Current projects

Agriculture Green Development Programme

Poster overview March 2025

Wageningen University & Research

China Agricultural University

Contents

Graduated PhDs from the AGD program

Class of 2019

Name (PhD model)	*Thesis title*
Theme Green and nutritious food provision & governance	
Jinghan Li (1+3)	Facilitating sustainable agriculture transformation in China: the role of Science and Technology Backyards as community-based innovation intermediaries
Hongyi Cai (1+3)	Healthy plates for a healthy planet: identifying opportunities and challenges for China
Taian Deng (2+2)	Impact of Household Production and Market Supply on Changes in Vegetable Consumption Among Rural Residents
Theme Green animal production	
Tao Zhang (2+2)	Decreasing nutrient loss from crop-livestock systems by manure redistribution with minimum cost and improved management
Zhenyu Wang (2+2)	Improved utilization of organic wastes to develop new feed resources
Shiyi Zhang (1+3)	The journey of protein and starch through the gastrointestinal tract of pigs Studying digestion kinetics by in vitro methodology
Hao Ye (1+3)	Dietary protein digestion kinetics in lactating sows - Lactation performance and subsequent reproduction
Tao Zhang (2+2)	Economic costs and environmental effects of optimizing recycling of livestock manure in crop-livestock production systems
Yaowen Zhang (2+2)	Fermentative Degradation Mechanism of Resistant Starch in the Intestinal Tract of Growing Pigs
Zhenyu Wang (2+2)	Microbiota-Mediated Regulative Mechanism of Dietary Fiber on Pathogen Colonization in Pigs
Guichao Dai (2+2)	Impacts of Structural Optimization Strategies on Food Availability Resource Use and Nutrient Losses of Crop and Livestock Production Systems in China

Graduated PhDs from the AGD program

Class of 2019

Name (PhD model)	*Thesis title*
Theme Green ecological environment	
Fanlei Meng (2+2)	Agricultural Green Development in China – Integrated Assessment of green food production, green products and a green environment
Zhibiao Wei (1+3)	Waste2C: From Waste to Crop – Quzhou as a Living Lab for Sustainable Agro-Food systems
Luncheng You (2+2)	Towards sustainable nitrogen and acidification management in the Quzhou and Zhaoyuan counties and the North China Plain
Hongyu Mu (1+3)	Field and residential exposure of pesticides: Integrated risk analysis on terrestrial ecosystems and rural residents
Qi Zhang (1+3)	Modeling emerging pollutants in waters in the world and China: pollution sources and reduction strategies
Yanan Li (1+3)	Modeling Nutrients, Cryptosporidium and Plastics from Land Activities into Rivers in the World and China: Causes, Hotspots and Strategies
Yu Gu (1+3)	Combined field and model-based approaches for large scale sustainable phosphorus management
Dongfang Zheng (2+2)	Soil phosphorus dynamics in response to soil properties and rhizosphere processes
Fanlei Meng (2+2)	Integrated Nitrogen Management Strategies in Crop and Livestock Systems for Synergistic Improvement of Water and Air Quality: A Case Study of Quzhou County, Hebei Province
Luncheng You (2+2)	Effects of optimal management practices on nitrogen use efficiency, transformation and losses in cropland and optimization potential analysis
Zhilong He (2+2)	NH3 mitigation potential in the integrated crop-laying hens system and its synergy effects on reactive nitrogen losses and greenhouse gas emissions
Theme Green plant production	
Jie Lu (1+3)	Increasing nutrient use efficiency in maize by merging functional structural root modelling and marker assisted breeding
Zhengyuan Liang (1+3)	Exploring sustainable and diversified crop production systems for the North China Plain
Lu Liu (2+2)	Zinc flow in food system and potential to close dietary zinc intake gap in China
Mengshuai Liu (2+2)	The roles of soil-borne fungal pathogens in plant-soil negative feedbacks under different cropping systems

WAGENINGEN
UNIVERSITY & RESEARCH

中國農業大學
CHINA AGRICULTURAL UNIVERSITY
1905

Graduated PhDs from the AGD program

Class of 2020

Name (PhD model)	*Thesis title*
Theme Green and nutritious food provision & governance	
Chenqiang Qin (2+2)	Research on extraction of rapeseed oleosome and protein mixture and its heat-induced gelation characteristics and 3D printing application
Theme Green animal production	
Hao Liu (1+3)	Forage quality in cereal-legume intercropping: meta-analyses and empirical studies
Dongdong Lu (2+2)	Mediation Mechanisms of Milk-derived Extracellular Vesicles in Maternal Resistant Starch Diet-promoted Early Intestinal Development in Piglets
Theme Green ecological environment	
Donghao Xu (1+3)	Large-scale impacts of nutrient management on soil acidification and cadmium mobilization in Chinese croplands
Haoran Li (1+3)	Meat the sustainable future: Name framing and labelling strategies towards consumers' sustainable food choices in China
Juhui Chen (2+2)	The impact of user-friendly labels on pesticide reduction
Sijie Feng (2+2)	Study on the Impact of Atmospheric Nitrogen Deposition on Nitrogen Inputs in Waters of Chinese Basins and Its Synergistic Control Strategies
Theme Green plant production	
Bo Wang (2+2)	Study on the water saving effects of diversified cropping systems in the North China Plain based on the SW AP model under climate change
Xiaoxia Guo (2+2)	Optimization and implementation strategy of wheat-maize planting technology based on multi-objective coordination: A case study in the North China Plain
Yalin Liu (2+2)	Quantitative and mechanistic study on the advantages of efficient nitrogen use in intercropping systems
Yuxiang Wang (2+2)	In-flight Radiometric Consistency Correction of UAV Optical Spectral Images Under Variable Illumination Conditions

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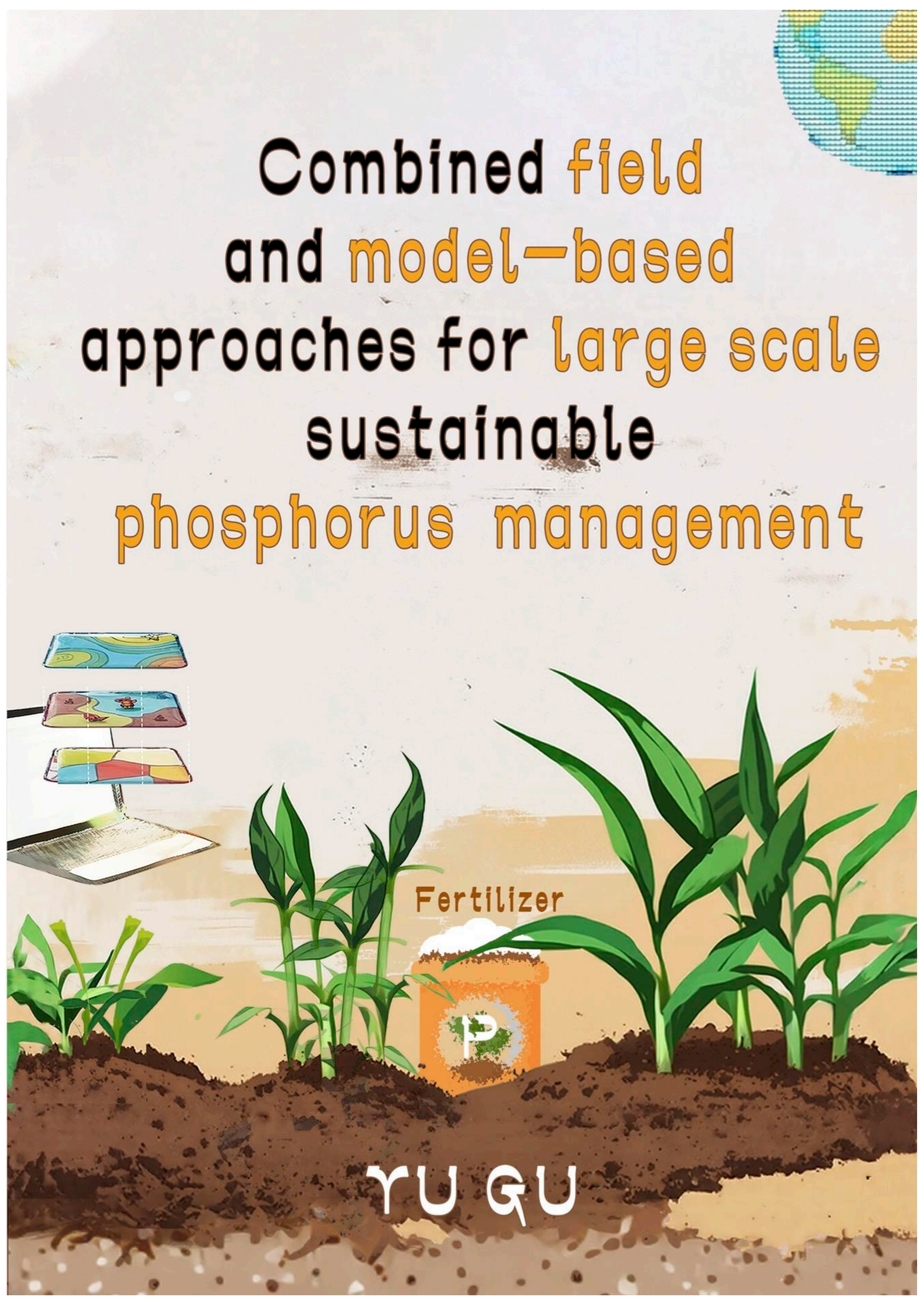
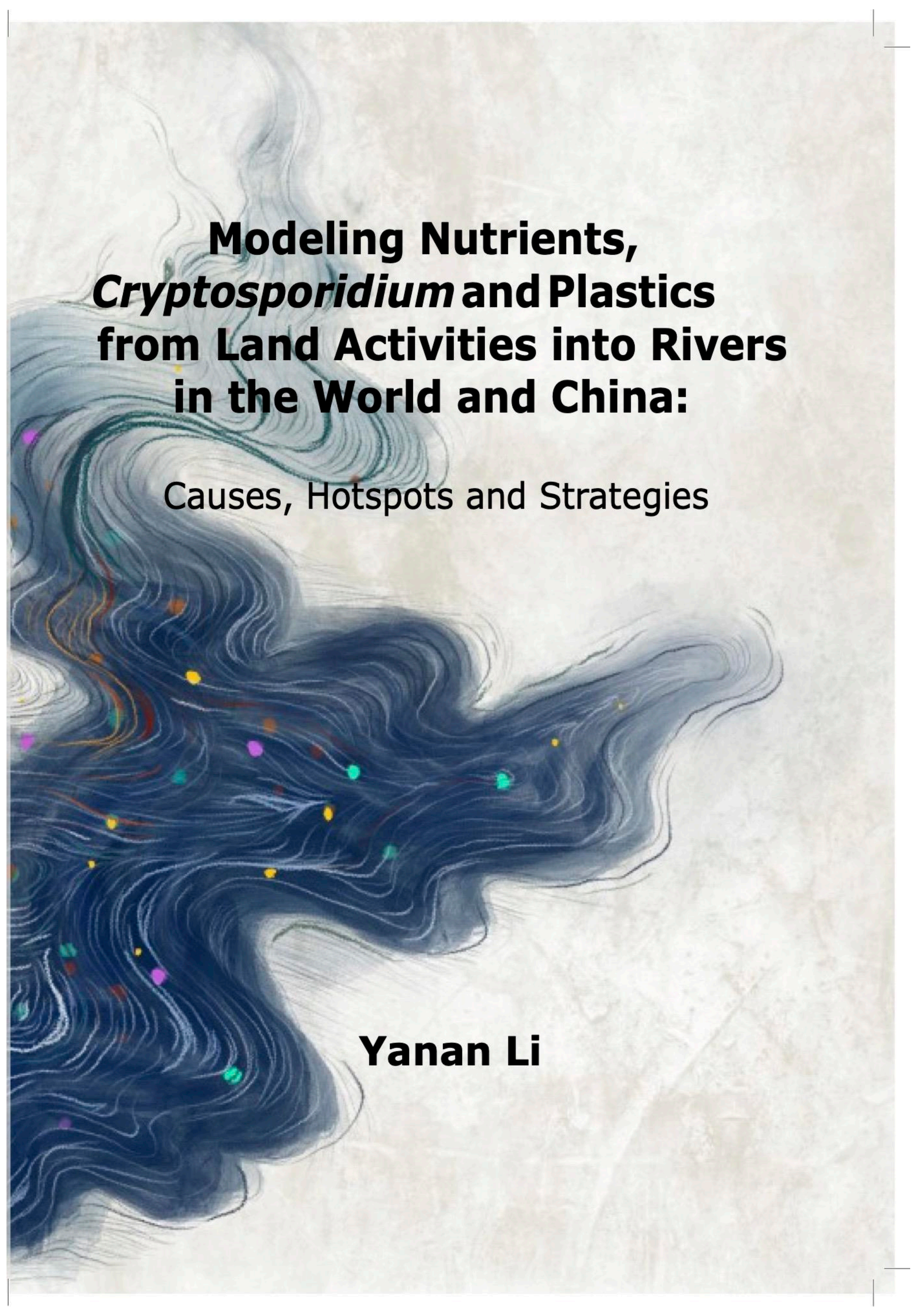
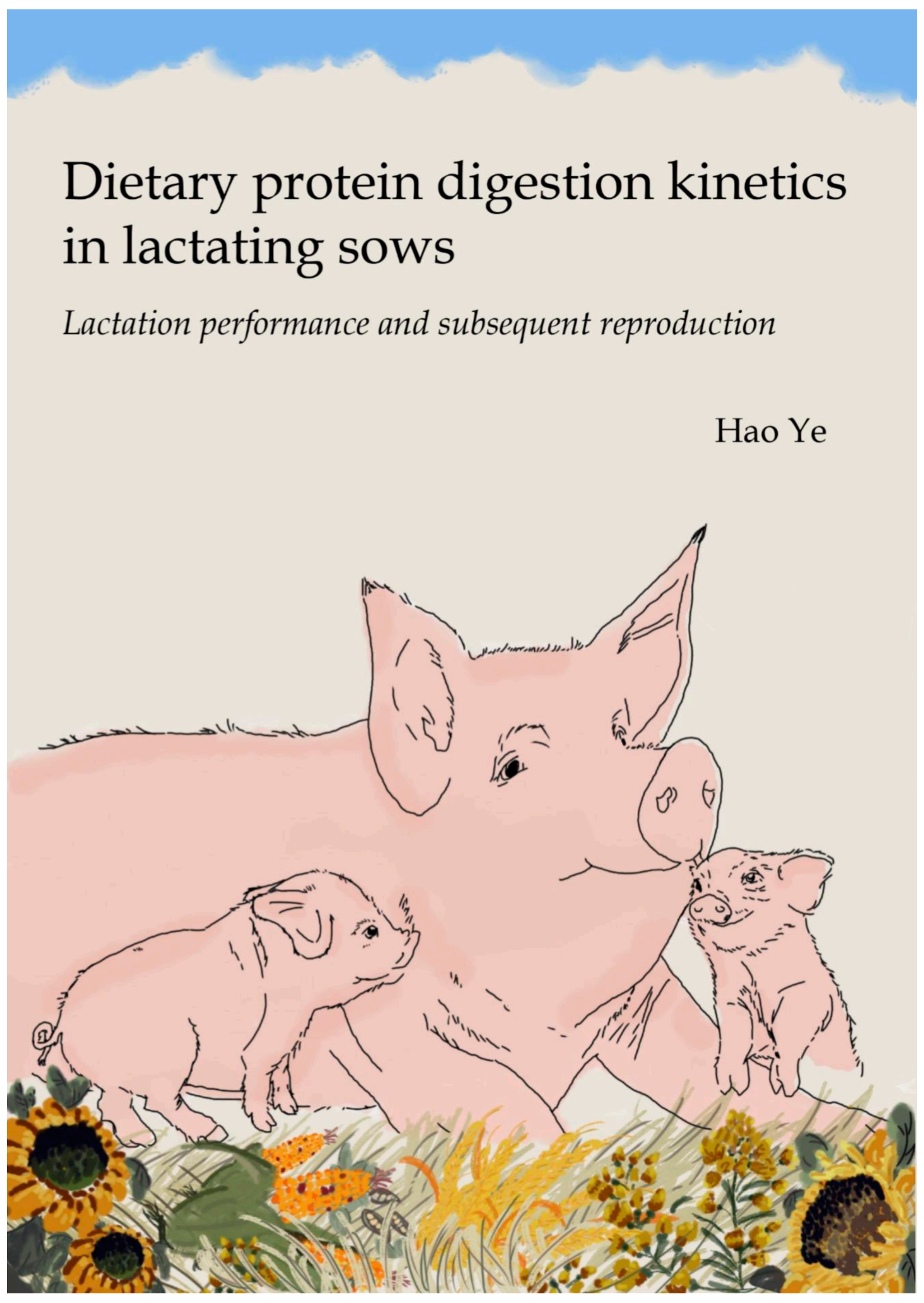
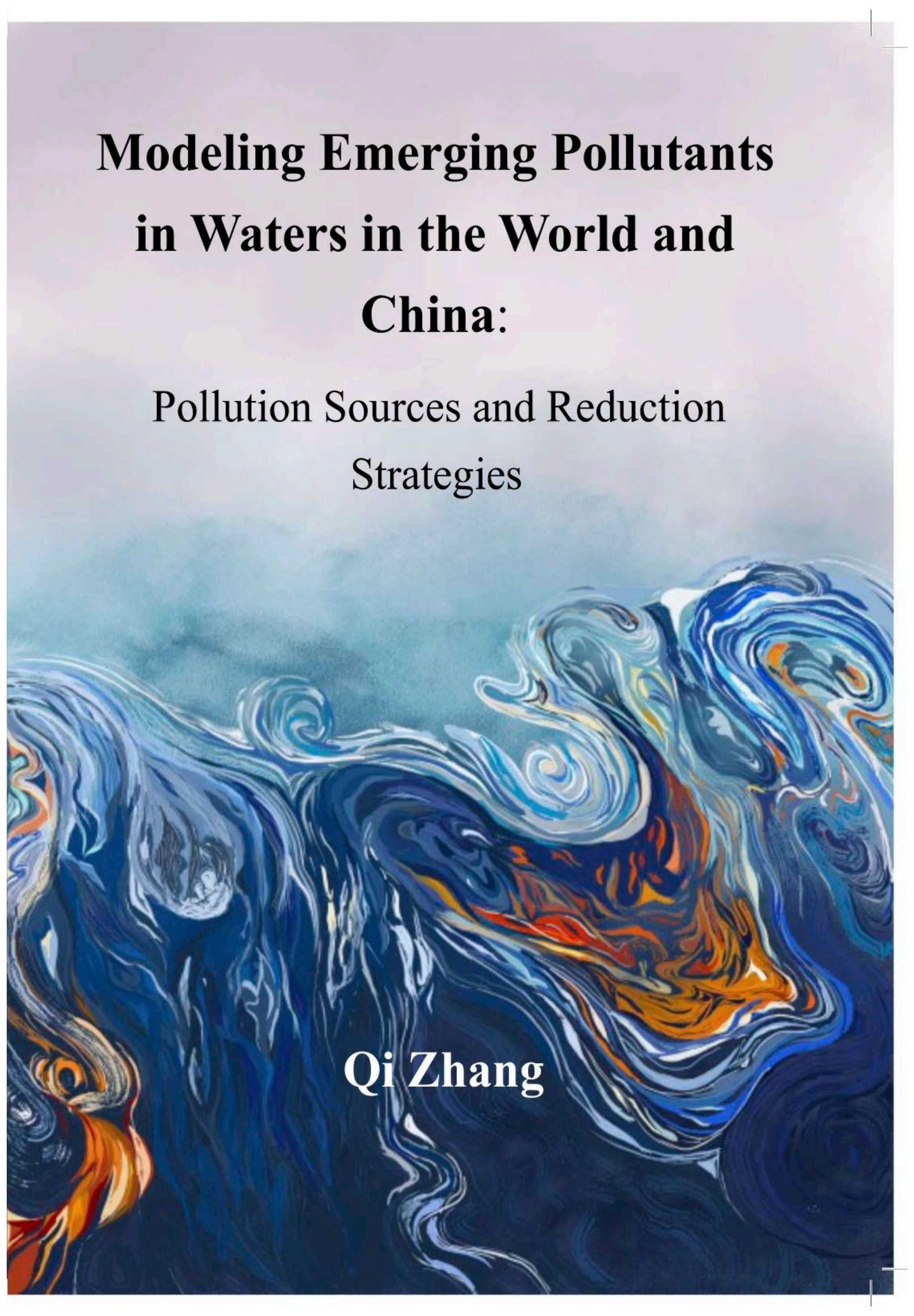
Graduated PhDs from the AGD program

