ICMGP 2024
CAPE TOWN • SOUTH AFRICA • 21 - 26 JULY
CAPE TOWN INTERNATIONAL CONVENTION CENTRE

Mercury stress and methylation promote carbon emission from rice paddy soils

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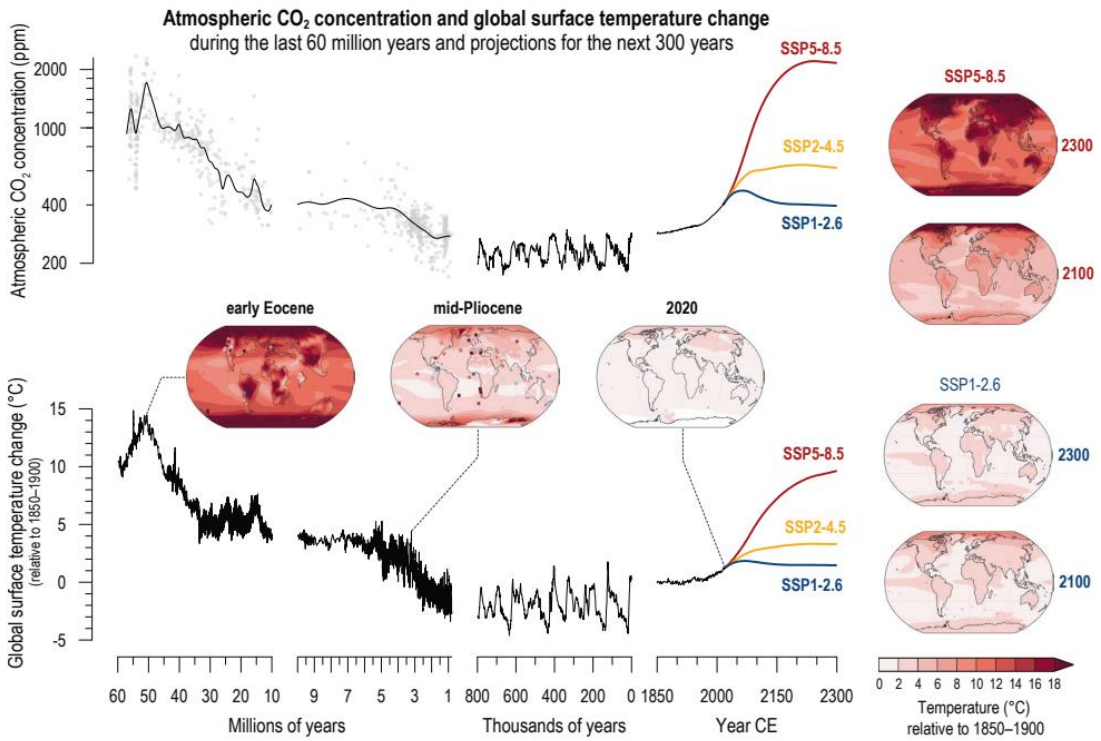
24 July 2024

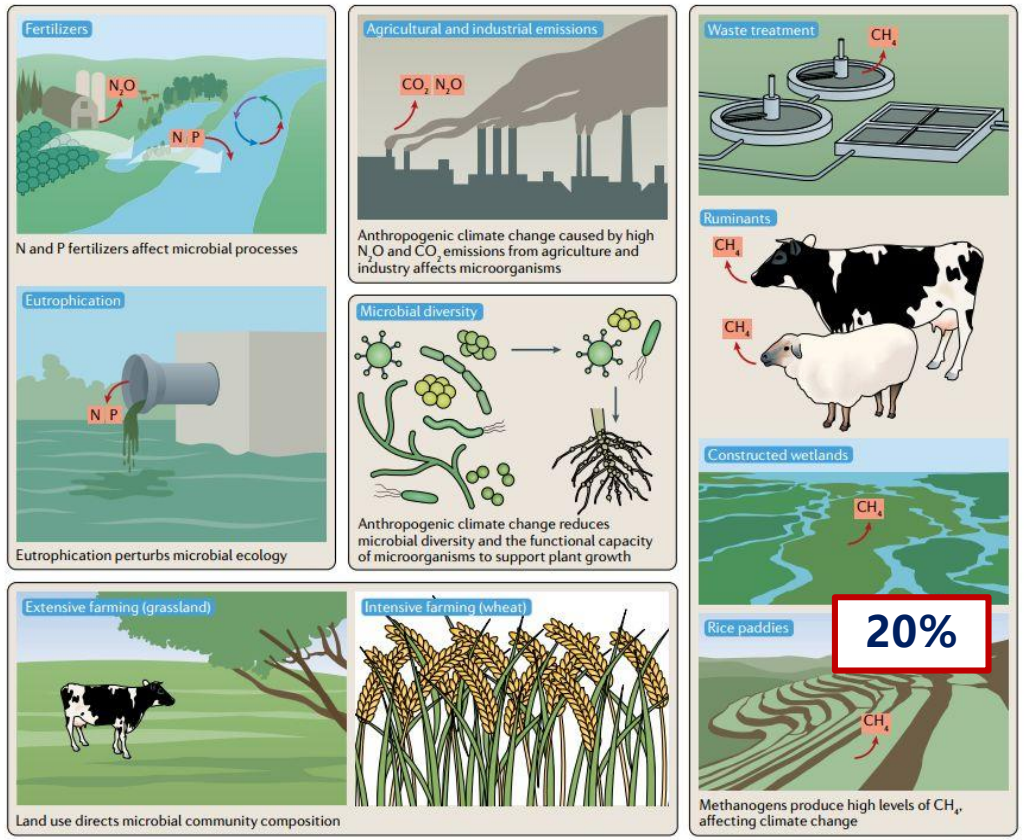
Background

Climate change from GHG emissions



IPCC, 2021

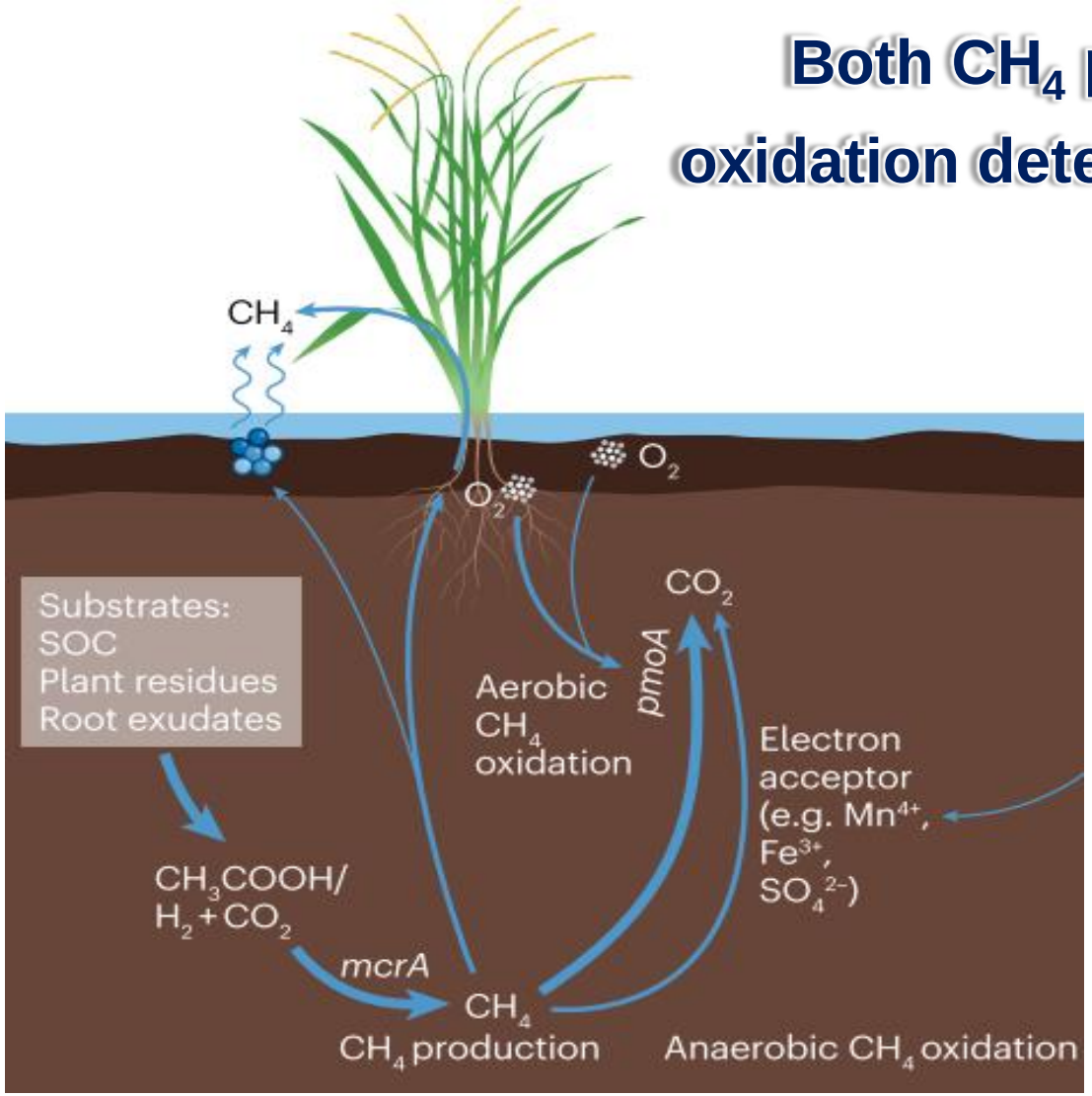
Paddy field is one of the most important agricultural sources for CH_4 emission



