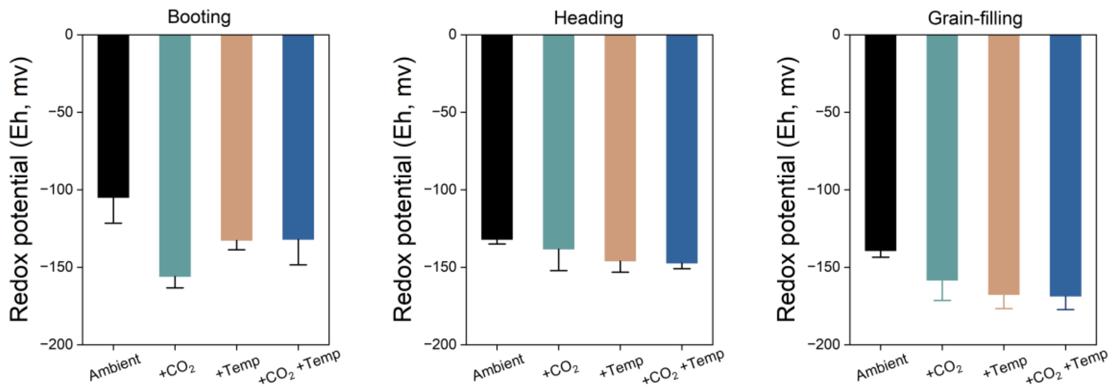
CO_2+Temp: +200 ppm + 2℃



- **Also, temperature is an important driver**

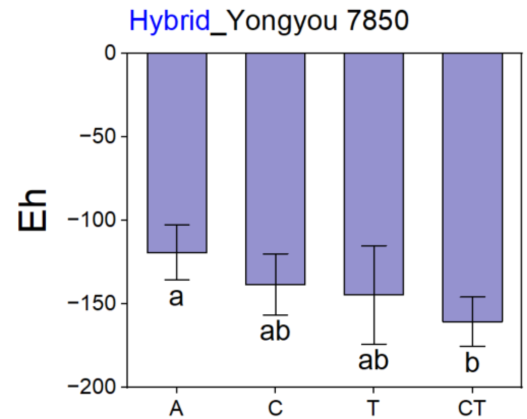
Mechanisms – pH and Eh

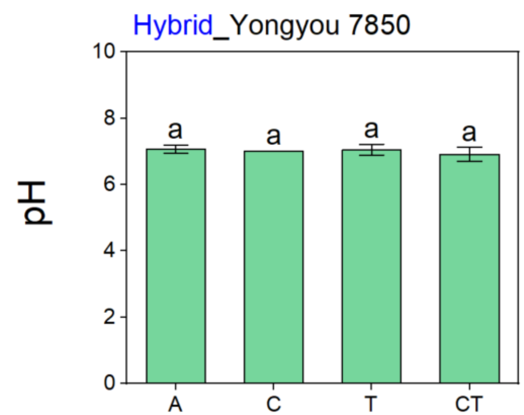
T-FACE 1



	Booting stage	Heading stage	Filling stage
pH			
Ambient	6.93 ± 0.03	6.81 ± 0.04	6.73 ± 0.04
CO_2	6.97 ± 0.02	6.86 ± 0.02	6.79 ± 0.12
Temp	6.86 ± 0.06	6.78 ± 0.02	6.71 ± 0.10
CO_2+Temp	6.85 ± 0.04	6.86 ± 0.07	6.75 ± 0.08
Eh (mV)			
Ambient	-105.0 ± 16.5	-132.0 ± 3.0	-139.3 ± 4.2
CO_2***	-156.0 ± 7.2	-138.3 ± 13.8	-158.3 ±13.1
Temp***	-132.7 ± 6.0	-146.0 ± 7.2	-167.7 ± 9.0
CO_2+Temp***	-132.0 ± 16.4	-147.3 ± 3.5	-168.7 ± 8.6