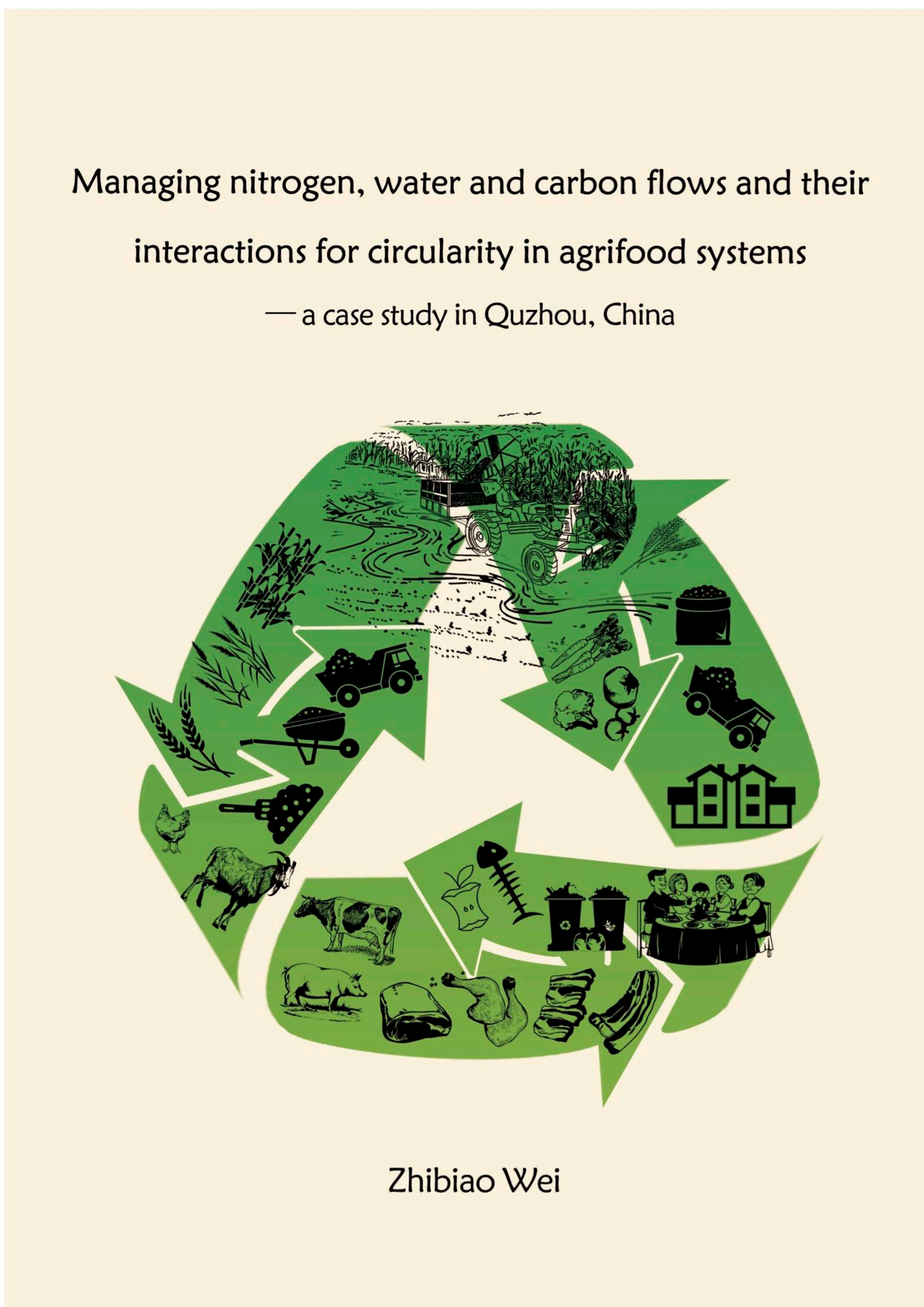
PhD Thesis Demonstration

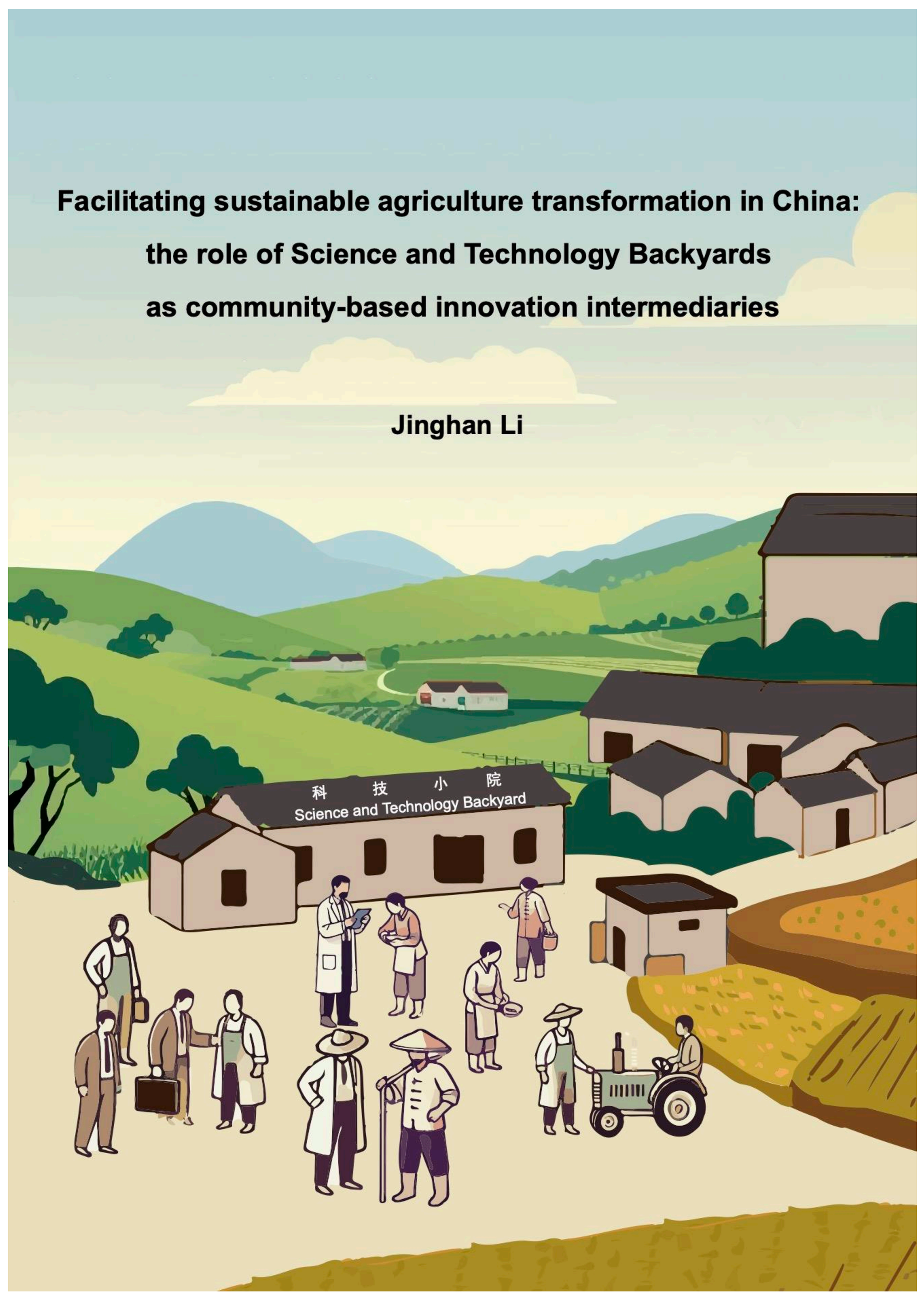


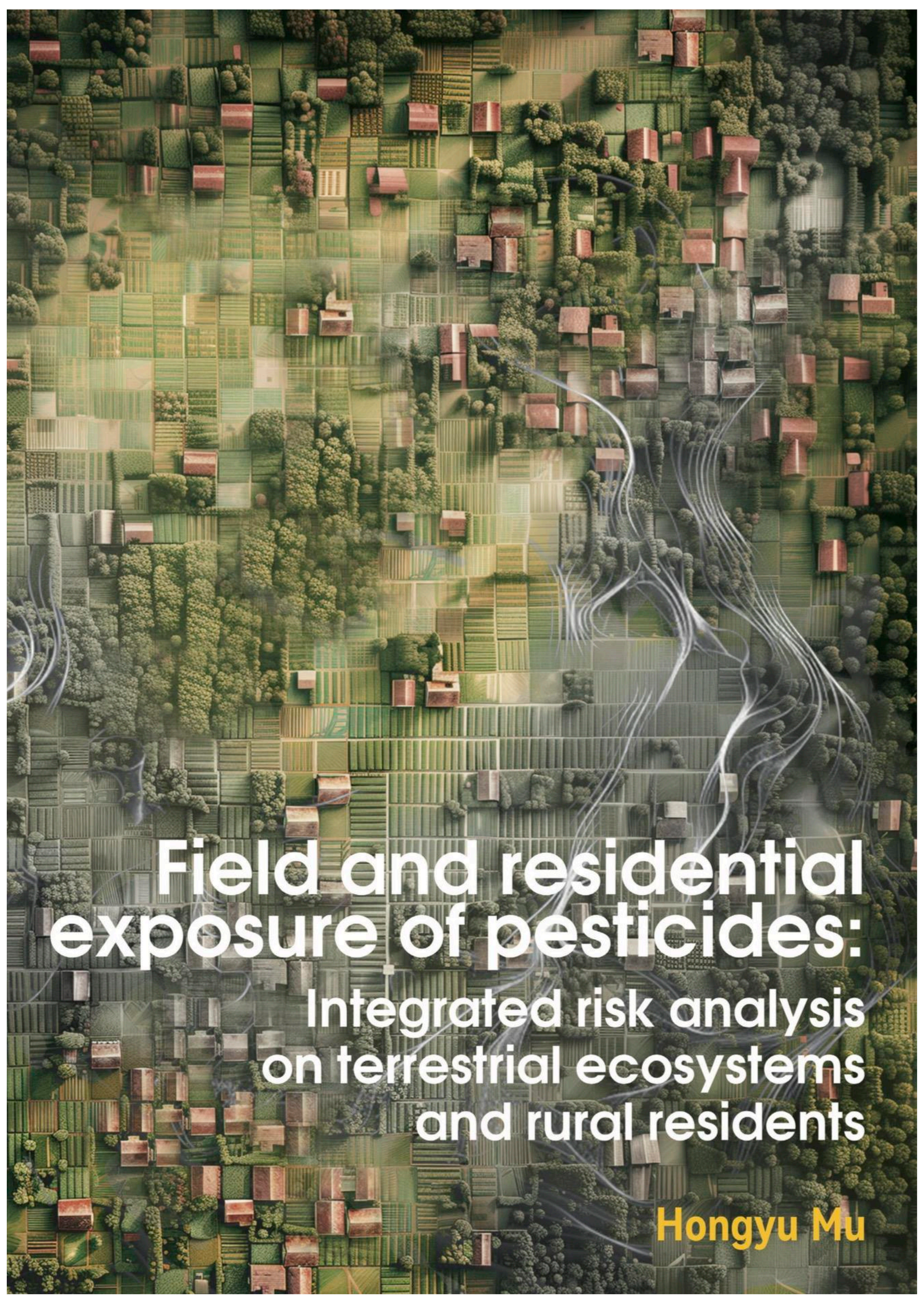


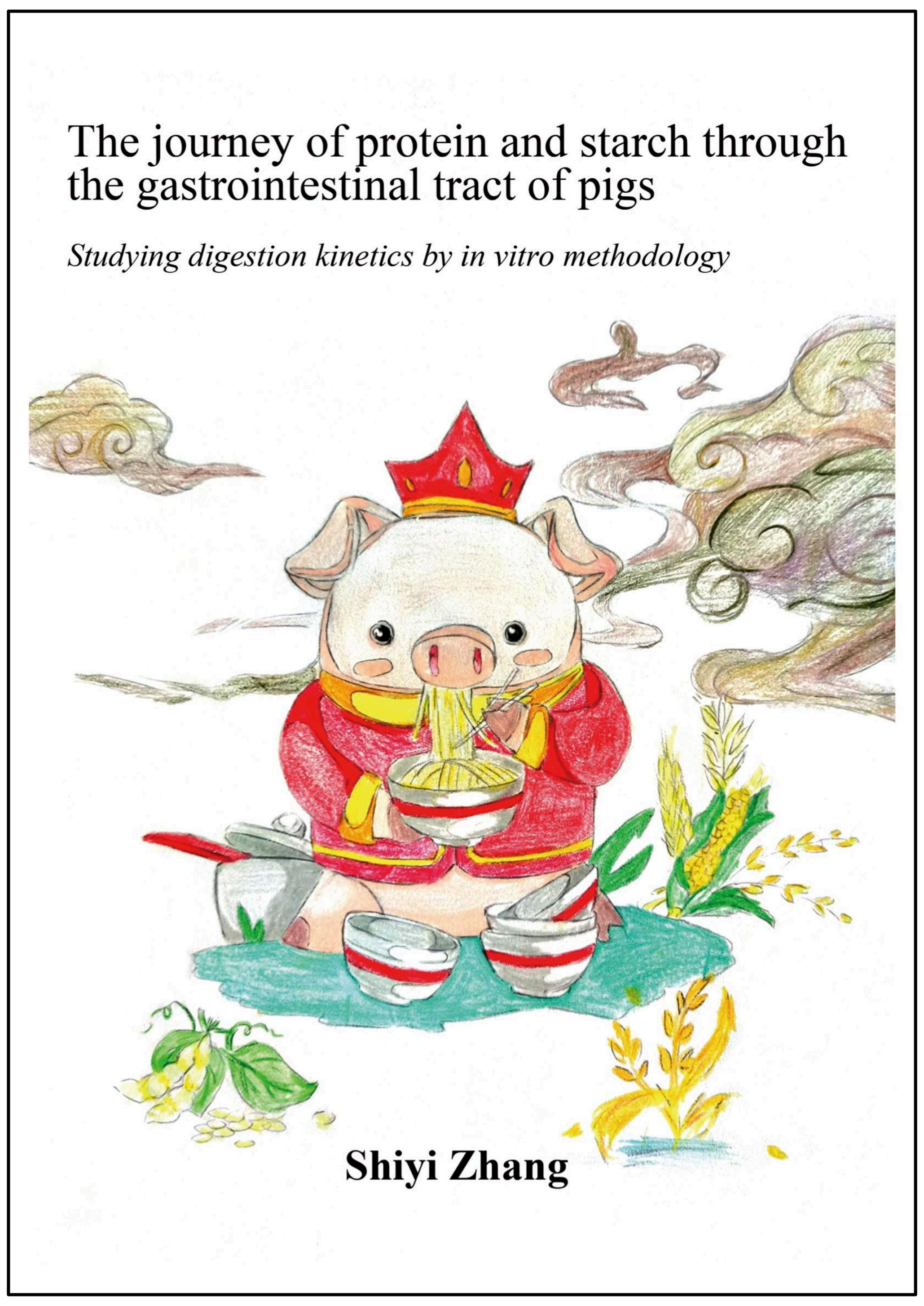


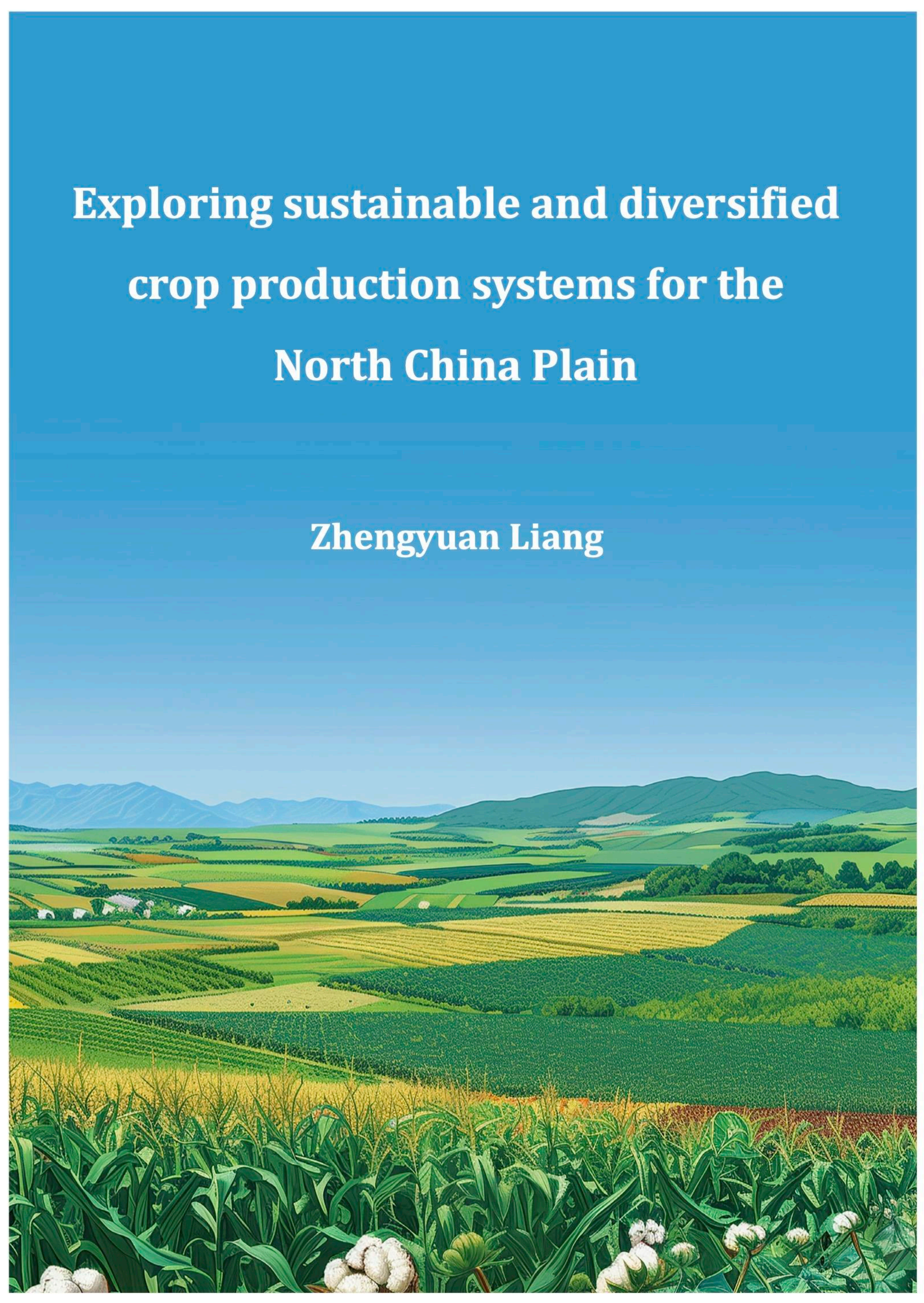






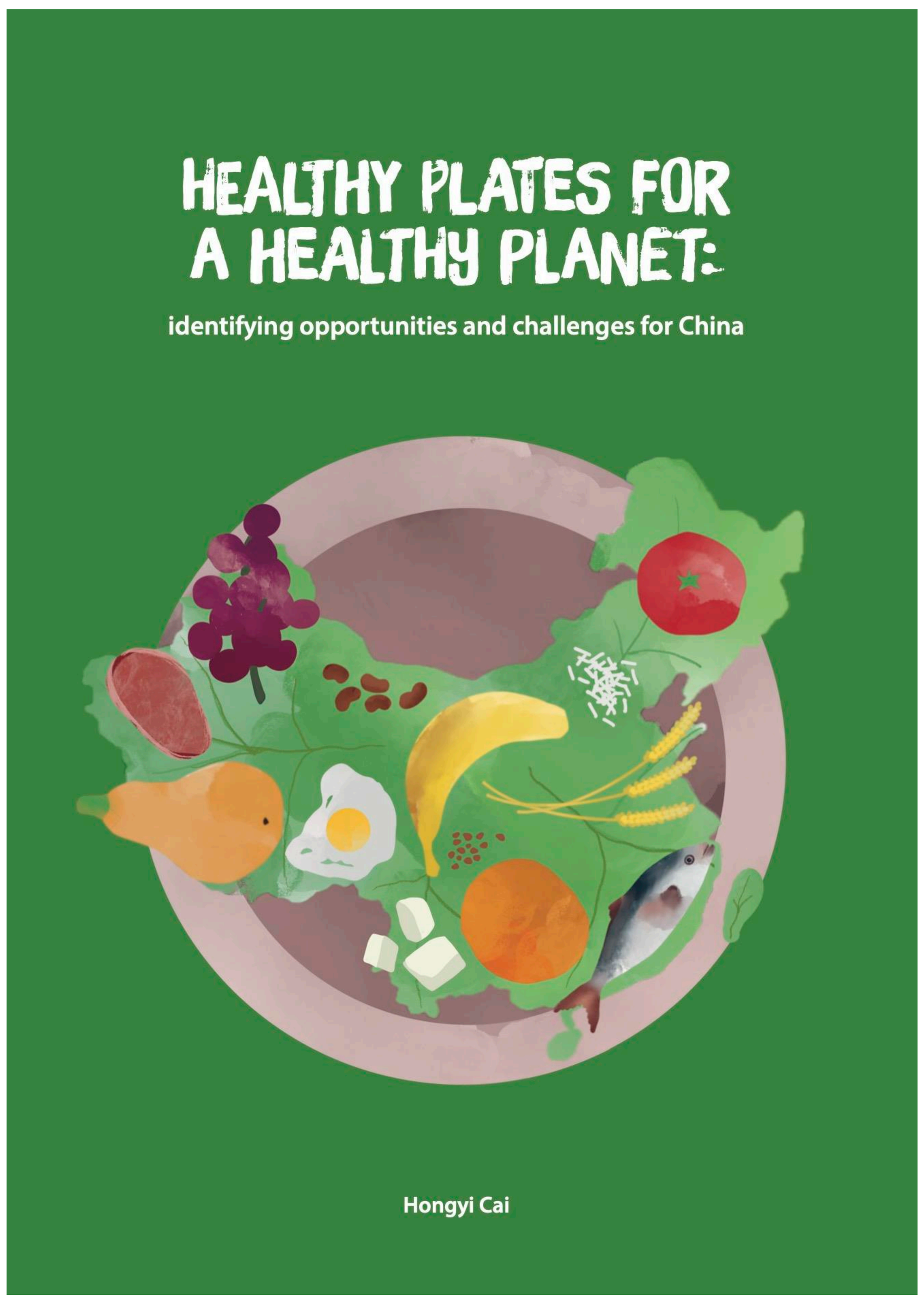


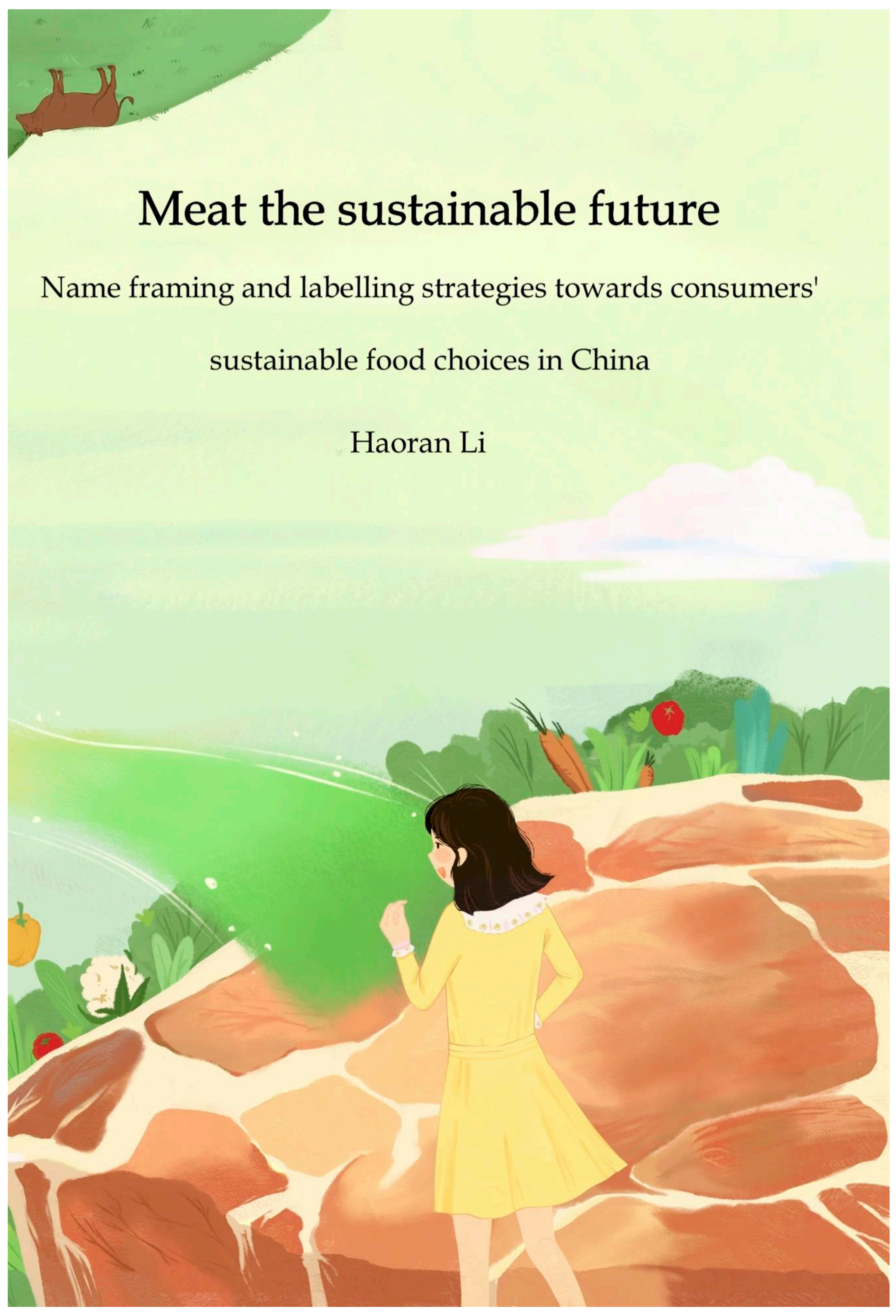


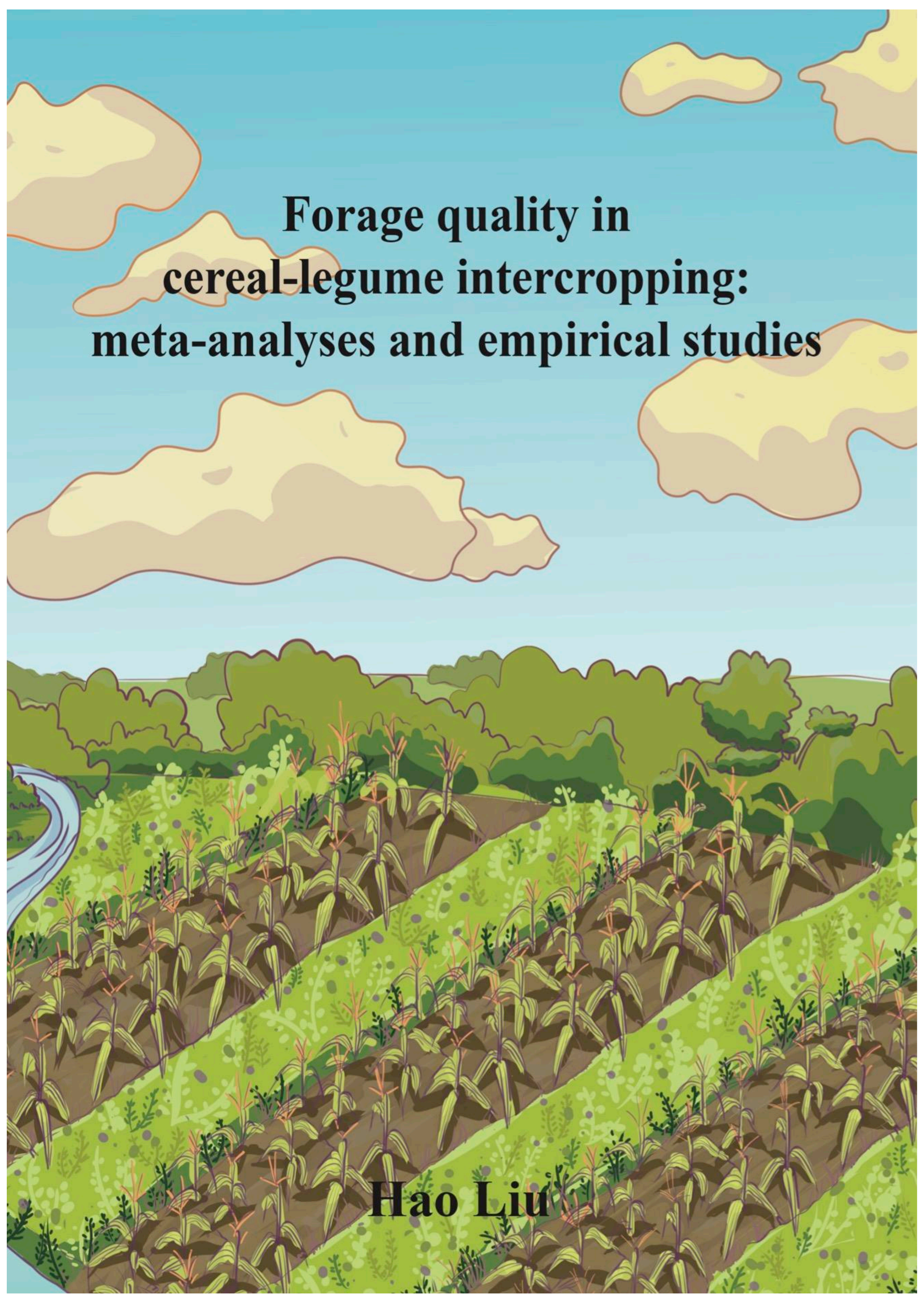


Graduated PhDs from the AGD program

PhD Thesis Demonstration







分类号：　　　单位代码：10019
密　级：　　　学　　号：B20193110807

中國農業大學

学位论文

家庭自产、市场供给对农村居民蔬菜消费变化的影响研究

Impact of Household Production and Market Supply on Changes in Vegetable Consumption Among Rural Residents

研　究　生：邓泰安
指 导 教 师：樊胜根　教授
合作指导教师：
申请学位门类级别：管理学　博士
专 业 名 称：食物经济与管理
研 究 方 向：食物消费与健康经济
所 在 学 院：经济管理学院

2024 年 10 月

分类号：　　　单位代码：10019
密　级：　　　学　　号：BS20203070569

中國農業大學

学位论文

云量变化条件下农业无人机光学遥感影像和辐射校正方法研究

In-flight Radiometric Consistency Correction of UAV Optical Spectral Images Under Variable Illumination Conditions

研　究　生：王昱翔
指 导 教 师：王新 副教授
合作指导教师：杨增玲 教授
Gert Kootstra 副教授
Haris Ahmad Khan
申请学位门类级别：工学博士
专 业 名 称：机械电子工程
研 究 方 向：农业装备智能测控
所 在 学 院：工学院

2024 年 12 月

分类号：　　　单位代码：10019
密　级：　　　学　　号：B20203030267

中國農業大學

博士学位论文

多目标协同的小麦玉米种植技术优化与实现策略——以华北平原为例

Optimization and implementation strategy of wheat-maize planting technology based on multi-objective coordination: A case study in the North China Plain

研　究　生：郭小夏
指 导 教 师：张福锁 教授
合作指导教师：王　冲 教授
庄明浩 副教授
申请学位门类级别：农学博士
专 业 名 称：植物营养学
研 究 方 向：养分资源管理
所 在 学 院：资源与环境学院

二〇二四年六月

China Agricultural University
Dissertation

Mediation Mechanisms of Milk-derived Extracellular Vesicles in Maternal Resistant Starch Diet-promoted Early Intestinal Development in Piglets

Ph. D. Candidate
Dongdong Lu

Supervisor
Professor Junjun Wang

Co-Supervisor
Associate Professor Dandan Han
Professor Bas Kemp
Associate Professor Nicoline Soede

Major
Animal Nutrition and Feed Science

Oct., 2024

Ph.D. Dissertation

Quantitative and mechanistic study on the advantages of efficient nitrogen use in intercropping systems

Candidate: Yalin Liu
Supervisor: Prof. Zhenling Cui
Associate Prof. Chunjie Li
Associate Prof. Wopke van der Werf
Associate Prof. TjeerdJan Stomph

Specialty: Plant Nutrition
College of Resources and Environmental Sciences
China Agricultural University

December 2024

Graduated PhDs from the AGD program

PhD Thesis Demonstration

Ph.D. Dissertation

NH_3 mitigation potential in the integrated crop-laying hens system and its synergy effects on reactive nitrogen losses and greenhouse gas emissions

Ph.D Candidate: Zhilong He
Supervisor: Associate Prof. Ying Zhang
Prof. Xuejun Liu
Prof. Wim De Vries

Speciality: Plant Nutrition
College of Resource and Environmental Sciences
China Agricultural University

June 2024

China Agricultural University
Dissertation

Microbiota-Mediated Regulative Mechanism of Dietary Fiber on Pathogen Colonization in Pigs

Ph. D. Candidate
Zhenyu Wang

Supervisor
Professor Junjun Wang

Co-supervisor
Professor Walter JJ Gerrits
Associate Professor Sonja de Vries

Major
Animal Nutrition and Feed Science

November, 2023

China Agricultural University
Dissertation

Fermentative Degradation Mechanism of Resistant Starch in the Intestine of Growing Pigs

Ph. D. Candidate
Yaowen Zhang

Supervisor
Professor Defa Li

Co-supervisor
Professor Junjun Wang
Professor Wouter Hendricks

Major
Animal Nutrition and Feed Science

May, 2024

PhD Dissertation

Economic costs and environmental effects of optimizing recycling of livestock manure in crop-livestock production systems

Candidate: Tao Zhang
Supervisors: Prof. Xiaolin Li
Prof. Yong Hou
Prof. Oene Oenema

Speciality: Plant Nutrition

College of Resource and Environmental Sciences
China Agricultural University

June 2023

PhD Dissertation

Integrated Nitrogen Management Strategies in Crop and Livestock Systems for Synergistic Improvement of Water and Air Quality: A Case Study of Quzhou County, Hebei Province

Candidate: Fanlei Meng
Supervisors: Prof. Fusuo Zhang
Dr. Wen Xu
Dr. Mengru Wang

Specialty: Plant Nutrient

College of Resource and Environmental Sciences
China Agricultural University

December 2023

Ph.D. Dissertation

The roles of soil-borne fungal pathogens in plant-soil negative feedbacks under different cropping systems

Candidate: Mengshuai Liu
Supervisor: Associate Prof. Chunxu Song
Co-Supervisor: Prof. Liesje Mommer
Co-Supervisor: Associate Prof. Jasper van Ruijven
Co-Supervisor: Dr. Jose G. Maciá-Vicente

Specialty: Plant Nutrition

College of Resource and Environmental Sciences
China Agricultural University

June 2024

Ph.D. Dissertation

Effects of optimal management practices on nitrogen use efficiency, transformation and losses in cropland and optimization potential analysis

Ph. D Candidate: Luncheng You
Supervisor: Prof. Fusuo Zhang
Associate Prof. Yongliang Chen
Prof. Wim de Vries
Dr. Gerard H. Ros

Speciality: Plant Nutritent
College of Resource and Environmental Sciences
China Agricultural University

December 2023

Ph.D. Dissertation

Zinc flow in food system and potential to close dietary zinc intake gap in China

Candidate: Lu Liu
Supervisor: Prof. Wen-Feng Cong
Prof. Fusuo Zhang

Speciality: Plant Nutrient
College of Resource and Environmental Sciences
China Agricultural University

December 2023

PhD Dissertation

Impacts of Structural Optimization Strategies on Food Availability and Resource use and Nutrient Losses of Crop and Livestock Production Systems in China

Candidate: Guichao Dai
Supervisors: Prof. Jhannes Thieo Lambers
Prof. Fusuo Zhang
Prof. Yong Hou

Speciality: Plant Nutrition

College of Resource and Environmental Sciences
China Agricultural University

June 2024

Graduated PhDs from the AGD program

PhD Thesis Demonstration

分类号：　　单位代码：10019
密 级：　　学　　号：BS20203060511

中國農業大學

学位论文

油菜籽油脂体和蛋白质混合物的提取及其热凝胶特性和 3D 打印应用研究

Research on extraction of rapeseed oleosome and protein mixture and its heat-induced gelation characteristics and 3D printing application

研　　究　　生：秦琛强
指　导　教　师：倪元颖 教授
申请学位门类级别：工学博士
专　业　名　称：农产品加工及贮藏工程
研　究　方　向：油脂和蛋白质提取及应用
所　在　学　院：食品科学与营养工程学院

2024 年 6 月

分类号：　　单位代码：10019
密　级：　　学　号：B20203110775

中國農業大學

学位论文

用户友好型标签对农药减量的影响

The impact of user-friendly labels on pesticide reduction

研　　究　　生：陈菊慧
指　导　教　师：白军飞 教授
申请学位门类级别：管理学 博士
专　业　名　称：食物经济与管理
研　究　方　向：食物经济理论与政策
所　在　学　院：经济管理学院

2025 年 1 月

分类号：　　单位代码：10019
密　级：　　学　　号：B20203030251

中國農業大學

学位论文

气候变化下基于 SWAP 模型的华北平原多样化种植制度适水效应研究

Study on the water saving effects of diversified cropping systems in the North China Plain based on the SWAP model under climate change

研　　究　　生：王博
指　导　教　师：张颖 副教授
合作指导教师：杨晓琳 副教授
申请学位门类级别：农学博士
专业领域名称：植物营养学
研　究　方　向：节水种植制度
所　在　学　院：资源与环境学院

二〇二四年 十二 月

PhD Dissertation

Study on the Impact of Atmospheric Nitrogen Deposition on Nitrogen Inputs in Waters of Chinese Basins and Its Synergistic Control Strategies

Candidate：Sijie Feng
Supervisors：Dr. Ying Zhang
Co-Supervisors：Prof. Fusuo Zhang
Dr. Wen Xu
Dr. Mengru Wang

Specialty: Plant Nutrient

College of Resource and Environmental Sciences
China Agricultural University

June 2024

Overview PhD projects – starting year 2019
Posters, March 2025

Theme: Green and nutritious food provision & governance

Name	*Model**	*Project*
1. Zhiwei Yu	2+2	Interplay of market-based and command-and-control policies in agri-environmental governance: Evidence from straw-burning policies in China

Theme: Green plant production

Name	*Model**	*Project*
2. Jiali Cheng	1+3	Designing diversified agricultural landscapes to enhance ecosystem services based on stakeholders' perspectives: modeling approach and application in North China Plain
3. Zhan Xu	1+3	Using best practices within a farmer community to enhance the sustainability of crop production by smallholder farmers
4. Yujie Yang	2+2	Evaluating genotype-environment-management interactions for maize cultivars to tap biological potential yield in different zones of China

Model*: There are two different types of PhD candidates, hence 2 models.
2+2 model: Graduates at CAU; project starts and ends in China; stays for two consecutive years in Wageningen.
1+3 model: Graduates at WU; project starts in China; stays for three consecutive years in Wageningen.

Interplay of market-based and command-and-control policies in agri-environmental governance: Evidence from straw-burning policies in China

Zhiwei Yu, Fan Li, Wei Si, Francesco Cecchi, Weifeng Zhang, Nico Heerink

Background

Straw burning is a common practice among farmers to dispose of excess grain residues after harvesting, and it is most prevalent in Northeast China. Two-thirds of straw-burning spots in China were located in this region in 2017 (Yin, et al., 2021). To address straw burning, Northeast China initiated a straw-burning management reform in 2018, which utilized both market-based and command-and-control policies (i.e., subsidy and monitoring) to control straw burning.

Objective

- Explore the effectiveness of subsidy conditional to stringent monitoring policies in Heilongjiang, using its neighboring province as a control group
- Examine the effectiveness of subsidy conditional to weak monitoring policies in Heilongjiang, compared to its neighboring province

Results

Effects of subsidy on farmers' straw-burning activities

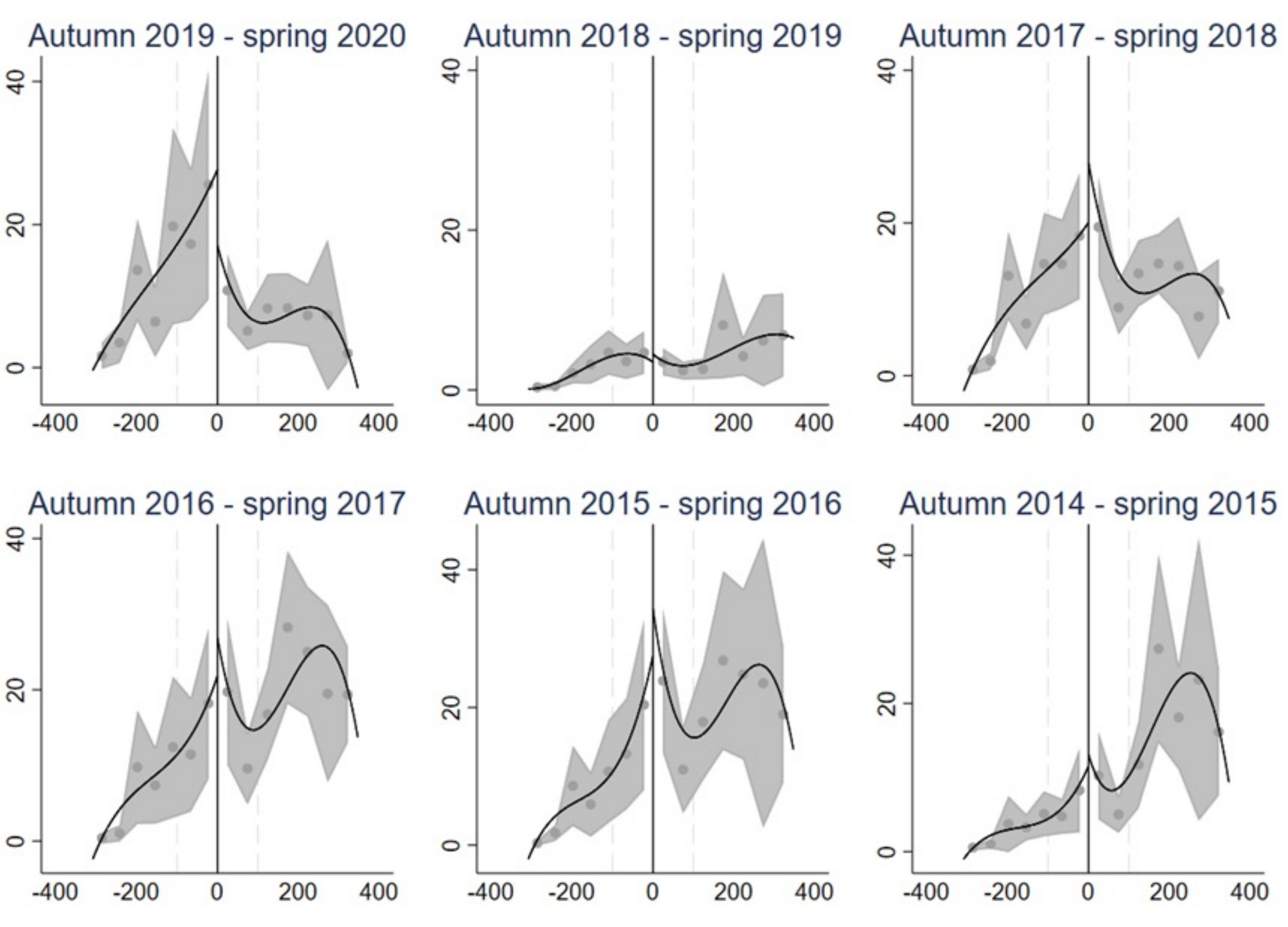


Figure 1. The Spatial-Regression-Discontinuity (SRD) graphic analysis of straw-burning spots

Table 1. Effects of subsidy on straw-burning spots

	SRD-DID		DID	
	OLS	Poisson	OLS	Poisson
	(1)	(2)	(3)	(4)
Panel A. Sample in both autumn and spring				
Treat × Autumn 2018 – Spring 2019	-3.90	-0.42**	-3.84	-0.47**
	(3.134)	(0.207)	(3.101)	(0.202)
Treat × Autumn 2019 – Spring 2020	-15.38***	-1.10***	-14.53***	-1.06***
	(3.048)	(0.138)	(2.899)	(0.136)
SRD variables	Y	Y		
County fixed effect			Y	Y
Observation	1,560	1,560	1,560	1,560
R^2	0.206		0.352	
Panel B. Sample in spring				
Treat × Spring 2019	-4.90	-0.48**	-5.49	-0.55***
	(3.429)	(0.193)	(3.541)	(0.186)
Treat × Spring 2020	-28.43***	-1.20***	-27.38***	-1.14***
	(6.992)	(0.174)	(6.644)	(0.175)
SRD variables	Y	Y		
County fixed effect			Y	Y
Observation	780	780	780	780
R^2	0.243		0.469	
Panel C. Sample in autumn				
Treat × Autumn 2018	-0.67	-0.96*	-1.11	-0.91*
	(3.144)	(0.524)	(2.988)	(0.484)
Treat × Autumn 2019	-2.75	-0.82	-2.96	-0.77
	(3.116)	(0.502)	(3.273)	(0.536)
SRD variables	Y	Y		
County fixed effect			Y	Y
Observation	780	780	780	780
R^2	0.226		0.392	

Heterogeneous analysis

Table 2. Heterogeneous analysis of subsidy effects on straw-burning spots

	Autumn and spring		Spring	
	Low	High	Low	High
	(1)	(2)	(3)	(4)
Panel A: COVID-19 cases				
Treat × Autumn 2018 and Spring 2019	4.48	6.40	2.70	7.08
	(2.895)	(5.423)	(2.510)	(6.082)
Treat × Autumn 2019 and Spring 2020	-5.08**	-44.00***	-13.06***	-92.46***
	(1.888)	(4.304)	(4.383)	(11.305)
Observation	720	840	360	420
R^2	0.223	0.269	0.305	0.361
Panel B: The proportion of maize planting area				
Treat × Autumn 2018 – Spring 2019	-3.20	-0.90	-3.88	-4.75
	(3.815)	(6.106)	(3.922)	(6.771)
Treat × Autumn 2019 – Spring 2020	-10.80*	-18.79***	-22.89	-36.91***
	(5.843)	(6.692)	(13.667)	(10.825)
Observation	852	708	426	354
R^2	0.208	0.248	0.225	0.333

Conclusions

- During periods of stringent straw-burning monitoring, subsidization yielded only a marginal reduction in straw-burning activities compared to the control group, indicating limited MBI impact when regulatory enforcement was robust
- During the COVID-19 pandemic, when monitoring efforts were relaxed, straw burning significantly rebounded in the control group. However, this rebound was substantially mitigated in the treatment group receiving subsidies, suggesting that subsidies can play a crucial role when regulatory enforcement weakens.
- The effectiveness of subsidies was more pronounced in regions with higher COVID-19 severity and greater maize proportions in grain-planting areas, where monitoring costs were higher, and farmers exhibited stronger resistance to straw-burning bans

Acknowledgements

This study was supported by China Scholarship Council (No. 201913043)

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Designing diversified agricultural landscapes to enhance ecosystem services based on stakeholders' perspectives: modeling approach and application in North China Plain

PhD candidate: Jiali Cheng (1+3), Farming System Ecology Group & Crop Analysis Group
WUR supervisors: dr. Wopke van der Werf, dr. Jeroen Groot, dr. Andries Richter
CAU supervisors: dr. Wenfeng Cong, dr. Chaochun Zhang

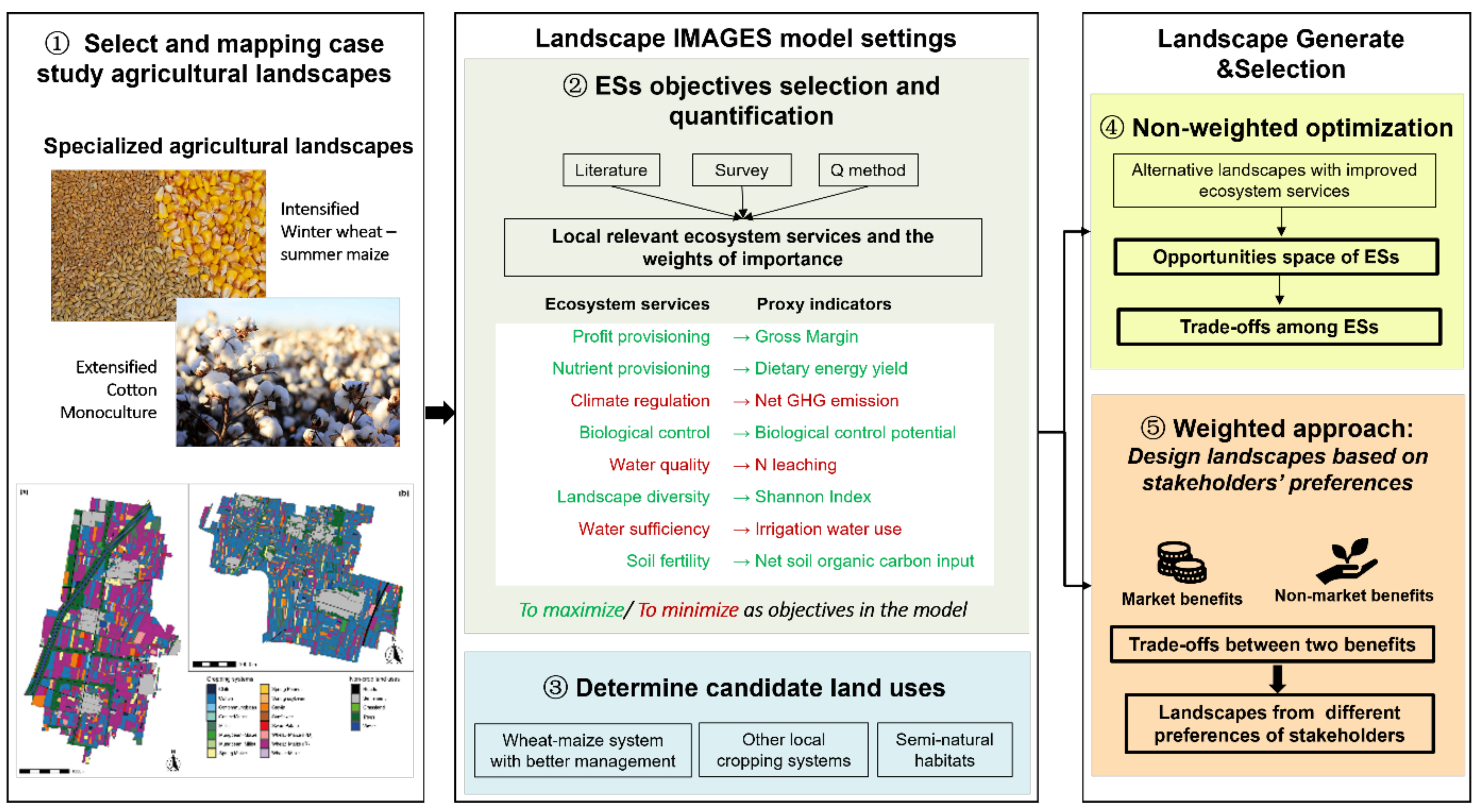
Background

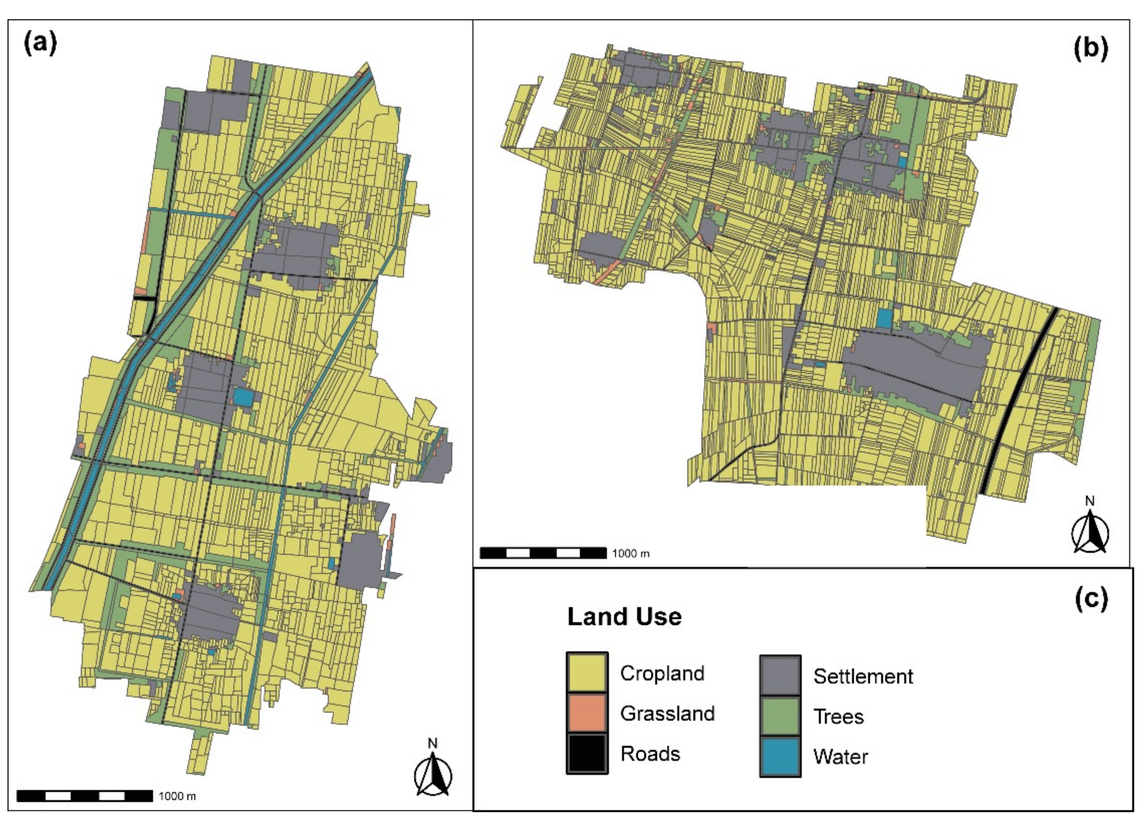
- Multifunctional landscapes aim to provide various ecosystem services (ESs), but dominance by a few cereal species has led to declined ESs.
- Redesigning intensified landscapes is crucial for sustainability, addressing a wide spectrum of ESs.
- Diversified landscapes are believed to reduce dis-services by promoting regulating and supporting services, but trade-offs and stakeholder preferences complicate planning.
- The North China Plain faces issues like groundwater decline and loss of biodiversity due to intensive cropping.
- Efforts to systematically design landscapes are limited, especially in regions like the North China Plain.
- The potential of crop diversification to meet stakeholders' preferences remains largely unknown.

Objectives

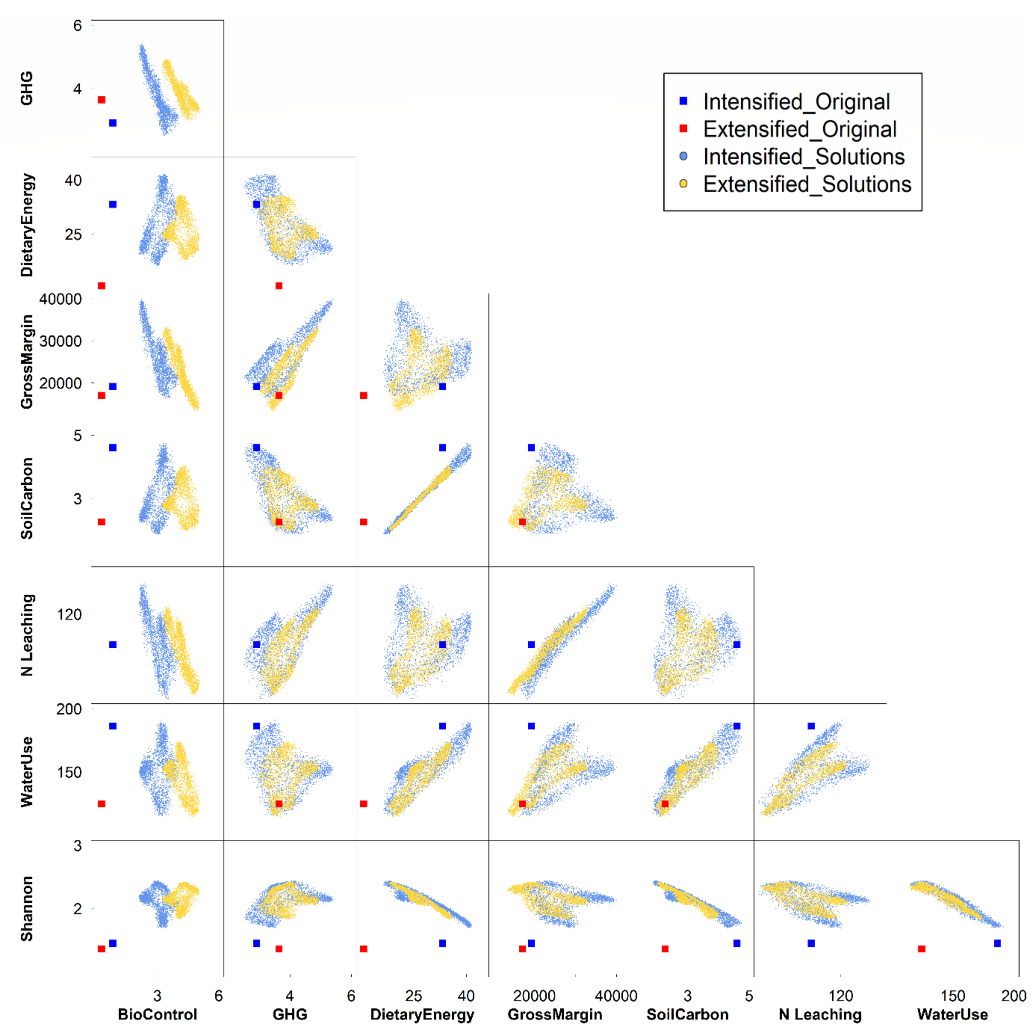
- The main objective of this study is to present a model-based methodological framework for redesigning multifunctional agricultural landscapes to tackle the local issues of ESs supply with consideration of stakeholders' preferences.
- Redesign the agricultural landscapes with improved field-scale crop management and more landscape-scale crop diversification that address compromises across a wide spectrum of ESs indicators.
- Investigate how these compromise landscapes meet the different preferences from different stakeholders.

Methodology framework

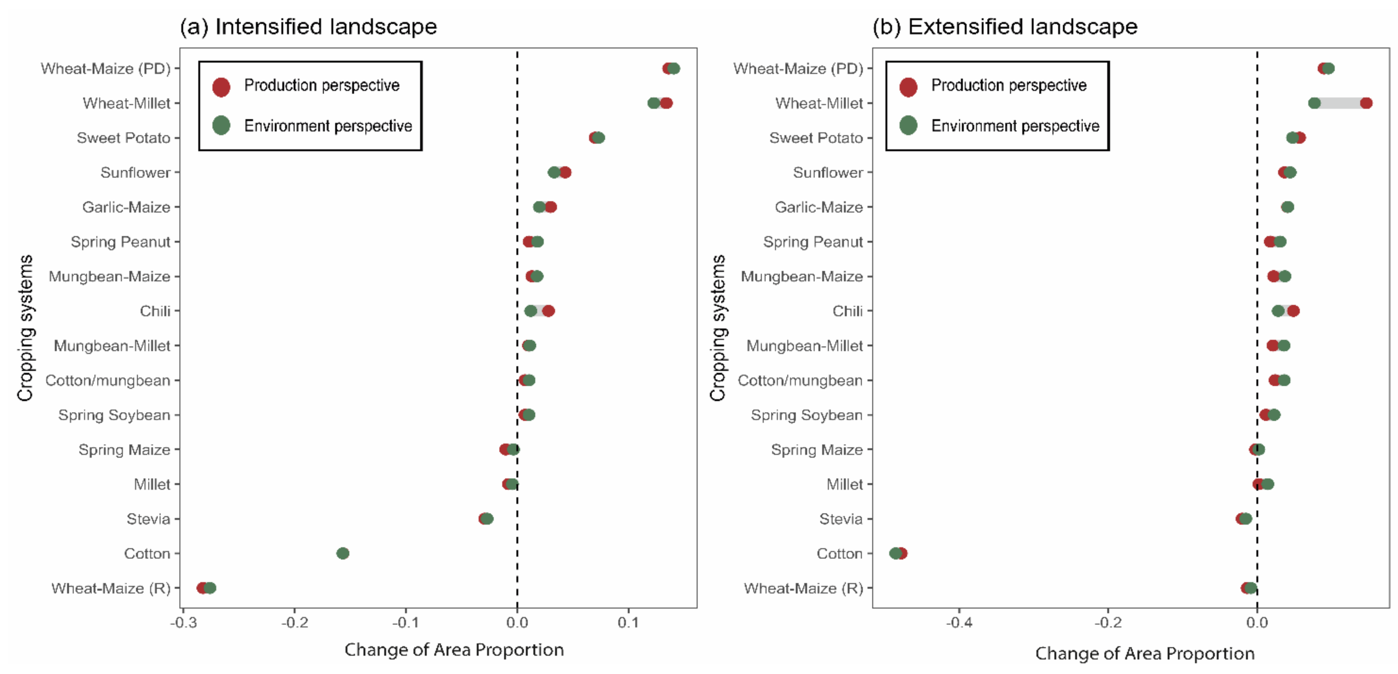




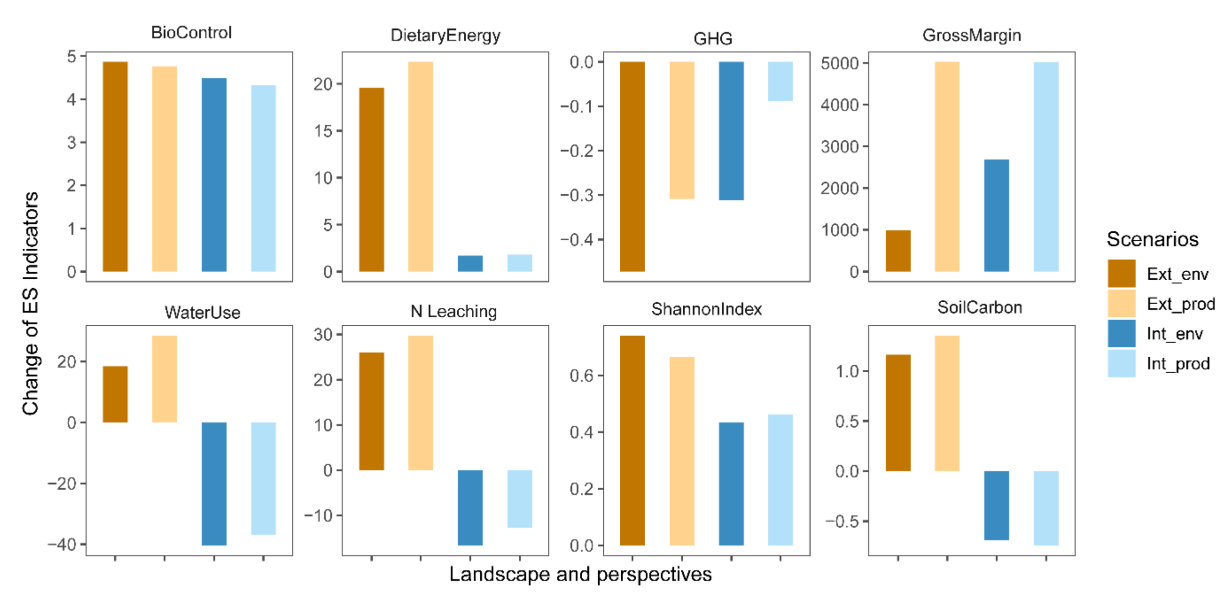
Results



Relations among ecosystem services indicators for Pareto-optimal landscape alternatives generated by multi-objective optimization for intensified (blue) and relatively extensified (orange) landscapes in Quzhou, North China Plain. The square symbols denote the ES performance of original landscapes. The units of indicators are specified in Table 1. The units of indicators: BioControl (% of maximum); GHG (Mg CO2 eq. ha^{-1} year^{-1}); DietaryEnergy (persons ha^{-1} year^{-1}); GrossMargin (CNY ha-1 year-1); SoilCarbon (Mg CO2 eq. ha-^{1} year-1); N Leaching (kg ha^{-1} year^{-1}); WaterUse (mm year-1); ShannonIndex (unitless).



Change of area proportion of different cropping systems compared with original landscapes and the selected landscapes according to people's perspectives. Wheat-maize (R) is the conventional wheat and maize system as the reference system. The sum of area changes of each landsdcapes is 0. Wheat-maize (PD) is the wheat and maize system with better management.



Change in ecosystem service (ES) indicator values of two test landscapes in two optimization scenarios compared to the original landscapes. "Ext" and " Int" indicate the test landcapes is extensified (ext) or intensified (int). "env" and "prod" indicated the selection of the landscapes are based on Production perspective (prod) or Environment perspective (env) The units of indicators: BioControl (%); GHG (Mg CO_2 eq. ha^{-1} year^{-1}); DietaryEnergy (persons ha^{-1} year^{-1}); GrossMargin (CNY ha^{-1} year^{-1}); SoilCarbon (Mg CO_2 eq. ha^{-1} year^{-1}); N Leaching (kg ha^{-1} year^{-1}); WaterUse (mm year^{-1}); ShannonIndex (unitless).

Conclusions

- Trade-offs between Gross margin and other non-provisioning ESs is strong.
- No single alternative landscape can enhance all ESs compared to the initial state and meet the preferences of all the stakeholders, but the generated alternatives make the trade-offs explicit and highlight the room for choices for different stakeholders.

Acknowledgements

We gratefully acknowlege the sponsors of this research:China Scholarship Council (NO.201913043) and Hainan University.

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Using best practices within a farmer community to enhance the sustainability of crop production by smallholder farmers

Zhan Xu
WUR supervisor: Dr. Wopke van der Werf, Dr. Jeroen Groot
CAU supervisor: Prof. Chaochun Zhang, Prof. Wenfeng Cong

Background

- Improving the sustainability of crop production on smallholder farms is often difficult as smallholder farmers face numerous resource constraints.
- While many strategies have been proposed, few studies have examined to what extent using best practice cropping systems and practices of farmers in a community can enhance crop production sustainability in the community as a whole.

Objectives

- To investigate how cropping systems and management practices adopted by some farmers with outstanding performance in the environmental, economic, and social domains can help other smallholder farms improve the sustainability of their crop production in those domains;
- To characterize the diversity of farming and identify the constraints faced by each farmer type;
- To identify farmers with outstanding performance across multiple sustainability indicators and investigate the underlying reasons by comparing management practices and cropping system allocation with other farmers;
- To redesign farming systems by the average management practices of all farmers in each farmer type and the average management practices of positive deviant farmers in each farmer type to further improve overall farm performance;
- To discuss the implications of these alternative solutions for advancing the sustainability of smallholder crop production.