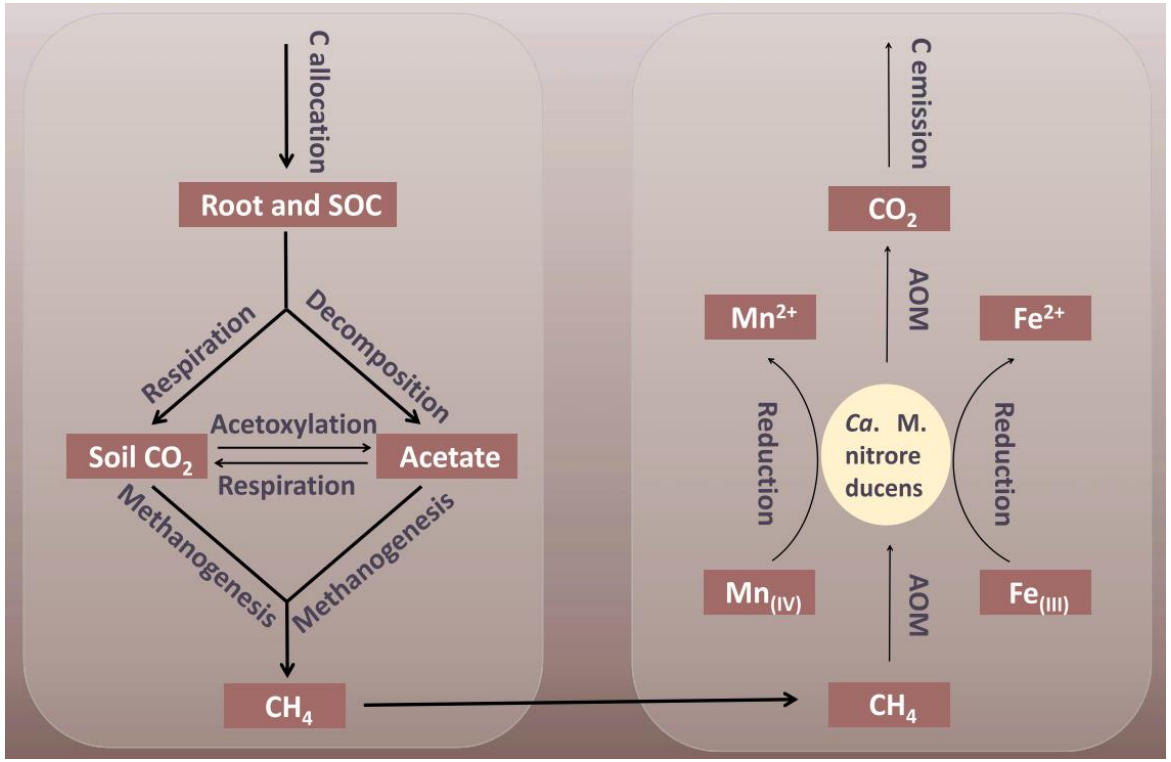
Cavicchioli et al., 2019

Background

Both CH_4 production (Methanogenesis) and CH_4 oxidation determined emission of CH_4 from paddy soils



Qian et al., 2023



Xu et al., 2023

Background

Environ. Sci. Technol. 2008, 42, 326–332

Human Exposure To Methylmercury through Rice Intake in Mercury Mining Areas, Guizhou Province, China

XINBIN FENG,*,† PING LI,†,‡ GUANGLE QIU,† SHAOFENG WANG,†,‡ GUANGHUI LI,†,‡ LIHAI SHANG,† BO MENG,†,‡ HONGMEI JIANG,†,‡ WEIYANG BAI,†,‡ ZHONGGEN LI,† AND XUEWU FU†,‡

and placental barriers without hindrance to reach its principal target tissue, the brain (3). Because Me-Hg compounds are no longer used as fungicides, the principal and probably sole route of human exposure is currently believed to be through consumption of fish, fish products, and marine mammals (3, 4). Many studies have found that Me-Hg concentrations in human hair show a positive correlation with fish consumption (5–7).The long-range atmospheric transport of Hg, and in certain areas, the effects of acid rain and water impoundment, have led to "blacklisting" of thousands of lakes in North America and North Europe because the fish exceeded the state or Federal health guidelines for Me-Hg (8, 9). Tremendous efforts have been devoted to understanding the relationship of Hg deposition

Feng et al., 2008

J. Agric. Food Chem. 2008, 56, 2465–2468 2465

JOURNAL OF AGRICULTURAL AND FOOD CHEMISTRY

Methylmercury Accumulation in Rice (*Oryza sativa* L.) Grown at Abandoned Mercury Mines in Guizhou, China

GUANGLE QIU,† XINBIN FENG,*,† PING LI,†,‡ SHAOFENG WANG,†,§ GUANGHUI LI,†,# LIHAI SHANG,† AND XUEWU FU†,‡

Qiu et al., 2008

ehp Environmental Health Perspectives

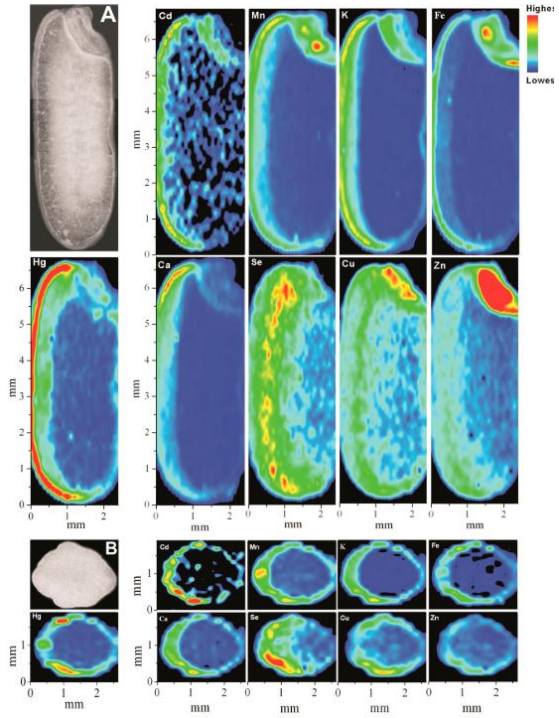
In Inland China, Rice, Rather than Fish, Is the Major Pathway for Methylmercury Exposure

Hua Zhang,[1,2] Xinbin Feng,[1] Thorjørn Larssen,[3,4] Guangle Qiu,[1] and Rolf D. Vogt[4]

[1]State Key Laboratory of Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, Guiyang, China; [2]Graduate University of Chinese Academy of Sciences, Beijing, China; [3]Norwegian Institute for Water Research, Oslo, Norway; [4]Department of Chemistry, University of Oslo, Oslo, Norway

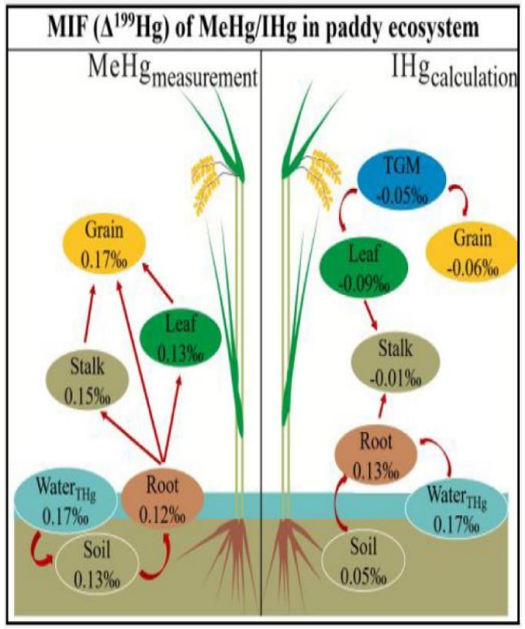
Zhang et al., 2010

Hg distribution in rice grain

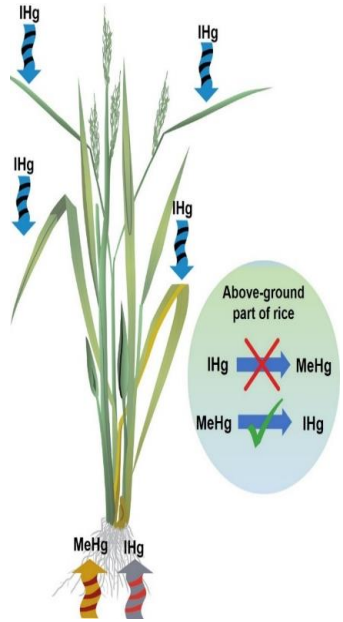


Meng et al., 2014

Sources of IHg and MeHg in rice



Qin et al., 2020



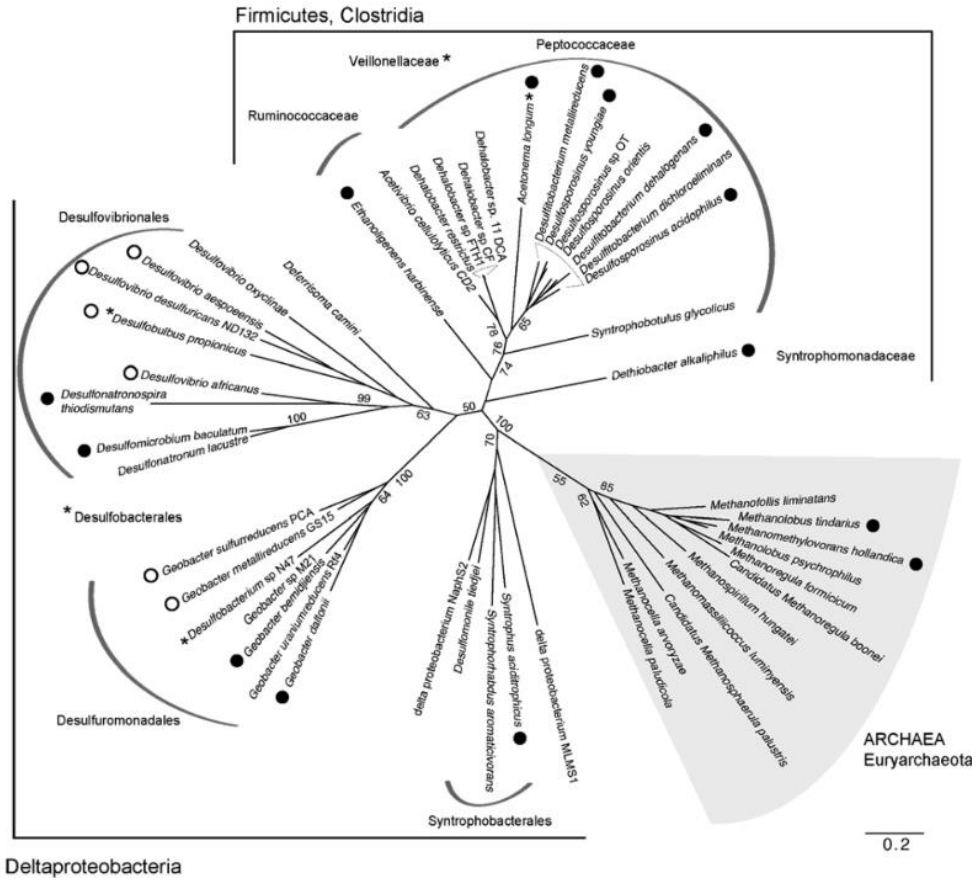
Liu et al., 2021

Previous understandings

- **MeHg was accumulated in rice grain**
- **Paddy soil is the unique source of MeHg accumulated in rice**
- ***In-situ* methylation is the source of MeHg in paddy soils**