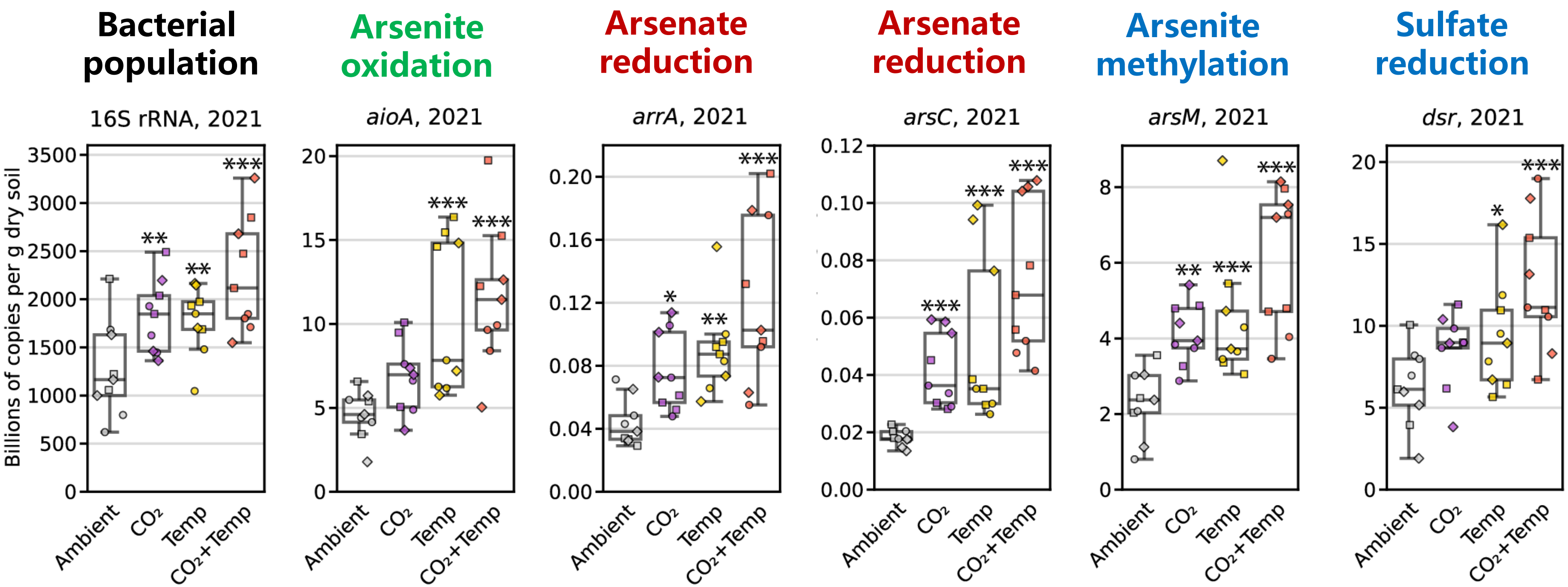
T-FACE 2





- No significant changes for pH
- Climate change reduced redox potential (Eh)