Methods

We developed a three-step methodological framework to identify opportunities for alternative farming systems aimed at improving crop production sustainability across multiple domains.

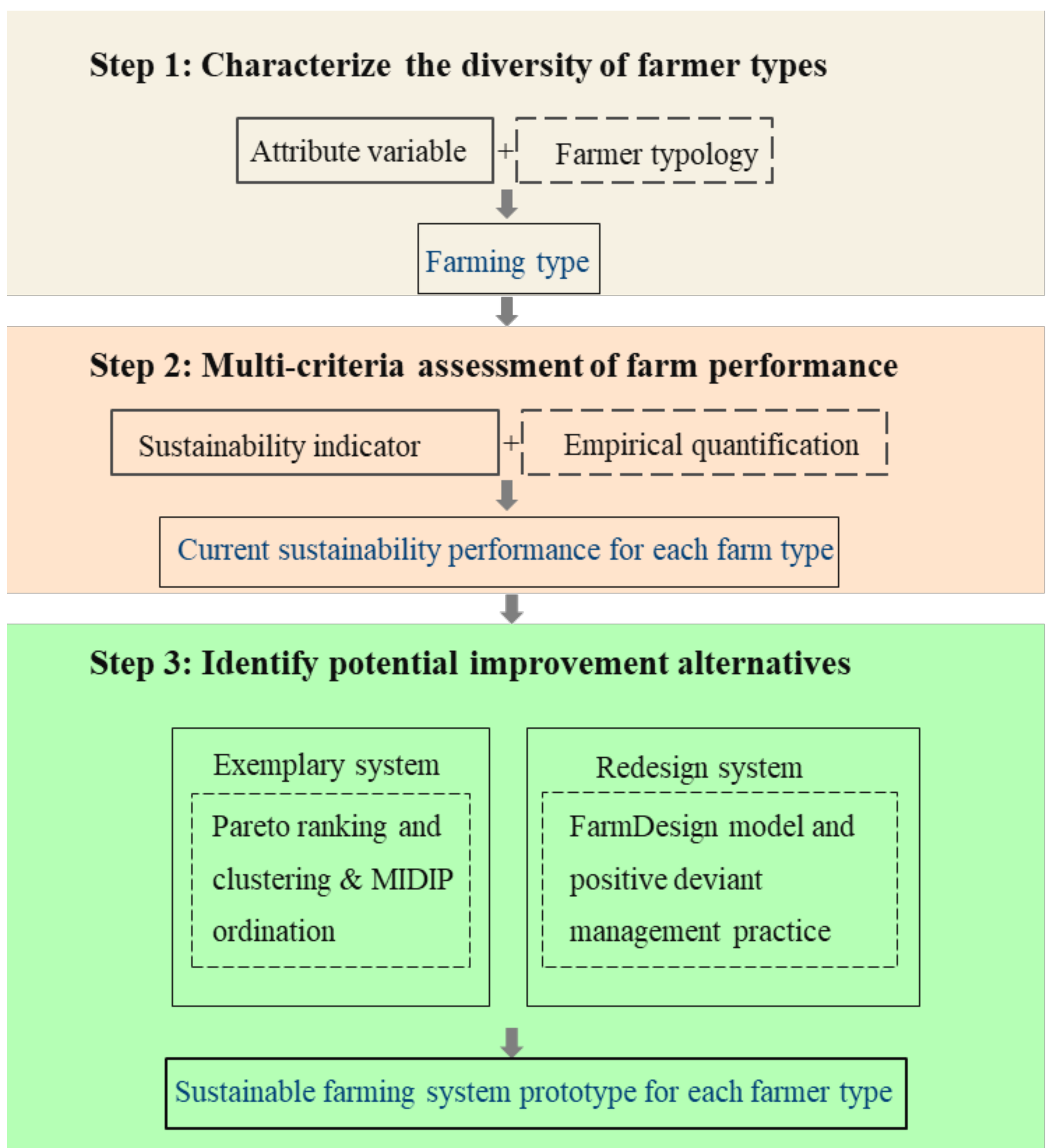

Fig.1 Overview of the three-step methodological framework for identifying alternative farming systems. Dashed-line boxes represent the methods used in each corresponding step. MIDIP is the multi-indicator distance to the ideal point.

Results

- Three farming types, labour-saving, full-time, and well-endowed farming systems, were identified based on variations in farmer, farm and household attributes. These farming types are representative of broader trends across China.

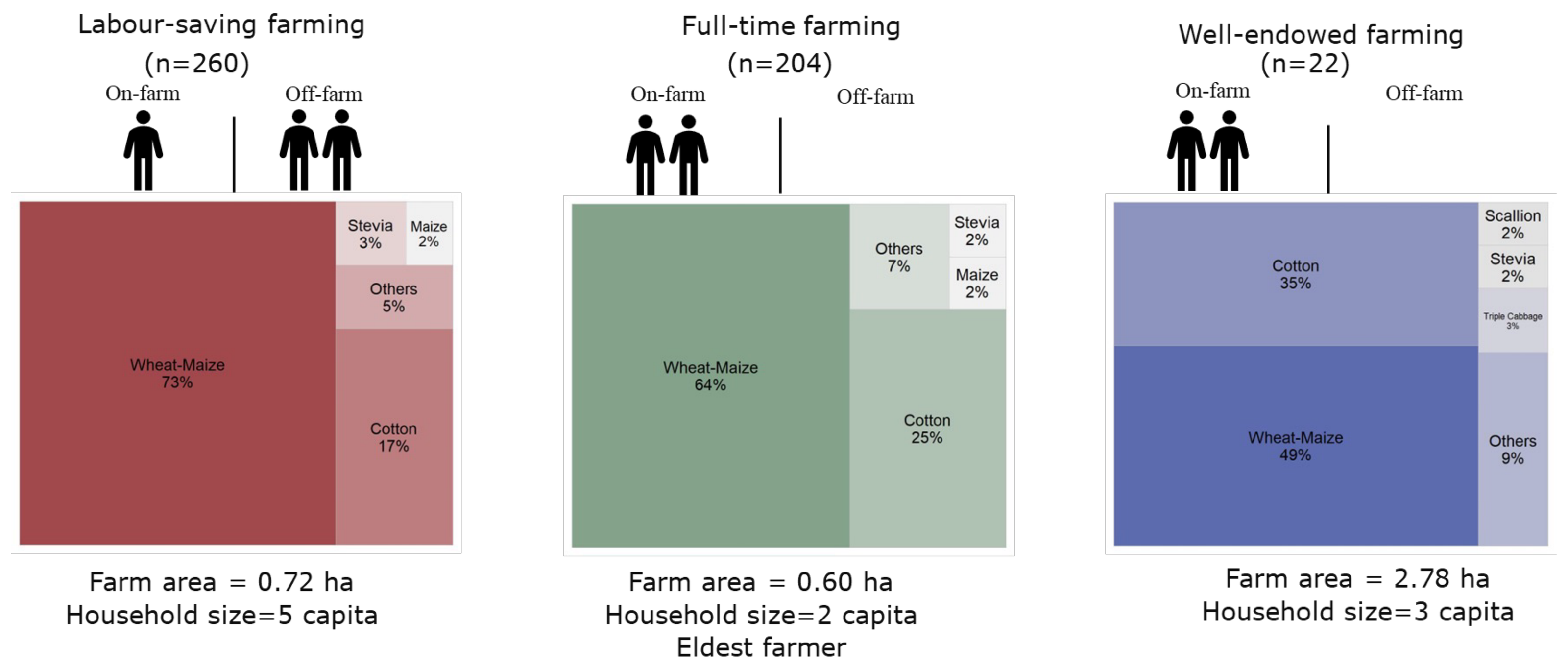

Fig. 2. Three smallholder farming systems and their related characteristics.

- Results show that integrating cropping system reallocation and positive deviant management practices could improve multi-dimensional sustainability performance across all farming types. If adopted countywide, these alternative configurations, combined with positive deviant management practices, could lead to a 36% increase in gross margin, a 26% rise in dietary energy yield, a 7-fold increase in vitamin C yield, a 47% improvement in crop diversity, and reductions of 43% in N surplus, 24% in pesticide use, and 6% in irrigation water consumption.

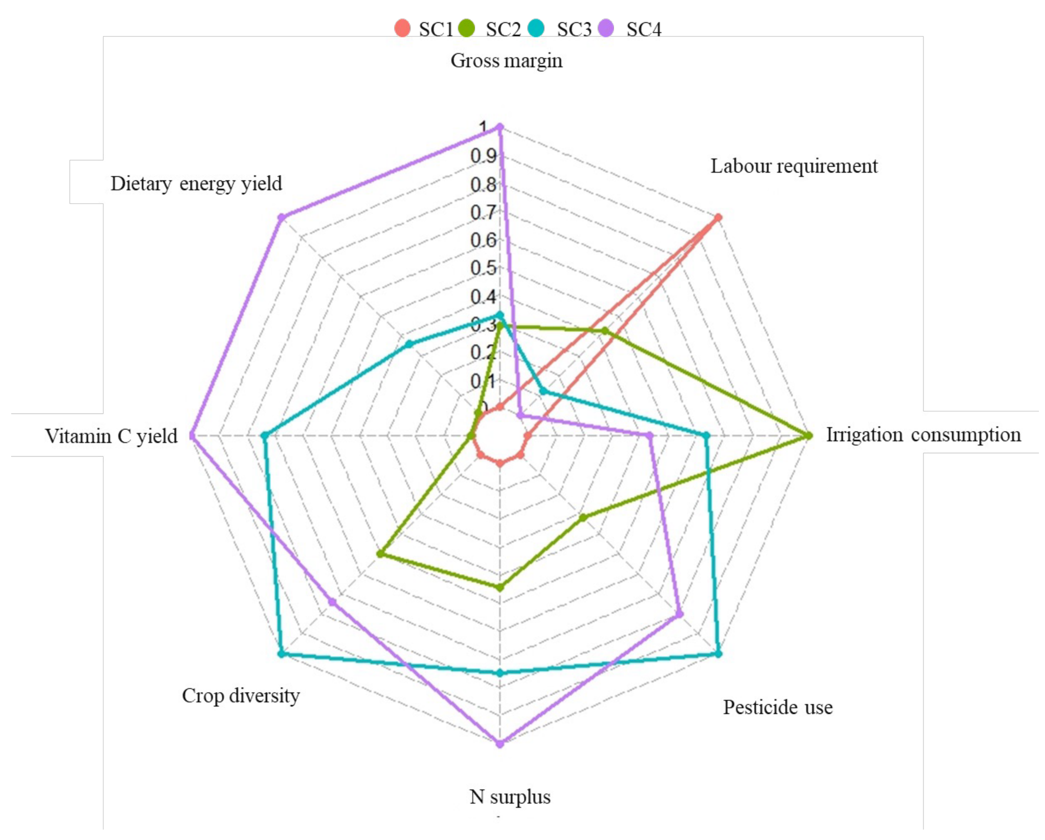

Fig. 3 Relative comparison of the four scenarios (SC1-SC4) based on sustainability indicators at the county scale. All sustainability indicators are rescaled to range from 0 (minimum) to 1 (maximum). Larger values indicate better performance for all indicators. SC1 (baseline): Average cropping system allocations and management practices per farming type. SC2 (Exemplary): Average cropping system allocations and management practices of exemplary farming per farming type. SC3 (Reallocation): Optimised allocation of average management practices (as in SC1). SC4 (Integration): Optimised allocation of management practices of exemplary farming (as in SC2).

Conclusions

- The findings demonstrate that while not all sustainability challenges can be addressed through existing cropping systems and management practices, many problems can be at least partially resolved.
- The findings highlight the potential of combining farmers' adopted cropping systems with best management practices within a farmer community that expand the envelope of options, leading to improved sustainability performance across a community of farms.

Acknowledgements

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Evaluating genotype-environment-management interactions for maize cultivars to tap biological potential yield in different zones of China

Author: Yujie Yang
Supervisors: CAU: Qingchun Pan, Lixing Yuan; WUR: Jochem Evers, Tjeerd Jan Stomph

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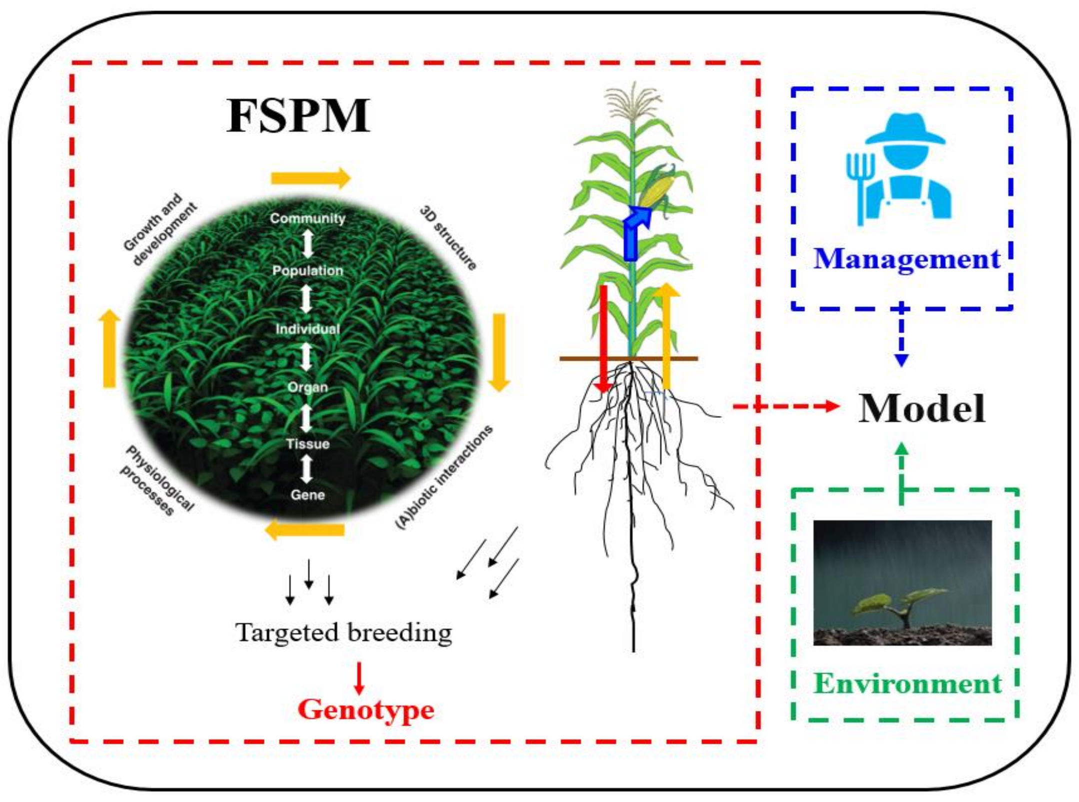
Background

In China:

➤ **Genotype**
2000-2019, 1362 maize varieties were authorized.

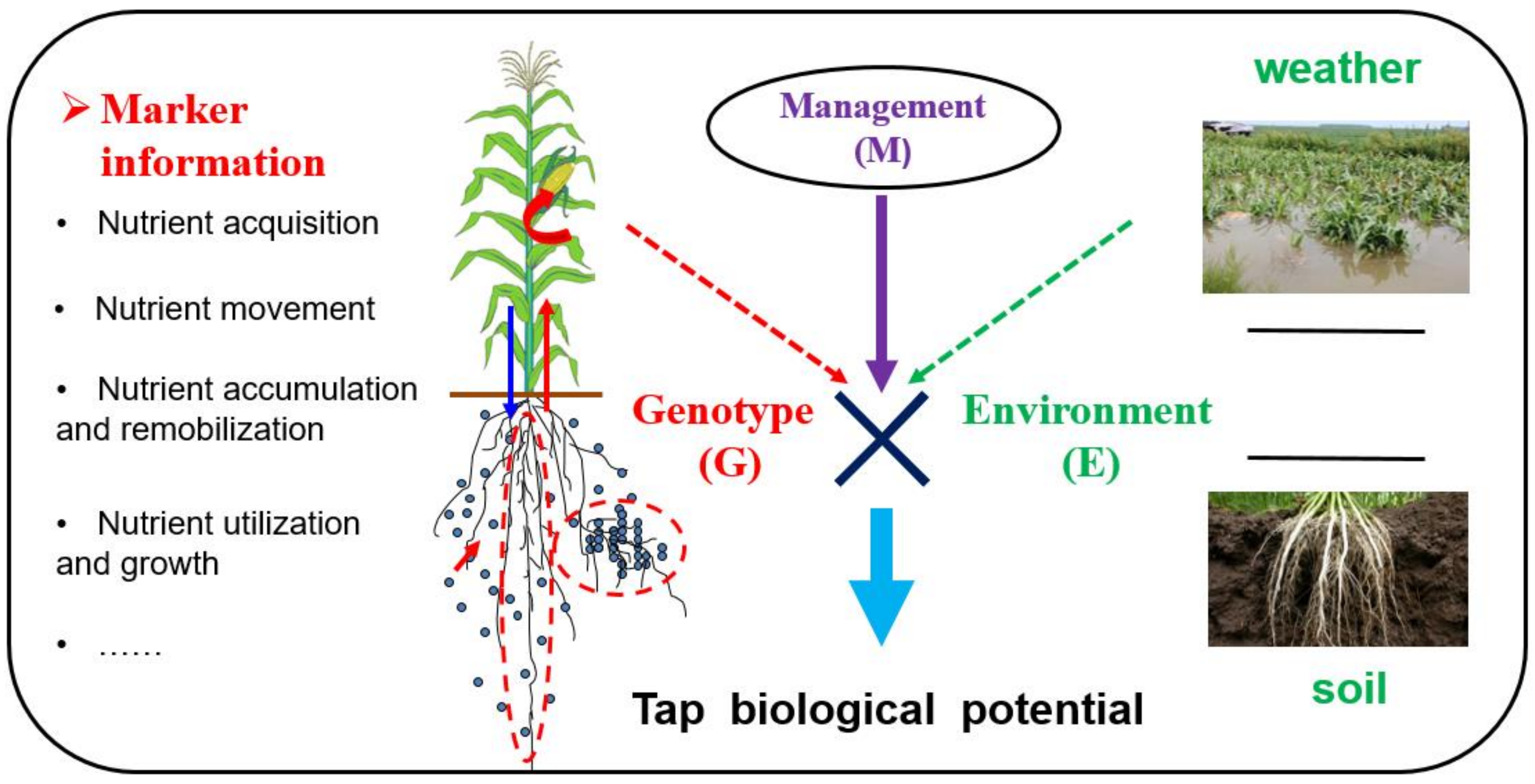
➤ **Environment**
- Longitude and latitude
- Precipitation
- Photoperiod
- Temperature
- ……

➤ **Management**
- Fertilizers
- Pesticide
- Planting patterns
- ……



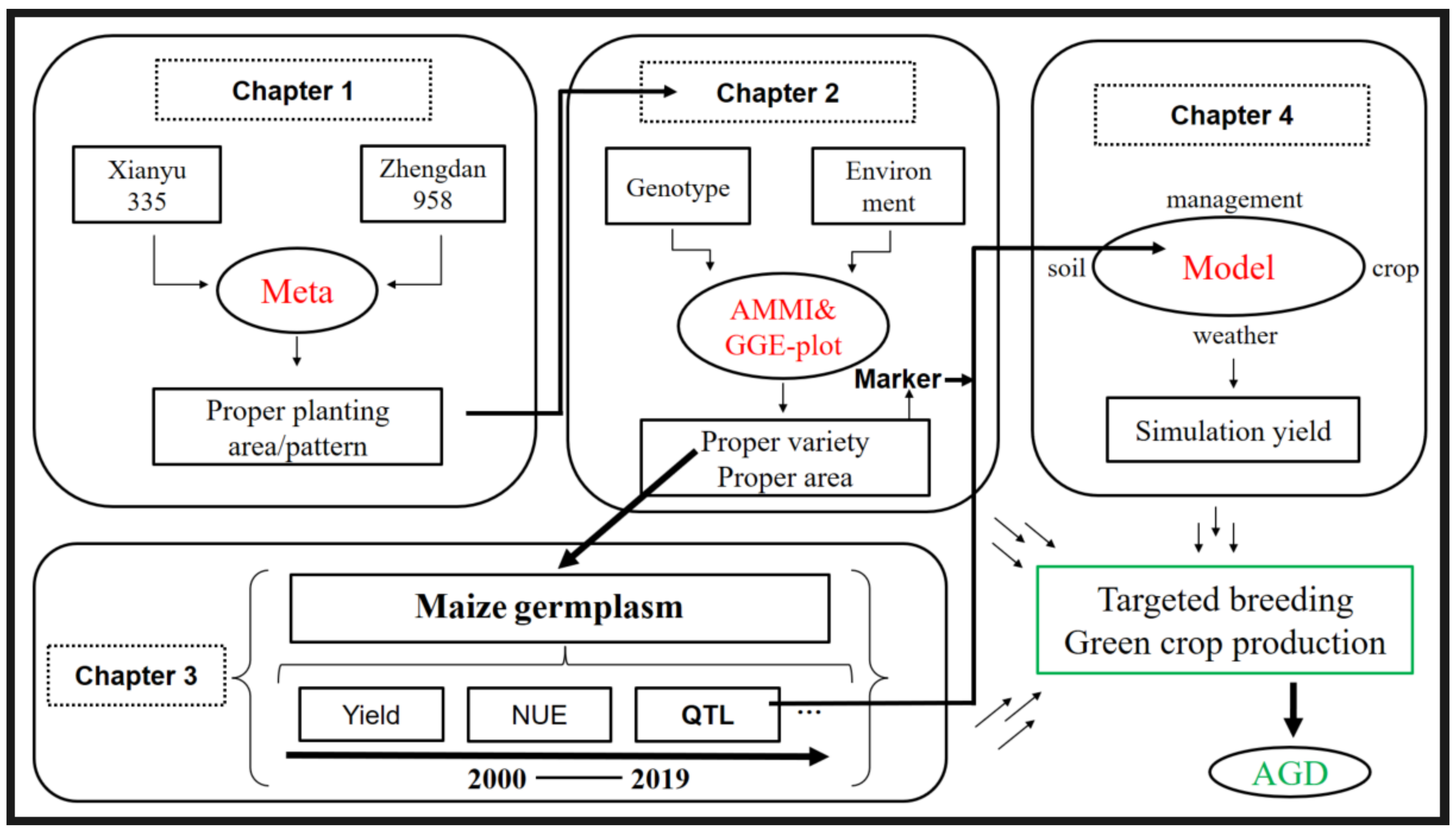
Research question: How to use GEM models to predict the potential yield of different maize varieties in different regions of China?

Objective



- High yield
- High efficient utilization of resource
- Low environmental cost

Method-roadmap



Results

A total of 1912 papers(xianyu335-559;zhengdan958-1353) were collected from Web of science and CNKI. These two cultivars are widely planted in China. We found the main contribution factors of the two varieties in high-yield and low-yield fields

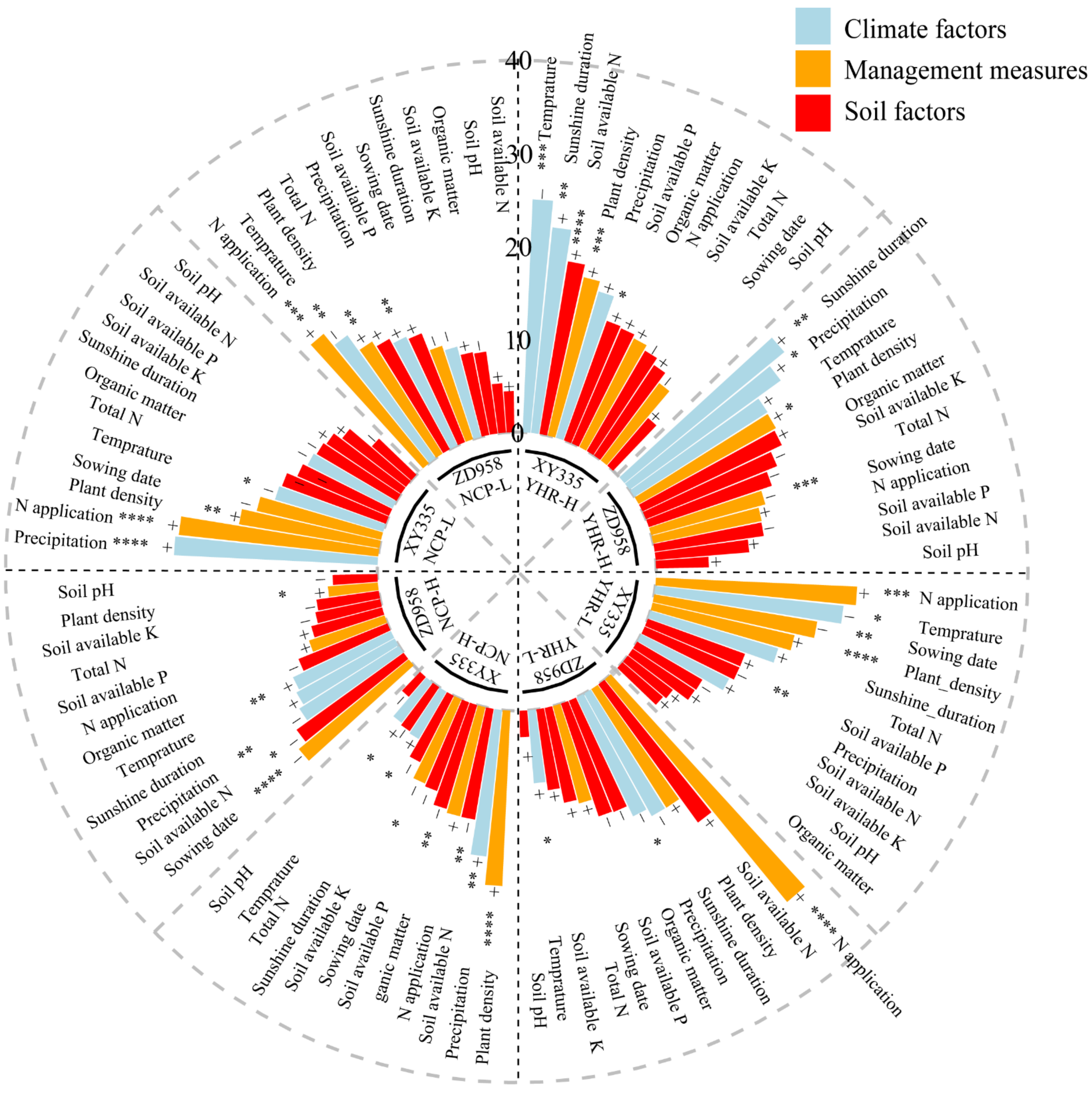


Figure 2. The contribution rate of different factors to both high and low yield of Zhengdan958 and Xianyu335 in different regions of China. Note: 1). The importance values are derived from a random forest analysis. **** p < 0.0001, *** p < 0.001, ** p < 0.01 and * p< 0.05. 2). "+" represents positive correlation with yield, "-" represents negative correlation with yield

Conclusions

➤ 1) Xianyu335 (love rainfall and nutrients) :In the Huang-Huai-hai high-yield field, it is not resistant to high temperature, enjoys light, and is suitable for the environment of high soil available nitrogen and phosphorus. In the north, soil with high available nitrogen is suitable, and in areas with high rainfall, high yield is mainly achieved by densification.

➤ 2) Zhengdan958 (poor and high temperature resistance) :In the Huang-Huai-hai high-yield field, sunshine, rainfall, high temperature resistance, moderate densification. In the northern high-yield fields, it is necessary to sow early, soil nitrogen should not be too high, and rainfall should not be too large. Love high temperature and long light.

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Overview PhD projects – starting year 2020
Posters, March 2025

Theme: Green and nutritious food provision & governance

Name	*Model**	*Project*
1. Yujun Wei	1+3	Optimizing Food Loss Utilization for Platform Chemical Production: A Quantitative Analysis
2. Ruijin Luo	2+2	Optimizing the Economic and Environmental Performance of the Gannan Navel Orange Supply Chain (GNSC)
3. Junhan Zhang	1+3	The impact of product deterioration on the(re)design of food supply chain networks: An application to a perishable food supply chain
4. Zhiyao Chang	2+2	Developing the Sustainable Alternative Diets with Respecting Regional Food Culture in China

Theme: Green animal production

Name	*Model**	*Project*
5. Rui Shi	1+3	Balancing farm profit and greenhouse gas emissions along the dairy production chain via breeding
6. Yujuan He	2+2	Legume-driven soil microbial legacies enhance maize growth by shaping root morphological traits and are contingent upon phosphorus input
7. Weitong Long	1+3	Unintended trade-offs between food security and environmental sustainability: Impacts of China's dietary shift and afforestation under a stringent climate mitigation policy
8. Fei Xie	2+2	Detecting excretion behaviour of group pigs and ammonia emitting area using thermal and RGB images

Theme: Green plant production

Name	*Model**	*Project*
9. Zhaoqi Bin	1+3	Application of plant-soil feedbacks in agriculture: using trait-based prediction for improving crop rotation
10. Ruotong Zhao	2+2	Mycorrhiza-mediated recruitment of complete denitrifying Pseudomonas reduces N2O emissions from soil
11. Bowen Ma	2+2	Developing diversified cropping systems for enhancing integrated sustainability on the North China Plain
12. Laiquan Luo	1+3	A hybrid design for a safe, versatile soft robotic gripper for agri-food
13. Jiyu Jia	2+2	Unlocking Soil Health: Are Microbial Functional Genes Effective Indicators?
14. Yizan Li	1+3	Assessing nutrient cycling for soil health and sustainable management in agroecosystems: A modelling approach
15. Yanjie Chen	2+2	Drivers of pollinator abundance and diversity in the North China Plain

Model*: There are two different types of PhD candidates, hence 2 models.
2+2 model: Graduates at CAU; project starts and ends in China; stays for two consecutive years in Wageningen.
1+3 model: Graduates at WU; project starts in China; stays for three consecutive years in Wageningen.

Optimizing Food Loss Utilization for Platform Chemical Production: A Quantitative Analysis

Yujun Wei, Susan Caroline Alvarado Cummings, Xuexian Li, Huub Rijnaarts, Wei-Shan Chen

Background

The fossil-based chemical industry significantly contributes to greenhouse gas (GHG) emissions and resource depletion, with only 2% of global chemical production being biobased. Utilizing food loss as feedstock for biobased platform chemicals presents an opportunity to mitigate emissions and valorize waste. However, challenges such as feedstock variability and process feasibility hinder widespread adoption. Food waste biorefineries offer environmental and economic benefits but face investment, market, and processing challenges. Optimal feedstock selection and process matching are crucial for successful valorization.

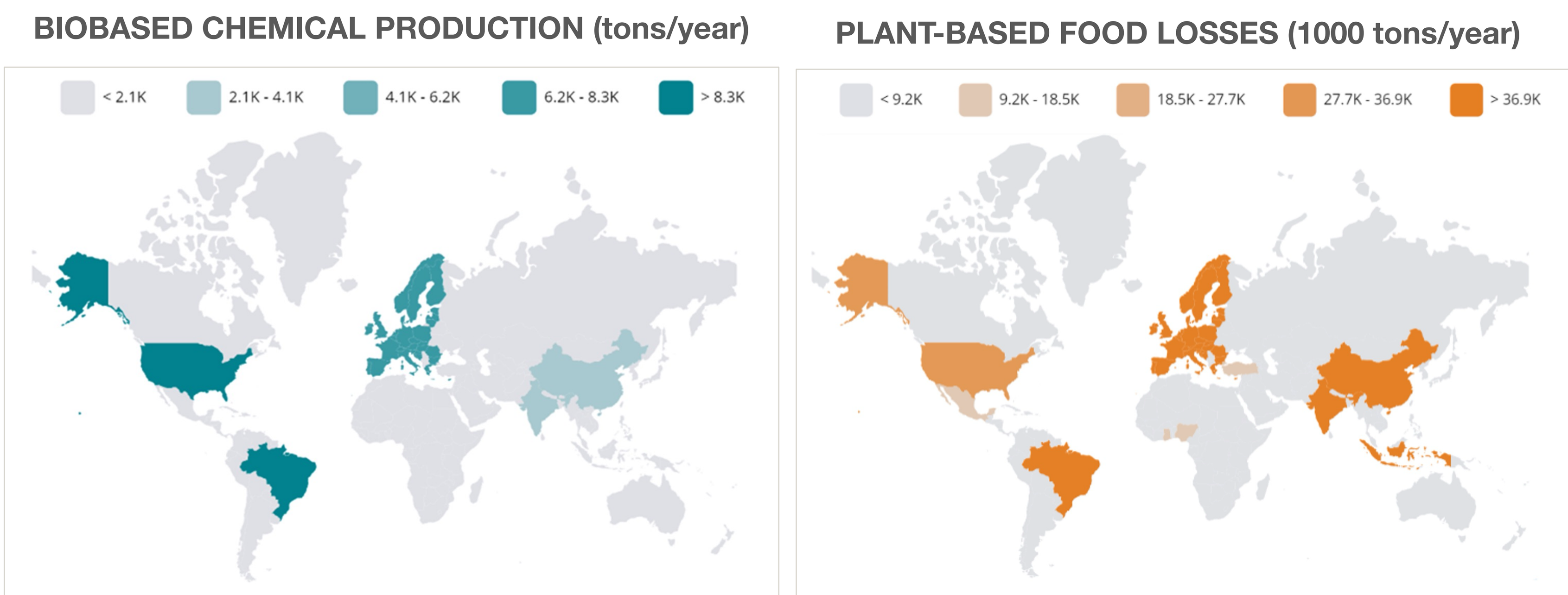

Fig 1. Geographical patterns of biobased chemical production and plant-based food losses

Objectives

This research will try to achieve the following research objectives:

(1) What existing data is available regarding food loss and the production of biobased chemicals, specifically pertaining to relevant regions, food loss types, and the main valorization pathways?

(2) What potential matches can be identified between specific food loss streams and biobased chemicals?

(3) How much of the biobased chemicals demands can theoretically be produced from food loss based on available data?

(4) What are the optimal solutions for matching food loss streams with biobased chemicals to minimize environmental impact and maximize economic benefits?

Methods

The research methodology consists of a series of steps designed to investigate the feasibility of obtaining biobased platform chemicals from food loss streams and valorization technologies. The steps are system and data boundaries, matchmaking, quantification, and decision analysis and optimization.

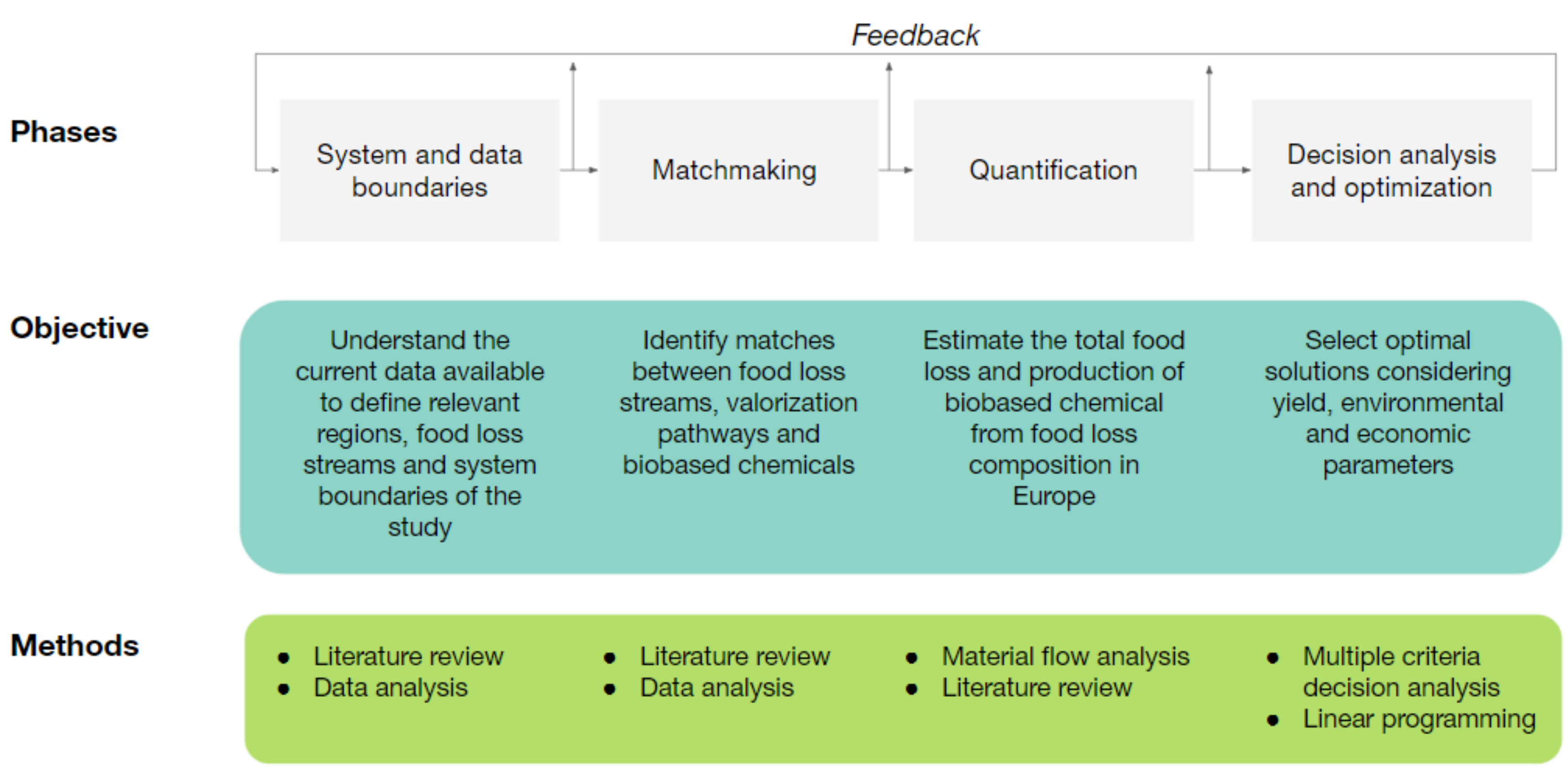

Fig 2. Overall methodological approach of this study.

Results & conclusions

Mass flow from crops to streams during Primary Production and Processing & Manufacturing in Europe:

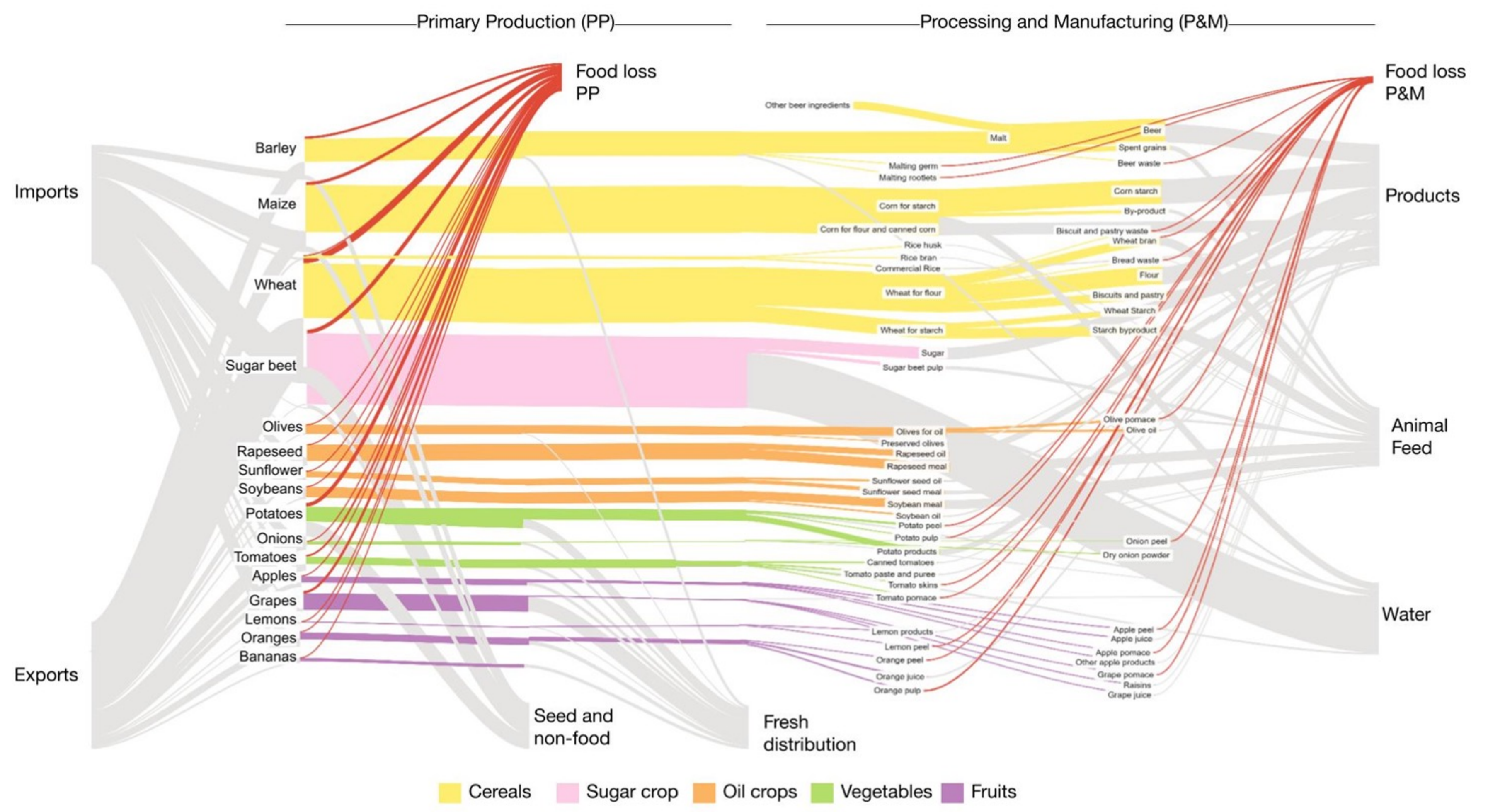

Figure 3. Mass flow from crops to streams during PP and P&M in Europe. The Sankey diagram highlights (red) the food loss streams derived from cereals, sugar crops, oil crops, vegetables, and fruits during PP and P&M, including those imported and exported.