Background

Microorganisms containing *hgcAB* orthologues



Gilmour et al., 2013

Archaeal Hg methylators

Kingdom	Phylum	Class	Order	Family	Strains
Archaea (8)	Euryarchaeota (8)	Methanomicrobia (7)	Methanosarcinales (2)	Methanosarcinaceae (2)	*Methanolobus tindarius* *Methanomethylovorans hollandica*
			Methanomicrobiales (4)	Methanospirillaceae (1)	*Methanospirillum hungatei* JF-1
				Methanocorpusculaceae (1)	*Methanocorpusculum bavaricum*
				Methanomicrobiaceae (1)	*Methanofollis liminatans* GKZPZ
				Methanoregulaceae (1)	*Methanosphaerula palustris* E1-9c
			Methanocellales (1)	Methanocellaceae (1)	*Methanocella paludicola* SANAE
		Thermoplasmata (1)	Methanomassiliicoccales (1)	Methanomassiliicoccaceae (1)	*Methanomassiliicoccus luminyensis* B10

Ma et al. 2019

Methanogens are anaerobic microorganisms involved in Hg methylation

Background

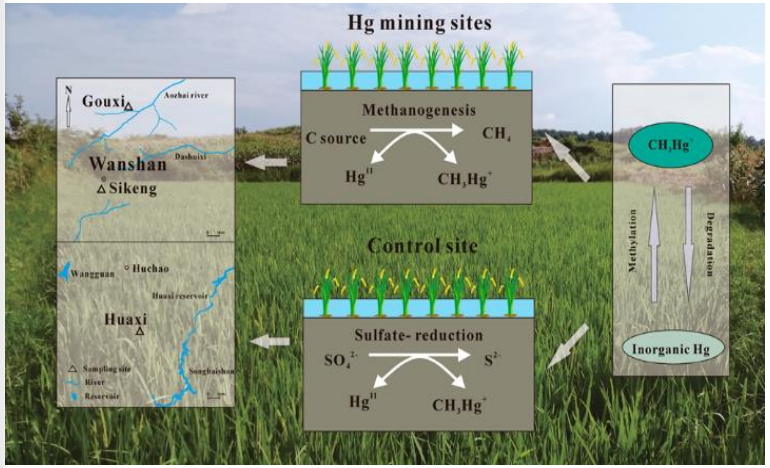
Our previous work: methanogenesis is coupled with MeHg demethylation

Environmental Science & Technology
pubs.acs.org/est
Article

Methanogenesis Is an Important Process in Controlling MeHg Concentration in Rice Paddy Soils Affected by Mining Activities

Qingqing Wu, Haiyan Hu,* Bo Meng,* Baolin Wang, Alexandre J. Poulain, Hua Zhang, Jinling Liu, Andrea G. Bravo, Kevin Bishop, Stefan Bertilsson, and Xinbin Feng

Cite This: *Environ. Sci. Technol.* 2020, 54, 13517−13526 Read Online

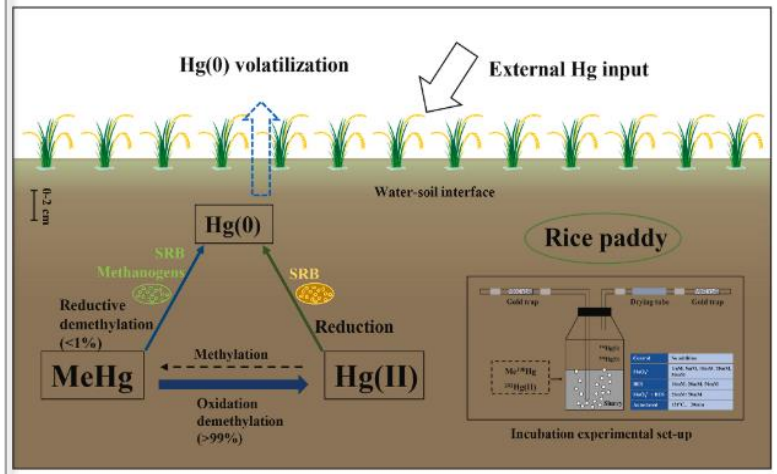


Wu et al., 2020

Journal of Hazardous Materials 460 (2023) 132486
Contents lists available at ScienceDirect
Journal of Hazardous Materials
journal homepage: www.elsevier.com/locate/jhazmat

Sulfate-reduction and methanogenesis are coupled to Hg(II) and MeHg reduction in rice paddies

Qingqing Wu [a,b], Baolin Wang [a], Haiyan Hu [a,*], Andrea G. Bravo [c], Kevin Bishop [d], Stefan Bertilsson [d], Bo Meng [a], Hua Zhang [a,*], Xinbin Feng [a,b]

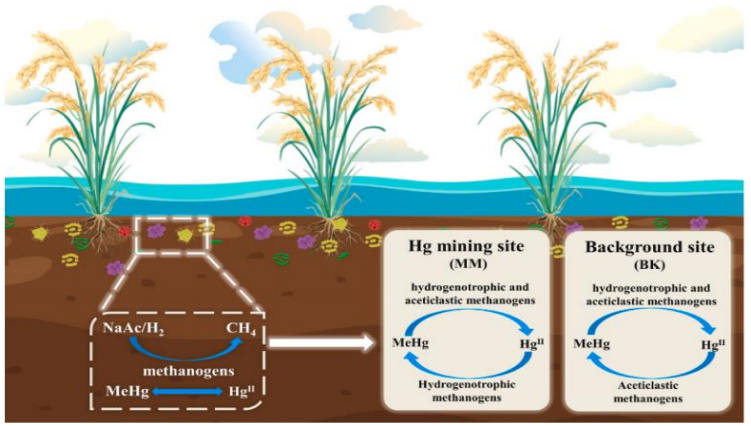


Wu et al., 2024

Science of the Total Environment 906 (2024) 167601
Contents lists available at ScienceDirect
Science of the Total Environment
journal homepage: www.elsevier.com/locate/scitotenv

Relative importance of aceticlastic methanogens and hydrogenotrophic methanogens on mercury methylation and methylmercury demethylation in paddy soils

Zhengdong Hao [a,b], Lei Zhao [c,d,*], Jiang Liu [a], Qiang Pu [a], Ji Chen [a], Bo Meng [a,**], Xinbin Feng [a,b]



Hao et al., 2024

Background

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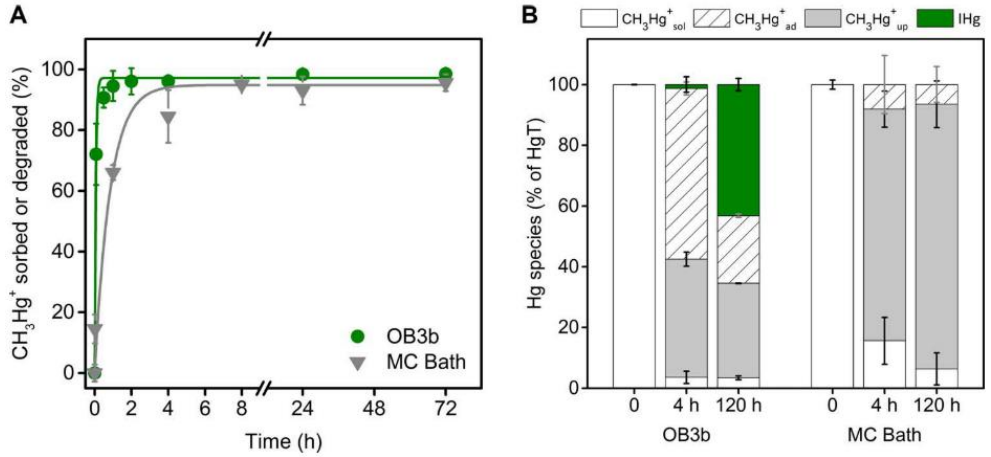
Methanotrophs mediated MeHg demethylation

SCIENCE ADVANCES | RESEARCH ARTICLE

ENVIRONMENTAL STUDIES

Methylmercury uptake and degradation by methanotrophs

Xia Lu,[1] Wenyu Gu,[2] Linduo Zhao,[1] Muhammad Farhan Ul Haque,[2] Alan A. DiSpirito,[3] Jeremy D. Semrau,[2] Baohua Gu[1]*



MeHg sorption and degradation

Lu et al., 2017

ISME

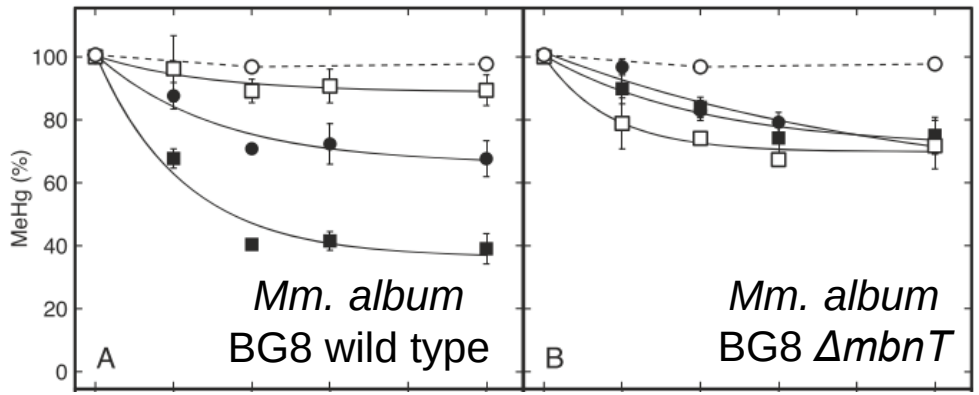
www.nature.com/ismej

ARTICLE

Check for updates

Evidence for methanobactin "Theft" and novel chalkophore production in methanotrophs: impact on methanotrophic-mediated methylmercury degradation

Christina S. Kang-Yun[1,8], Xujun Liang[2,8], Philip Dershwitz[3], Wenyu Gu[1,7], Aloys Schepers[4], Andrew Flatley[4], Josef Lichtmannegger[5], Hans Zischka[5,6], Lijie Zhang[2], Xia Lu[2], Baohua Gu[2], Joshua C. Ledesma[3], Daly J. Pelger[3], Alan A. DiSpirito[3] and Jeremy D. Semrau[1]✉