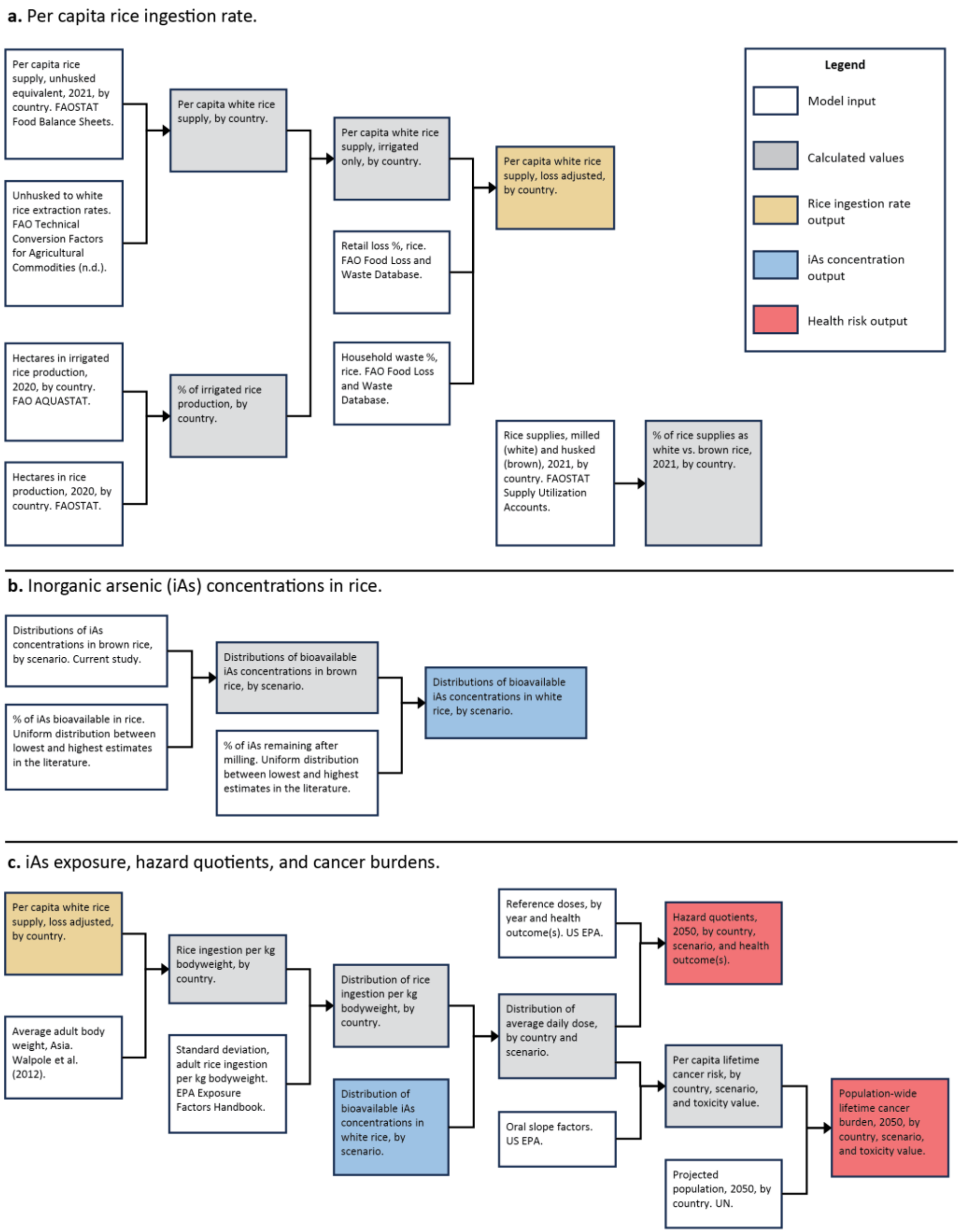
Mechanisms - Abundance of soil microbial genes involved in the transformation of arsenic species



arsC	Booting stage	Heading stage	Grain-filling stage
	Change (%)	Change (%)	Change (%)
CO_2	+70%	+78%**	+276%***
Temp	+69%	+65%**	+489%***
CO_2+Temp	+231%***	+153%***	+593%***

- **Bacterial population increases substantially.**
- **The arsenic reduction process was stimulated by climate change, especially at grain-filling stage.**

Health risk assessment – Data flow diagram



Step 1: Rice ingestion rate

Step 2: Inorganic As conc.

Step 3: Health risk assessment

Health risk assessment

Mean inorganic arsenic exposure due to rice ingestion

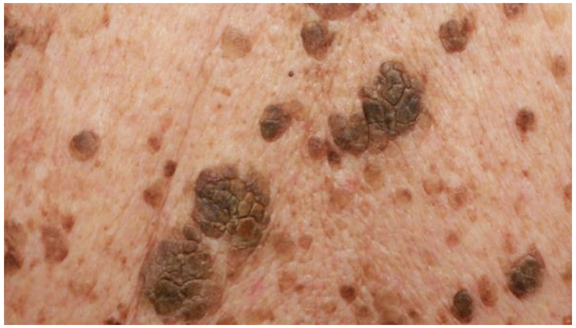
Country	Ambient	CO_2	Temp	CO_2+Temp
Vietnam	3.95×10^{-4}	4.22×10^{-4}	4.71×10^{-4}	5.69×10^{-4}
Indonesia	3.29×10^{-4}	3.52×10^{-4}	3.92×10^{-4}	4.74×10^{-4}
China	2.20×10^{-4}	2.35×10^{-4}	2.62×10^{-4}	3.15×10^{-4}
Bangladesh	1.79×10^{-4}	1.92×10^{-4}	2.13×10^{-4}	2.59×10^{-4}
Philippines	1.76×10^{-4}	1.88×10^{-4}	2.09×10^{-4}	2.53×10^{-4}
Myanmar	1.35×10^{-4}	1.45×10^{-4}	1.61×10^{-4}	1.95×10^{-4}
India	1.04×10^{-4}	1.11×10^{-4}	1.24×10^{-4}	1.49×10^{-4}