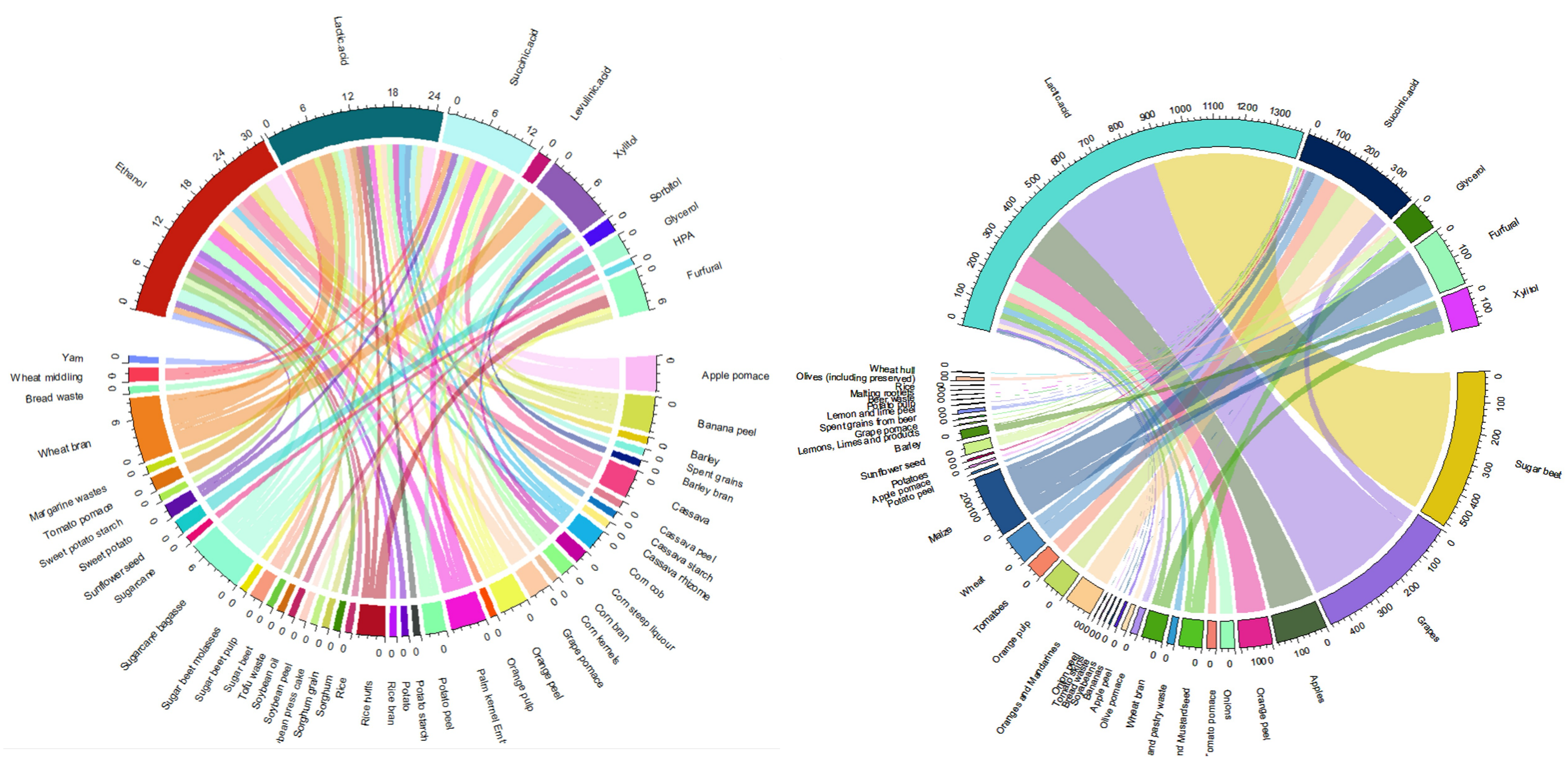

Figure 4. Comparison of the literature review frequency (left) vs the suggested allocation from this study (right).

Figure 5. Total profit and emissions based on multi-objective programming results.

This study highlights key aspects of food loss valorization and biobased chemical production. Food loss quantification confirms its potential to meet biobased chemical market demands. Among various chemicals, lactic acid and succinic acid emerged as promising candidates, emphasizing the need for further research on optimal chemicals. The unique composition of food loss streams affects their suitability for different chemical productions, reinforcing the importance of demand-driven valorization. While the study provides a strong foundation, limitations include model simplicity and data comparability issues. Future research should refine decision tools and standardize methodologies to optimize sustainable food loss biorefineries.

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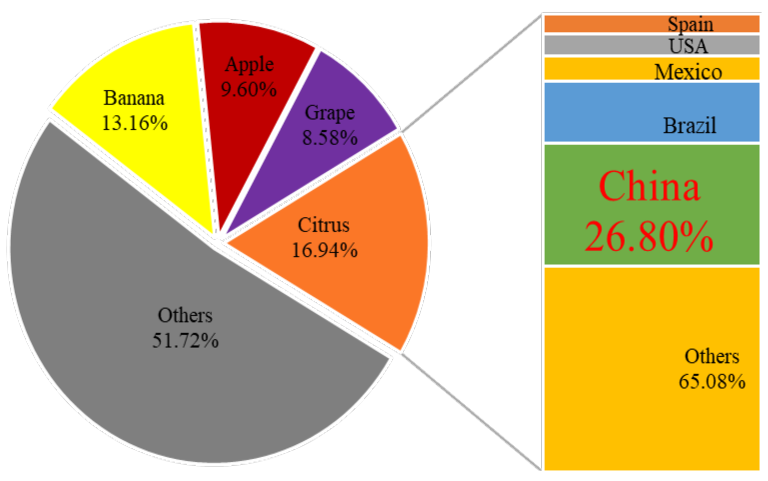
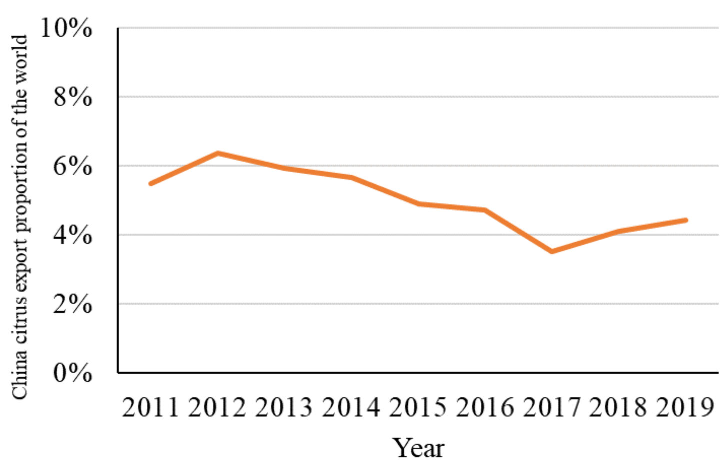
Optimizing the Economic and Environmental Performance of the Gannan Navel Orange Supply Chain (GNSC)

Ruijin Luo*, Junhan Zhang
Supervisors: Xuexian Li, Ting Meng, G.D.H. (Frits) Claassen, Sander de Leeuw

Background





Citrus - Most popular fruit
China – Largest production

Export – Low & fluctuated

Input – High
Efficiency – Low
Activeness – Moderate

Objectives

1. Framing a food supply chain assessment method from economic and environmental perspectives via life cycle thinking and multi-criteria decision making analysis.
2. Determining the economic and environmental performance of navel orange supply chains in southern Jiangxi as an umbrella case study.
3. Exploring agriculture green development (AGD) options for China's green navel orange industry to redesign and transform the existing structure towards a circular and market driven one.

Methods

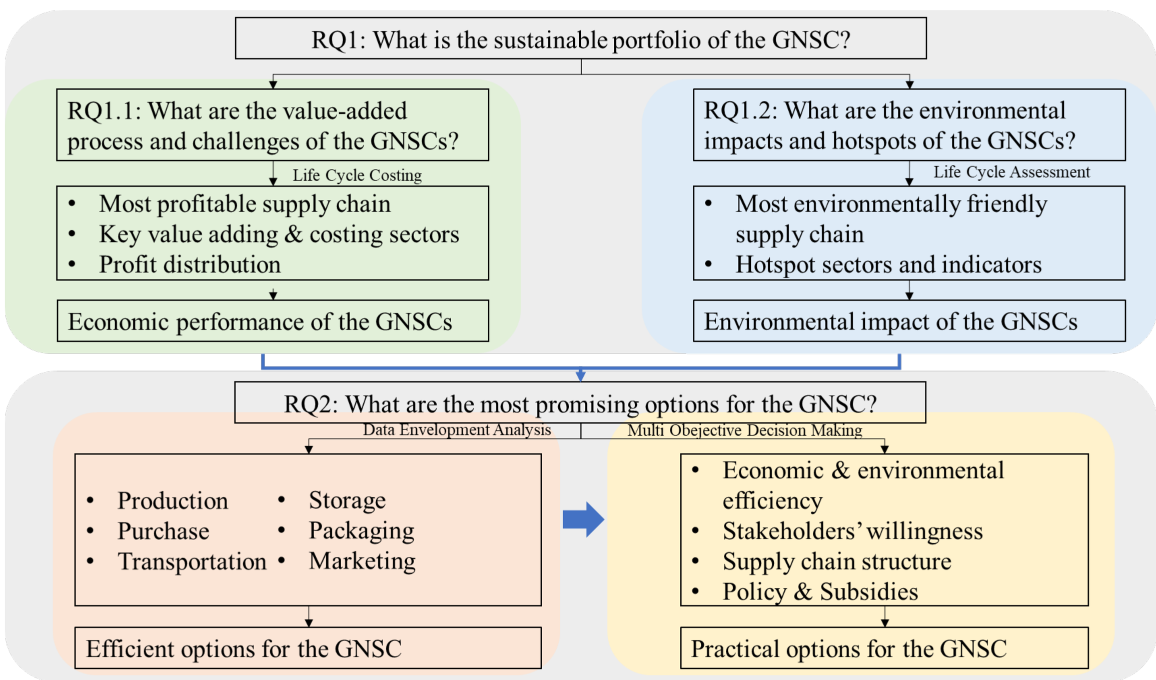


Fig.1 Technical routes

1. Life Cycle Assessment (LCA)

Life cycle assessment (LCA) is a methodology for assessing environmental impacts associated with all the stages of the life cycle of a commercial product, process, or service. For instance, in the case of a manufactured product, environmental impacts are assessed from raw material extraction and processing (cradle), through the product's manufacture, distribution and use, to the recycling or final disposal of the materials composing it (grave).[1] [2] The aim is to document and improve the overall environmental profile of the product.[2]

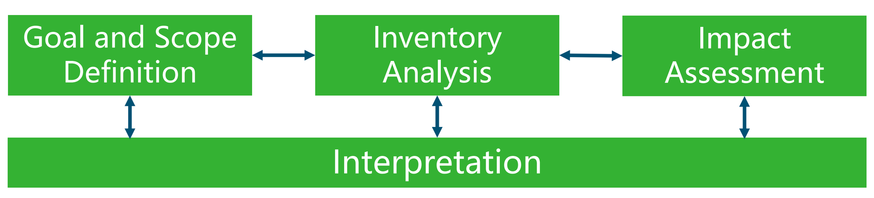


Fig.2 Illustration of the general phases of a life cycle assessment, as described by ISO 14040

2. Data Envelopment Analysis (DEA)

Data envelopment analysis is a process of defining valid measures of performance comparison among peer Decision Making Units (DMUs), using them to determine the relative positions of the peer DMUs and, ultimately, establishing a standard of excellence to explore improvement options to achieve the excellence[3]. Dimensions typically measured are quality, time and cost.

3. Multiple Objective Decision Analysis (MODA)

Multiple objective decision analysis, also known as multi-objective optimization is a sub-discipline of operations research that explicitly evaluates multiple conflicting criteria in decision making and choosing the best solution[4]. MODA has been an active area of research since the 1970s. MCDA is divided into multiple approaches in order to evaluate several alternatives or design an alternative (solution) by solving a mathematical model.

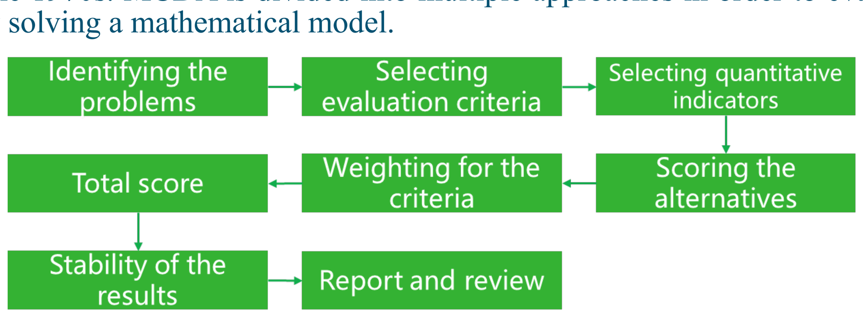


Fig.3 Multi Objective Decision Analysis Procedure

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An Umbrella Case – Southern Jiangxi Navel Orange

- Most famous and valuable citrus
- Since: 1970s
- Brand value: 67.8 billion CNY (2020)
- Harvested area: 1.1×10^5 ha
- Output: 1.4×10^6 t

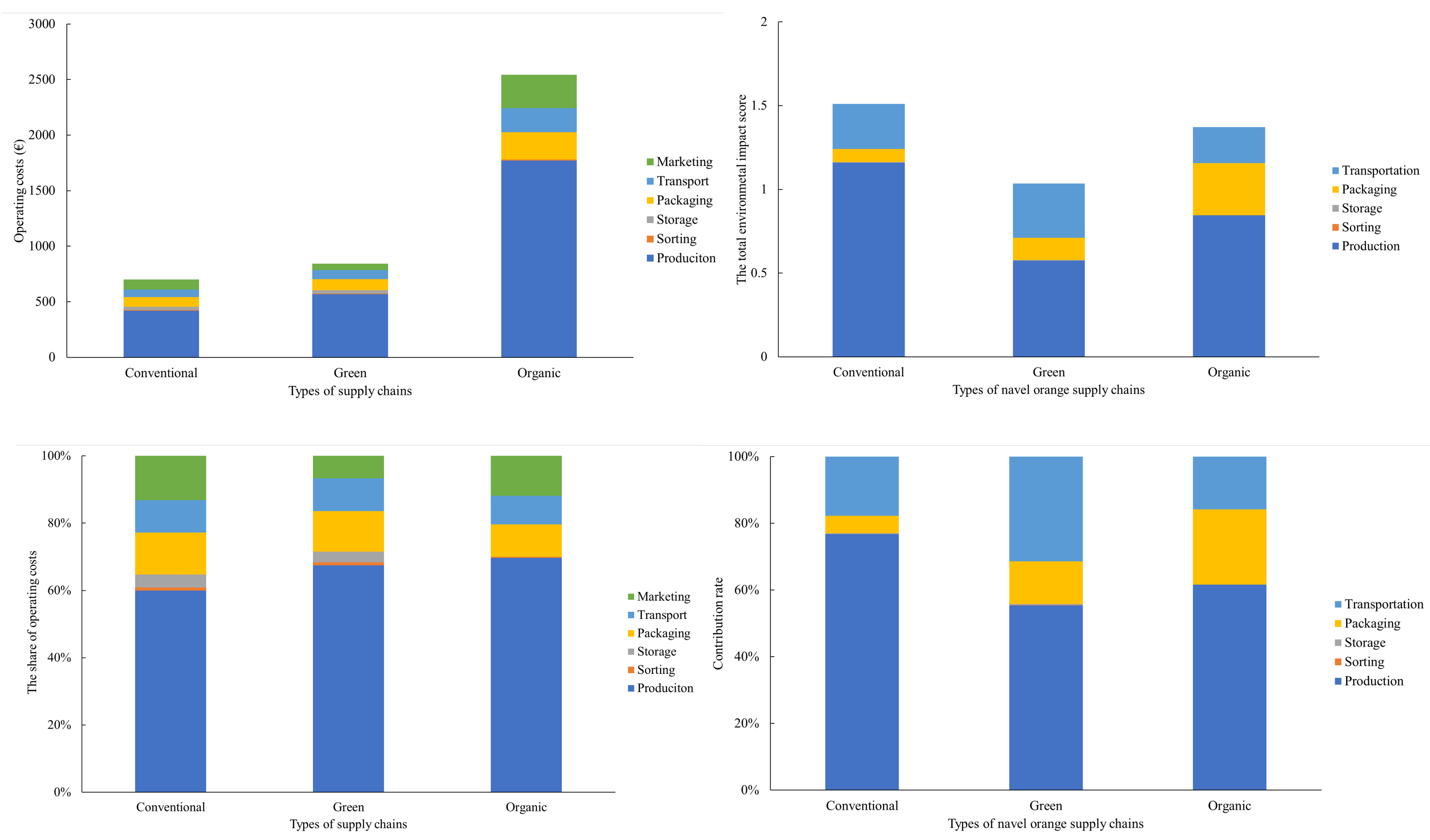

Fig.3 The economic and environmental performance of navel orange supply chains in southern Jiangxi and their contribution rates.

- Green labeled GNSC is economically and environmentally less costing than its organic counterpart.
- Production, packaging and transportation are the most economically and environmentally costing sectors.
- Fossil fuel potential, terrestrial ecotoxicity potential and agricultural land occupation potential are identified as more critical indicators to GNSCs.
- Green labeled GNSC is less profitable than its organic and conventional counterparts.

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The impact of product deterioration on the(re)design of food supply chain networks:
- An application to a perishable food supply chain

Junhan Zhang, Ruijin Luo, Xuexian Li, Ting Meng
Peter Kirst, Sander de Leeuw, G.D.H. Claassen

Background

Given the increasing demand for freshness, the need to reduce food waste, and to ensure food safety, it is crucial to consider quality deterioration processes in the (re)design of food supply chains.
Past developments in food supply chains focused foremost on efficiency and economic profitability, resulting in large-scale centralized processing facilities. This has become a liability as efficiency in large-scale processing limits product differentiation and flexibility.
Decentralized, (upstream) pre-processing, and improved pre-treatments can affect product deterioration in an early stage, resulting in more diverse and intermediate product flows that can be used in existing and new value chains and provide new markets.

Objectives

To identify the benefits of alternative supply chain structures, we propose a generic model based on mixed-integer linear programming.
The modelling structures are applicable to a broad variety of different (food) supply chains.

Methods

$$\max \sum_{t\in\{1,\dots,T\}} \left(\sum_{m,n,t,q} c^x_{mntq} x_{mntq} - \sum_{n,t,q} c^I_{ntq} I_{ntq} - \sum_n c^y_n y_n \right) \quad (1)$$

s. t.

$$I_{ntq} = \sigma_n I_{n(t-1)(q+\delta(n))} + \sum_{m\in P(n)} \omega_{mn} x_{mntq} - \sum_{m\in S(n)} \omega_{nm} x_{nmtq} \quad \forall t\in\{1,\dots,T\}, q\in Q, n\in N \quad (2)$$

$$F^{\min}_n y_n \le \sum_{m\in P(n)} \sum_{q\in Q} x_{mntq} \le F^{\max}_n y_n \quad \forall n\in N, t\in\{1,\dots,T\} \quad (3)$$

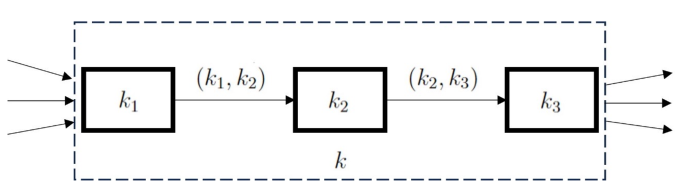
$$I^{\min}_n y_n \le \sum_{q\in Q} I_{ntq} \le I^{\max}_n y_n \quad \forall n\in N, t\in\{1,\dots,T\} \quad (4)$$

$$x_{nmtq} \ge 0 \quad \forall (n,m)\in A, t\in\{1,\dots,T\}, q\in Q \quad (5)$$

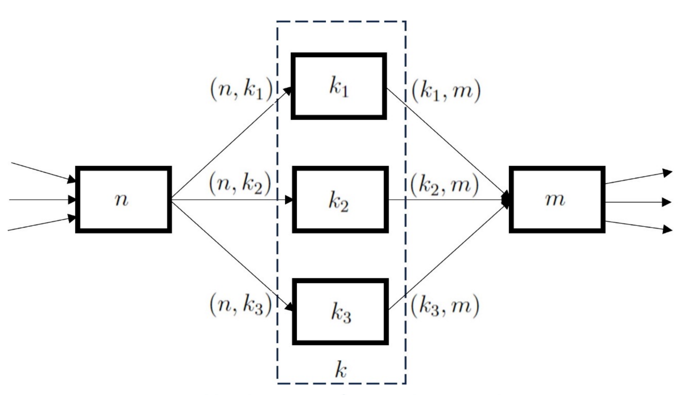
$$I_{ntq} \ge 0 \quad \forall n\in N, t\in\{1,\dots,T\}, q\in Q \quad (6)$$

$$y_n \in \{0,1\} \quad \forall n\in N \quad (7)$$

It is possible to add artificial nodes in the network in a sequencial or parallel way to model the redesigned network:



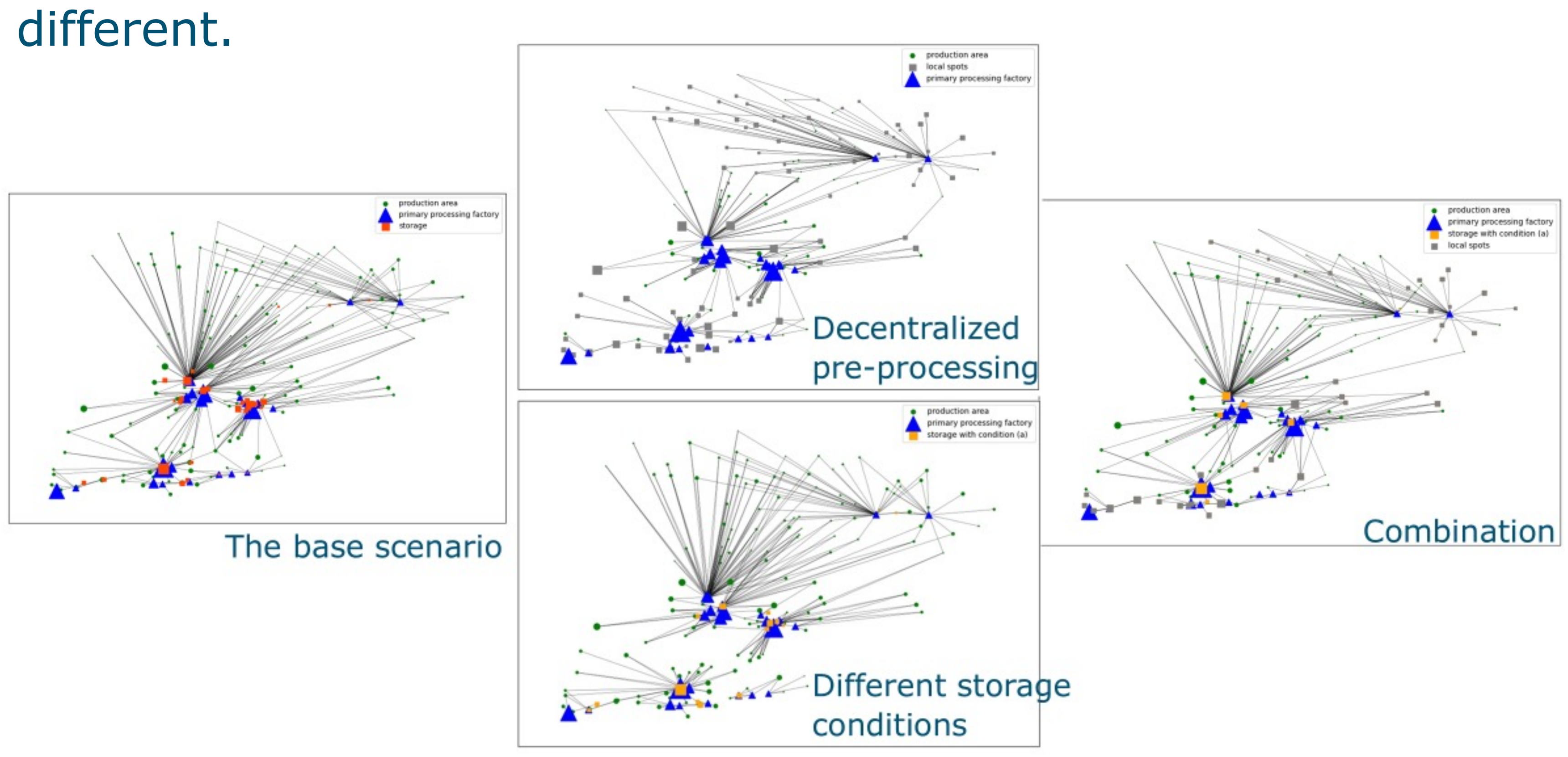
Serial artificial nodes



Parallel artificial nodes

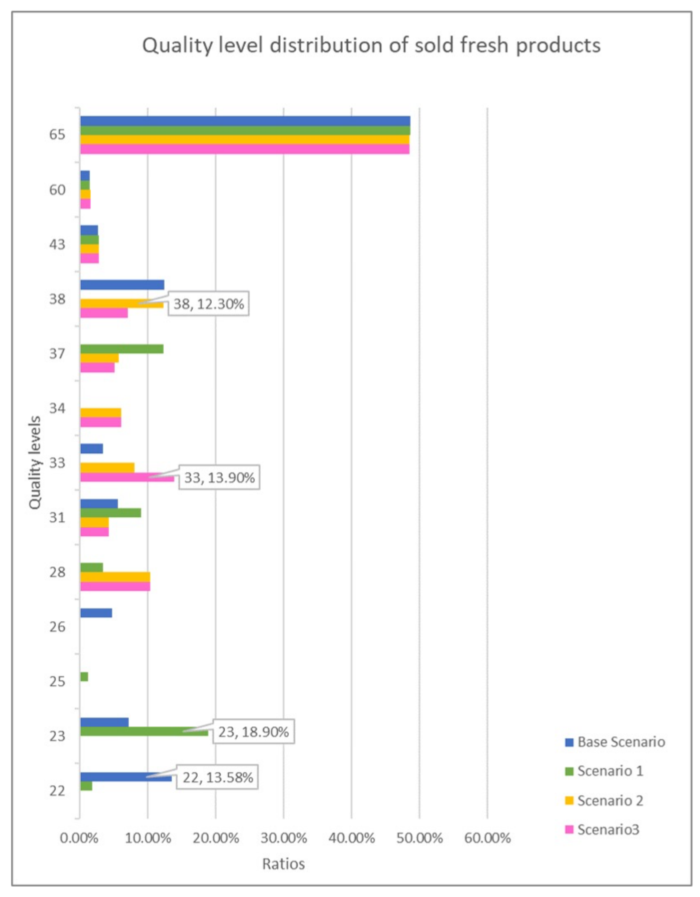
Results

The optimal network configurations in different scenarios are different.



The objective function value, representing the total gross profit, is the highest in Scenario 3 with combined decentralized pre-processing and improved storage. Compared to the base scenario, the total profit is 4.6% higher in Scenario 1 with only decentralized pre-processing, 6.7% higher in Scenario 2 with only improved storage, and 7.2% in Scenario 3 with the combination.

Besides economic performance, the network redesign also affects the quality of the final products, particularly those sold to the fresh market. The weighted average quality level of all products sold to the fresh market is 47.2 in the base scenario and Scenario 1 but increases by 4.6% to 49.5 in Scenario 2 and by 4.4% to 49.3 in Scenario 3.



Conclusions

This paper aims to emphasize the impact of quality deterioration for the strategic (re)design of FSC networks. To achieve this, a generic modelling framework and two additional modelling structures are suggested that can be applied to a wide range of product-specific circumstances. We demonstrate that the general building blocks can be used by decision-makers to (re)design entire or partial food supply chains.
Future research could extend the proposed NFPP model in several directions to enhance its applicability and robustness. First, applying the NFPP model to various high- or low-perishable products, such as strawberries or grains, could provide additional insights into the impact of quality deterioration on supply chain network design under different levels of perishability.

Acknowledgements

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Developing the Sustainable Alternative Diets with Respecting Regional Food Culture in China

Zhiyao Chang, Elise F. Talsma, Hongyi Cai, Shenggen Fan, Yuanying Ni, Xin Wen, Pieter van 't Veer, and Sander Biesbroek

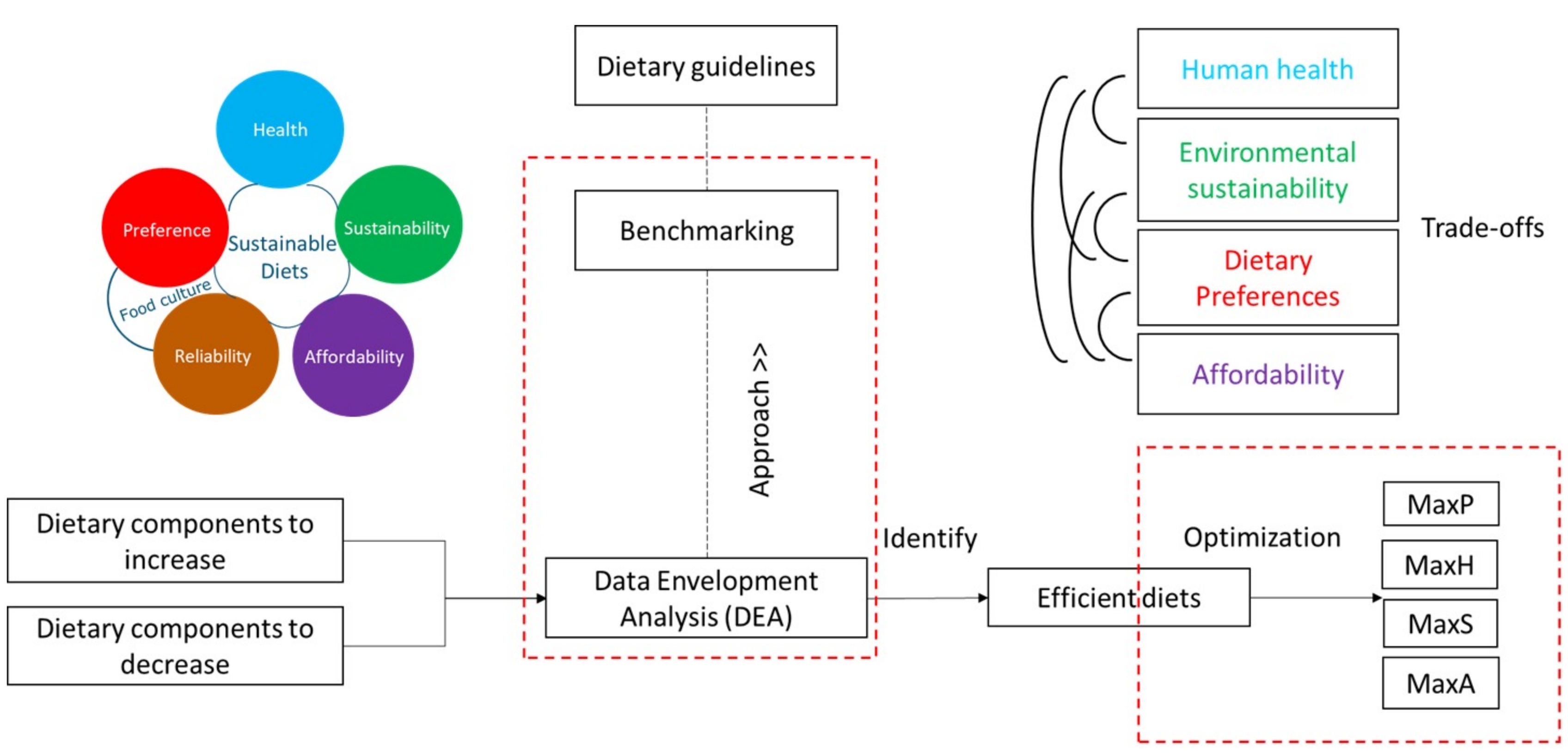
Background

Diet shifting towards a more sustainable pattern is urgently needed for China. Diet modelling can integrate multiple dimensions of sustainability to identify improved diets. This study aimed to define Chinese diets that are nutritious, affordable and have lower environmental footprints, while accounting for diet preference by a benchmarking approach.

Objectives

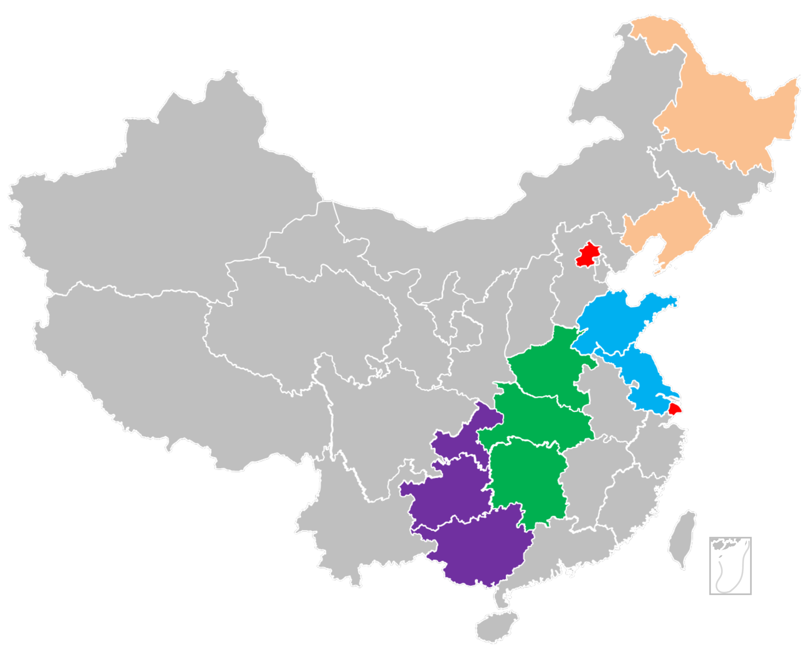
- To identify benchmarked diets among Chinese regions for adults using the DEA method.
- To achieve alternative diets that improve each/all sustainability dimension(s) regarding nutrient quality, environmental footprints, affordability, and diet preferences.
- To investigate trade-offs between every two of the four sustainability dimensions when optimizing the alternative diets.

Framework



Methods

1) Study population and dietary data



15,725 participants (10,324 adults) till 2011

12 provinces or municipalities till 2011

289 communities in 2011

24-h dietary recall (Dietary data)

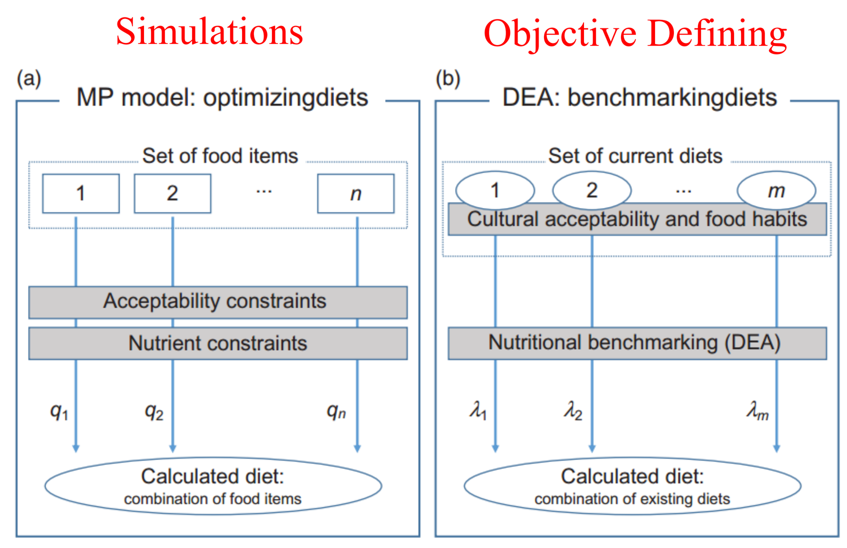
- Northeast region
- Metropolitan cities
- East region
- Central region
- Southwest region

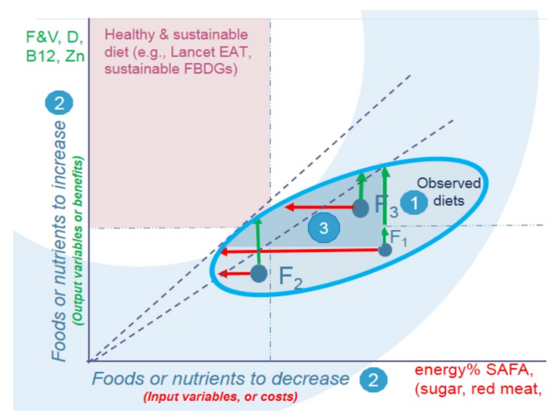
2) Sustainability indicators

- ❖Nutrition quality: Nutrient-rich Diet Index (NRD15.3)
- ❖Environmental footprints based on Chinese Food Life Cycle Assessment Database (CFLCAD):
  GHG emissions
  Total water use
  Land use
- ❖Affordability: Diet cost
- ❖Preference: Diet similarity index (DSI)

3) Diet optimization: DEA model

Data envelopment analysis (DEA) was applied to benchmark diets for increasing the adherence to food-based dietary guidelines and alternative diets were optimized as linear combinations of benchmarked diets that complied with different sustainability goals: maximized nutrient quality (Nutrient Rich Diet score, NRD15.3), minimized greenhouse gas emissions, GHGE (the other environmental footprints: Total water use (TWU) and Land use (LU) were calculated meantime but not optimized), minimized diet cost, maximized diet preference (i.e. minimized absolute deviation from observed diets), and an integrated scenario. Trade-off analyses were also conducted between sustainability indicators.





Results

Improved diets were obtained as linear combinations from 13% to 22% of all diets that served as a benchmark for males and females from the five regions. When nutrient quality, environmental sustainability, and affordability were optimized separately in each sex and region subgroup, the NRD15.3 was 22% to 35% higher, GHGE was 17% to 38% lower, TWU was 14% to 35% lower, LU was 21% to 33% lower, and diet costs was 23% to 32% lower. When diet preference was optimized, around 90% of food consumption remained similar as observed diets compared to less than 80% in the other scenarios. When the four objectives were considered simultaneously, all indicators improved, albeit less than in the separate scenarios. The improvement of sustainability indicators was larger when the benchmarking was done for sex only and not for individual regions. In trade-off models, increasing the nutrient quality was always accompanied by decreases in environmental sustainability and affordability.

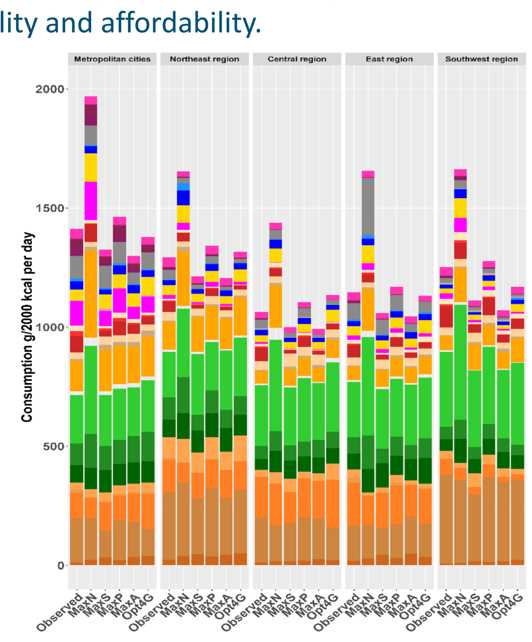


Figure 1. Food group consumption in observed and modelled diets (women).

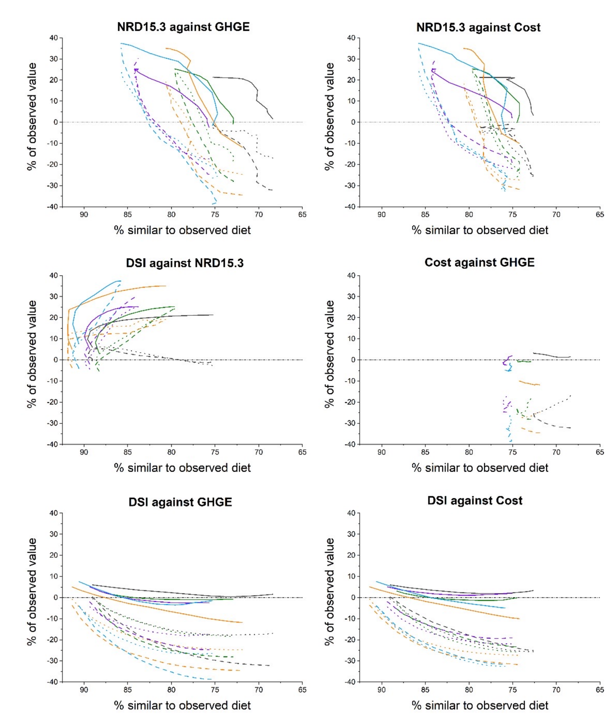


Figure 2. Trade-offs analysis for men among five regions. Metropolitan cities: ——, NRD15.3; - - -, GHGE, ⋯⋯, Cost; East region: ——, NRD15.3; - - -, GHGE, ⋯⋯, Cost; Central region: ——, NRD15.3; - - -, GHGE, ⋯⋯, Cost; Northeast region: ——, NRD15.3; - - -, GHGE, ⋯⋯, Cost; Southwest region: ——, NRD15.3; - - -, GHGE, ⋯⋯, Cost.

Discussion and conclusion

Realistic and more sustainable diets considering multiple indicators are possible for Chinese consumers, the trade-off effects might be further magnified when attempting to simultaneously pursue multiple sustainability goals. To attain ultimate sustainable diets, a necessary stepwise process is needed through the efforts of generations.

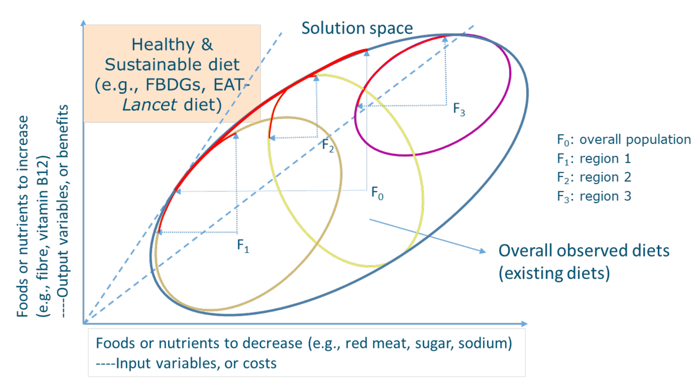


Figure The conceptual diagram of identified DEA-efficient diets (peers) under the individual regions versus overall population circumstance. Red lines are the DEA-efficiency frontiers for each scenario

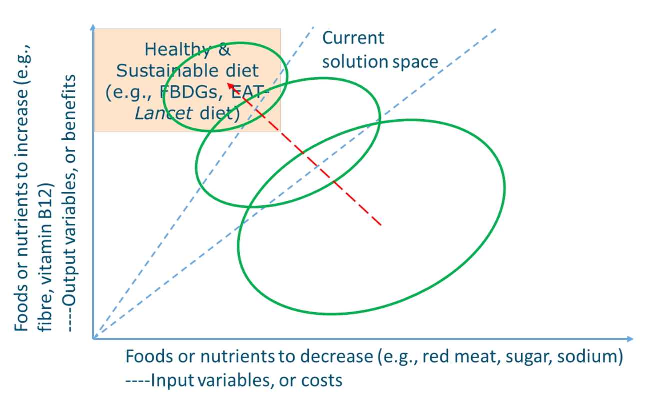


Figure Achieving fully sustainable diets is a necessary stepwise process through the efforts of generations

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Balancing farm profit and greenhouse gas emissions along the dairy production chain via breeding

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Background

- Dairy farming is responsible for approximately 20% of the greenhouse gas (GHG) emissions caused by all global livestock
- Selective breeding can help in GHG mitigation
- For breeding a parameter is needed that penalizes increase of GHG
- The penalty should cover all GHG produced along the dairy chain
- GHG breeding might be in conflict with economic profit

Objectives

- Define a GHG penalty for the breeding goal traits, to quantify the GHG-impact in breeding programs
- Design optimal breeding programs for selecting against GHG and economic profit

Methods

- Data: from a typical commercial Holstein dairy farm in Beijing, China

Table 1. Characteristics of the study farm in Beijing, China.