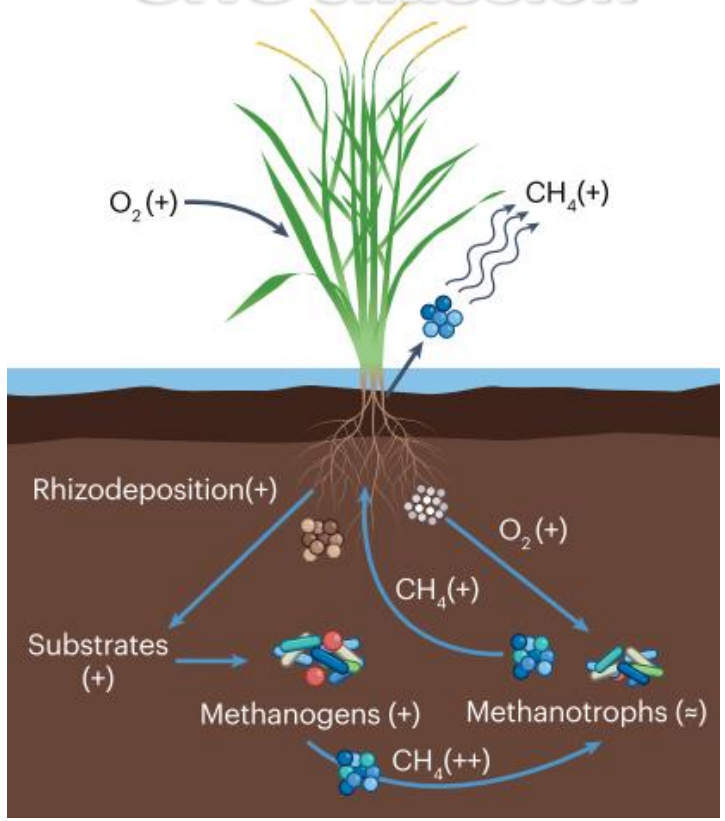


Degradation of MeHg by different methanotrophs

Kang-Yun et al., 2022

Question

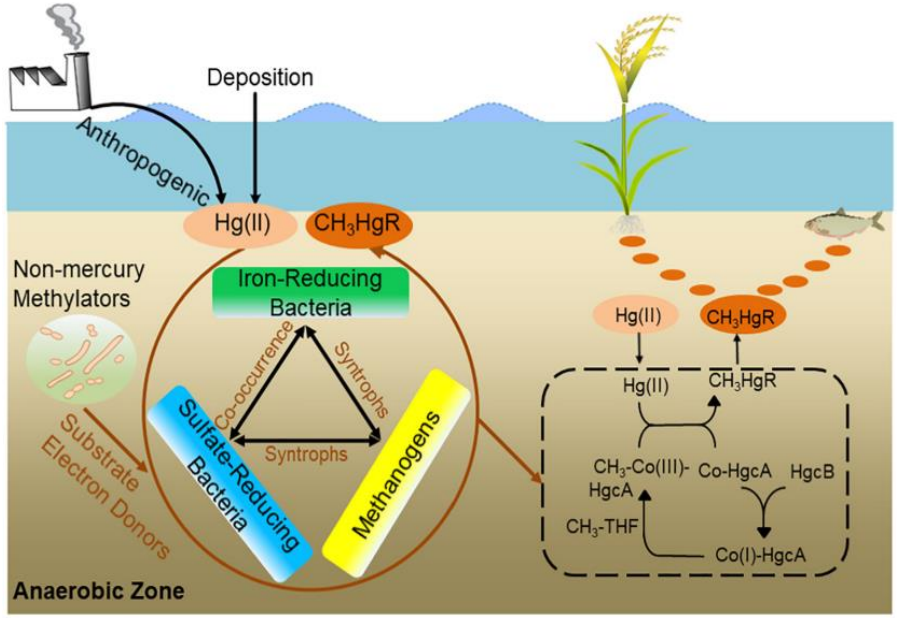
GHG emission



Qian et al., 2023

?

Production of MeHg

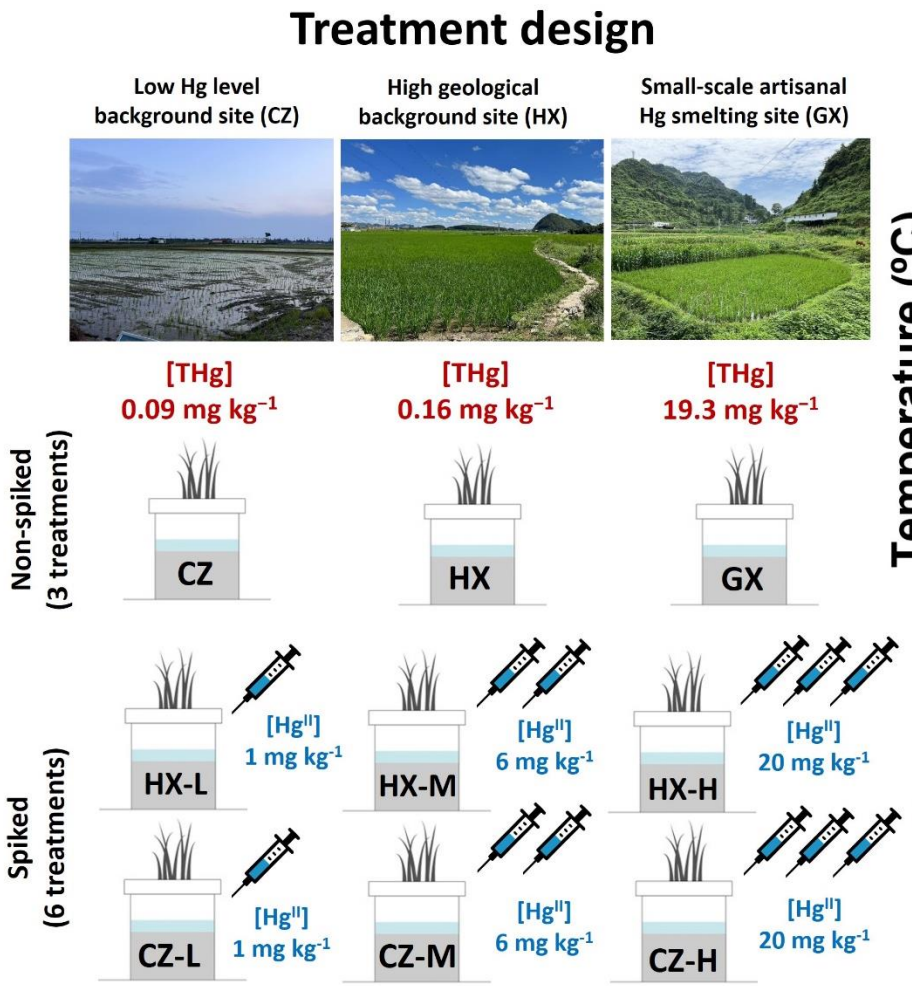


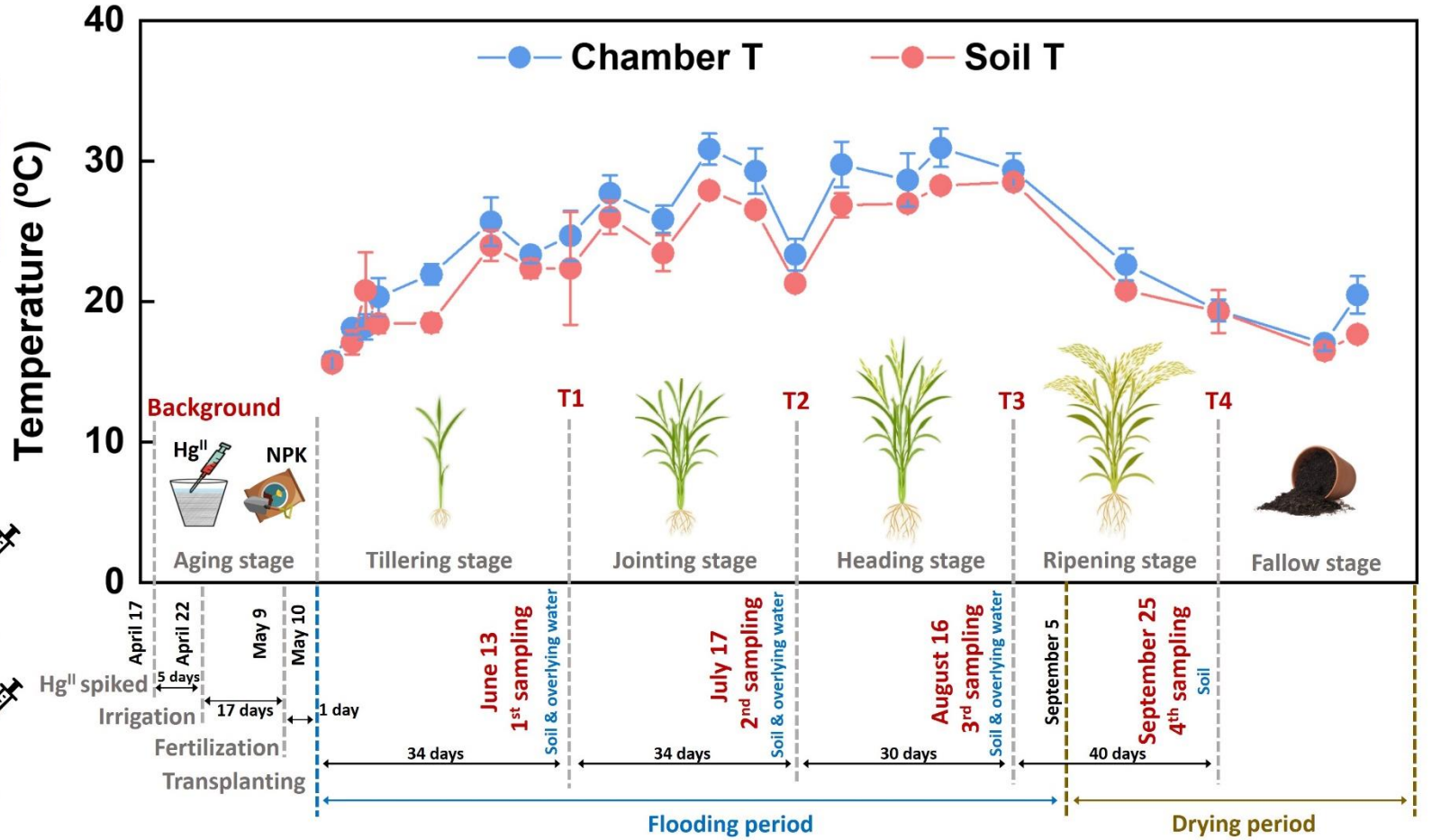
Tang et al., 2020

Interplay between GHG emission and MeHg dynamics in paddy ?