- **Climate change increases inorganic arsenic exposure by more than 40%**

Health risk assessment

Non-cancer desease risks

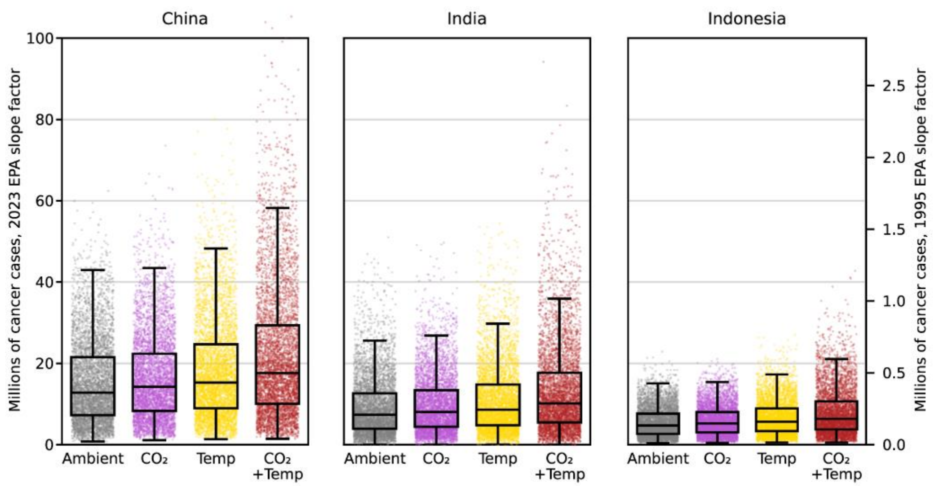
Health outcome (reference dose year)	Ambient	CO_2	Temp	CO_2+Temp
Viet Nam				
Hyperpigmentation, keratosis, vascular complications (1991)	1.1 (0.6-1.8)	1.2 (0.7-1.9)	1.3 (0.8-2.1)	1.5 (0.9-2.5)
Cardiovascular disease (2023)	11.0 (6.1-17.6)	12.1 (7.0-18.6)	12.9 (7.7-20.6)	14.7 (8.6-24.5)
Ischemic heart disease, diabetes (2023)	7.2 (4.1-11.6)	8.0 (4.6-12.3)	8.5 (5.1-13.6)	9.7 (5.7-16.1)
Adverse pregnancy and birth outcomes (2023)	4.4 (2.5-7.1)	4.9 (2.8-7.5)	5.2 (3.1-8.3)	5.9 (3.5-9.9)
Indonesia				
Hyperpigmentation, keratosis, vascular complications (1991)	0.9 (0.5-1.5)	1.0 (0.6-1.6)	1.1 (0.7-1.8)	1.3 (0.7-2.1)
Cardiovascular disease (2023)	9.0 (5.1-14.7)	10.1 (5.8-15.4)	10.8 (6.4-17.1)	12.2 (7.2-20.5)
Ischemic heart disease, diabetes (2023)	6.0 (3.4-9.7)	6.6 (3.8-10.2)	7.1 (4.2-11.3)	8.1 (4.7-13.5)
Adverse pregnancy and birth outcomes (2023)	3.6 (2.1-5.9)	4.0 (2.3-6.2)	4.4 (2.6-6.9)	4.9 (2.9-8.2)



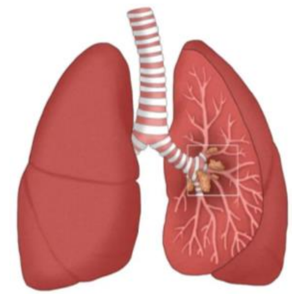
- **Human face higher risks of non-cancer risks due to climate change**