Item	Unit	Value
Number of cows	head	1,523
Number of youngstock	head	1,429
Milk yield	kg/cow/year	11,533
Protein content of milk	%	3.3
Fat content of milk	%	4.5
Age at first calving	month	26
Replacement rate	% per year	33.5

- Economic consequences assessed by bio-economic model
- GHG emissions: life-cycle assessment (LCA)
  - ✓ Emission sources: fertilizer manufacturing, field operations, processing and transportation of crops and concentrates, enteric fermentation from animals, manure management, and the production and combustion of energy
  - ✓ GHGs: CO_2, CH_4, and N_2O
- Breeding program on the following traits
  - ✓ Production: milk yield (MY), protein yield (PY), and fat yield (FY)
  - ✓ Reproduction: calving interval (CI)
  - ✓ Longevity: productive life (PL)
  - ✓ Health: clinical mastitis (MAS)

Results

- Intensity value = extra GHG (in CO2 -eq) from 1-unit increase of a trait

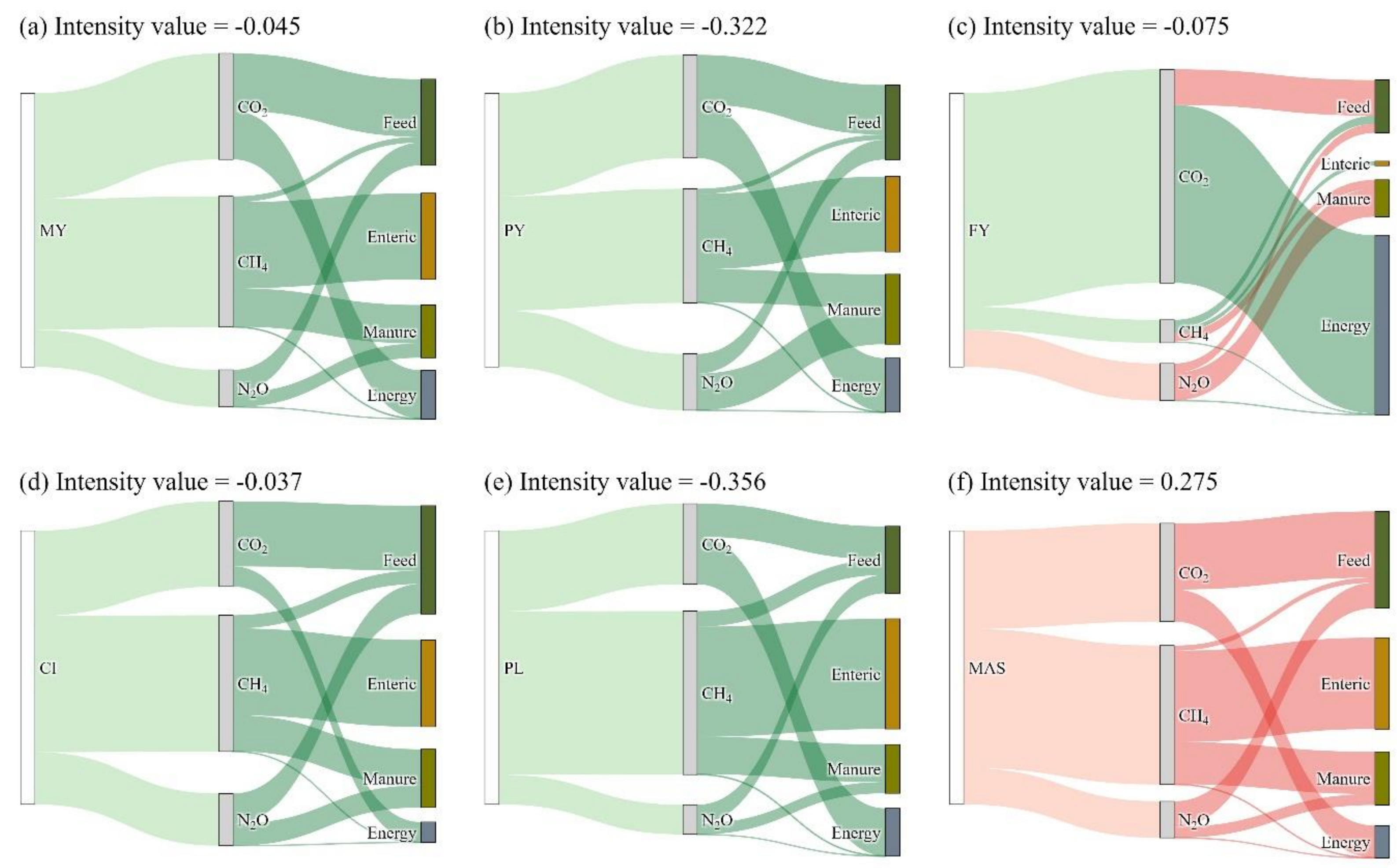

Fig 1. contribution of GHG-sources (Feed, Enteric, Manure, Energy) to intensity value of a trait

- The breeding programs are balanced for GHG-reduction and economic profit, without negative consequences for other breeding goal traits
- Breeding animals with optimal indices could reduce GHG emissions by 6 to 10 CO_2-eq per ton of fat-protein-corrected milk, while increasing profitability by 822 to 1,355 Chinese Yuan per cow unit

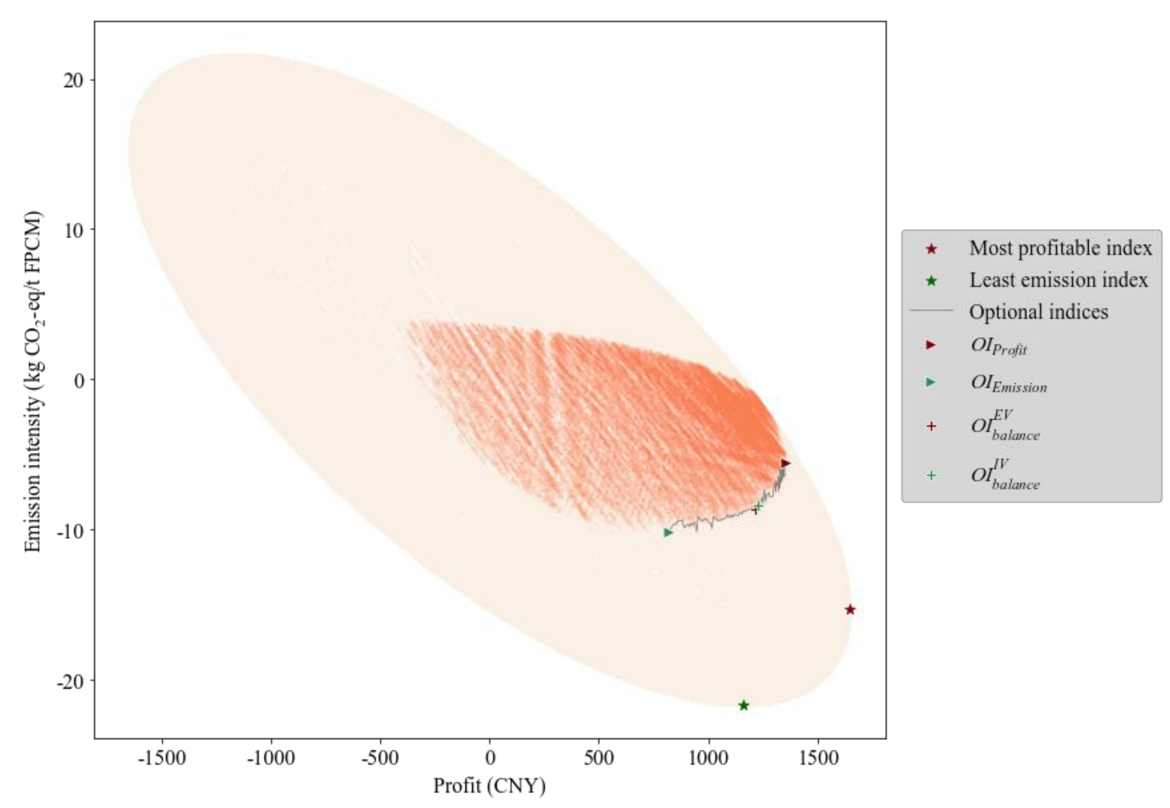

Fig 2. Economic (x-axis) and environmental (y-axis) consequences of different breeding programs

Conclusions

- The constructed Intensity Value is a GHG-penalty for a breeding trait and is based on GHG from on the entire dairy chain
- Intensity values can be used in breeding programs to reduce GHG production and to balance with breeding for economic profit

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Legume-driven soil microbial legacies enhance maize growth by shaping root morphological traits and are contingent upon phosphorus input

PhD Student: **Yujuan He** Supervisors: **Jingying Jing ,Yingjun Zhang, Paul C. Struik**

Background

Various plant species trigger the multiplication of different microorganisms as they grow (Bardgett and Van Der Putten 2014; Philippot et al. 2013). When these plants eventually disappear, their microbial legacies remain in the soil and subsequently affect the following plant growth in the same soil (Teste et al. 2017; Van der Putten et al. 2013). However, the optimal grass: legume ratio in ley pastures that could benefit the subsequent crop and the mechanisms of their biotic legacy effects on the subsequent crop are unknown.

Hypotheses

In this study, we hypothesized that:

(1)Legumes and grasses differ in their impacts on the composition of soil fungal and bacterial communities.

(2) Legumes in leys enhance subsequent maize growth by inducing accumulation of beneficial microorganisms and reducing pathogenic fungi.

(3) Phosphorus fertilizer enhances the legacy effect of legumes.

Methods

An experiment with two factors was set up in a greenhouse at China Agricultural University in a randomized block design, with nine soil legacy inocula (based on monocultures of *Medicago sativa*, *Onobrygis viciifolia*, *Dactylus glomerata*, F*estuca arundinacea*, and mixtures of two legumes (L) and two grasses (G) in L:G ratios of 3:7, 4:6, 5:5, 6:4 and 7:3) and with three P addition levels: 0, 20, 50 mg kg^{-1} soil (P0, P1 and P2). Each pot contained two maize plants and 1.5 kg soil (10% inoculum soil, 90% sterilized soil).

Results

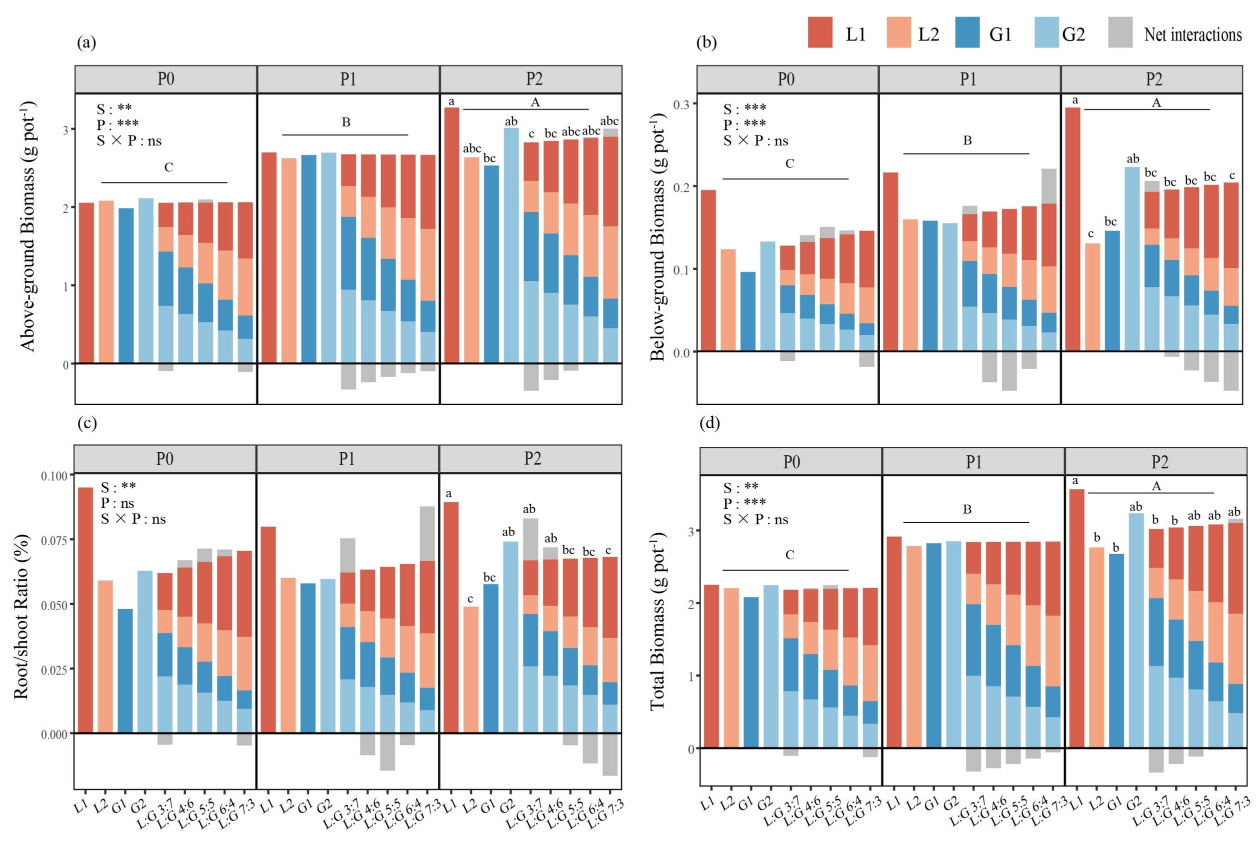

Fig. 1 The aboveground biomass (a), below-ground biomass (b), root/shoot ratio (c) and total biomass (d) under different soil legacies and P levels of maize. The aboveground, belowground and total biomass increased with increasing P level.

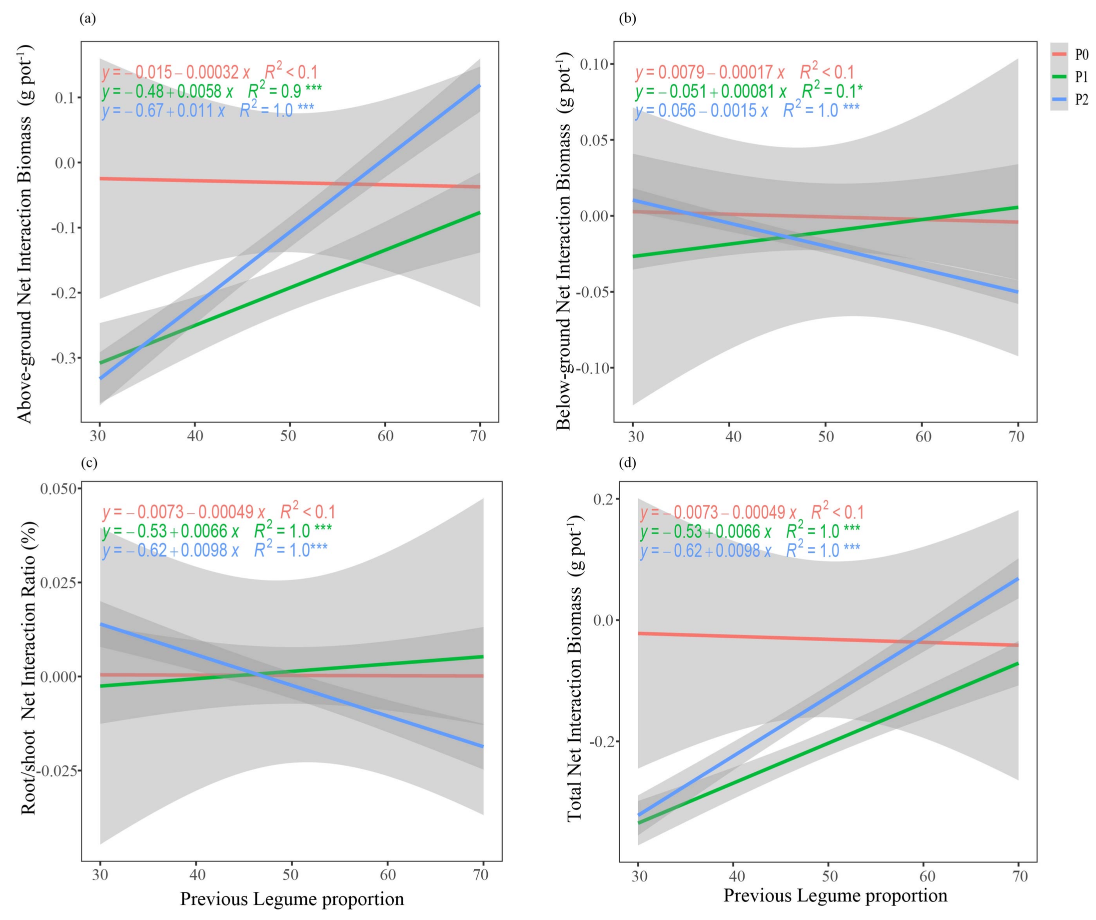

Fig. 2 The above-ground biomass (a), below-ground biomass (b), root/shoot ratio (c) and total biomass (d) predicted by the Diversity-Interactions model under different soil legacies and P levels of maize. Pairwise comparison tests were performed across the different P levels (uppercase letters) and nine soil legacies (lowercase letters) separately. * $P < 0.05$; ** $P < 0.01$; *** $P < 0.001$.

Fig. 3 Linear discriminant analysis effect size (LEfSe) of soil bacterial (a) and fungal (b) communities. Enriching beneficial bacteria by previous legume monoculture to promote maize growth. Accumulation of pathogenic fungi by previous grass monoculture to inhibit maize growth.

Conclusions

We explored soil biotic legacies conditioned by different species in monocultures and mixtures to affect the growth at early growing stage of maize under different phosphorus fertilizer levels. Our results demonstrated that species-specific effects and the proportion of legumes in prior mixtures shaped the bacterial and fungal legacies, which in turn affected subsequent crop growth. These effects were partly brought about by effects on root traits, especially at high phosphorus levels.

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Unintended trade-offs between food security and environmental sustainability: Impacts of China's dietary shift and afforestation under a stringent climate mitigation policy

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Background

Food, land, and climate are deeply interconnected and play a crucial role in achieving Sustainable Development Goals (SDGs), particularly SDG 2 (zero hunger), SDG 13 (climate action), and SDG 15 (life on land). However, measures designed to advance one SDG may create trade-offs or unintended consequences for others, highlighting the need to assess their broader systemic impacts. This study bridges the gap by analysing the linkages between food security, sustainable land management, and climate change in the food-land-climate nexus, with a particular emphasis on China and cross-border impacts on its major food and feed trading partners, given its critical role in global markets for food and feed. A sustainable food system should be able to feed everyone on Earth while also stabilising global land use, and reducing climate change (Foley et al., 2011).

Scenarios & Indicators

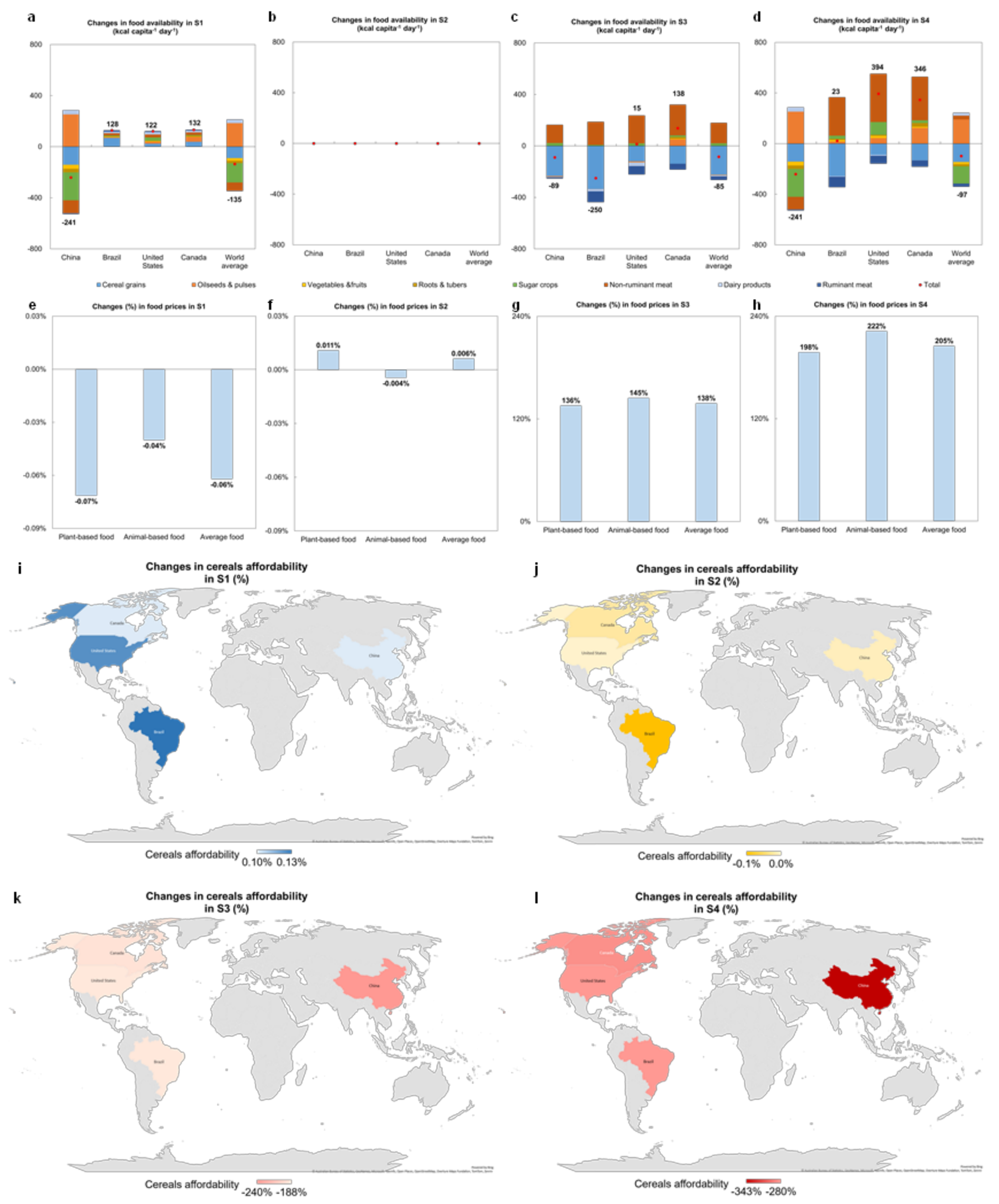
To achieve that, we focused on the improvement of one or more components in the food-land-climate nexus. In this study, four scenarios were simulated: three scenarios focusing on improving one nexus component, and one combined scenario focusing on improving all nexus components. The food scenario (S1) indicates a dietary shift in China toward the EAT-Lancet diet recommendations (Willett et al., 2019), aligning with SDG 2 (zero hunger). The land scenario (S2) represents a unilateral afforestation policy based on China's National Forest Management Plan (2016– 2050) (Forest Park of National Forestry and Grassland Administration (FPNFGA), 2016), supporting SDG 15 (life on land). The climate scenario (S3) presents the implementation of a global uniform carbon tax to reduce GHG emissions, in line with the Paris Agreement (IPCC-WGIII, 2014; UNFCC, 2015) and SDG13 (climate action). The combined scenario (S4: S1+S2+S3) integrates all land, food, and climate measures. Key food security indicators (food prices, affordability, and availability) and environmental sustainability indicators (cropland use, pastureland use, nitrogen fertiliser use, phosphorus fertiliser use, emissions of GHGs, emissions of acidification poulltants, and emissions of eutrophication pollutants) were assessed for China and its major food and feed trading partners (MTP, including Brazil, the United States, and Canada).

Framework & Methods

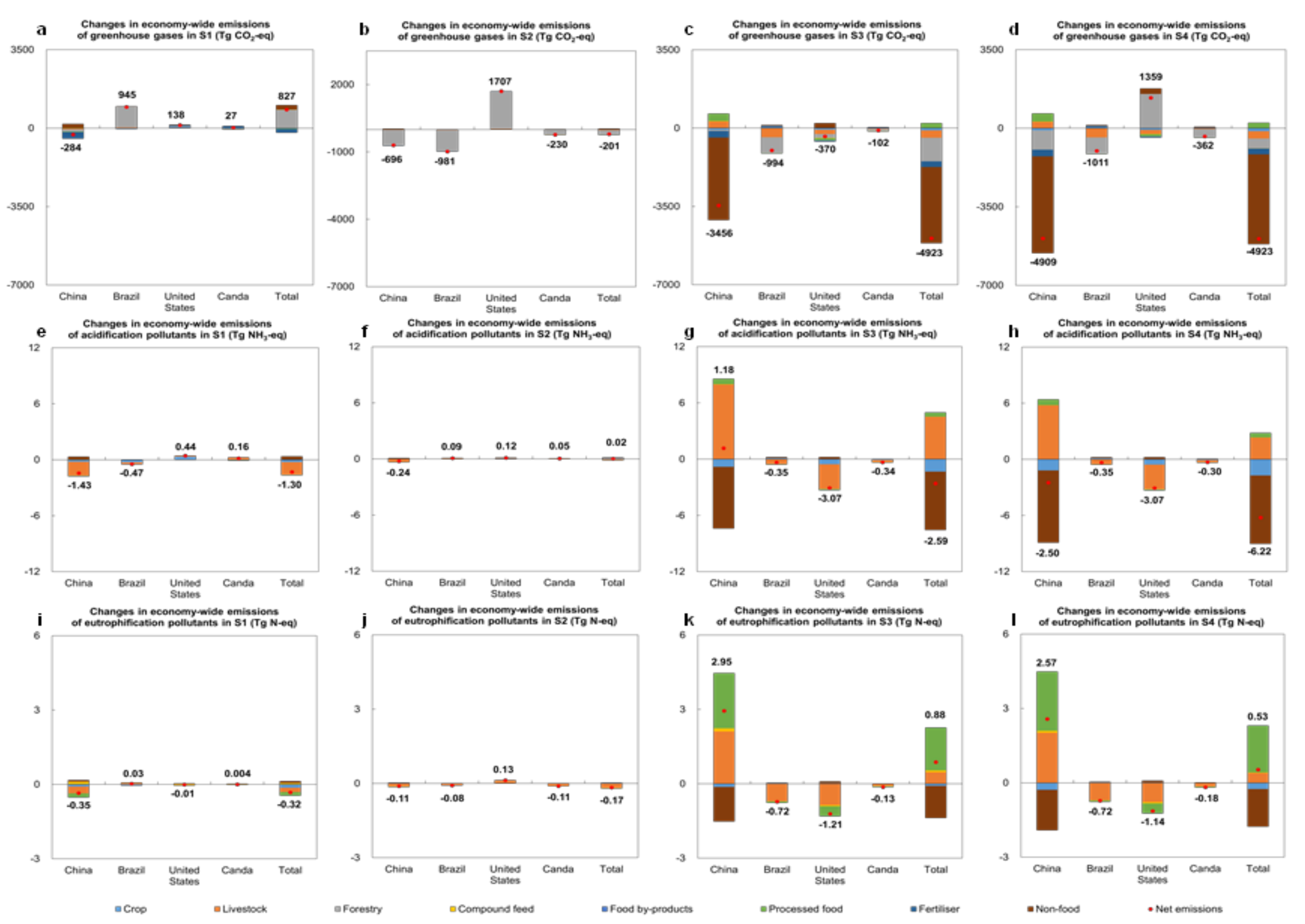
- **Model type:** Static applied general equilibrium (AGE) model of the global economy
- **Data source:** Global Trade Analysis Project (GTAP) model version 10
- **Scope:** 65 sectors, 141 regions (Base year: 2014)

Results

➢Impacts of mitigation measures on food security.



➢Impacts environment sustainability.



Conclusions

- This paper has attempted to analyse the linkages between food security, sustainable land management, and climate change in the food-land-climate nexus, with a particular emphasis on China.
- Our results indicate interesting results for achieving sustainable food systems and land management under climate change.

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Detecting excretion behaviour of group pigs and ammonia emitting area using thermal and RGB images

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Supervisors: Chaoyuan Wang, André Aarnink, Marc Bracke, Peter Groot Koerkamp, Baoming Li

Background

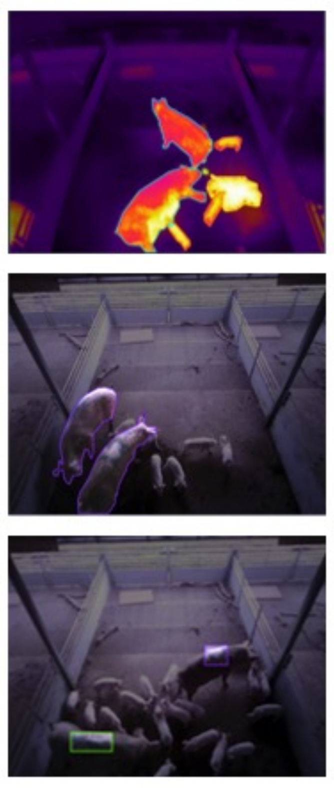
	Pig behaviour recognition	Monitoring of ammonia emitting area
Current studies	Aggression, drinking, eating, mounting, posture and nursing	Urine puddle's area size and depth, floor type
Limitation	Detection and tracking of pig's elimination behaviour	Precise and automatic detection of urine puddles, distribution of urine puddles and estimation of fouling area

Objectives

- Detecting excretion behaviour in group pigs using thermal and RGB images
- Predicting ammonia emitting area based on the urine puddle size and excretion behaviour pattern.

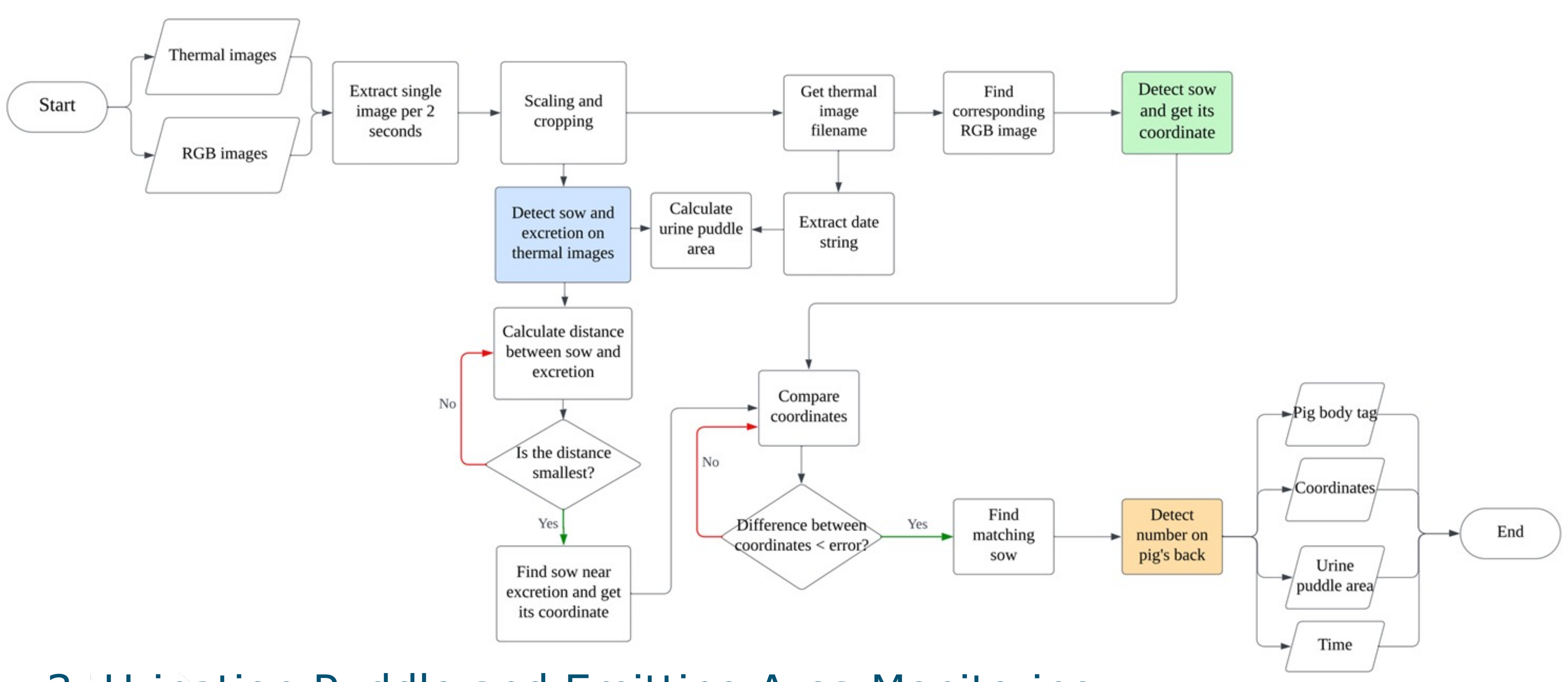
Methods

1. Data collection and annotation

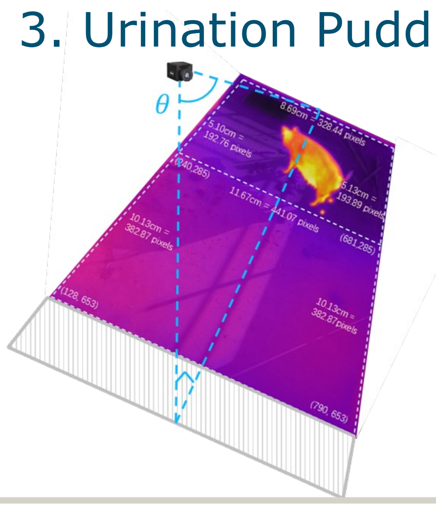


Model	Set type	Time of data collection		Number of images	Proportion of different sets to total dataset (%)
		Pen 12	Pen 13		
Model_Thermal	Training set	Day 1 - Day 6	Day 1 - Day 6	4237	74
	Validation set	Day 6 – Day 7	Day 6 – Day 7	709	12
	Testing set	Day 7 – Day 8	Day 7 – Day 8	746	13
Model_RGB Sow	Training set	Day 1 - Day 6	Day 1 - Day 2	2216	65
	Validation set	Day 6 – Day 7	Day 3	709	21
	Testing set	Day 7 – Day 8	Day 4	499	15
Model_RGB Tag	Training set	Day 1 - Day 6	Day 1 - Day 2	1992	64
	Validation set	Day 6 – Day 7	Day 3	636	21
	Testing set	Day 7 – Day 8	Day 4	439	15

2. Pipeline of detection and segmentation process using Model_Thermal (blue box), Model_RGB Sow (green box) & Model_RGB Tag (orange box)



3. Urination Puddle and Emitting Area Monitoring



Camera's tilt angle $\theta = arctan\left(\frac{h}{L_{actual}}\right)$

$$Width\ ratio = \frac{w_{actual}}{b_{pixel}}$$

$$Length\ ratio = \frac{l_{actual}}{b_{pixel}}$$

$$\textbf{Actual area} = \frac{Pixel\ area \times Width\ ratio\ \times Length\ ratio}{cos(\theta)}\ (m^2)$$

Results

1. Performance of three detecting models

Model_Thermal: Detection and Segmentation of Sows, Urine, and Feces in Thermal Images

Class		Precision	Recall	F1-Score	mAP50
Sow	Box	0.982	0.939	0.960	0.991
	Mask	0.984	0.941	0.962	0.992
Urine	Box	0.915	0.815	0.862	0.933
	Mask	0.917	0.853	0.884	0.925
Faeces	Box	0.797	0.770	0.783	0.843
	Mask	0.800	0.772	0.786	0.841

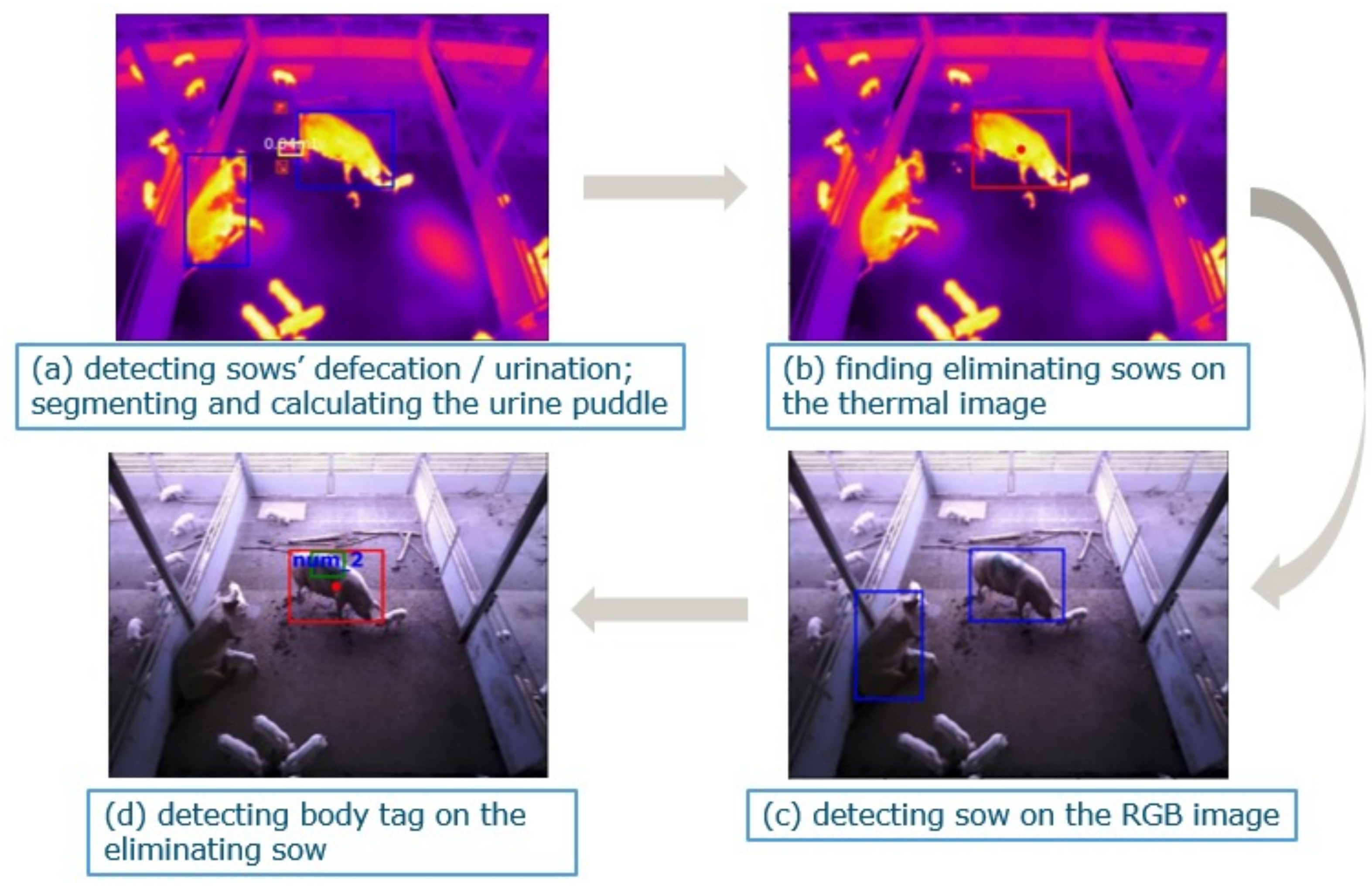
Model_RGB Sow: Detection of Sows in RGB Images

Class		Precision	Recall	F1-Score	mAP50
Sow	Box	0.993	0.999	0.996	0.913
	Mask	0.993	0.999	0.996	0.902

Model_RGB Tag: Detection of Body Tag on Sows' Back in RGB Images

Class		Precision	Recall	F1-Score	mAP50
Num_1	Box	0.809	0.807	0.808	0.842
Num_2	Box	0.916	0.863	0.889	0.949

2. Predicting of the Emitting Area Inside the Pen



Conclusions

- ❑ The model to detect pigs' elimination behaviour achieved high accuracy: for detecting faeces: 84.3%; for detecting urine puddles: 93.3%; for segmenting urine puddles: 92.5%.
- ❑ By calculating urine puddles segmented by this model and simplifying urine puddles into circular shapes, and using the urine puddle locations, urine puddle replacement can be effectively simulated. This allows for more precise modelling of the live time of urine puddles and the emitting area.

Acknowledgements

We gratefully acknowlege the sponsors of this research:China Scholarship Council (NO.201913043) and Hainan University.

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Application of plant-soil feedbacks in agriculture: using trait-based prediction for improving crop rotation

Zhaoqi Bin, G.F. (Ciska) Veen, Guangzhou Wang, Junling Zhang, Wim H. van der Putten

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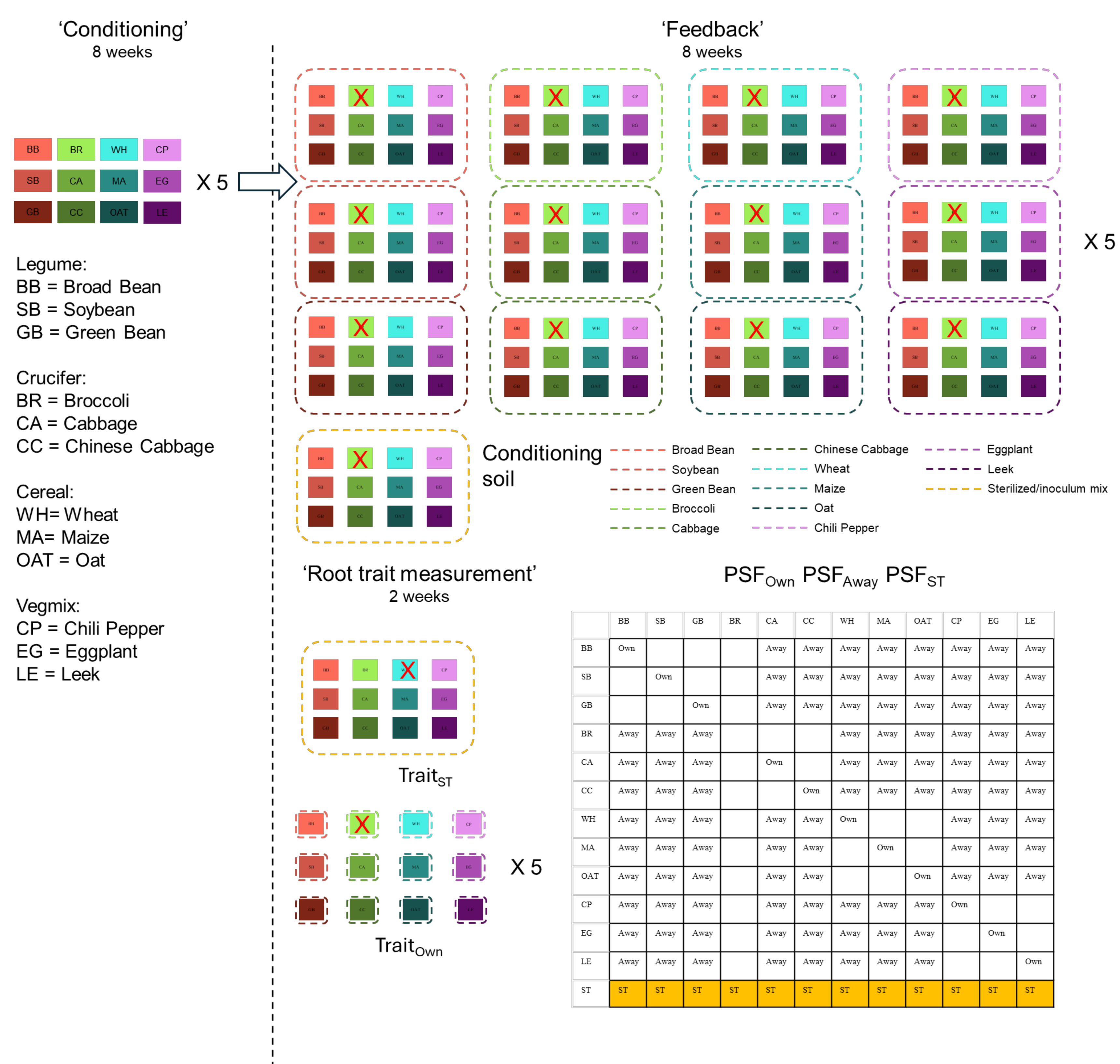
Background

Plant-soil Feedback (PSF) describes the net outcome of interactions between plants and the biophysicochemical properties of the soil that influence plant performance. PSF has been extensively studied in natural ecosystems and is comparable to the long-standing practice of crop rotation in agriculture, where farmers grow well-known combinations of phylogenetically unrelated crop species in sequential cycles to enhance soil fertility and control outbreaks of soil-borne enemies. To optimize crop rotation further and harness the positive legacy effects of one crop on the next, we need to assess and predict the impacts of novel combinations of crop species in rotations. In natural PSF research, root traits are known predictors of PSF. However, how root traits predict PSF for crops in agroecosystems, which are often intentionally selected to express specific aboveground and belowground functional traits, remains poorly understood.