Methods & Materials

Treatment design

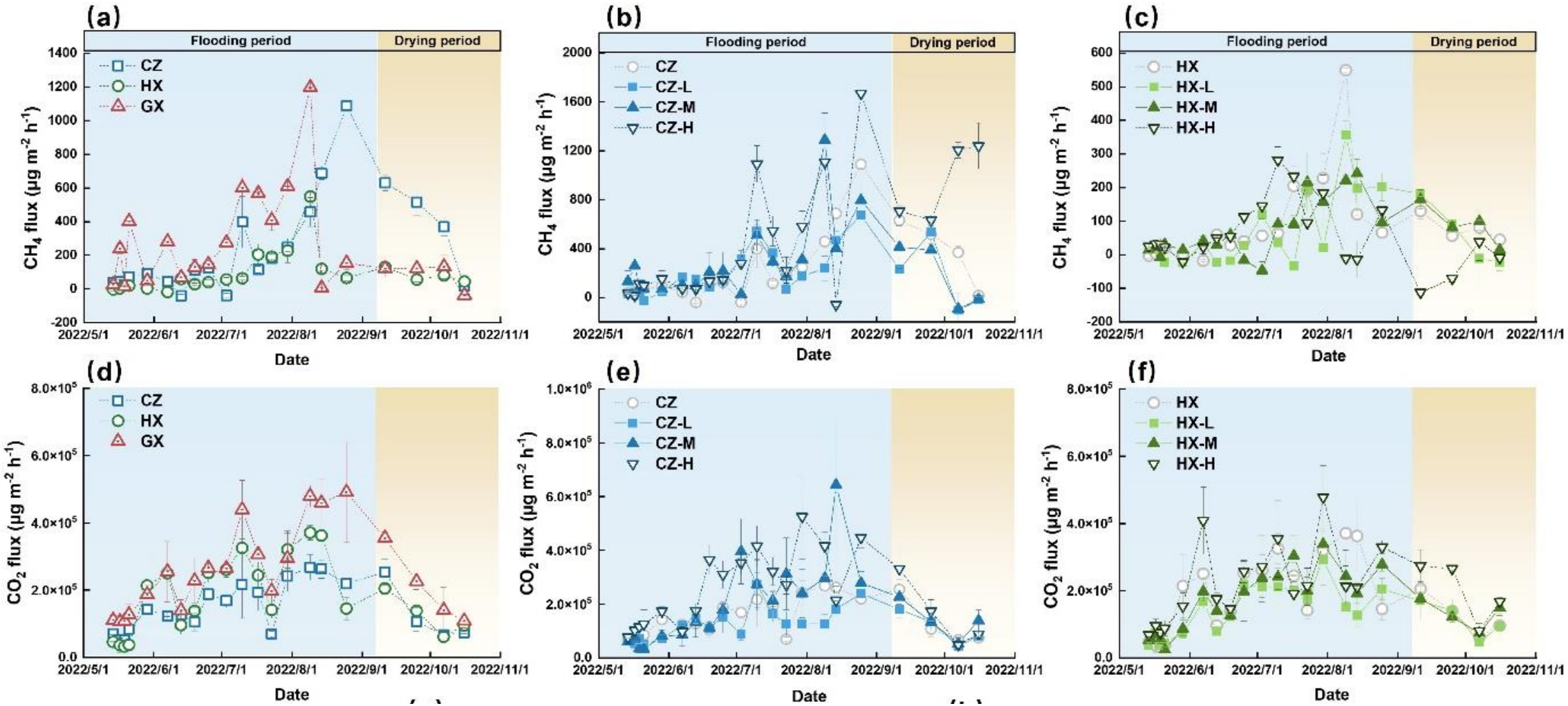




Measurements

- CO_2, CH_4 flux
- THg, MeHg
- SOC, MBC, MAOC, POC, MNC, BNC, FNC, RQ, qCO_2, DOM compositions
- qPCR for *hgcA, dsrB, mcrA, and pmoA* genes and *mcrA* amplicon sequencing