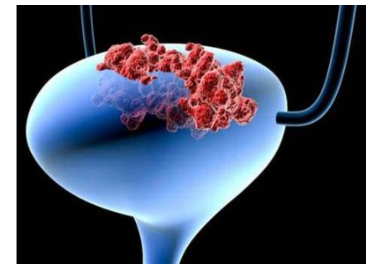
Health risk assessment

Projected lifetime cancer risks in 2050

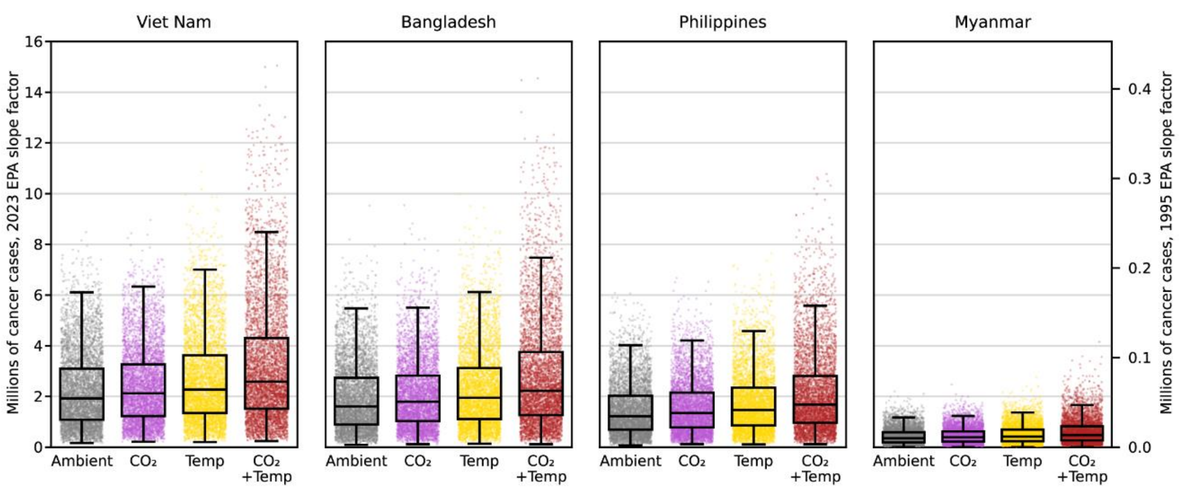


$$CB_{s,c,o} = D_{s,c} \times OSF_o \times Pop_c$$





Lung cancer **Bladder cancer**



1. Current cancer slope factor

2. Draft proposed cancer slope factor

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY EPA EMERGENCY RESPONSE

- **The number of lifetime bladder and lung cancer cases increased substantially.**