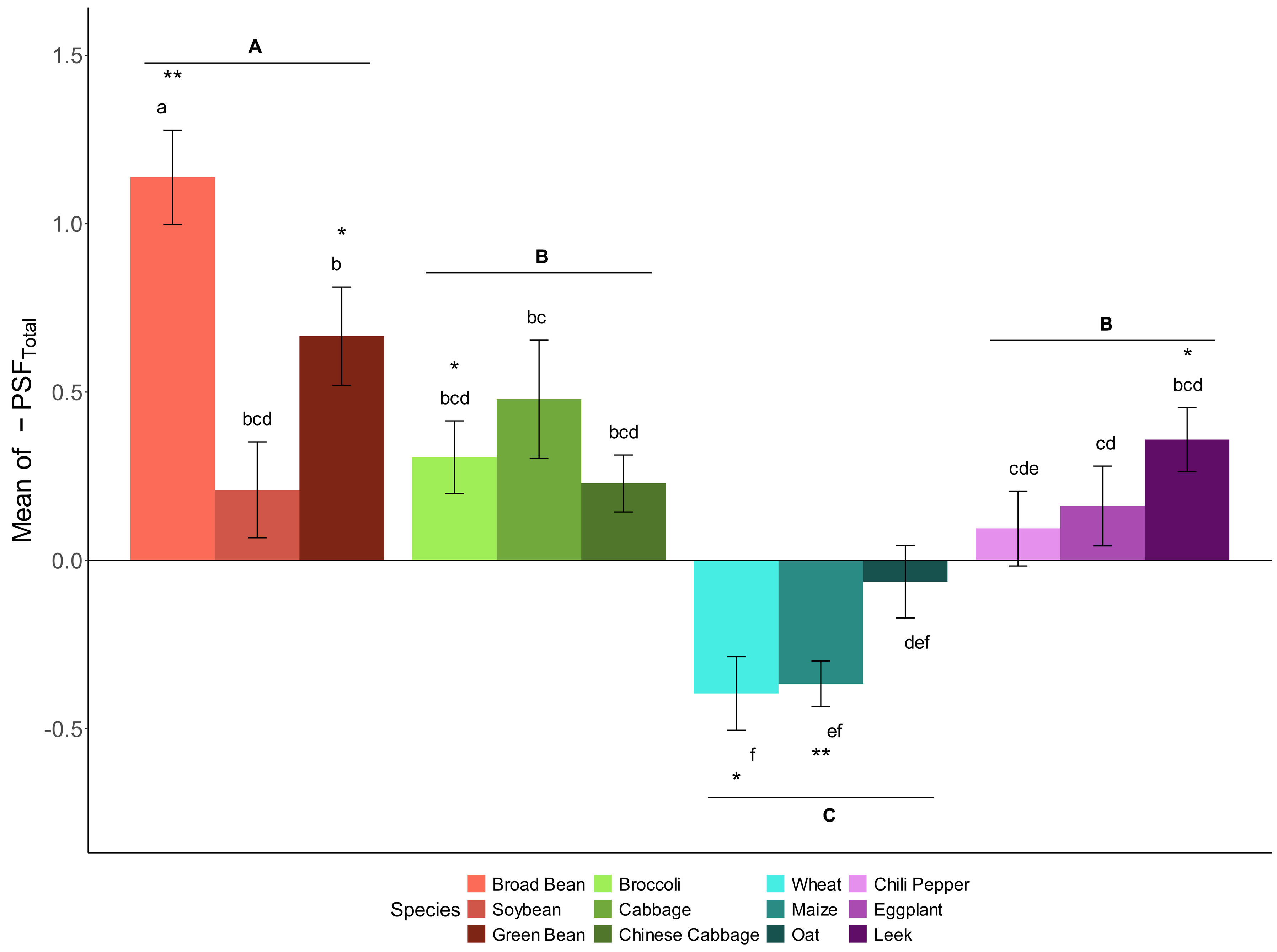
Methods

In this study, we conducted a two-phase greenhouse experiment to investigate PSFs of twelve crop species, grouped into three taxonomically related groups and one mixed group, which are commonly cultivated in temperate agricultural systems. Root morphological traits were quantified in a separate bioassay using both sterilized soil and species own conditioned soil. These traits were then correlated with the PSFs.

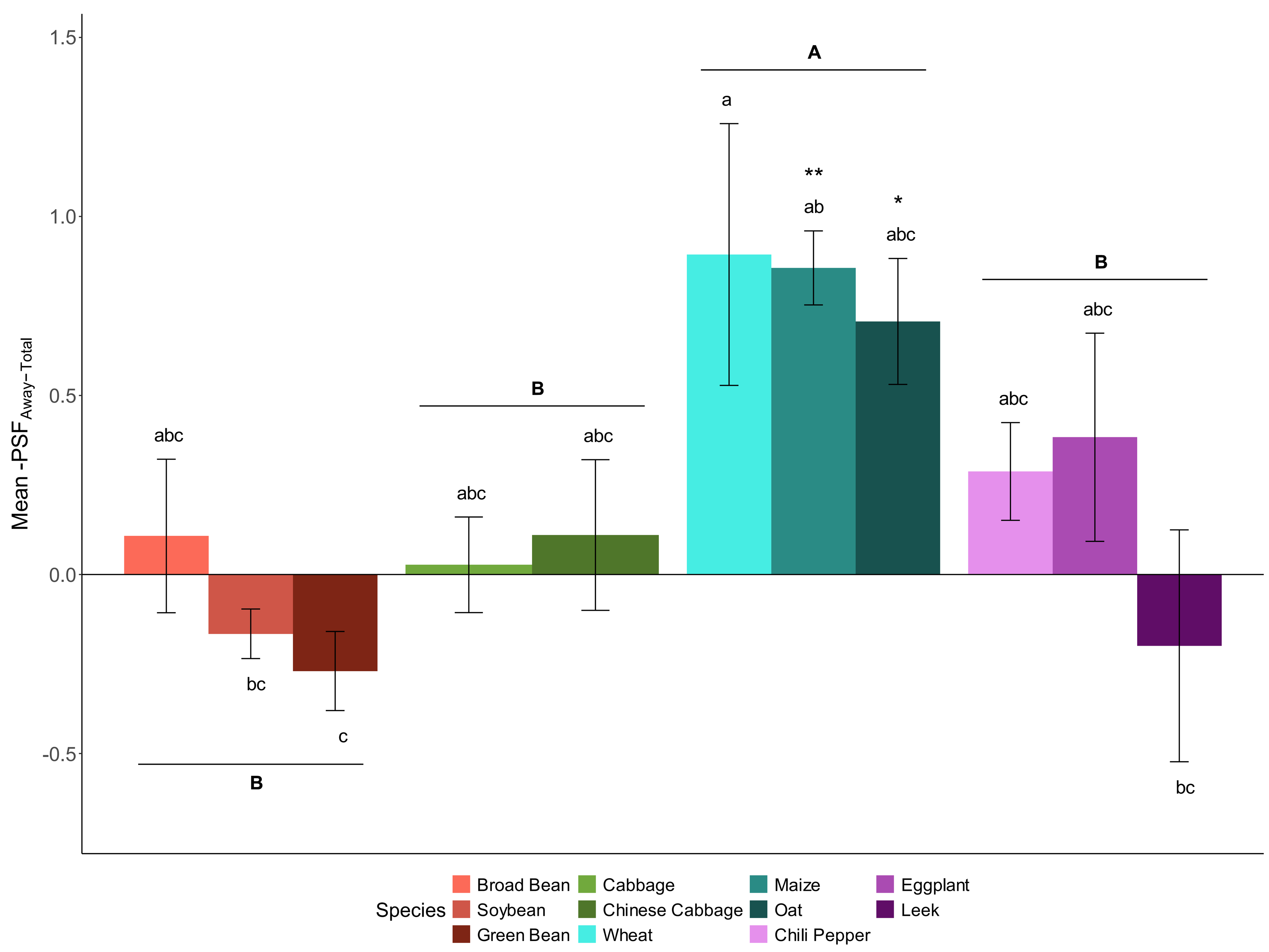


Main Results

Overall, most crops produced more biomass in soil conditioned by broad beans and less in soil conditioned by wheat, suggesting that broad beans are an effective soil conditioner.



Cereals (oat, maize and wheat) generally benefited in soils conditioned by crops from other taxonomic groups, suggesting that cereals are good responders.



Acknowledgements

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Mycorrhiza-mediated recruitment of complete denitrifying *Pseudomonas* reduces N_2O emissions from soil

PhD Students: **Ruotong Zhao**   Supervisors: **Junling Zhang; Wim H. van der Putten; Ciska Veen; Guangzhou Wang**

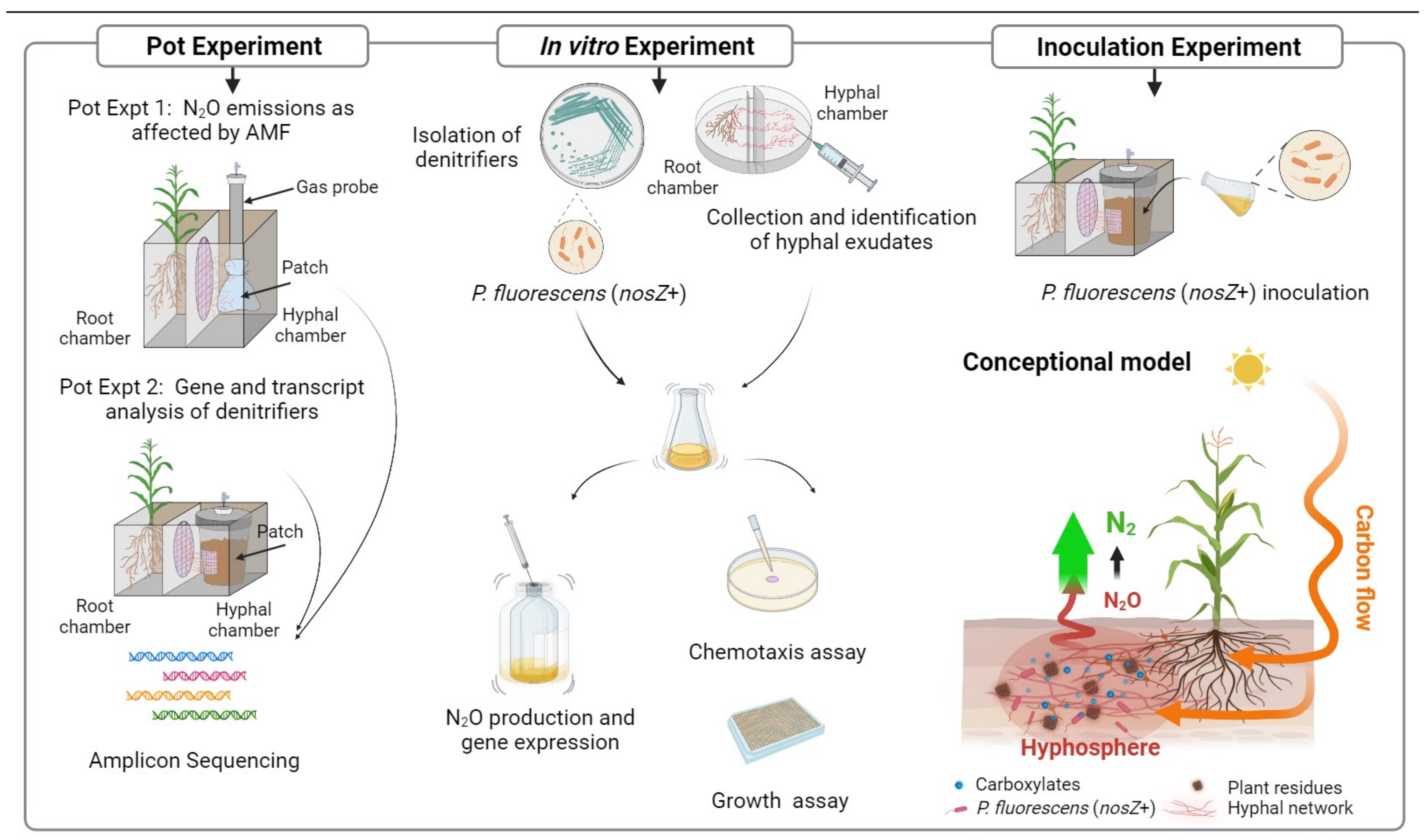
Background

Arbuscular mycorrhizal fungi (AMF) play a critical role in soil ecosystems, with their extensive hyphal networks forming a distinctive hyphosphere that is closely linked to microbes involved in nitrogen cycling. However, the exact mechanisms by which AMF and the microbes in their hyphosphere collaborate to impact N2O emissions from 'hot spot' residue areas remain poorly understood. In this study, we investigated the key microbial players in the hyphosphere that are involved in the production and consumption of N2O, utilizing both amplicon and shotgun metagenomic sequencing. Additionally, we assessed the chemotaxis, growth, and N2O emission responses of isolated N2O-reducing bacteria to hyphal exudates through in vitro cultures and inoculation experiments.

Objectives

Previous research has indicated that arbuscular mycorrhizal fungi (AMF) may influence denitrifying microbes indirectly by enhancing water uptake or promoting soil aggregation. However, the direct interaction between AMF and the hyphosphere microbiome, particularly in relation to complete denitrifiers, remains unclear. Considering that AMF receive a significant portion (4-20%) of photosynthetic carbon from plants, and their hyphal networks extend into non-rhizosphere areas, this gap in knowledge holds key implications for leveraging soil microbiomes. It offers potential for developing better agricultural management practices aimed at improving nutrient use efficiency while reducing N2O emissions. This issue is particularly crucial for sustainable agriculture, as intensive farming practices today are leading to a notable decrease in AMF diversity and abundance, thereby limiting their ability to mitigate N2O emissions.

Methods



Flow chart of the experiments. The study comprised several experiments: two pot experiments, *in vitro* experiments and an inoculation experiment. The two pot experiments (pot expts 1 and 2) tested whether the proliferation of AMF into microsites of residues may reduce N_2O emissions and disassemble the regulation pathway. We isolated denitrifiers and identified the key components of hyphal exudates. We then examined the chemotaxis, growth, N_2O emission and denitrifying gene expression of *P. fluorescens* in response to AMF exudates and key compounds under *in vitro* culture conditions; finally, the inoculation experiment validated the effects of AMF or citrate exuded by AMF on N_2O emissions and *nosZ* gene expression of *P. fluorescens* in pot culture. A conceptual model is used to illustrate the pathways by which AMF interact with *P. fluorescens* to mitigate N_2O production.

Results

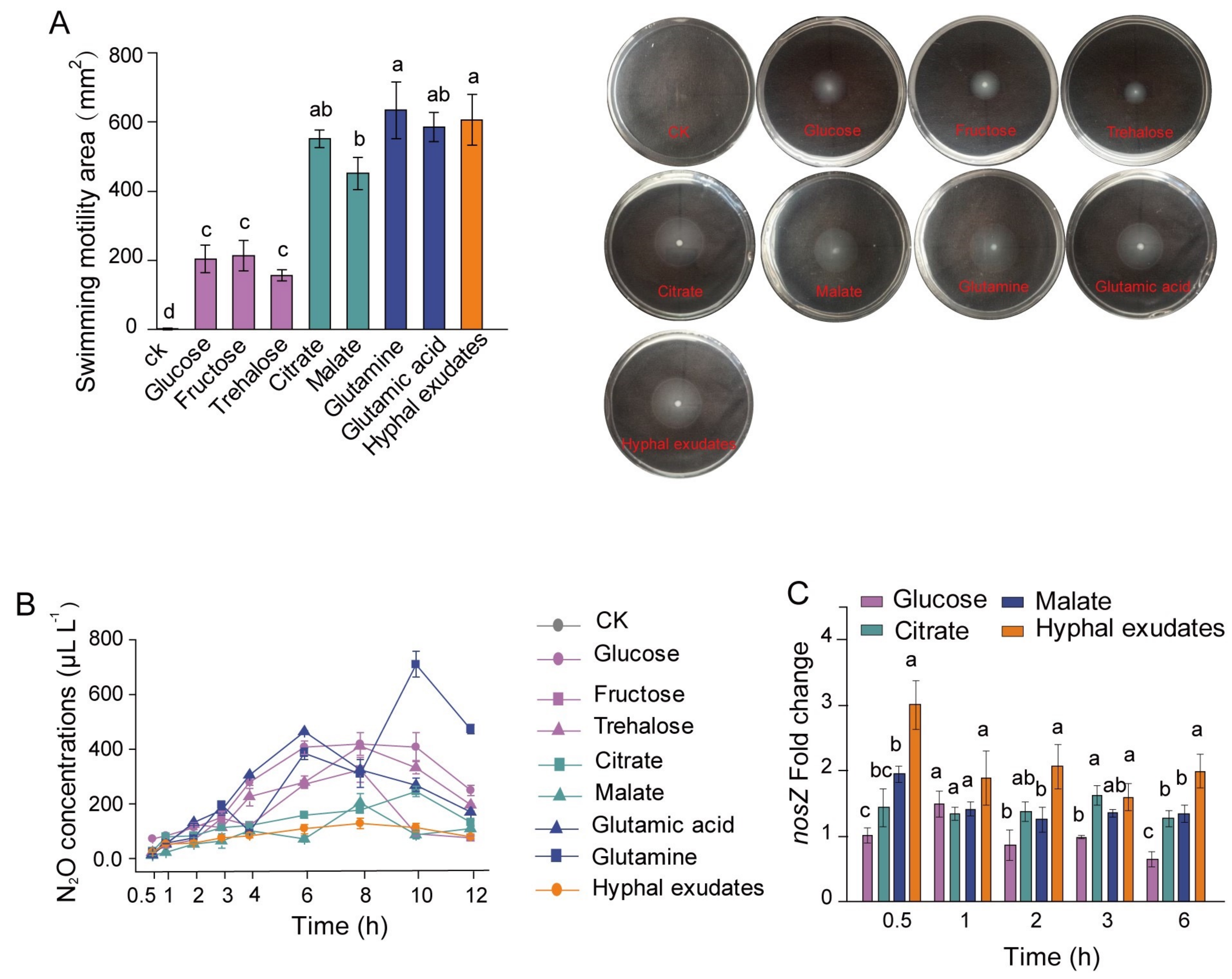


Figure 1. The response of Pseudomonas fluorescens to AMF hyphal exudates and the major compounds in the in vitro experiments. A, P. fluorescens swimming motility area in response to AMF hyphal exudates and major compounds (n = 3). B, Dynamic N_2O concentrations in the headspace of serum bottles emitted by P. fluorescens in response to hyphal exudates and major compounds (n = 3). C, Expression of the nosZ gene of P. fluorescens in response to hyphal exudates and major compounds (n = 3).

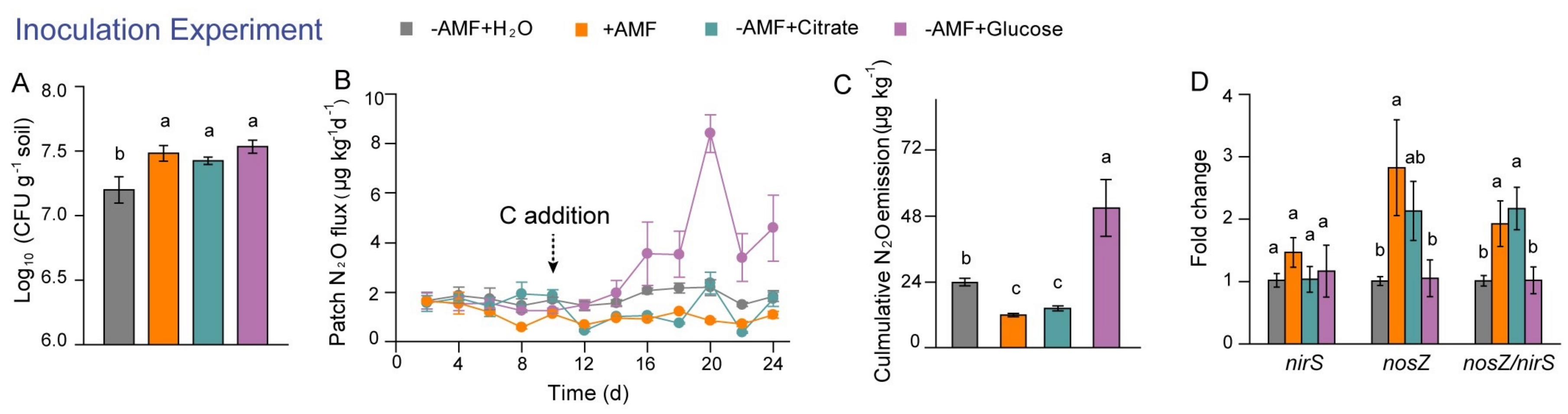


Figure 2. Fig. 7. Response of Pseudomonas fluorescens to AMF hyphal exudates and the major compounds in the inoculation experiment. A, Numbers (CFU) of P. fluorescens in patches in response to AMF, glucose, and citrate (n = 4). B, C, N_2O flux (f) and cumulative N_2O emission (g) from patches inoculated with P. fluorescens in response to AMF, glucose, and citrate (n = 4). D, Expression of the nosZ gene in patches inoculated with P. fluorescens in response to AMF, glucose, and citrate (n = 4). Different lowercase letters (d, e, g and h) indicate significant differences among treatments by the least significant difference (LSD) test at the 5% level following one-way analysis of variance ($P < 0.05$).

Conclusions

Our study provides novel insights into the importance of AMF in mediating nitrogen transformation processes conducted mainly by denitrifiers that lead to cascading effects on soil N_2O emission. We demonstrate that AMF enriched the N_2O -reducing Pseudomonas in the hyphosphere, which was responsible for the decline in N_2O emissions in the residue patches. Notably, carboxylates exuded by hyphae acted as attractants recruiting P. fluorescens JL1 and as stimulants triggering the expression of nosZ gene. These insights provide a novel mechanistic understanding of the intriguing interactions between AMF and microbial guilds in the hyphosphere, and collectively indicate how these trophic microbial interactions substantially affect the denitrification process at microsites. This knowledge opens novel avenues to exploit cross-kingdom microbial interactions for sustainable agriculture and climate change mitigation.

Acknowledgements

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Developing diversified cropping systems for enhancing integrated sustainability on the North China Plain

PhD student: Bowen Ma
Chinese supervisors: Dr. Wenfeng Cong, Dr. Chaochun Zhang, Prof. Fusuo Zhang
Dutch supervisors: Dr. Jeroen Groot, Dr. Wopke van der Werf

Background

- Transforming traditional high-input and high-output agriculture into green agriculture in China urgently requires the introduction of new sustainable diversified cropping systems.
- Crop diversification through intercrops, long-term rotation and cover crops provides options to enhance integrated sustainability.

Objectives

- To evaluate the agronomic, economic, environmental performance of different rotation systems with wheat and maize, peanut or soybean, with or without maize intercropping with legumes under different N managements.
- To design and verify new diversified crop rotation systems with enhanced integrated sustainability in the North China Plain(NCP).

Research framework

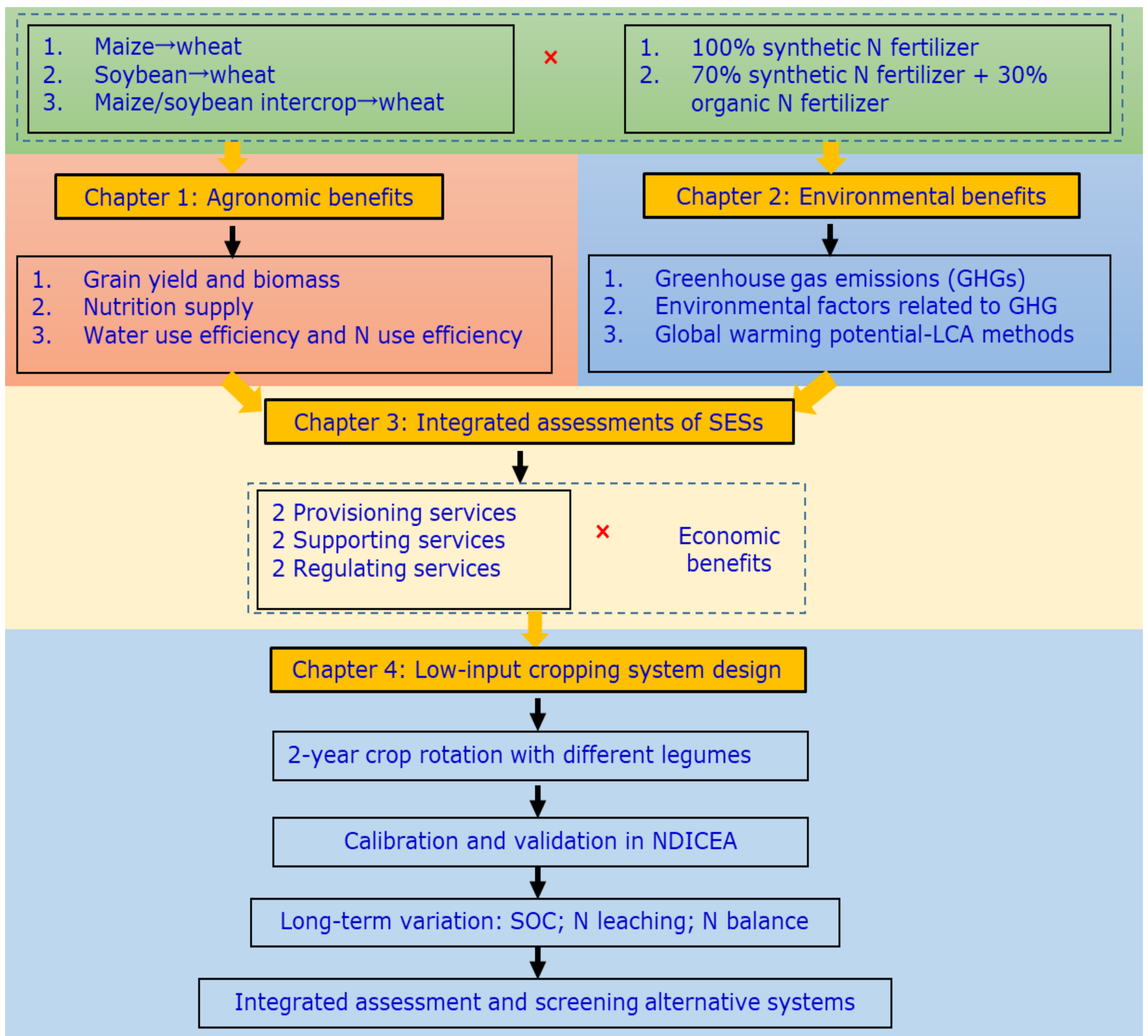

Figure 1. Framework of the project.

Methods

- The field experiment will be established in June 2021 at Quzhou Experimental Station (36.87ᴼN, 115.02ᴼE), China Agricultural University, Hebei province. The main cropping system is a rotation of winter wheat and summer maize which accounts for >80% of agricultural fields in this region.
- A completely randomized design will be employed with three treatment (Table 1) and three replicates.

Table 1. The treatments of experiment.

Treatments	Cropping systems (1-year rotation)	Fertilizer managements
T1	Summer maize → Winter wheat	FM1: Optimized chemical N fertilizer application (Opt. N) (maize: 185 kg N ha^{-1}; wheat: 175 kg N ha^{-1})
		FM2: The total nitrogen input was the same as that of FM1; 30% of chemical N fertilizer will be replaced by organic N fertilizer
T2	Summer soybean → Winter wheat	FM1: Optimized chemical N fertilizer application (soybean: 45 kg N ha^{-1}; wheat: 175 kg N ha^{-1})
		FM2: The total nitrogen input was the same as that of FM1; 30% of chemical N fertilizer will be replaced by organic N fertilizer
T3	Summer maize-soybean intercropping → Winter wheat	FM1: Optimized chemical N fertilizer application (intercropping: maize 111 kg N ha^{-1}; soybean 18 kg N ha^{-1}) (wheat: 175 kg N ha^{-1})
		FM2: The total nitrogen input was the same as that of FM1; 30% of chemical N fertilizer will be replaced by organic N fertilizer

Results

- Compared with expected cumulative N_2O emission of intercrop, observed grain yield of intercrop significantly decreased by 18%.

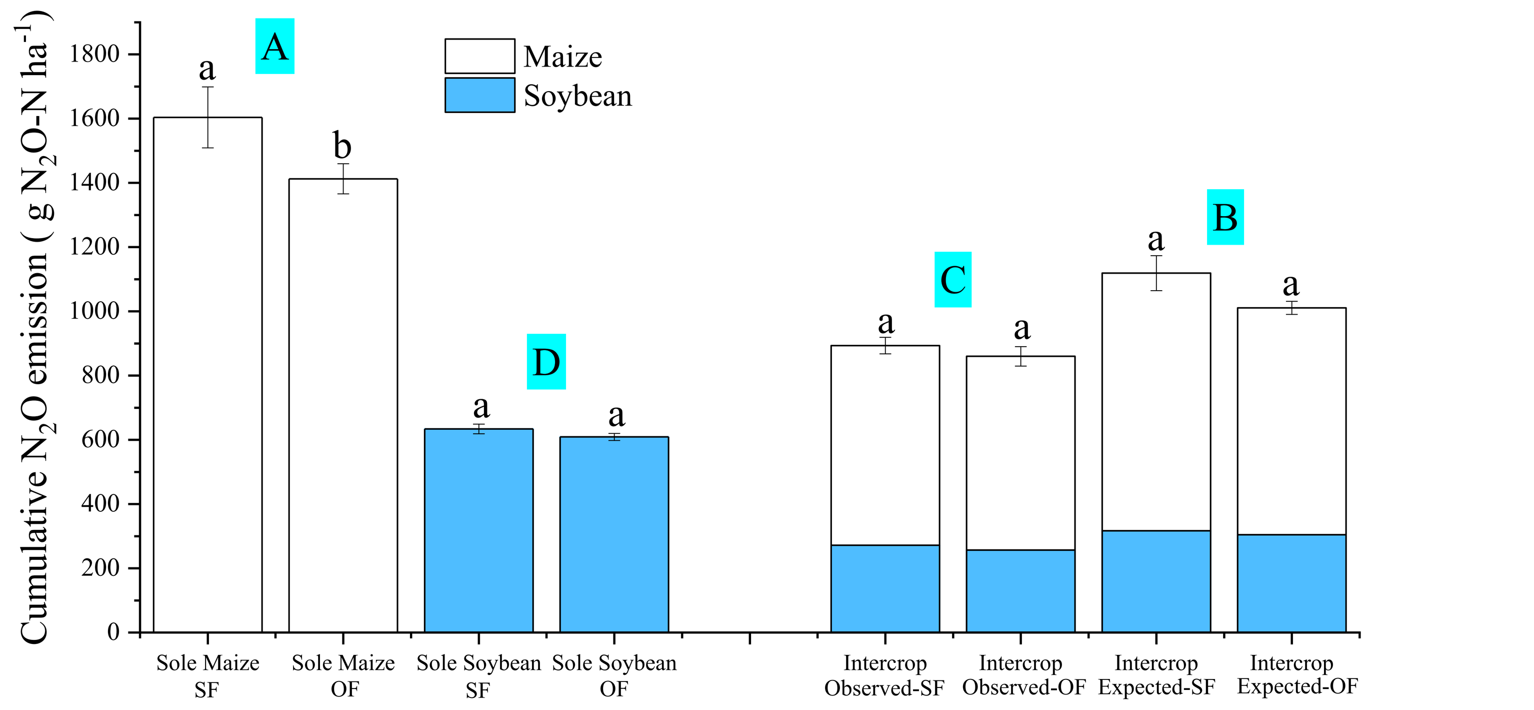

Figure 2. Cumulative N_2O emission of maize, soybean and intercrop under two fertilizer treatment (SF: synthetic fertilizer; OF: 70% Synthetic N fertilizer + 30% Organic N fertilizer). Expected value is calculated as the weighted mean value in the sole crops, with weighing according to the relative density (intercrop/sole crop) of each species in the intercrop.

- The N_2O emissions were significantly positively correlated with soil temperature and soil mineral N concentration but were significantly negatively correlated with soil pH.

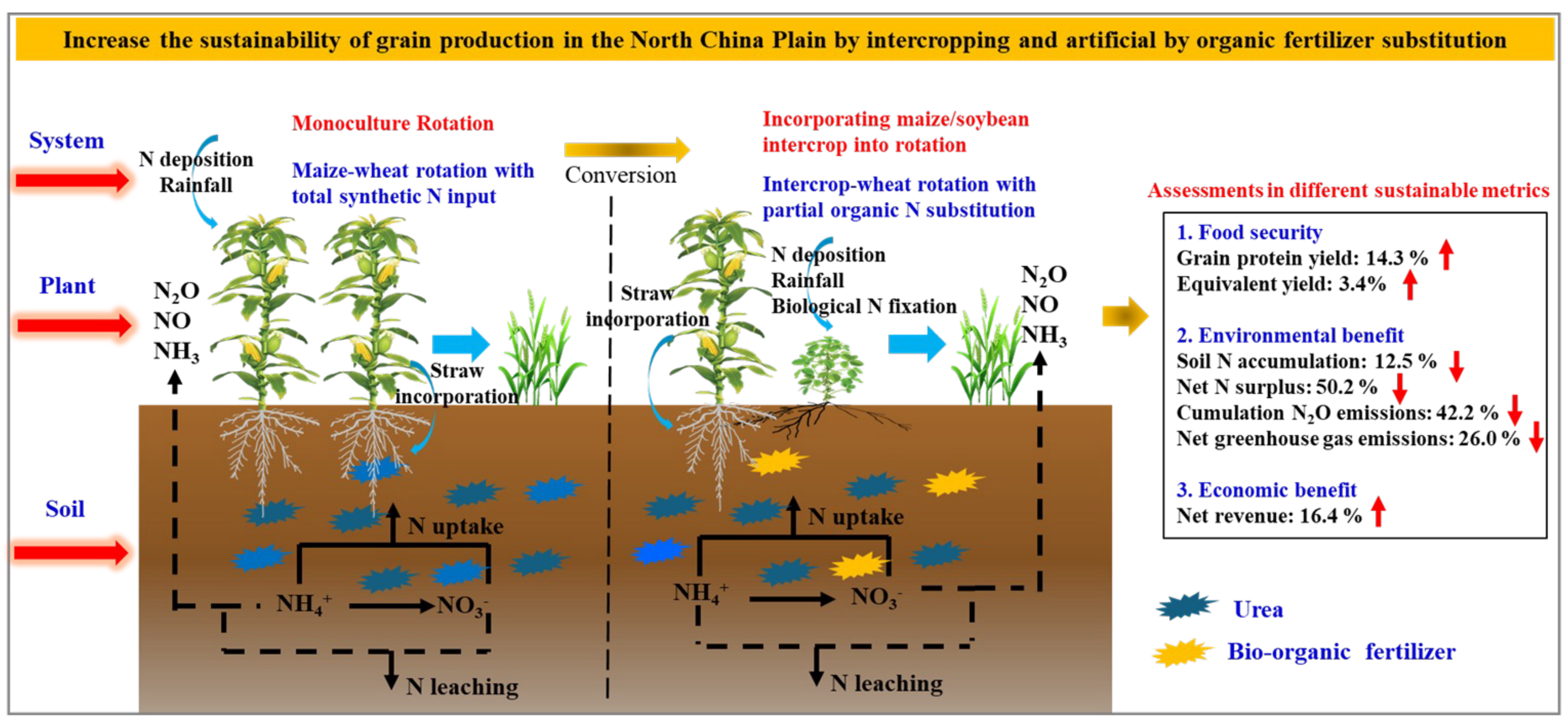

Figure 3. Improved sustainability of grain production by intercropping and partial organic substitution.

Conclusions

- Compared to conventional maize-wheat double cropping, maize/soybean intercropping-wheat double cropping enhanced edible protein supply, improved economic production efficiency, increased gross income, and mitigated greenhouse gas emissions and nitrogen surplus, albeit at the cost of reduced total grain yield..

Acknowledgements

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A hybrid design for a safe, versatile soft robotic gripper for agri-food

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CAU: Lujia Han, Kailiang Zhang
PhD candidate: Laiquan Luo

Background

The delicate, high-value agri-food relies heavily on the human labor, which is very costly and time-consuming, Indicatively, in Dutch greenhouse horticulture, an average of 29% of the total costs goes to human labor, which amounts to €300.000 per company per year. However, the current mass-automation or specialized robotic gripper does not hold because of the large variability and rigid robotic grippers have a high risk of damaging delicate agricultural produce.

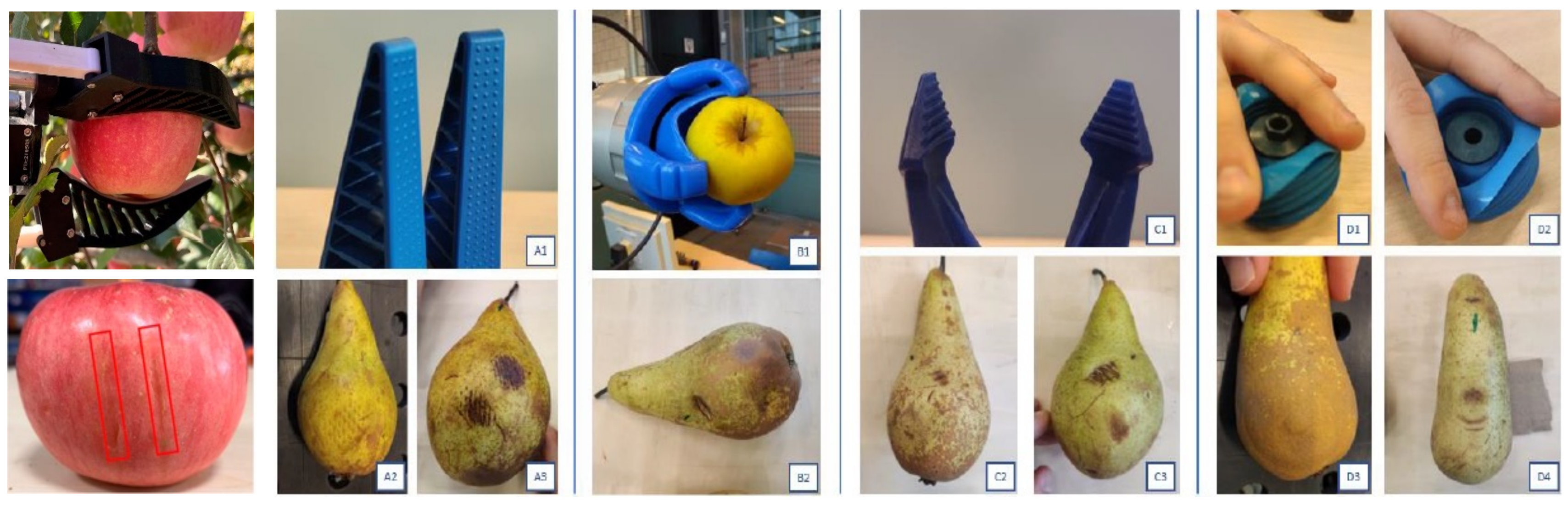

Fig. 1 Examples of grasping damage to the fruit cause by grippers.

Objectives

Soft robotics is a promising solution for agri-food grasping, as it intrinsically has high adaptability feature highly required in grasping of agri-food with vast variability of appearance, geometrical and mechanical properties. The stiffness variability also enables a single versatile robotic system to deal with the safety issue in delicate agri-food grasping. In this context, soft robotics is a suitable alternative approach for rigid robotic approach. So, the main objective in this project is to design and fabricate a safe, versatile soft gripper to address the existing challenges for agri-food grasping.

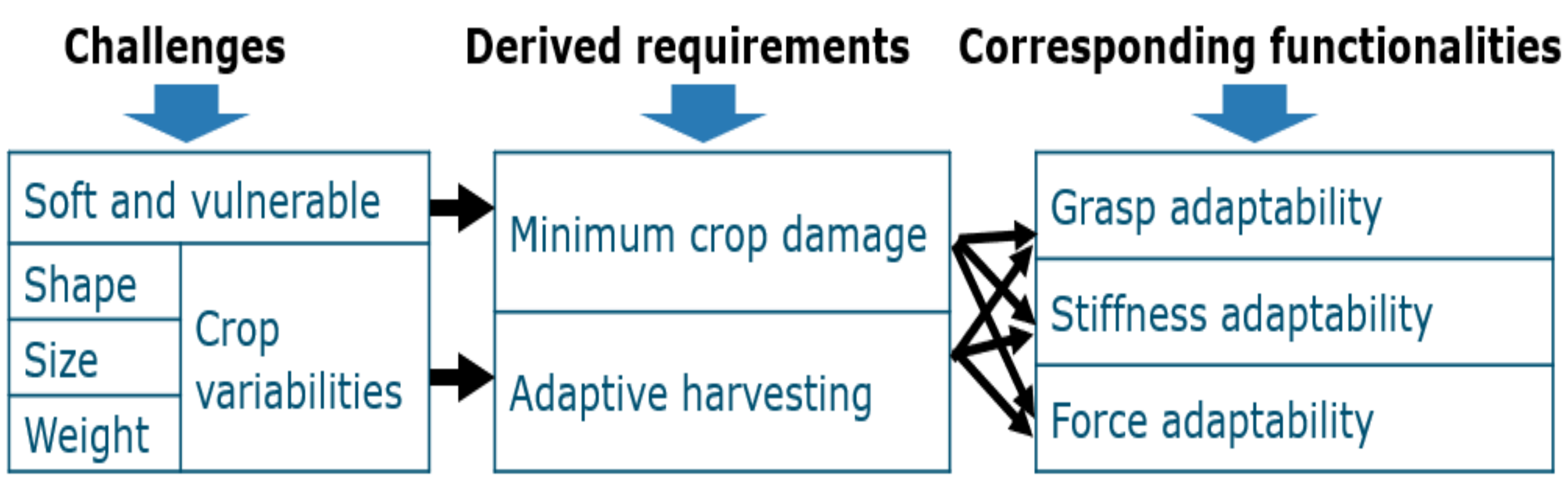

Fig. 2 The challenges, requirements and functionalities for the safe and versatile soft robotic gripper.

Methods

Meta-analysis and hybrid design were used for the gripper design. By listing the pros and cons of all the existing soft robotic gripper mechanisms, it can give us a guideline for selecting the suitable candidate mechanisms for hybrid design. Here in Figure 3 examples of soft robotic gripper mechanisms are categorized into three categories which are grasping by actuation, grasping by stiffness and grasping by adhesion. It also gives a qualitative overview of the suitability of the three different gripper technologies for different object shapes. To enhance their advantages and complement their disadvantages, one mechanism from each category has been selected for the gripper hybrid design. And choose the suitable design based on the task.