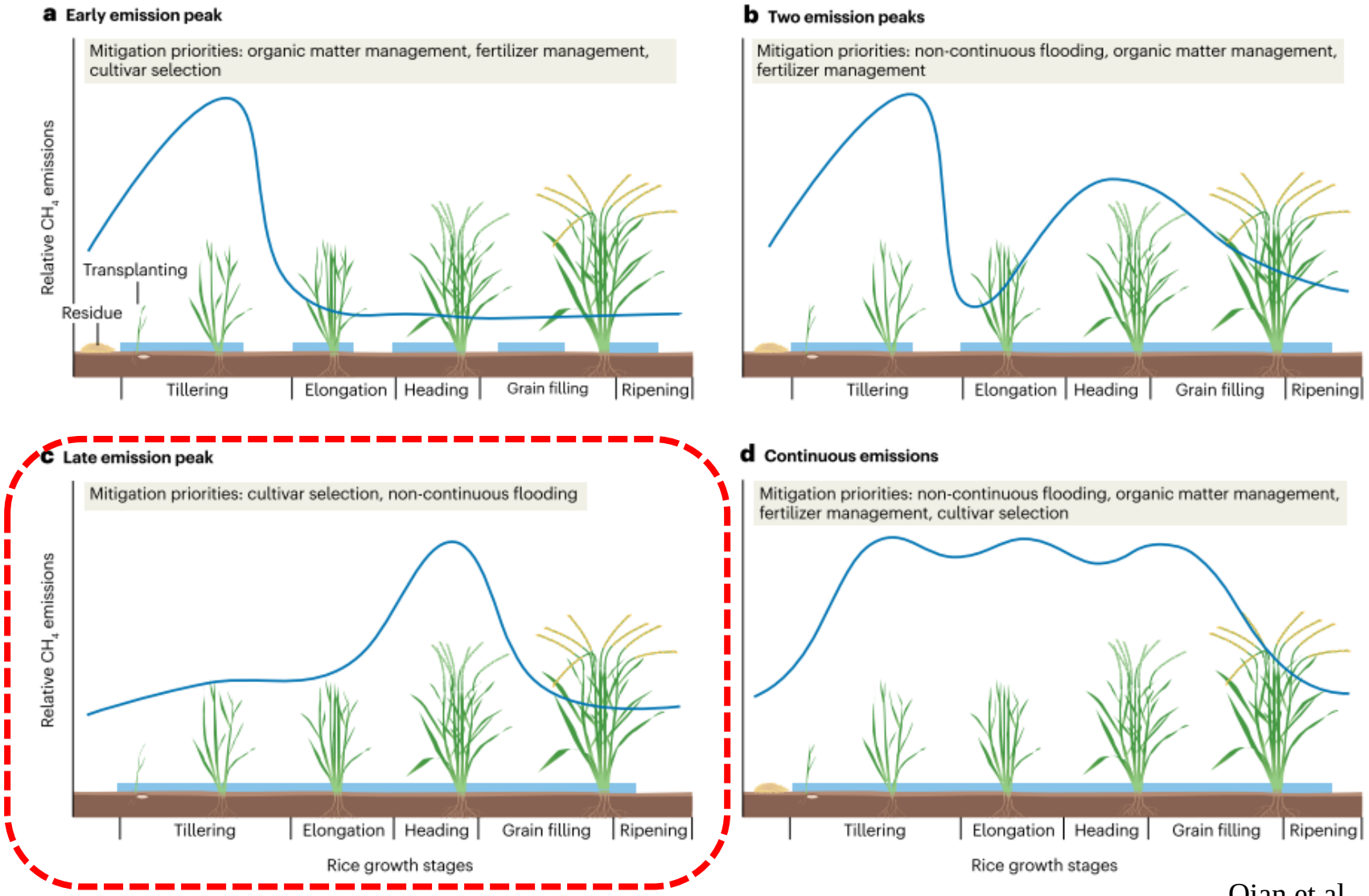
Results & Discussions



Fluxes of CH_4 and CO_2 during rice growth

Results & Discussions

"Late emission peak" pattern

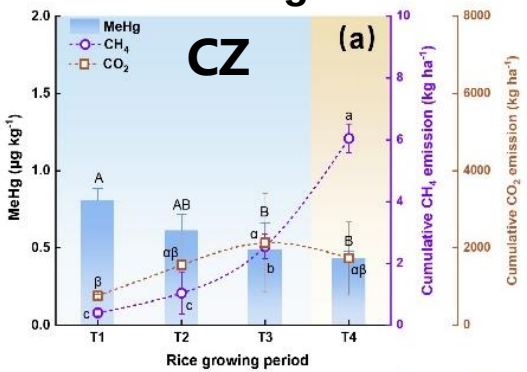


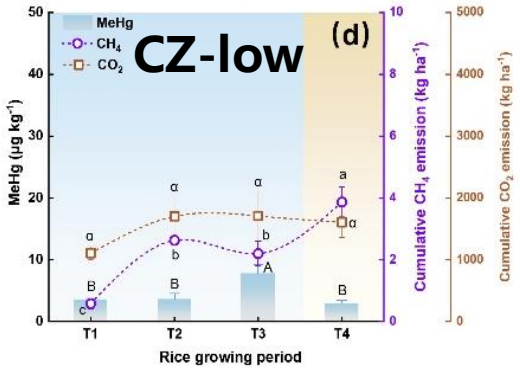
Qian et al., 2023

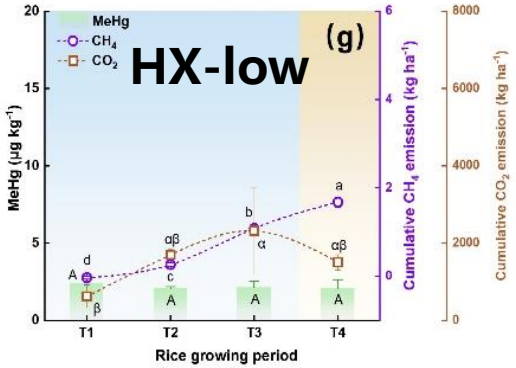
Results & Discussions

MeHg dynamics and cumulative emissions of CH_4 and CO_2

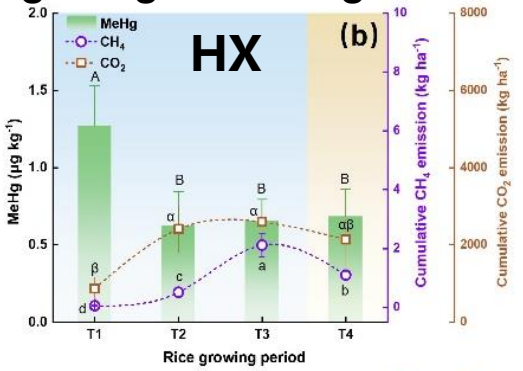
Low level background site

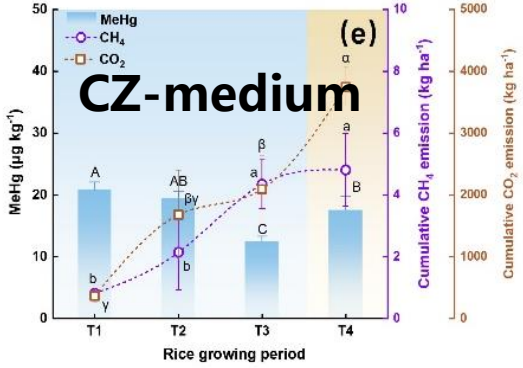


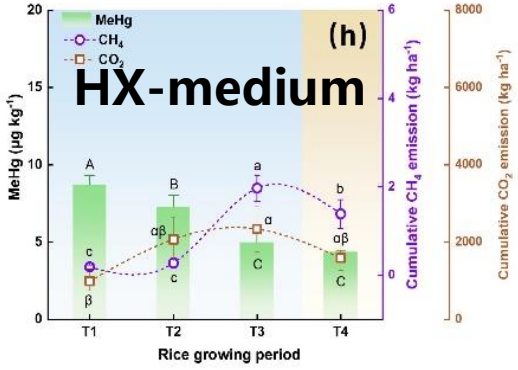




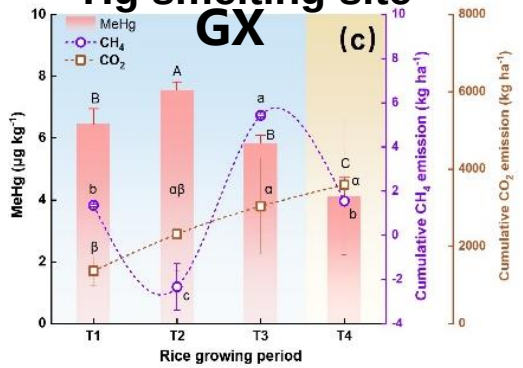
High geological background site

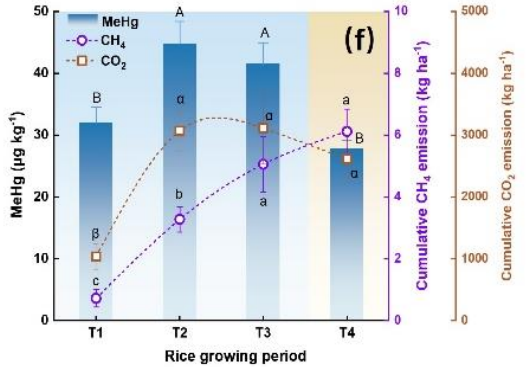




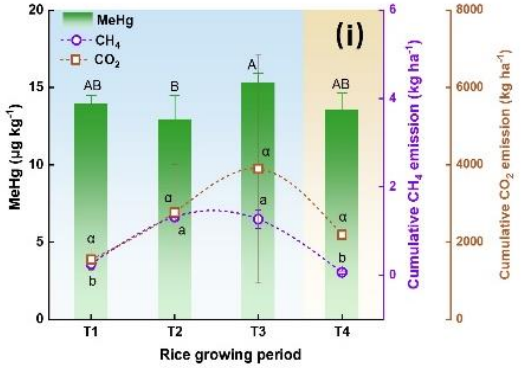


Abandoned artisanal Hg smelting site



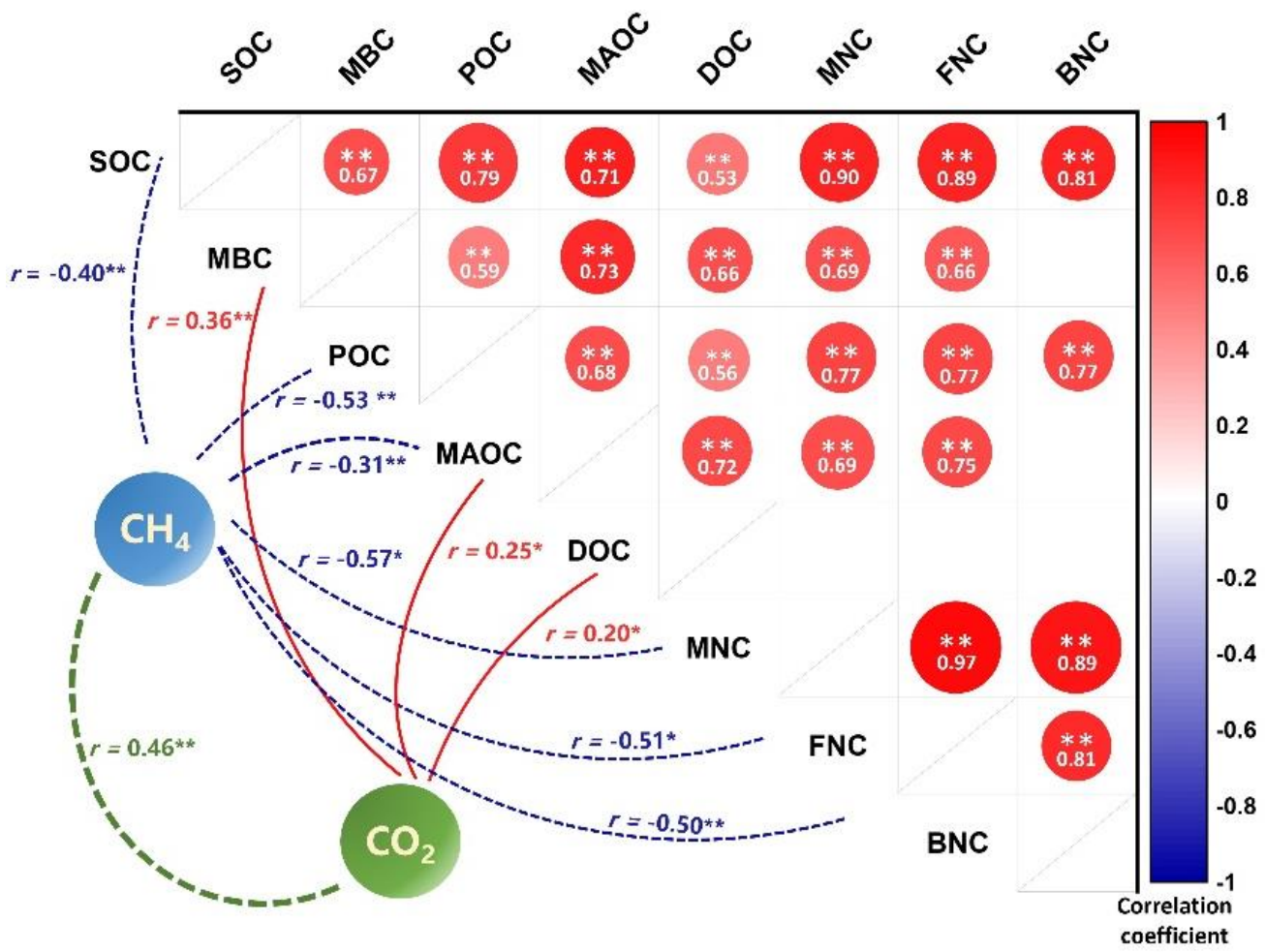


CZ-high



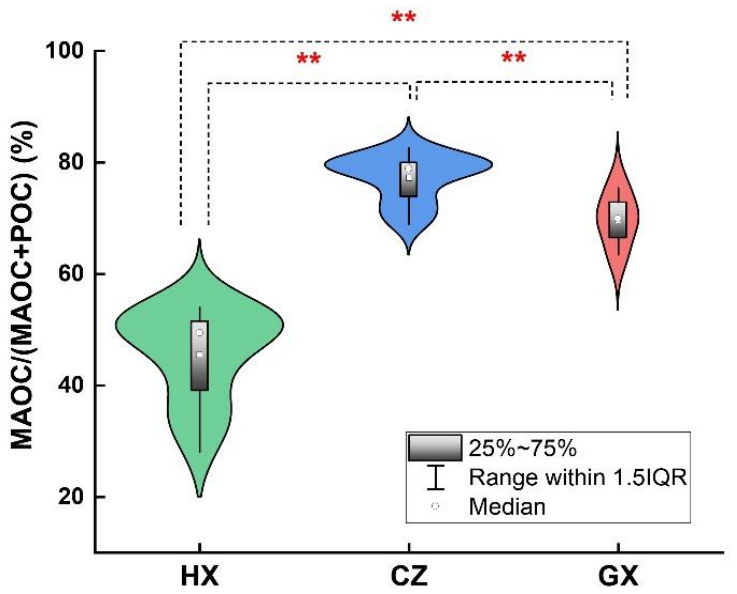
HX-high

Results & Discussions



Correlation between cumulative emissions of CO_2 and CH_4 and soil organic carbon fractions

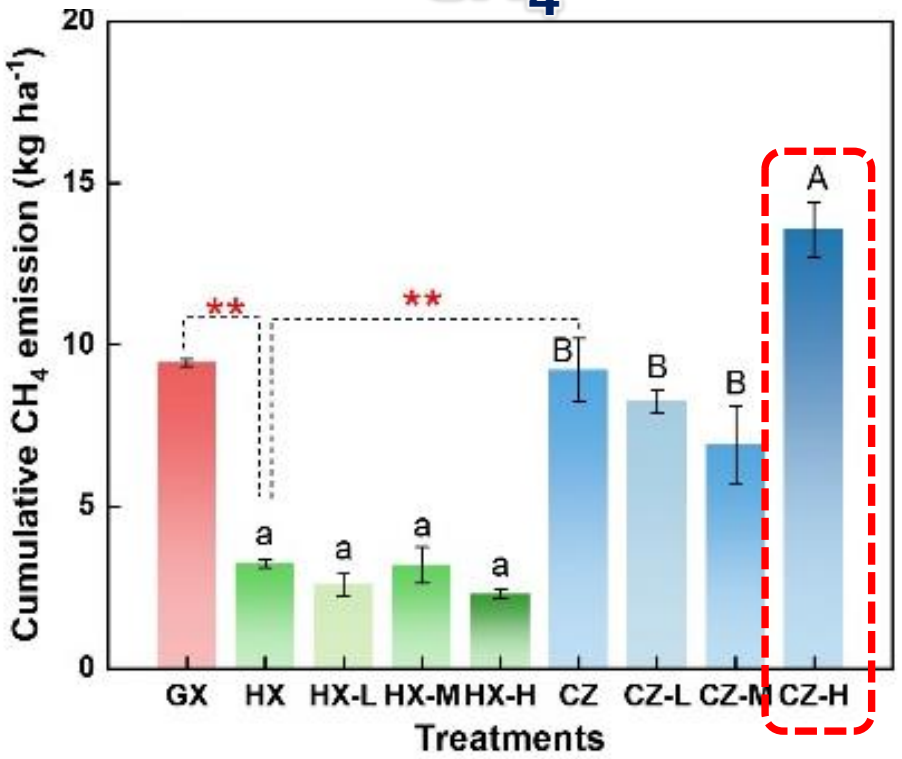
- **CO_2 *v.s.* CH_4 indicates SOC mineralization**
- **CO_2 *v.s.* MAOC indicates CO_2 emission was influenced by minerals in soil**