Take home messages

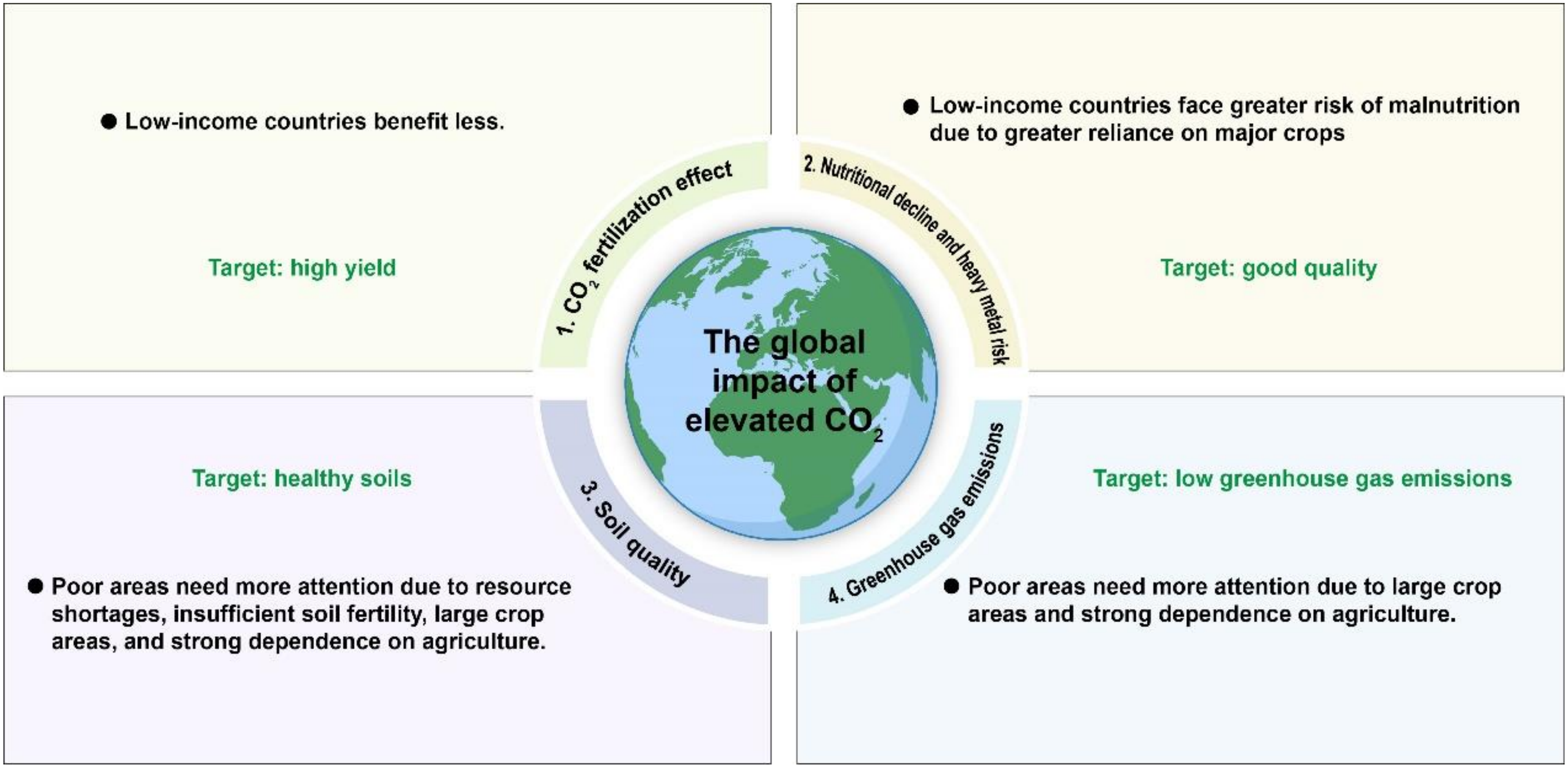
Nutrient decline

- Zn, Fe, Protein and vitamin decreased globally.
- Increased transpiration, enlarged root system and enhanced nitrate absorption can help to mitigate nutrient decline.
- More adaption actions for crops are needed.

Heavy metal risk

- Climate change increases in inorganic arsenic accumulation in rice grain.
- More no-cancer diseases and cancer risk in Asian
- How to decline arsenic？？

Our goal: Climate Change-Resilient Agricultural Ecosystem



Thank you

中國科學院南京土壤研究所
INSTITUTE OF SOIL SCIENCE, CHINESE ACADEMY OF SCIENCES

南京農業大學
NANJING AGRICULTURAL UNIVERSITY

JOHNS HOPKINS
BLOOMBERG SCHOOL
of PUBLIC HEALTH

COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

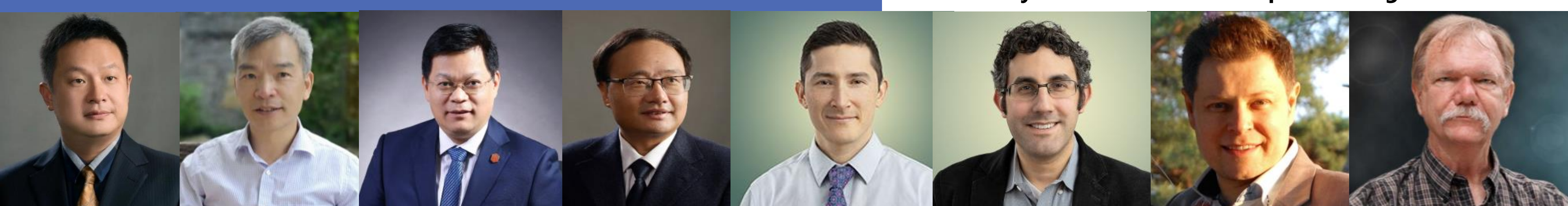
Acknowledgements

National Natural Science Foundation of China

Carbon Peaking and Carbon Neutrality Special Fund for Science and Technology from Nanjing Science and Technology Bureau

Key Research and Development Program of Jiangsu Province

National Key Research and Development Program



朱春梧 赵方杰 朱永官 颜晓元 Brent Kim Keeve Nachman Irakli Loladze Lewis Ziska