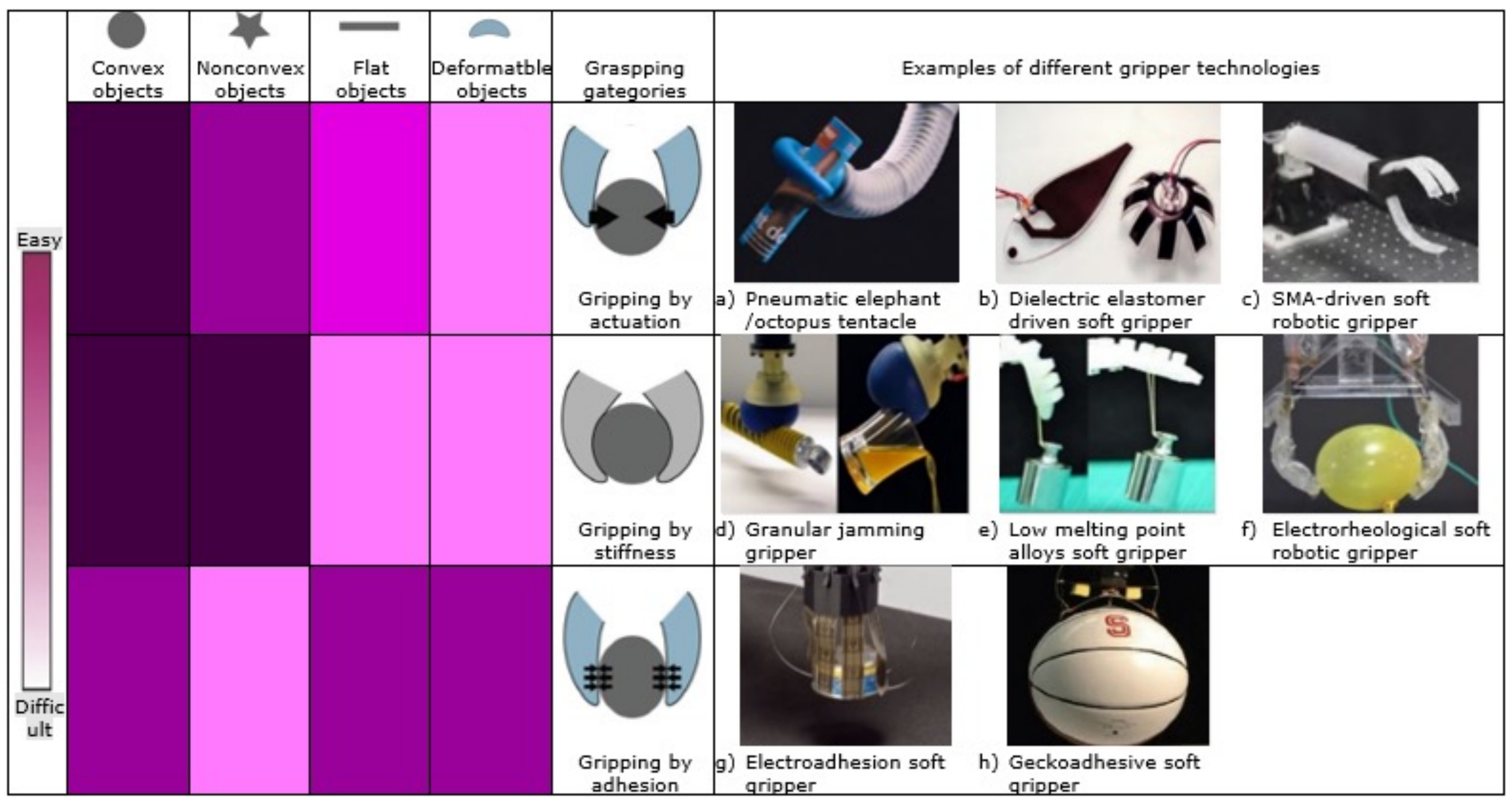

Fig. 3 Examples of soft gripper mechanisms and a qualitative overview of the suitability of different gripper technologies for object shapes.

Results

A hybrid design solution has been proposed through meta-analysis. Tendon driven from grasping by actuation, granular jamming from grasping by stiffness have been chosen, their functionalities and strength are shown in Tab. 1. The schematic view of the hybrid design gripper finger is shown in Fig. 4

Mechanisms	Functionalities	Shape deformability	Size range	Multiple direction approach	Surface condition adaptability
Tendon driven	• Global grasping adaptability • Grasping force	Low	**High**	**High**	**High**
Granular jamming	• Local grasping adaptability • Adaptable stiffness	**High**	**High**	Low	**High**

Tab. 1 The complementary functionalities of candidate mechanisms.

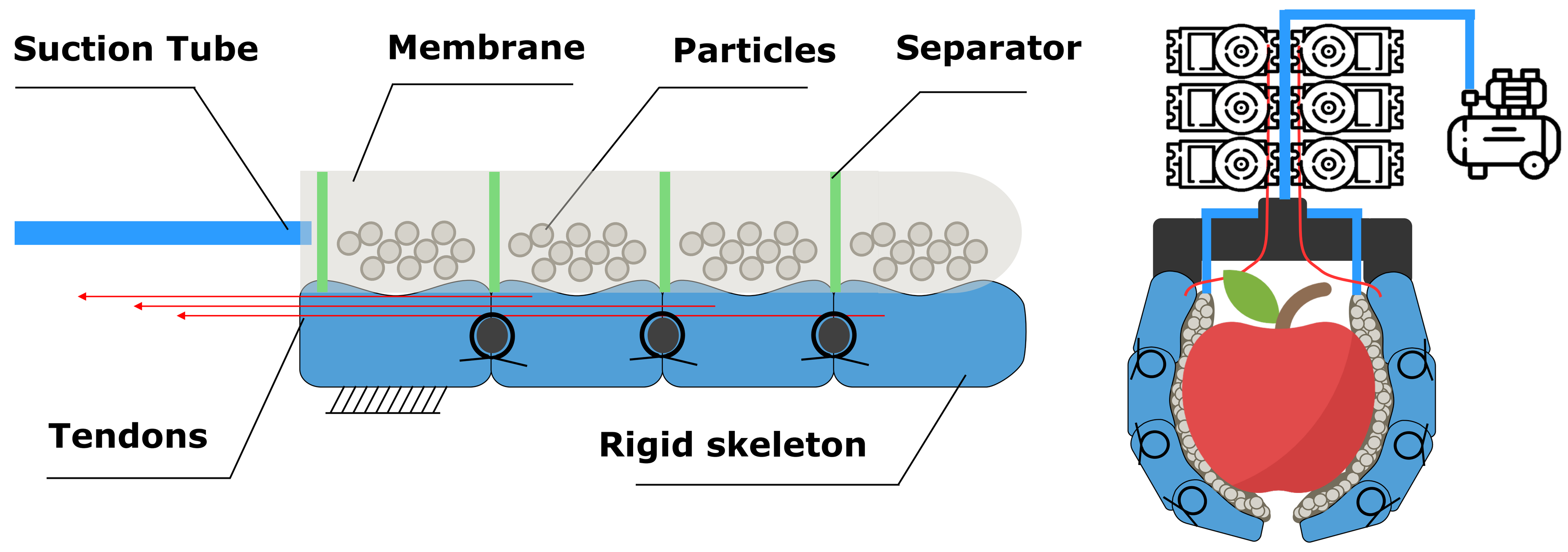

Fig. 4 The schematic view of the finger and gripper design.

Conclusions

A conclusion can be made that the tendon-driven and granular jamming are selected as candidate mechanisms for our safe and versatile agri-food grasping task. As they have complementary functionalities to enhance grasping adaptability. which will improve the performance of adaptive grasping and robust holding for the agri-food with vast variability.

Acknowledgements

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Unlocking Soil Health: Are Microbial Functional Genes Effective Indicators?

Jiyu Jia, Ron de Goede, Guangzhou Wanga,, Junling Zhang, Rachel Creamer

Background

Healthy soils are essential for maintaining food security and agricultural sustainability and can promote water and air quality, provide a habitat for biodiversity, facilitate the mineralization and cycling of nutrients, reduce the occurrence of pests and diseases, support the utilization and storage of carbon, and enhance crop production. The capacity of soils to provide these diverse functions is commonly termed 'soil multifunctionality', which has recently been included in the foresight report on soil health. However, soil multifunctionality is highly threatened by global changes and anthropogenic forces. In this respect, the importance of developing robust, reliable, and resilient indicators for monitoring soil health has been emphasized, in particular when establishing an early warning system for halting soil degradation. In this regard, biological indicators can provide a more comprehensive understanding of soil health, as they reflect the living component of the soil and its dynamic processes. The measurement of biological properties can capture the activities of soil microbes, enzymes, and other biota that play a vital role in nutrient cycling, carbon storage, and ecosystem services, that are important in the maintenance of soil quality and health. Soil microbial community plays crucial roles in promoting soil functions and maintaining soil health. Microbial functional gene abundances are actively involved in soil processes which supports soil functions and wider soil health. However, their suitability as indicators to assess soil health is still debatable.

Objectives

This study aims to investigate the relationship between the abundance of a range of microbial functional genes, soil nutrients and carbon cycling and their relationships with crop yield. The response of the microbial functional genes and several indicators of soil functioning, focusing on C, N and P turnover, were examined in a decade long-term field experiment with different fertilization treatments (different combinations of chemical and organic fertilizers). We hypothesized that: (1) compared to conventional soil carbon and nutrient indicators, the abundances of functional genes would show greater variability in response to different fertilization treatments; (2) the abundances of specific microbial functional genes are strongly correlated with conventional measurements of soil carbon and nutrient cycling; and (3) soil amended with organic fertilizers would have higher abundances of microbial functional genes, this would contribute to crop yields compared to soils receiving the chemical fertilizer only.

Methods

Soil samples were collected from a long-term field experiment with an annual rotation of winter wheat and summer maize at the China Agricultural University Quzhou Experimental Station (36°42′ N, 114°54′ E; 40 m a.s.l.), Hebei province, north China. Field plots (each 50 m2, 5 m × 10 m) were established in 2010. There are five annual treatments with four replicate plots per treatment as follows: (1) Control, no fertilizer; (2) NPK, chemical fertilizer only; (3) NPKM, chemical fertilizer plus manure compost (6000 kg ha-1 yr-1, dry weight); (4) NPKSW, chemical fertilizer plus straw return (wheat straw, 6.0 Mg ha-1 yr-1; maize straw, 6.8 Mg ha-1 yr-1); (5) MNPKSW, chemical fertilizer plus manure compost and straw return (wheat straw, 7.3 Mg ha-1 yr-1; maize straw, 6.9 Mg ha-1 yr-1), provided on yearly bases.

Seventeen functional genes involved in the C (*cbbL, GH31*), N (*nifH, ureC, chiA, A-amoA, B-amoA, narG, nirK, nirS, norB and nosZ*), and P cycling (*gltA, bpp, phoD, phoC, pqqC*) were selected. These functional genes are useful indicators in environmental monitoring and ecological studies and they have been used to reflect key biogeochemical processes (Table 1)

To investigate the relationship between soil microbial functional genes and associated functional processes, we identified soil properties that are related to the process in which the microbial functional genes are active (Table 1). This resulted in selecting the following soil properties as proxies for soil functioning (henceforth termed proxy indicators): 1) the C pool/cycling (total carbon, soil organic carbon, permanganate oxidizable carbon, soil respiration and the enzymes α-1,4 glucosidase [AG, EC 3.2.1.20]); 2) the N pool/cycling (total N, ammonium and nitrate N, nitrous dioxide emission, and the enzyme β-N-acetylglucosaminidase [NAG, EC 3.2.1.14.30]); 3) the P pool/cycling (available P, the enzyme acid phosphatase [ACP, EC 3.1.3.1] and alkaline phosphatase [ALP, EC 3.1.3.2]).

Table 1. Microbial functional genes, the soil ecological processes in which they participate, and soil properties that can be used as proxy indicators for the soil ecological processes.

Microbial functional gene		Enzyme encoding	Soil ecological process	Soil proxy indicator
Carbon	*cbbL*	Ribulose-1,5-bisphosphate carboxylase/oxygenase (EC 4.1.1.39)	Calvin cycle (carbon fixation)	TC, SOC, POXC
	GH31	α-glucosidases (EC 3.2.1.20)	Starch degradation	AG, SOC, soil respiration
Nitrogen	*nifH*	Nitrogenase reductase	Nitrogen-fixation	TN, NH_4^+-N, NO_3^--N
	ureC	Urease (EC 3.5.1.5)	Urea hydrolysis (Urea - NH3/NH4+)	NH_4^+-N, NO_3^--N
	chiA	Chitinase A (EC 3.2.1.14)	Chitin degradation	NAG
	A-amoA	Ammonia monooxygenase subunit A (EC 1.14.99.39)	Nitrification (NH_4^+ - NH2OH)	NO_3^--N
	B-amoA	Ammonia monooxygenase subunit A (EC 1.14.99.39)	Nitrification (NH_4^+ -NH2OH)	NO_3^--N
	narG	Nitrate reductase alpha subunit (EC 1.7.99.4)	Denitrification (NO_3^--NO2-)	NO_3^--N, N2O
	nirK	Copper-containing nitrite reductase (EC 1.7.2.1)	Denitrification (NO_2^- -NO)	NO_3^--N, N2O
	nirS	Cytochrome cd1 nitrite reductase (EC 1.7.2.9)	Denitrification (NO_2^- -NO)	NO_3^--N, N2O
	norB	Nitric oxide reductase subunit B (EC 1.7.2.5)	Denitrification (NO-N_2O)	NO_3^--N, N2O
	nosZ	Nitrous oxide reductase (EC 1.7.2.4)	Denitrification (N_2O-N_2)	NO_3^--N, N2O
Phosphorus	*gltA*	Citrate synthase (EC 2.3.3.1)	Phosphorus dissolution	AP
	bpp	β-propeller phytase	Phytic acid mineralization	AP
	phoD	Alkaline phosphatase (EC 3.1.3.1)	Organic P mineralization	ALP, AP
	phoC	Acid phosphatase (EC 3.1.3.2)	Organic P mineralization	ACP, AP
	pqqC	Pyrroloquinoline-quinone synthase C	Inorganic P dissolution	AP

Results

In general, the abundance of soil microbial functional genes and most proxy indicators were significantly affected by the fertilization treatments. The CV values of the proxy indicators related to the C cycle ranged from 8% to 36% and the corresponding values were 35-52% for the related functional genes of *cbbL* and *GH31* (Fig.1). The CVs of the proxy indicators related to the N cycle, combining all treatments, ranged from 10% to 54%, strongly overlapped with the CV values (23-54%) of the functional microbial genes (Fig.1). Moreover, the CV values of the proxy indicators related to the P cycle, combined for all treatments (11-62%), overlapped with those of the microbial functional genes (23-62%) (Fig.1).

In general, all CVs of the functional genes across all treatments were >23%, and 62% of the soil proxy indicators had a CV≤ 20%. Among the proxy indicators, soil respiration emission (23%), NO3-N content (54%), NH_4^+-N content (36%), and AP (62%) had relatively high CV values. The value of their corresponding functional genes were GH31 51%, B-amoA 54%, and phoC 63%, respectively. Within treatments the CV values of all C, N and P cycling gene were lower than those of their corresponding proxy indicators (Fig. 1).

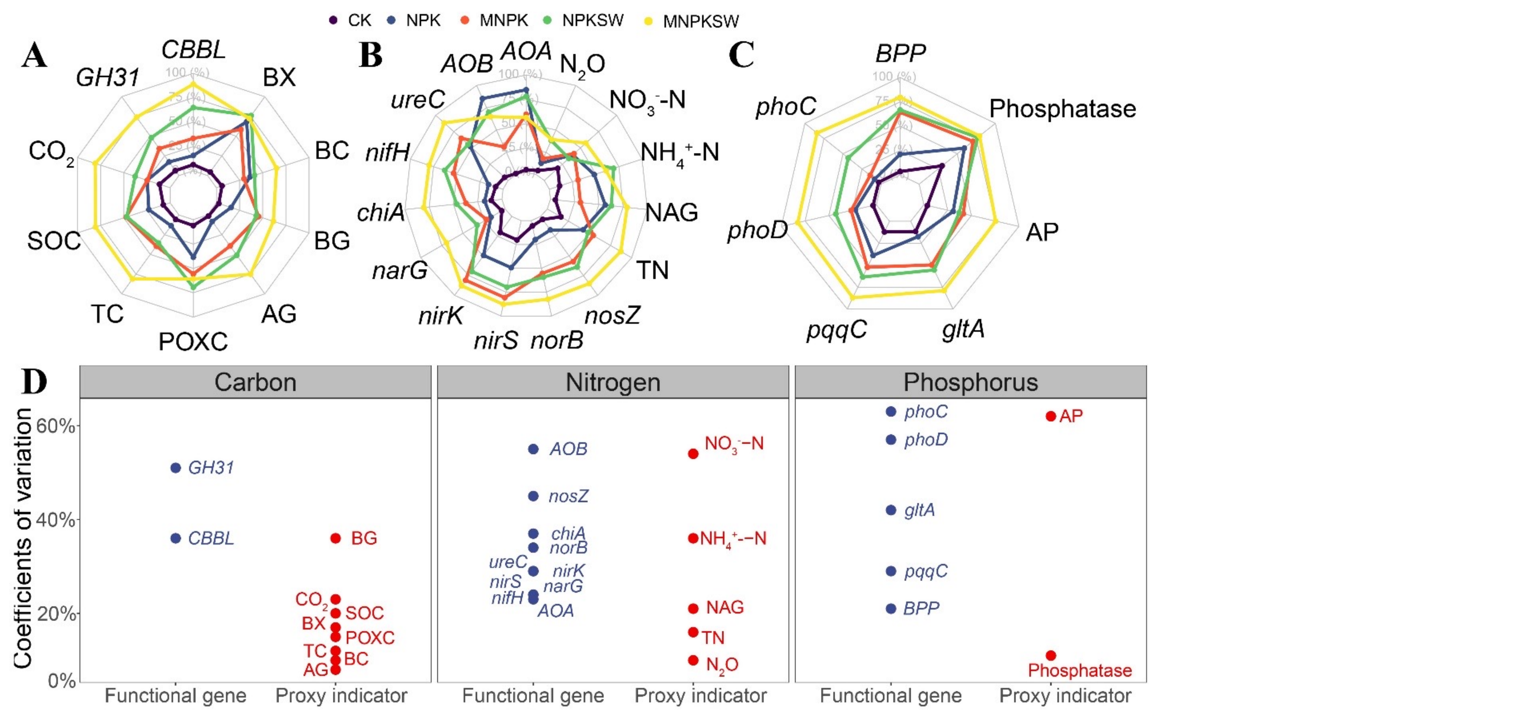

Fig.1. Radar diagram of microbial functional genes (in italics) and soil proxy indicators for the carbon (A), nitrogen (B) and phosphorus (C) cycling process and their coefficients of variation (D). The coefficient of variation was calculated as the ratio of the mean to the standard deviation of a parameter for all fertilization treatments combined, and expressed as a percentage.

The carbon PLS-PM showed that straw carbon input increased the abundance of gene *GH31* which was positively related to α-glucosidase activity (Fig. 2A). The increased α-glucosidase activity promoted CO_2 emissions. Manure and straw carbon input both increased POXC content which was positively correlated with the abundance of the cbbL gene. Furthermore, the abundance of the *cbbL* gene was positively linked to SOC content. The nitrogen PLS-PM indicated that organic fertilization increased SOC content which was positively correlated with the abundances of *nifH, chiA* and *ureC* genes (Fig. 2B). The abundance of the *nifH* gene was positively correlated with the *B-amoA* gene abundance. In contrast, the *chiA* gene abundance was negatively correlated with the *B-amoA* gene abundance. Inorganic N content was positively correlated with the *ureC* gene abundance which was positively correlated with the abundances of *B-amoA* and *A-aomA* genes. The abundance of *B-amoA* was significantly related to NO_3^--N content which positively affected yield (Fig. 2B). The nitrogen PLS-PM suggested that no direct relationship was found between inorganic N input and NO_3^--N or maize yield, but indirect effects through changes in the microbial community was observed on maize yield. The phosphorus PLS-PM indicated that organic inputs increased SOC content which showed significantly positive relationships with the abundances of *gltA, phoC, phoD, pqqC* and *bpp*. The abundances of *phoD* and *phoC* genes was positively correlated with the activities of ACP and ALP. ALP was positively correlated with maize yield but not with AP content (Fig. 2C). In contrast, there was a significant relationship between ACP and AP content but not with maize yield. In contrast to the nitrogen PLS-PM, the phosphorous PLS-PM suggested a direct relationship between inorganic fertilizer input and yield.

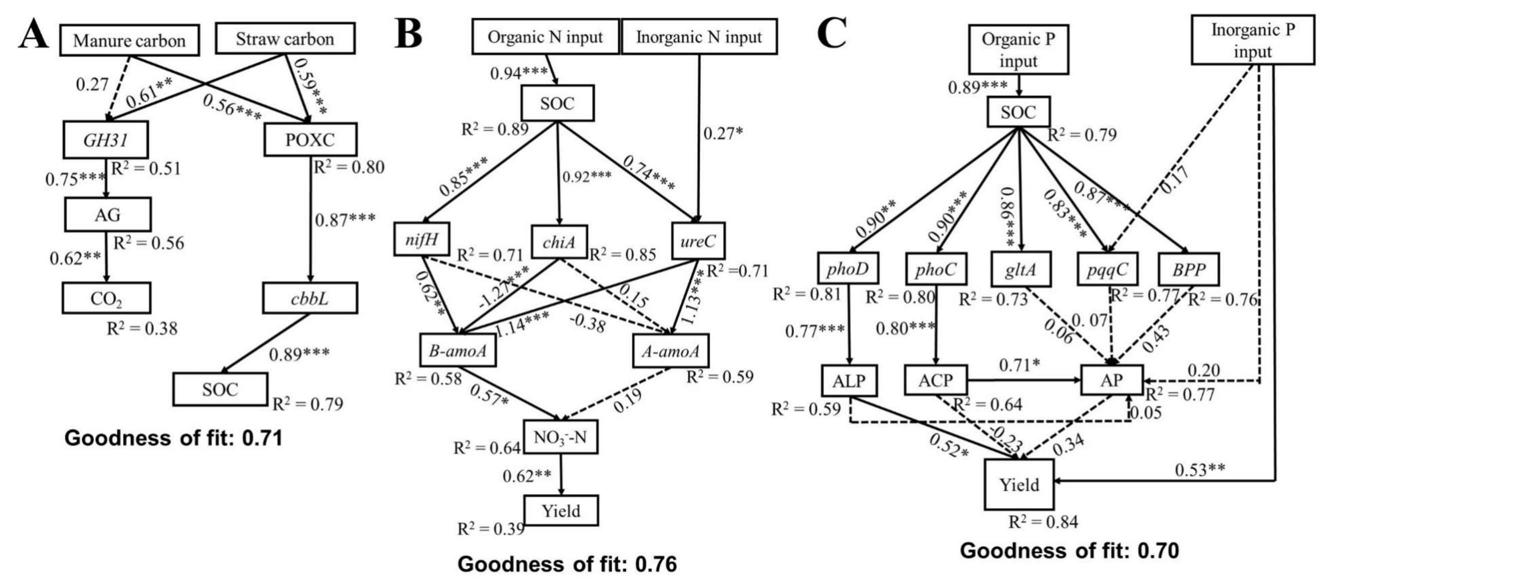

Fig. 2. Partial least squares path analysis for the effects of manure and straw carbon input on the carbon cycling process (A); and the effects of organic and inorganic nitrogen (B) and phosphorus (C) input on the nitrogen and phosphorus cycling process and crop yield, respectively. * indicates $p < 0.05$; ** indicates $p < 0.01$, *** indicates $p < 0.001$, respectively. Continuous and dashed lines indicate significant and nonsignificant relationships, respectively. R2 denotes the proportion of variance explained.

Conclusions

Our results showed that fertilization significantly affected the abundance of soil microbial functional genes involved in C, N and P cycling. Most functional genes, in particular *phoC, phoD, B-amoA, chiA, GH31* and *cbbL* showed higher variability among treatments and lower variability among replicates within treatments than their corresponding proxy indicators, indicating that functional genes were more responsive to fertilization than the selected proxy indicators for soil functioning. Furthermore, regression analysis showed that microbial functional gene abundances and the corresponding proxy indicators were strongly correlated. Partial least squares path analysis showed that the organic fertilization increased soil microbial functional gene abundances, especially *GH31, cbbL, chiA, B-amoA, phoC*, and phoD, which promoted the C sequestration and decomposition, N mineralization, ammonia oxidation and P cycling process, producing positive effects on maize yield. These microbial functional genes offer a more detailed understanding of soil functions than conventional proxy indicators due to their more direct and specific relationship with the underlying biochemical processes. The results strongly endorse that the use of functional genes that can serve as crucial biomarkers for understanding the complex dynamics of soil processes and as indispensable biological indicators for assessing soil health.

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Assessing nutrient cycling for soil health and sustainable management in agroecosystems: A modelling approach

Yizan Li, Gerard Velthof, Jiyu Jia, Jiangzhou Zhang, Carmen Vazquez, Junling Zhang, Ron de Goede, Rachel Creamer

Background

Nutrient cycling is a critical ecosystem function underpinning soil health, which is essential for maintaining nutrient availability, supporting crop productivity, and minimizing environmental impacts, particularly in intensive cropping systems like the wheat-maize rotation in the North China Plain. Addressing challenges such as nutrient inefficiencies and environmental risks from over-fertilization necessitate tools for evaluating nutrient cycling and optimizing through improved nutrient management.

Objectives

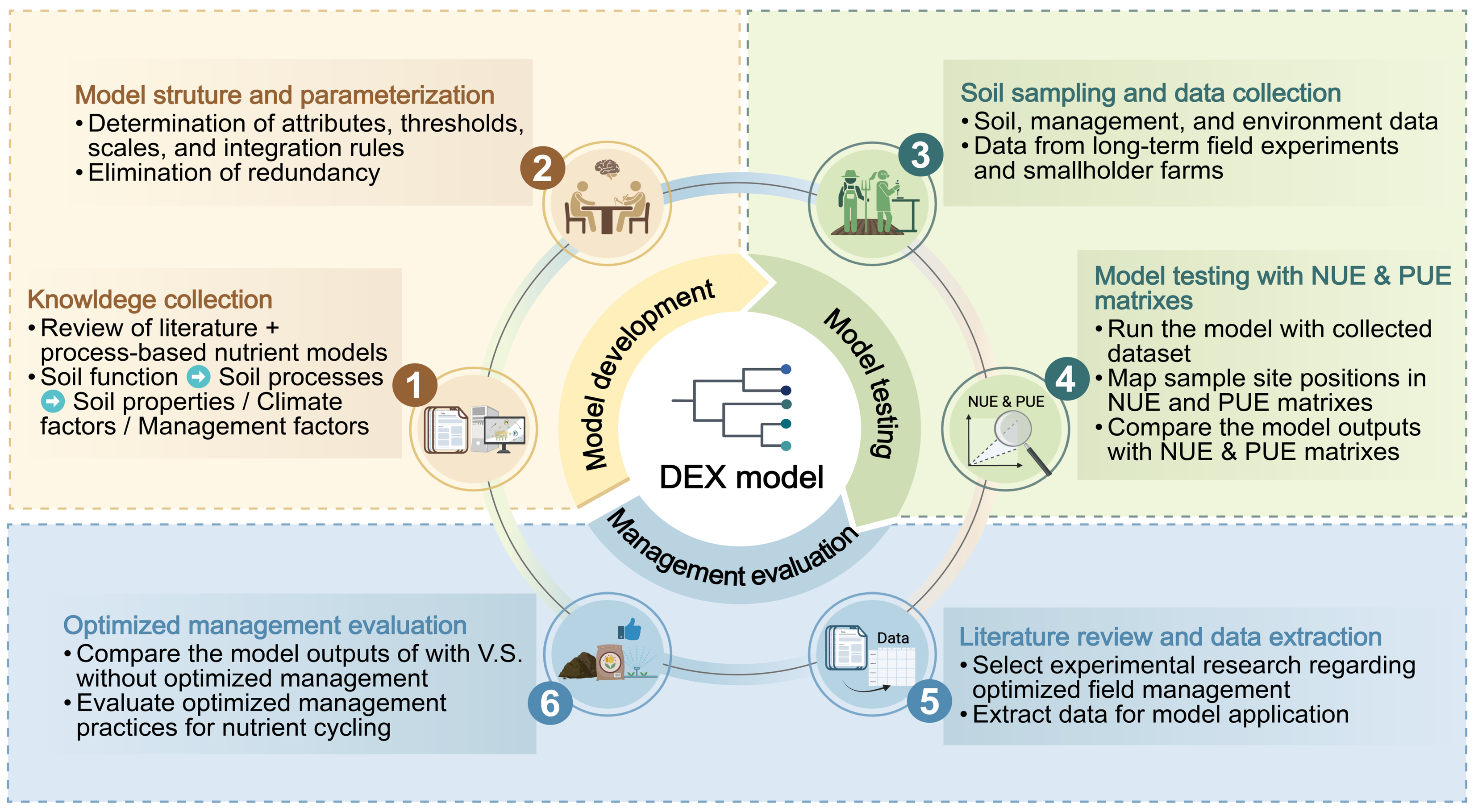
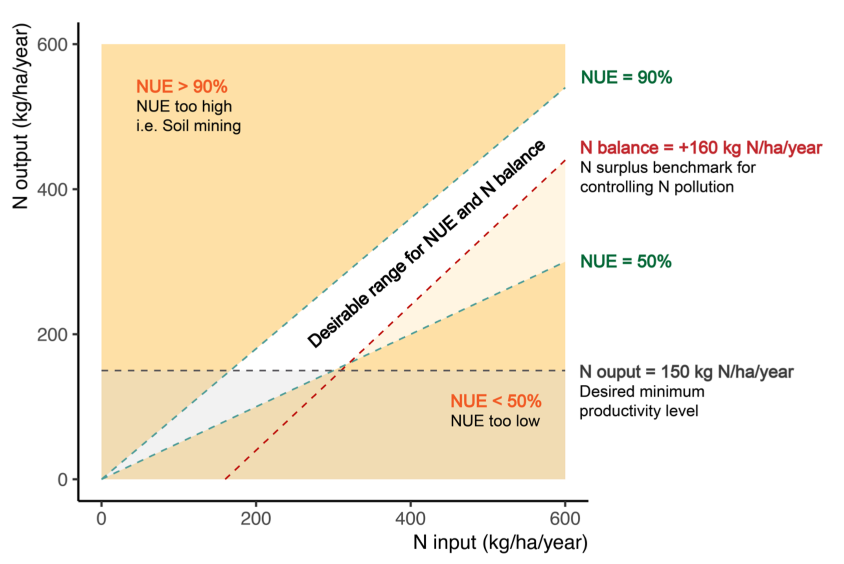


Figure 1. Framework for building and applying the soil nutrient cycling model.

This study focused on the wheat-maize rotation in the North China Plain. The aim was (1) to develop a decision-support model to assess soil nutrient cycling, integrating the principles of the 4R Nutrient Stewardship Framework for field management optimization; (2) to test the model using datasets from long-term field experiments and smallholder farms, with NUE and PUE schemes serving as proxy indicators; (3) applying the model to evaluate nitrogen (N) and phosphorus (P) cycling and test the impacts of optimized management practices on nutrient cycling.

Methods

This research followed the Decision Expert integrative methods to refine classification of soil nutrient cycling into a hierarchical tree structure. To evaluate the model performance, NUE and PUE on a field scale were employed as key proxy indicators. The model outputs, categorized as the levels of N and P cycling (Suitable/Neutral/Unsuitable), were compared against their locations within the NUE and PUE schemes.



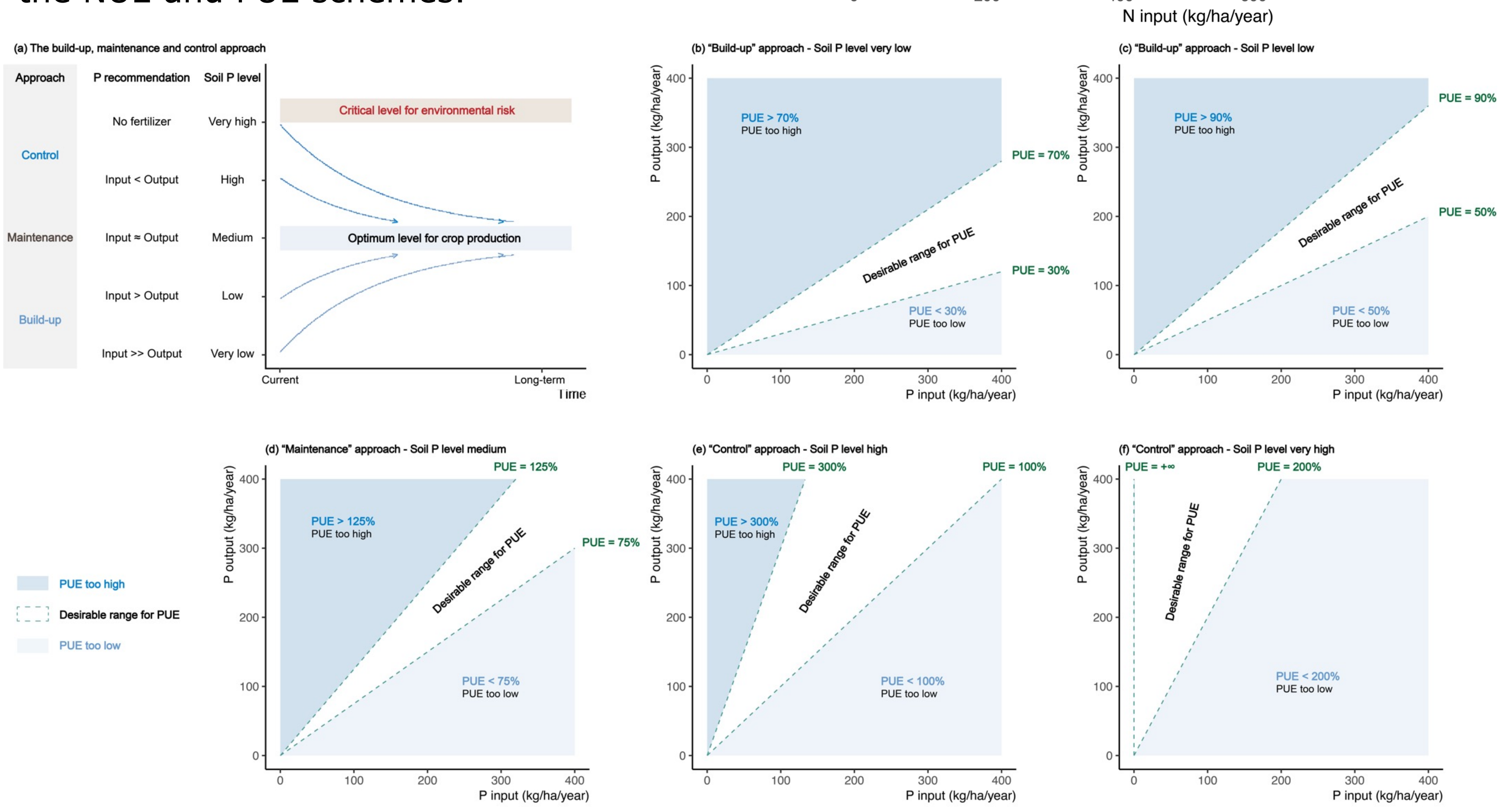


Figure 2. Schemes of determining desirable range of NUE and PUE.

Results and conclusions

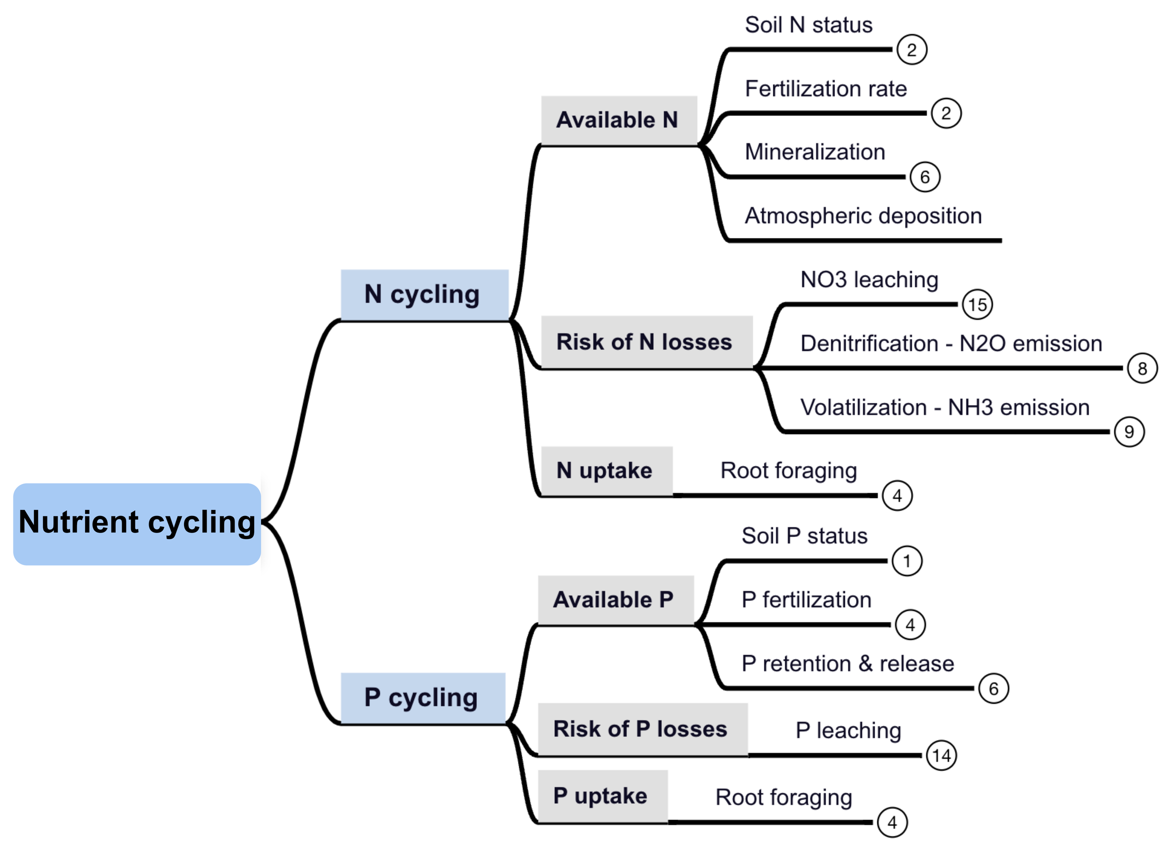
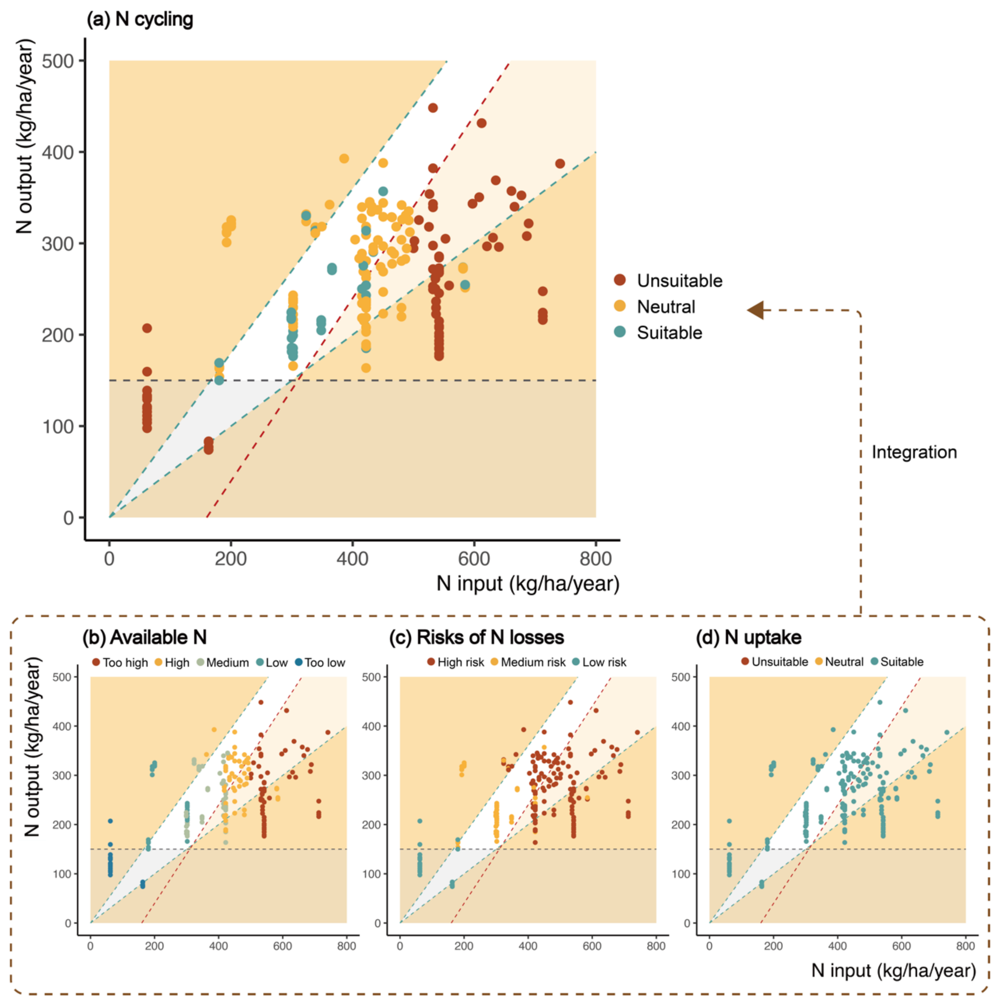


Figure 3. Main contents of the nutrient cycling model.

The developed model for evaluating soil nutrient cycling employed a hierarchical structure, divided into two primary branches: N cycling and P cycling, which reflected the major pathways influencing soil nutrient availability, risk of losses, and crop uptake. The model included a total of 101 attributes, of which 29 served as input attributes.



The model's evaluation results align with scientific understanding and effectively capture the dynamics of N and P cycling and associated environmental risks. This consistency supports the model's ability and validity in assessing soil nutrient cycling. The optimized field management strategies demonstrated potential for improving nutrient cycling, though trade-offs were observed.

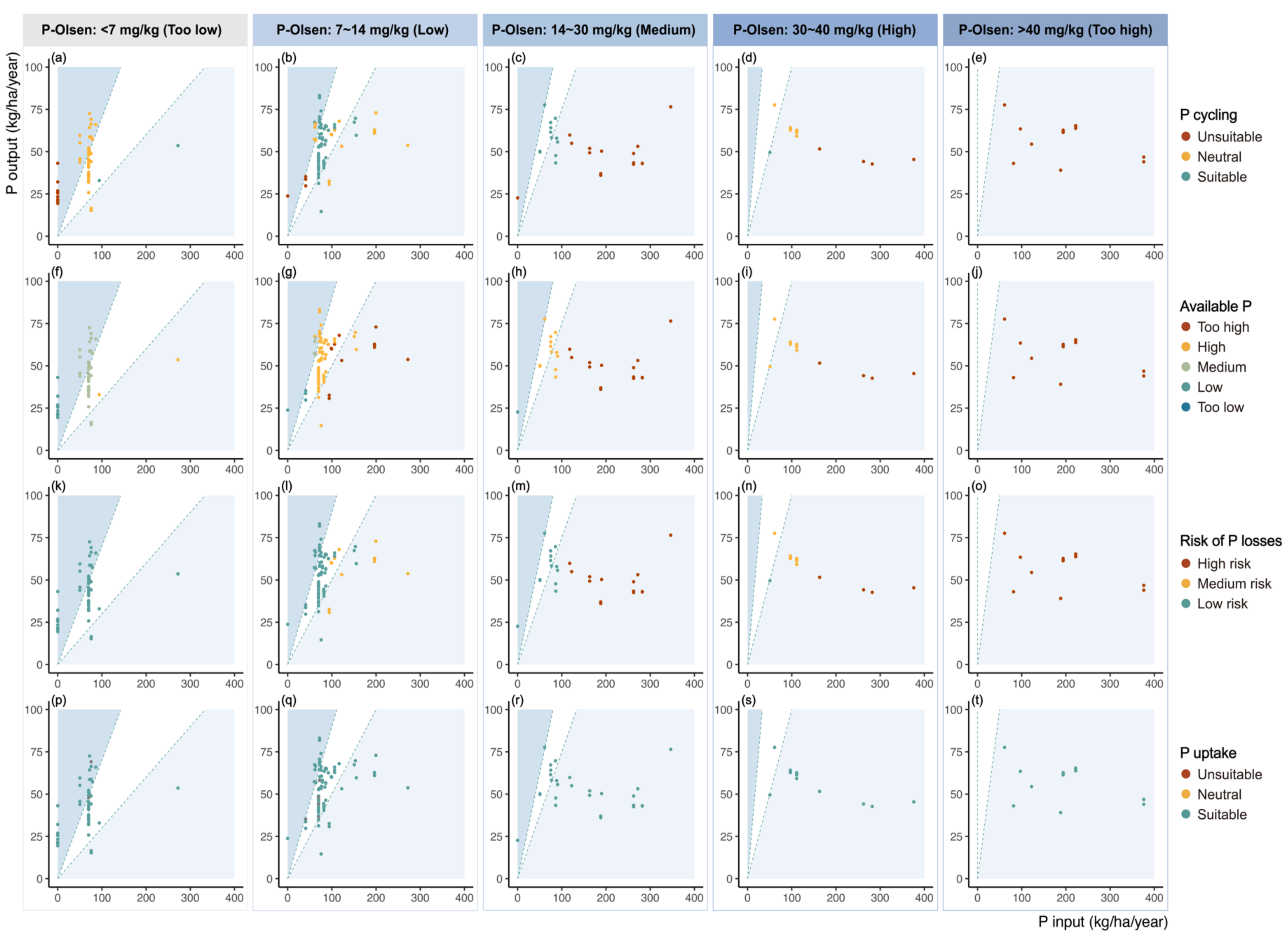


Figure 4. Results of model assessed N and P cycling in the NUE and PUE schemes.