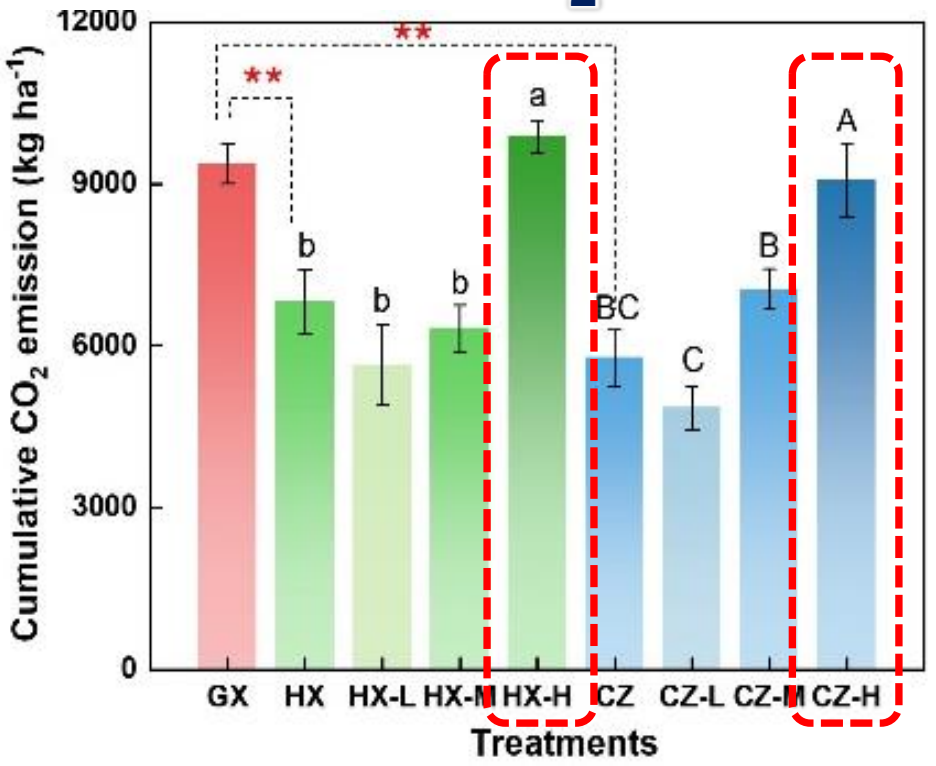
Ratio of MAOC

Results & Discussions

CH_4



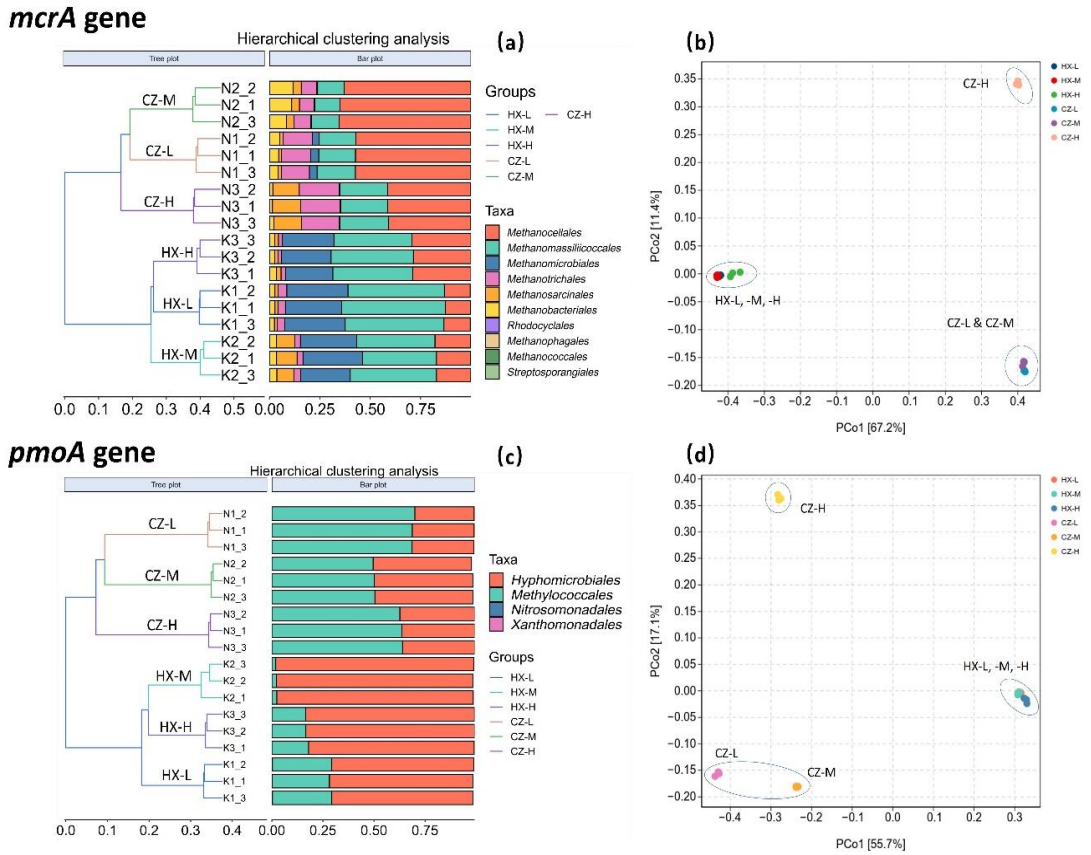
CO_2



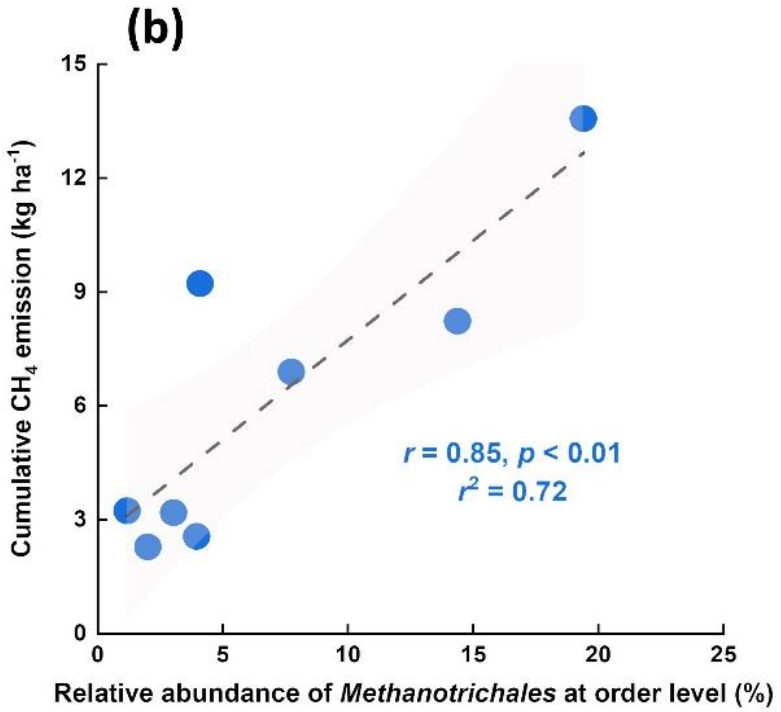
Cumulative emissions of CH_4 and CO_2 during entire rice growth period

Hg stress promoted CO_2 and CH_4 emission

Results & Discussions



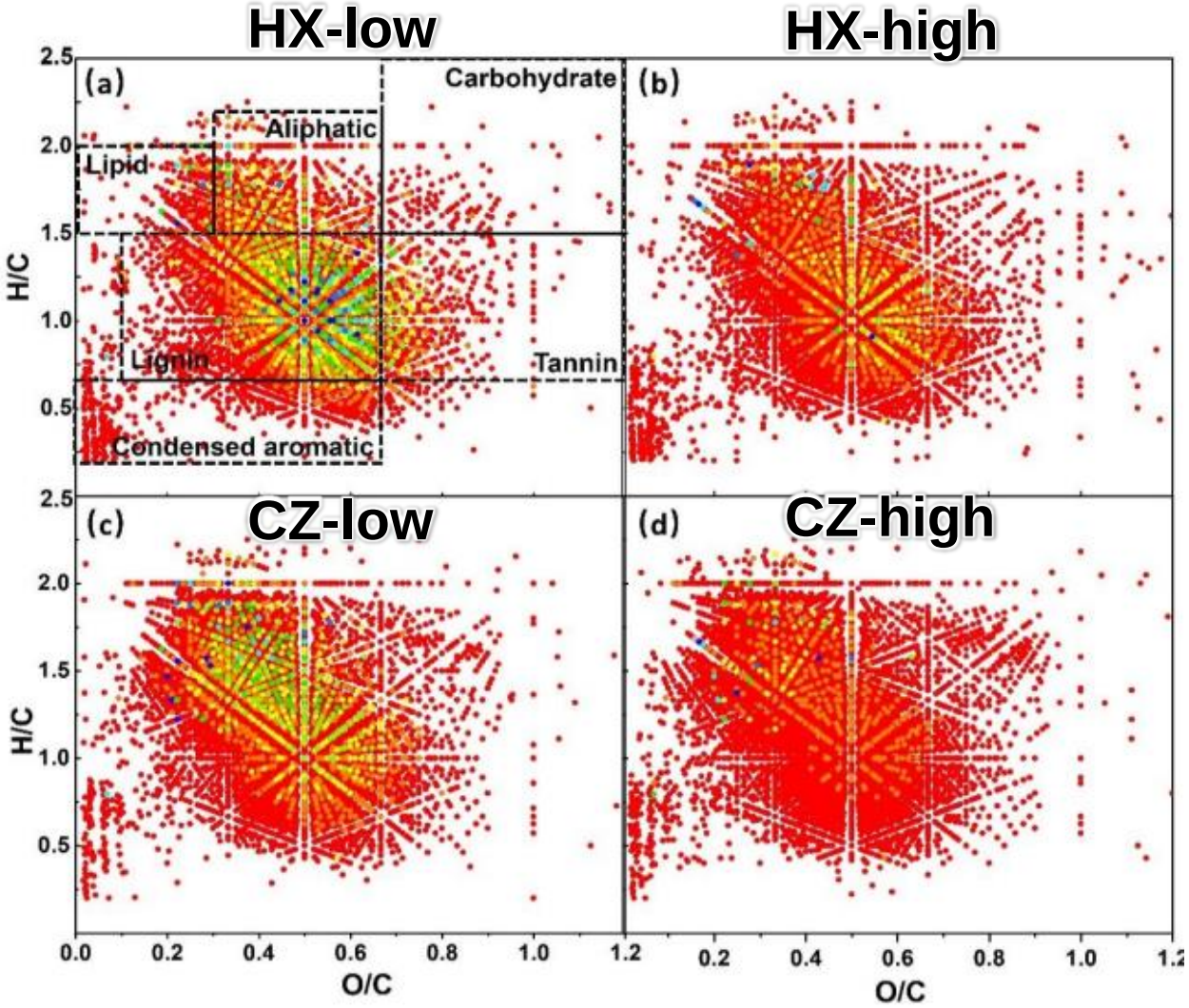
Amplicon sequencing of *mcrA* and *pmoA* genes

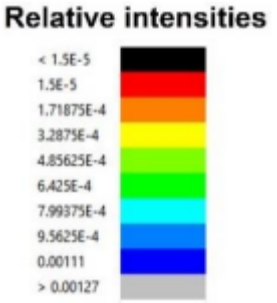


Abundance of Archaea *Methanotrichales v.s.* cumulative emission of CH_4

Communities carrying *mcrA* gene explained CH_4 emission under Hg stress

Results & Discussions

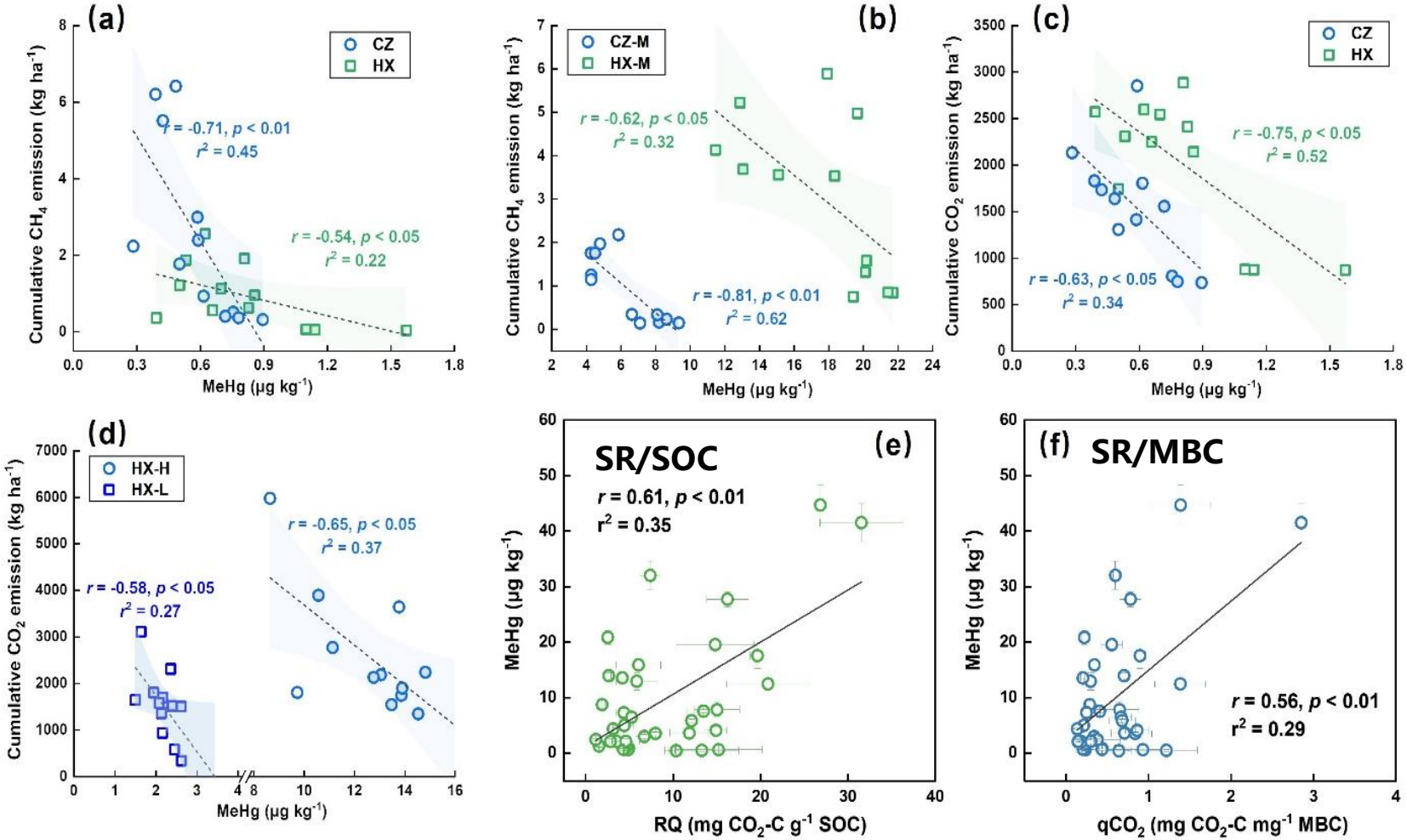




FT-ICR-MS spectra of soil DOM

Less lignin-like compounds in the highly stressed treatments than those in HX-low and CZ-low, respectively, implying that Hg stress has led to a more labile composition of DOM in paddy soils

Results & Discussions



Soil THg *v.s.* cumulative emissions of CH_4 and CO_2 at different growth periods

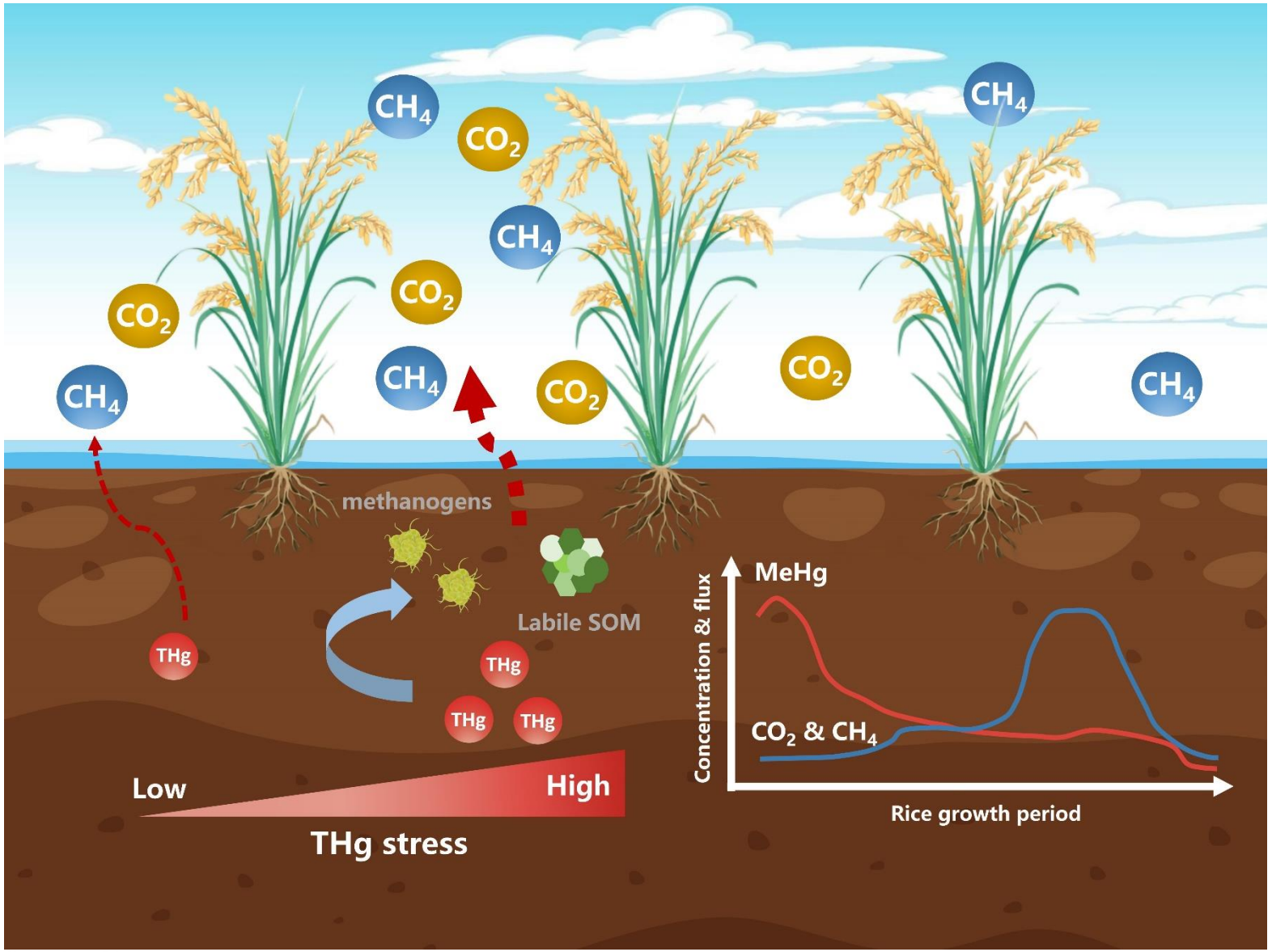
[MeHg] is negatively correlated with the cumulative emission of CO_2 and CH_4

- **Methanogenesis coupled demethylation?**
- **Differences on kinetics?**

[MeHg] is positively correlated with RQ and qCO_2

Soils with more labile organic carbon generated more MeHg

Take home massage



- Hg stress promoted CO_2 and CH_4 emission in rice paddy fields
- Soil MeHg was negatively correlated with the emission of CO_2 and CH_4 during rice growth
- Positive correlation between MeHg and respiration quotient suggests that soils with more labile organic carbon generated more MeHg

Huang et al. 2024 *Under review*

Thanks for coming !

Special thanks for ….

Dr. Xinbin Feng

Dr. Bo Meng

Dr. Feiyue Wang

Dr. Dingyong Wang

Dr. Tao Jiang