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Drivers of pollinator abundance and diversity in the North China Plain

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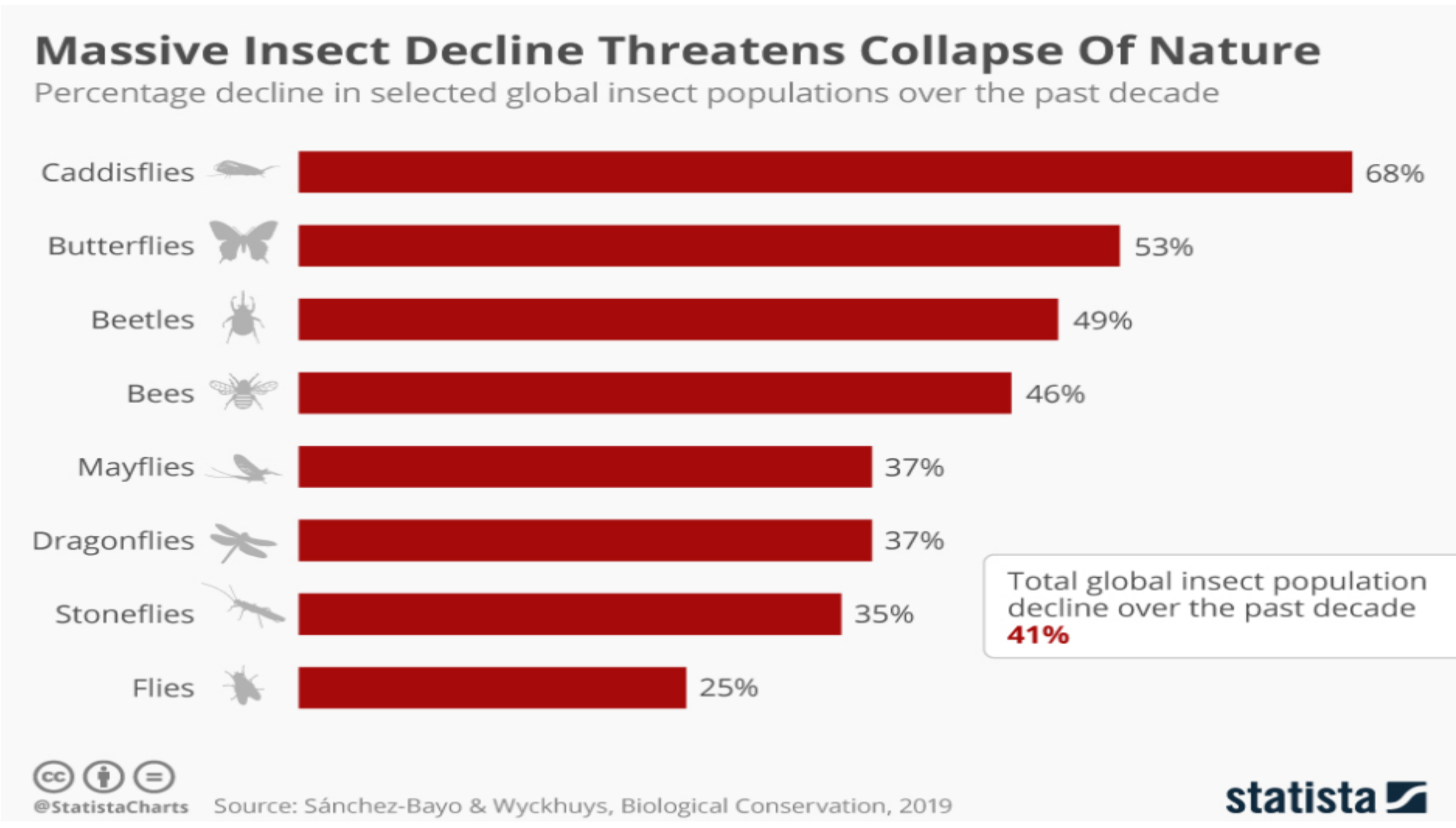
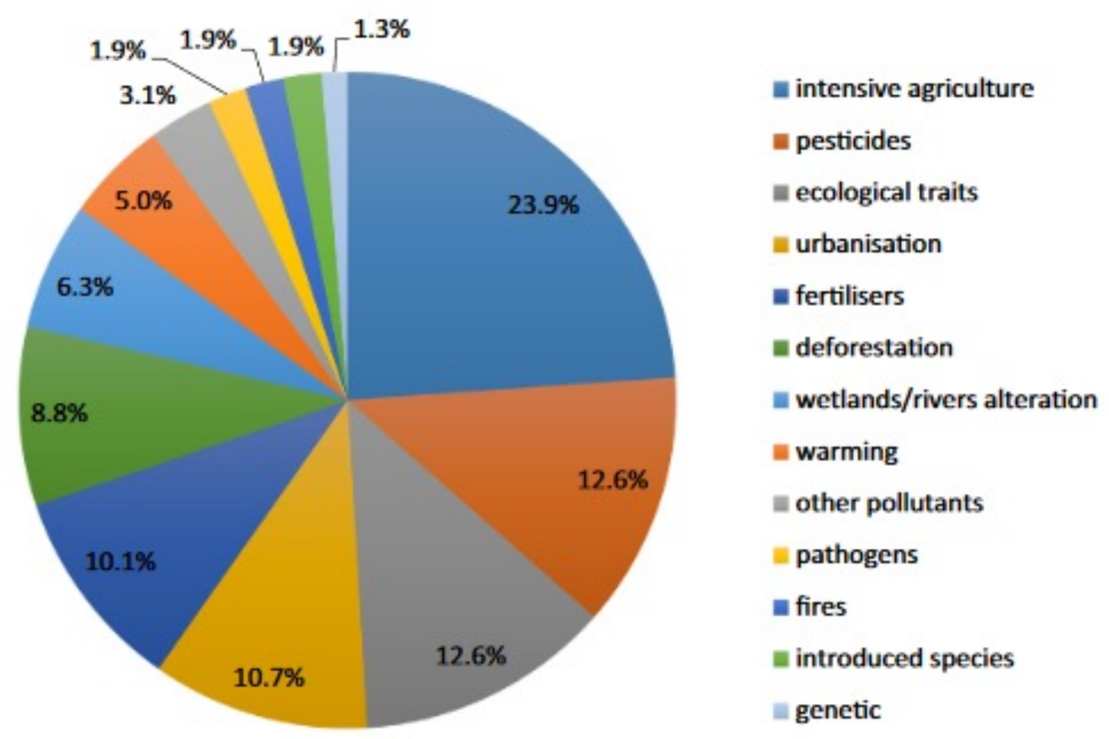
CAU supervisors: Chaochun Zhang, Wenfeng Cong

WUR supervisor: Wopke van der Werf

Background





(Sánchez-Bayo & Wyckhuys, Biol Conserv, 2019)

The worldwide insect showed a declining tendency. Multiple factors caused the insect decline, with 24% of research reporting agricultural intensification as the main factor.

Methods

A two-year field experiment was established in Quzhou County to analyze the driving factors of pollinator abundance and diversity in the intensive cereal production landscape. We chose 24 sites in three seasons (autumn, spring and summer). At each site, pan trap stations were installed to collect the pollinators in this region. Using a drone and combing the ArcGIS software to get each landscape's composition. Based on the county-level farmer survey of management information (Xu et al., Data in brief, 2024), it is used to quantify the agrochemical use in the landscape. The effect of land use types and agrochemical use in landscape on pollinator abundance and diversity were analyzed.

Fig. 1 Pan trap stations were used to collect pollinator samples

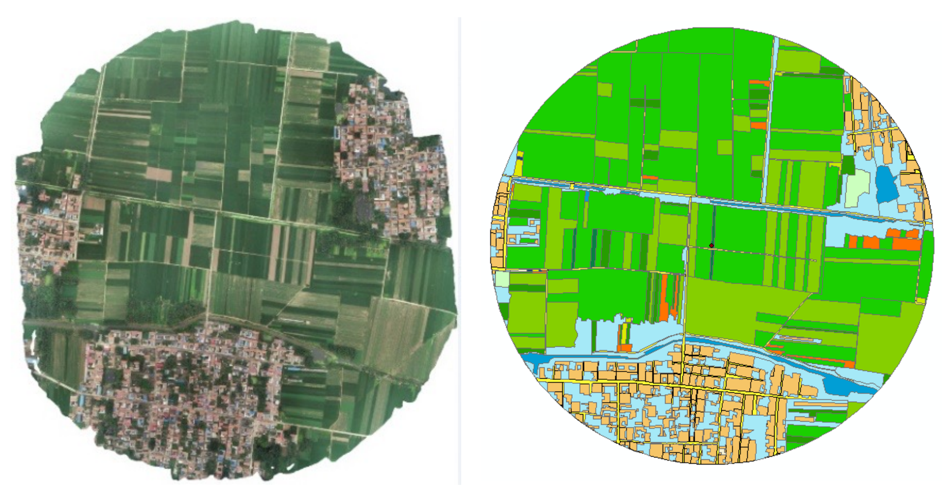


Fig. 2 A drone was used to get the images of landscapes, and ArcGIS was used to quantify landscape composition

Results

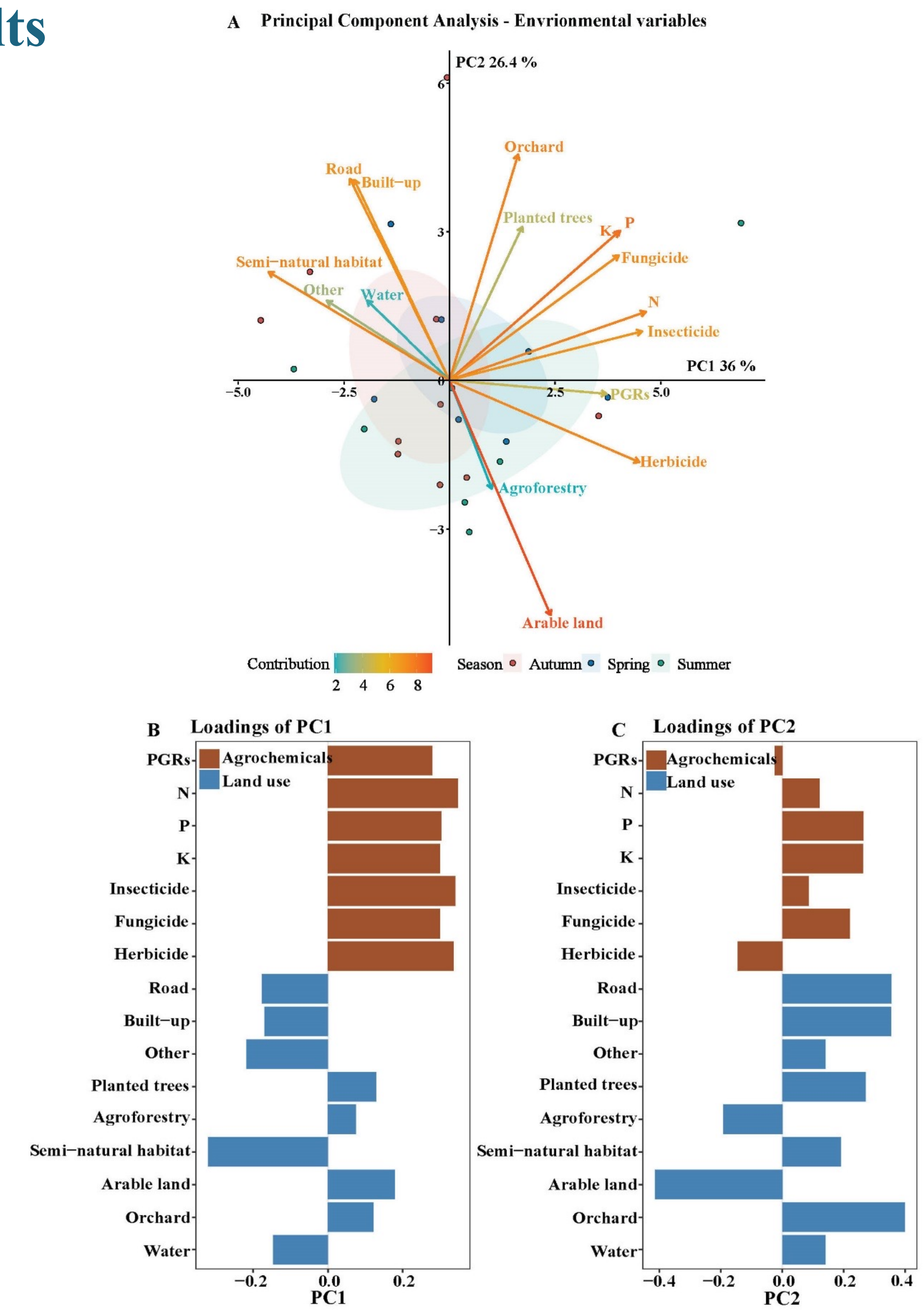


Fig. 3 Biplot (A) and loadings of the first two components (B and C) in a PCA of land use and landscape-wide exposure to agrochemicals

The landscape-wide exposure to agrochemicals and the percentage of semi-natural habitat characterized PC1, and PC2 characterized the landscape with less arable land and more other land use categories (Fig. 3).

Table 1 Effect of the first two principal components on the abundance and rarefied richness of pollinators

Response variable	Coefficients	Estimate	Std. Error	Z value	Pr (>|z|)
Abundance	Intercept	3.485	0.160	21.787	**< 0.001**
	PC1	-0.190	0.516	-0.368	0.713
	PC2	-1.213	0.511	-2.373	**0.018**
	Spring	-0.299	0.251	-1.191	0.233
	Summer	-0.893	0.255	3.502	**< 0.001**
Rarefied richness	Intercept□	7.177	0.539	13.323	**< 0.001**
	PC1□	0.998	1.720	0.581	0.568
	PC2□	2.057	1.707	1.205	0.243
	Spring□	-2.994	0.840	-3.562	**0.002**
	Summer□	-2.008	0.855	-2.348	**0.030**

The abundance of pollinators was negatively associated with PC2, indicating that the abundance of pollinators was associated with more arable land (Table 1).

Conclusions

Pollinator abundance was positively associated with the percentage of arable land in landscape. The diversity of pollinators was not affected by land use types and agrochemical uses. More arable land and lower agrochemical use supported higher pollinator abundance.

Acknowledgements

I gratefully acknowlege the sponsors of this research: China Scholarship Council (NO.201913043) and Hainan University.

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Overview PhD projects – starting year 2021

Posters, March 2025

Theme: Green and nutritious food provision & governance

Name	*Model**	*Project*
1. Yutong Jiao	1+3	Impacts of e-commerce on smallholders' dietary pattern in rural China

Theme: Green animal production

Name	*Model**	*Project*
2. Yuan Feng	1+3	Agriculture Green Development: conceptual framework, assessment, historical trends, and development pathways
3. Haixing Zhang	2+2	Assessment System and Pathway Analysis for the Sustainability of Agricultural Food Systems Based on Sustainable Development Goals in China
4. Wenqi Lou	2+2	Combining daily rumination time and milk yield for selecting more resilient dairy cows
5. Yuhang Sun	1+3	A typology of farms and spatial patterns in the North China Plain to support crop-livestock integration
6. Chuanlan Tang	1+3	Interventions to increase nitrogen circularity in food systems in the North China Plain
7. Xiaoying Zhang	2+2	Mitigation of environment pollution by efficient recycling of nitrogen and phosphorus in regional integrated crop-livestock system

Theme: Green ecological environment

Name	*Model**	*Project*
8. Weikang Sun	1+3	Optimization of manure management options in view of crop nutrient demands, environmental benefits and costs
9. Ling Zhang	2+2	Sunstainable development of China's agriculture driven by the nutrient management policy
10. Rong Cao	1+3	Potential of agricultural management strategies to minimize the gap between current and critical ammonia emissions for ecosystems in China
11. Jianan Chen	2+2	Estimation of ammonia emissions over China using IASI satellite-derived surface observations
12. Yinan Ning	1+3	The impacts of soil and water conservation on streamflow and sediment discharge
13. Jichen Zhou	2+2	Quantifying above-ground biomass, SOC and erosion with a detailed crop map and PESERA model in the Yangtze River Basin
14. Songtao Mei	1+3	Modelling antibiotic concentrations in rivers in China: hotspots, sources and risk assessment
15. Hanyue Zhang	1+3	UV exposure and tillage abrasion on macro/micro-plastic fragmentation
16. Mingyu Zhao	2+2	Fate and risk of atmospheric pesticides in the North China Plain

Theme: Green plant production

Name	*Model**	*Project*
17. Xueyuan Bai	2+2	Pursuing China's Sustainable Food Security through Strategic Cropland Productivity Improvement
18. Yuze Li	1+3	Predicting Rhizosphere-Competence-Related Catabolic Gene Clusters with RhizoSMASH
19. Mingxue Sun	2+2	Unveiling the influence of domestication on taxonomic and functional microbiome composition in foxtail millet
20. Yijun Li	1+3	Optimizing crop supply chains for healthy diets in China
21. Xin Zhang	2+2	Consumers' preferences for whole grain foods: A discrete choice experiment with directional information interventions
22. Tao Song	2+2	Why do smallholders grow intercrops – a case study in Hangjinhou county, China
23. Mengxue Mao	2+2	Root exudates driven root-soil microsite interactions to improve soil nutrient retention and supply capacity for sustainable crop production
24. Man Pu	1+3	Geochemical mechanisms of enhancing the phosphorus bioavailability by maize root exudates
25. Xiaofan Ma	1+3	Plant-arbuscular mycorrhizal fungi-bacteria tripartite interaction
26. Zihang Yang	2+2	Unraveling mechanisms for arbuscular mycorrhizal fungi recruit and activate hyphosphere bacteria to improve plant phosphorus uptake
27. Wenying Huo	1+3	Finding adaptations of symbiosis signalling cascade: from mycorrhizal symbiosis to nitrogen-fixing symbiosis
28. Pugang Yu	2+2	Uncovering the coordination mechanisms between plant and rhizosphere microbiome under different nitrogen levels
29. Zewen Hei	2+2	Soil N index enhancement by organic fertilizer application depends on aggregate size
30. Shunran Hu	1+3	Dynamics and functions of rhizobiomes during plant maturation

Model*: There are two different types of PhD candidates, hence 2 models.
2+2 model: Graduates at CAU; project starts and ends in China; stays for two consecutive years in Wageningen.
1+3 model: Graduates at WU; project starts in China; stays for three consecutive years in Wageningen.

Impacts of e-commerce on smallholders' dietary pattern in rural China

Yutong Jiao
Agricultue Green Development (AGD) program
Chair group: Development Economics & Marketing and Consumer Behaviour
Supervisors:,dr. Paul T.M. Ingenbleek, dr. ir. MM (Marrit) van de berg, prof. Nico Heerink, prof. Shenggen Fan

Introduction

Smallholder farmers, estimated at 250 million in China, contribute approximately 20% of global food production (FAO, 2023). Despite their critical role in addressing global food security, the average landholding size per smallholder is only 0.52 hectares (Zheng et al., 2022; Xinhua, 2019). This limited landholding poses challenges to their own nutritional and health well-being (Wagstaff, 2002). Smallholders often face restricted access to diverse food options in rural areas and inconvenient access to urban markets (Fan et al., 2013), leading to higher rates of malnutrition, poor health outcomes, and increased mortality (Wagstaff 2002). Therefore, addressing smallholder farmers' health challenges, it is essential to improve their access to more diversified food options and upgrade their dietary patterns.

E-commerce provides a new marketing channel that not only creates opportunities to increase smallholder farmers' income (Ma et al., 2024; Li and He, 2024) but also significantly influences their dietary intake patterns (Cui et al., 2023; Shen et al., 2023). According to Shen et al. (2023), e-commerce helps balance dietary intake by reducing the consumption of staple foods while increasing the intake of legumes, nuts, and dairy products. Additionally, e-commerce enhances dietary quality by diversifying food access and types, thereby enriching smallholders' food environments (Ma et al., 2022; Shen et al., 2023). Evidence from Xiong et al., (2024) indicates that online purchases increased dramatically during the COVID-19 pandemic due to the need for distance shopping, which has further accelerated the development of logistic systems (Liu et al., 2020). Consequently, e-commerce emerges as a potential solution to address the malnutrition challenges faced by smallholder farmers in rural China.

Although existing literature has demonstrated that e-commerce can improve the dietary quality of rural smallholder farmers, there is a lack of updated evidence reflecting the post-COVID-19 pandemic period. All existing studies have relied on data collected prior to the pandemic. However, the pandemic has likely influenced people's dietary cognition, encouraging improved dietary quality to prevent diseases (Janssen et al., 2021; Bao et al., 2022).

Given these gaps, this article makes contributions to the existing literature: (1) it evaluates the impact of e-commerce on smallholders' dietary patterns using data collected after the COVID-19 pandemic; and (2) it adds sweets, snacks, and convenience foods in the e-commerce survey to compare their intake with that of fresh food types.

Data and Method

Data was collected in the summer of 2023 in Hebei province, covering major agricultural production areas in northern China. To ensure representative samples, we employed a stratified sampling approach, randomly selecting four counties and, within each county, incorporating two villages. To select households for interviews, a distance-based grouping method was used in each village, categorizing households into two groups based on their distance from the village committee office. From each group, 10–12 households were then randomly selected for participation. In cases where a village did not have enough eligible households to meet the sampling amount, we supplemented the sample by selecting households from an adjacent village with similar characteristics.

Detailed data was collected on food consumption for each household member, farming structure, backyard gardening, market access for agricultural products, internet connectivity, and demographic characteristics. We adopted the 24-hour recall method to record all food items listed in the China Food Composition Table (CFCT) 2009 (approximately 1,500 items) consumed by household members. This data included the name of the food, food code (as shown in CFCT 2009), ingredients, weight, cooking methods, and time of consumption (breakfast, lunch, dinner, and other snacks time). The food consumption data was first captured at the individual level to enhance precision, and then to aggregated at the household level; as meals are typically shared within rural households, we do not expect significant differences between individual- and household-level dietary diversity.

In total, we gathered data from 39 villages in Hebei province, totaling 723 observations. After excluding questionnaires with incomplete information, we retained 696 observations for analysis.

Analytical model:

The impact of e-commerce channel on dietary pattern can be modeled as the ordinary least squares (OSL) follows:

$$Y_i = \beta_0 + \beta_1 E\text{-}commerce_i + \beta_2 X_{ij} + \varepsilon_{ij} \quad (1)$$

In the evaluation of the impacts of e-commerce (online food shopping) on rural household dietary patterns, several potential endogeneity issues may arise. Unobserved heterogeneity in particular can lead to biased estimates when the coefficients of interest are estimated with OLS. This refers to unmeasured household-specific factors, such as health consciousness, dietary preferences, or socio-cultural practices, that may influence both the likelihood of engaging in online food shopping and dietary outcomes To address this challenge, we employ the two-stage least squares (2SLS) model as follow:

$$E\text{-}commerce_i = \delta_0 + \delta_1 Z_i + \delta_2 X_{ij} + \varepsilon_{ij} \quad (2)$$

$$Y_i = \sigma_0 + \sigma_1 \widehat{E - commerce_i} + \sigma_2 X_{ij} + \varepsilon_{ij} \quad (3)$$

Two exogenous variables were used as instrumental variables (IV) to estimate the effect of online shopping on dietary patterns while addressing endogeneity.

Result

The results of the statistical analysis indicate that online food shopping has a positive impact on the dietary patterns of rural households, as measured by both CFPS and diet diversity indicators. These findings are consistent with the broader literature on e-commerce's role in improving food consumption patterns, with notable contributions emerging in the post-COVID-19 period.

When comparing our results to the latest findings from Shen et al. (2023), we observe that the positive effects of e-commerce are evident in both studies. Shen et al. (2023) reported CFPS coefficients of 0.017* (OLS) and 0.043*** (2SLS) and diet diversity coefficients of 0.124*** (OLS) and 0.042 (2SLS), whereas our study shows significantly higher coefficients, reflecting a stronger impact of e-commerce on dietary improvement. This increased effect may be attributed to the accelerated adoption of digital platforms during the pandemic, which enhanced rural households' access to online food shopping. Furthermore, heightened awareness of health and nutrition, driven by the pandemic's focus on disease prevention and the importance of balanced diets, may have contributed to the greater impact of online food shopping on dietary patterns post-pandemic.

Variables	CFPS		Diet Diversity	
	OLS	IV (LIML)	OLS	IV (LIML)
online food shopping	.1626***	.8673*	.5504***	3.1776***
	(0.005)	(0.070)	(0.000)	(0.006)

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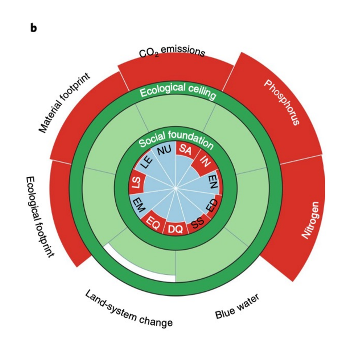
Agriculture Green Development: conceptual framework, assessment, historical trends, and development pathways

Yuan Feng

CAU Supervisors: Zhu, Qichao, PhD; Hou, Yong, PhD; Zhang, Fusuo, PhD

WUR Supervisors: Hans-Peter Weikard, PhD; Xueqin Zhu, PhD

Background



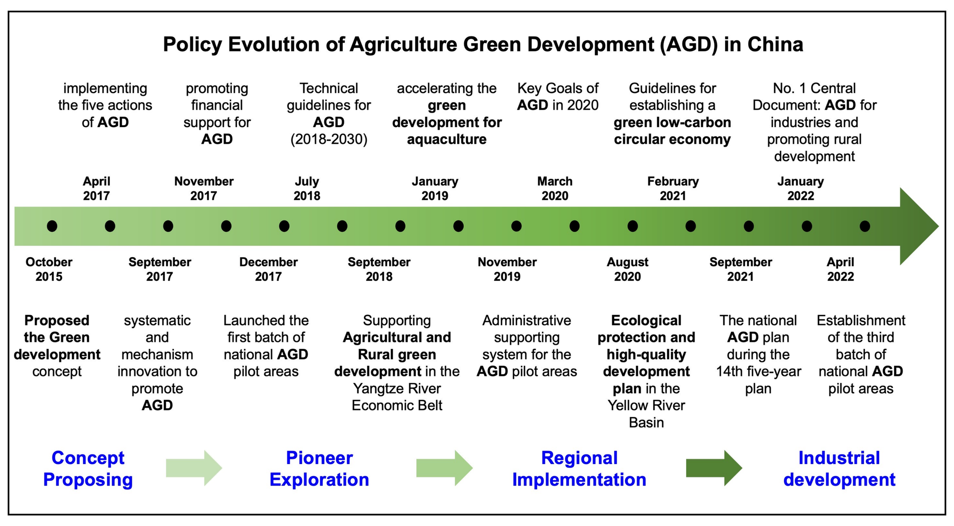
Global performance relative to the biophysical boundaries and social thresholds (2015)
(Fanning et al. Nature sustainability, 2021)

Global sustainability is facing a double burden of social wellness and environmental pollution. Agriculture is essential to many social goals and environmental boundaries such as Nitrogen, Phosphorus, Carbon, and Ecological footprint.

China's performance on SDGs

Sachs et al., SDG Index and Dashboards Reports, 2021

China's overall performance on UN SDGs increased over time. However, neither the SDGs nor agricultural sustainability have developed synergetically – that the socio-economic development is not aligned with environmental development.



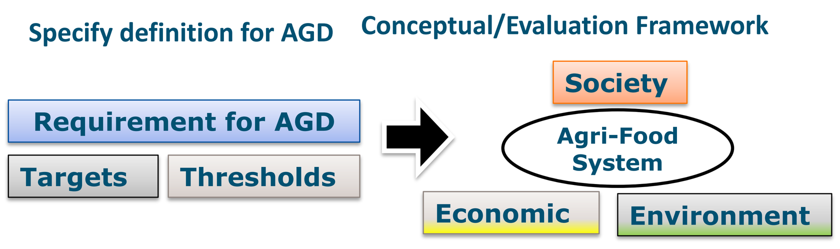
Zhang and Feng et al., FASE, 2023

In 2016, the Chinese government promoted Agriculture Green Development (AGD) as a national strategy for agriculture, aiming to increase resource use efficiency, decrease agricultural non-point source pollutants, and encourage rural revitalization.

Objectives: This project focus on two perspectives: AGD theoretical exploration and economic case studies

Part 1: AGD Theoretical exploration

Objective 1: Define AGD theory with framework, indicators, thresholds, and critical loads



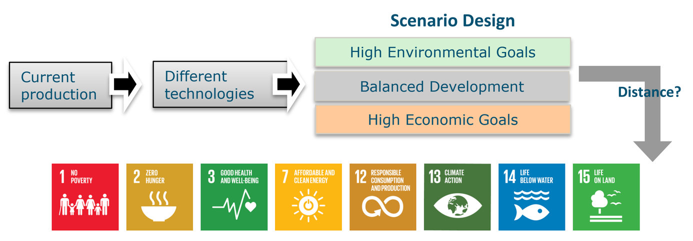
To establish a comprehensive evaluation framework for assessing China's agricultural transformation towards green development from 1990 to 2020. It draws on concepts from planetary boundaries and integrates social indicators to construct a national-level assessment tool to identify sustainability gaps compared to global benchmarks.

Objective 2: Quantitative AGD's contribution in global sustainability and explore pathways

To specify AGD needs by clustering and comparison to similar agricultural countries. To evaluate AGD's contribution to UN SDGs. This chapter relates SDG goals (specified in a total of 169 targets) to the impacts of AGD. Specific attention is given to synergies and trade-offs.

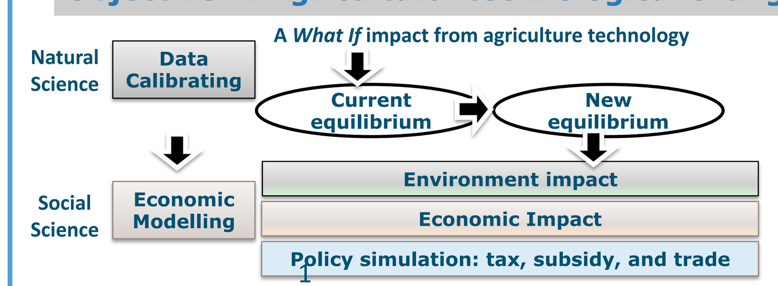
Part 2: Economic case studies for Agriculture Green Development

Objective 3: optimal control for raising fertilizer technologies application at the provincial scale in China



Assess China's fertilizer pathways towards achieving Sustainable Development Goals (SDGs) using optimal control theory and the Net Present Value (NPV) framework. By setting key temporal milestones, this analysis explores economic and environmental trade-offs of different technological pathways. The study aims to identify strategies that align with both SDG food production and environmental goals.

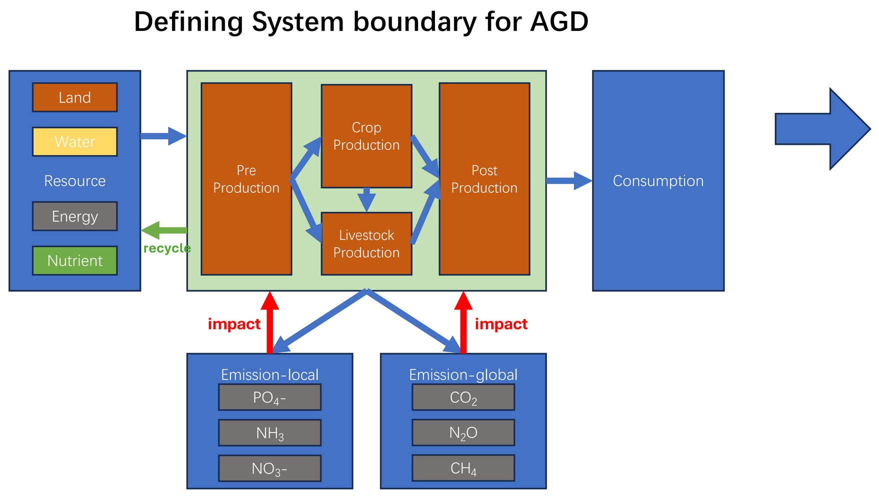
Objective 4: Agricultural technological change: market and policy analysis, taking fertilizer as an example



Quantitatively assessing the impacts of improvements through green agricultural technology, such as fertilizer inhibitors, on China's agricultural sector using an applied general equilibrium model. The goal is to simulate the economic and environmental outcomes of widespread inhibitor application, offering insights for policy and technology adoption.

Methodology– Part 1

Defining System boundary for AGD



Classification of agriculture in different countries through evaluation of indicators

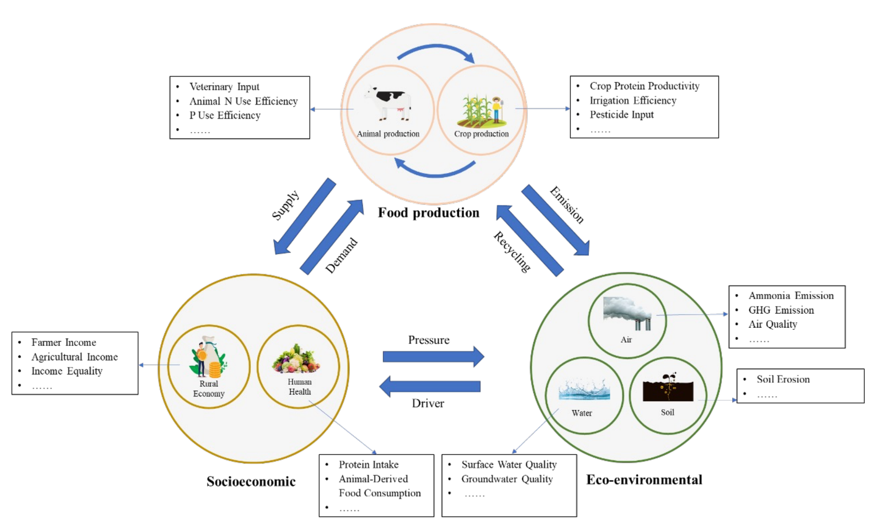
Human-land relations
(Cultivated land area per capita)

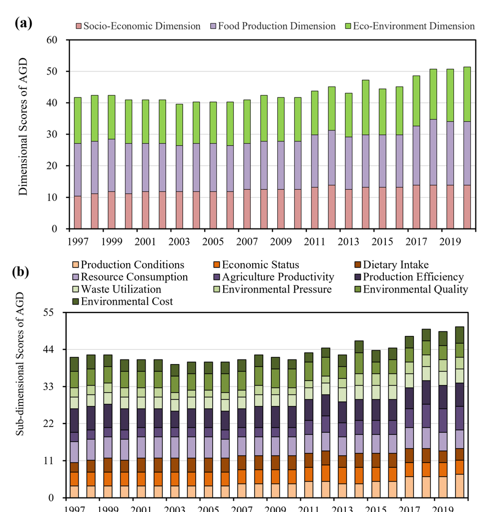
Industrial structure
(value of agricultural products produced)

Food trade
(Importers and exporters)

Climate change
(emitters vs. victims)

Preliminary results – Part 1





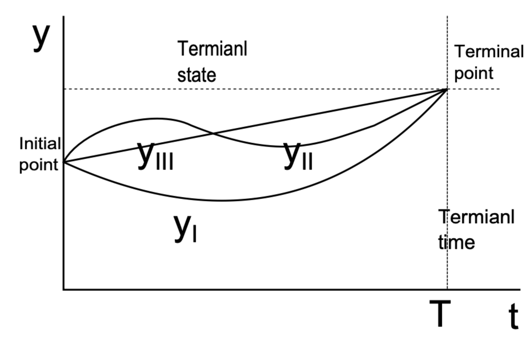
We first conceptualized a flow framework that depicts the relationship of our agri-food system with food production, socio-economic outcome, and environmental impact.

Indicator evaluation: A **target-threshold** indicator evaluation system is proposed to measure China's agriculture transformation, for the areas of: **Social**: agri-food system's impact on human society, such as income, nutrition, health, etc.; **Environmental**: environmental impact from food production, especially land, air, and soil related indicators; **Food production**: key productivity indicators along the agriculture industry chain.

Results:

1. China is currently at a medium level in the Agriculture Green Development initiative
2. There was a trend for increasing development scores for 2010-2020 compared to 1997-2010
3. Trade-offs between eco-environmental factors and socioeconomic/food production factors were found to be the major barriers to the transformation
4. More effort is needed to address the insufficient and uneven development to provide coordinated improvement

Methodology– Part 2.1



Initial and terminal points.
Describing the paths: location $(t, y(t))$ and direction $(y'(t))$
[Arc] values: $F[t, y(t), y'(t)]$
Path values: $V[t, y(t), y'(t)] = \int_0^T F[t, y(t), y'(t)]dt$
The fundamental problem:

$$\max_y V[y] = \int_0^T F[t, y(t), y'(t)]dt$$

s.t. Boundary conditions

Methodology: Cost-benefit analysis, optimal control

Fertilizer technology: literature review to determine impacts and coefficients of fertilizer technology, for example:

Urease Inhibitor (UI) and Nitrification Inhibitor (NI)

UI:	↑ yield	↓NH3	
NI:	↗ yield	↓NO3	↑ N2O

Costs/Benefits:
Economic: Yield changes, fertilizer inputs
Environmental: social cost of nitrogen, social cost of carbon
Social: Human health (cost of nitrate water treatment)

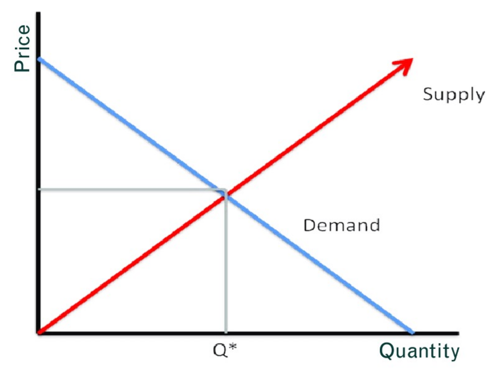
Optimal Control: $\text{Maximize } J = \int_0^T [pY(t) - cF(t) - hS(t)]\, e^{-rt} dt$

Determine the optimal fertilizer technology input F(t) over time t (years) to maximize NPV, taking into account discounting, economic impacts, and environmental impacts.

Objective: Identify the type of technology that provides the best total return to the crop, based on different social costs.

Methodology– Part 2.2

General Equilibrium Theories



General equilibrium theory attempts to explain supply, demand, and prices in a whole economy with several or many interacting markets, aiming for an overall state where supply equals demand in all markets simultaneously

Welfare Maximization and Applied General Equilibrium modelling

$$\text{Social Welfare W} = \max \textstyle\sum_i \alpha_i \log U_i$$

$$Y_{i,j} = A_{i,j}EM_{i,j}\left[\begin{matrix}(CAP_{i,j})^{\eta_{1i,j}}(LAB_{i,j})^{\eta_{2i,j}}(LAD_{i,j})^{\eta_{3i,j}}(NFE_{i,j})^{\eta_{4i,j}}(PFE_{i,j})^{\eta_{5i,j}}(NewFertilizer_{i,j})^{\eta_{6i,j}}\\(RICE_{i,j})^{\eta_{7i,j}}(MAIZE_{i,j})^{\eta_{8i,j}}(WHEAT_{i,j})^{\eta_{9i,j}}(VF_{i,j})^{\eta_{9i,j}}\end{matrix}\right]^{1-\xi_{i,j}}$$

Welfare maximization in economics refers to the optimal allocation of resources to maximize the overall well-being or utility of society, ensuring that the sum of individual utilities is as high as possible.

In this case, the model maximizes social welfare where the production function focuses on Chinese agricultural-related goods.

Acknowledgements

We gratefully acknowledge the sponsors of this research: China Scholarship Council (NO.201913043).

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Assessment System and Pathway Analysis for the Sustainability of Agricultural Food Systems Based on Sustainable Development Goals in China

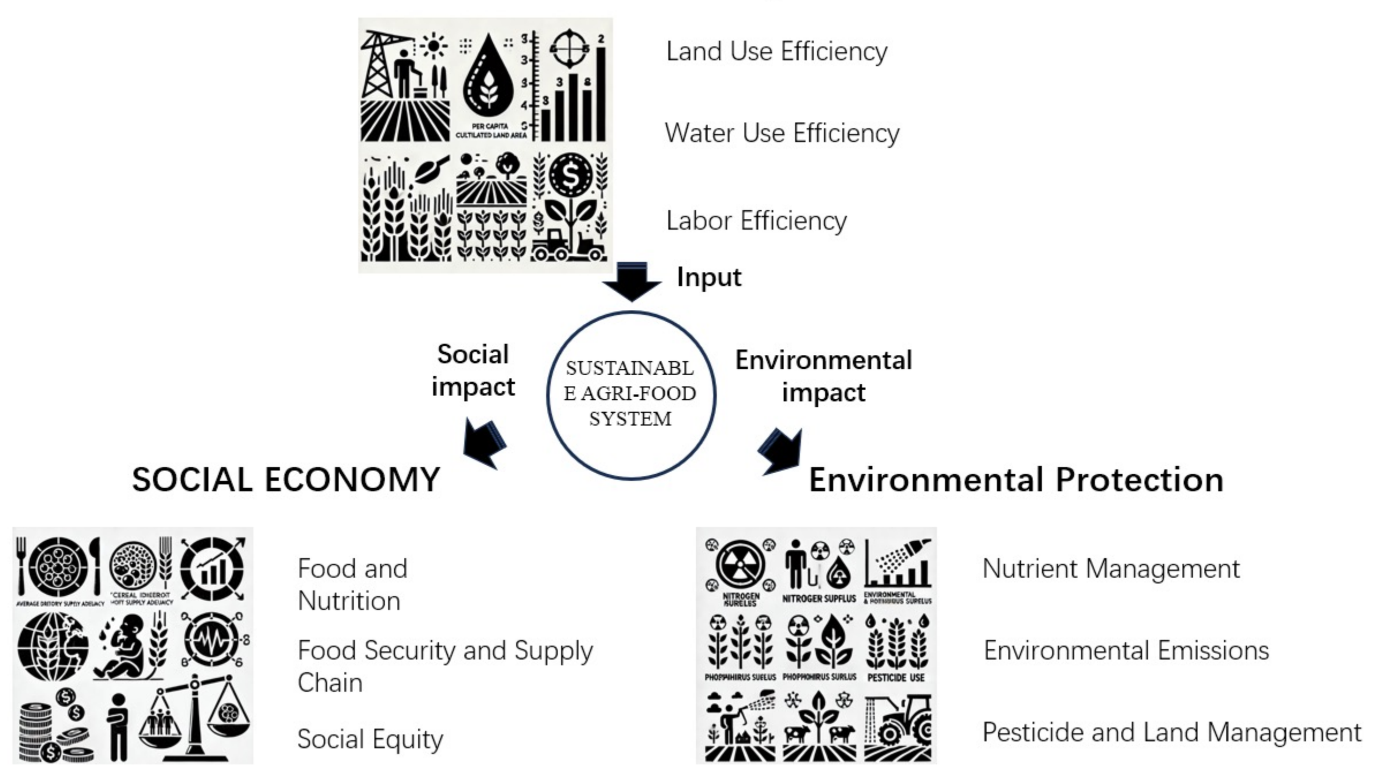
PhD candidate: Haixing Zhang

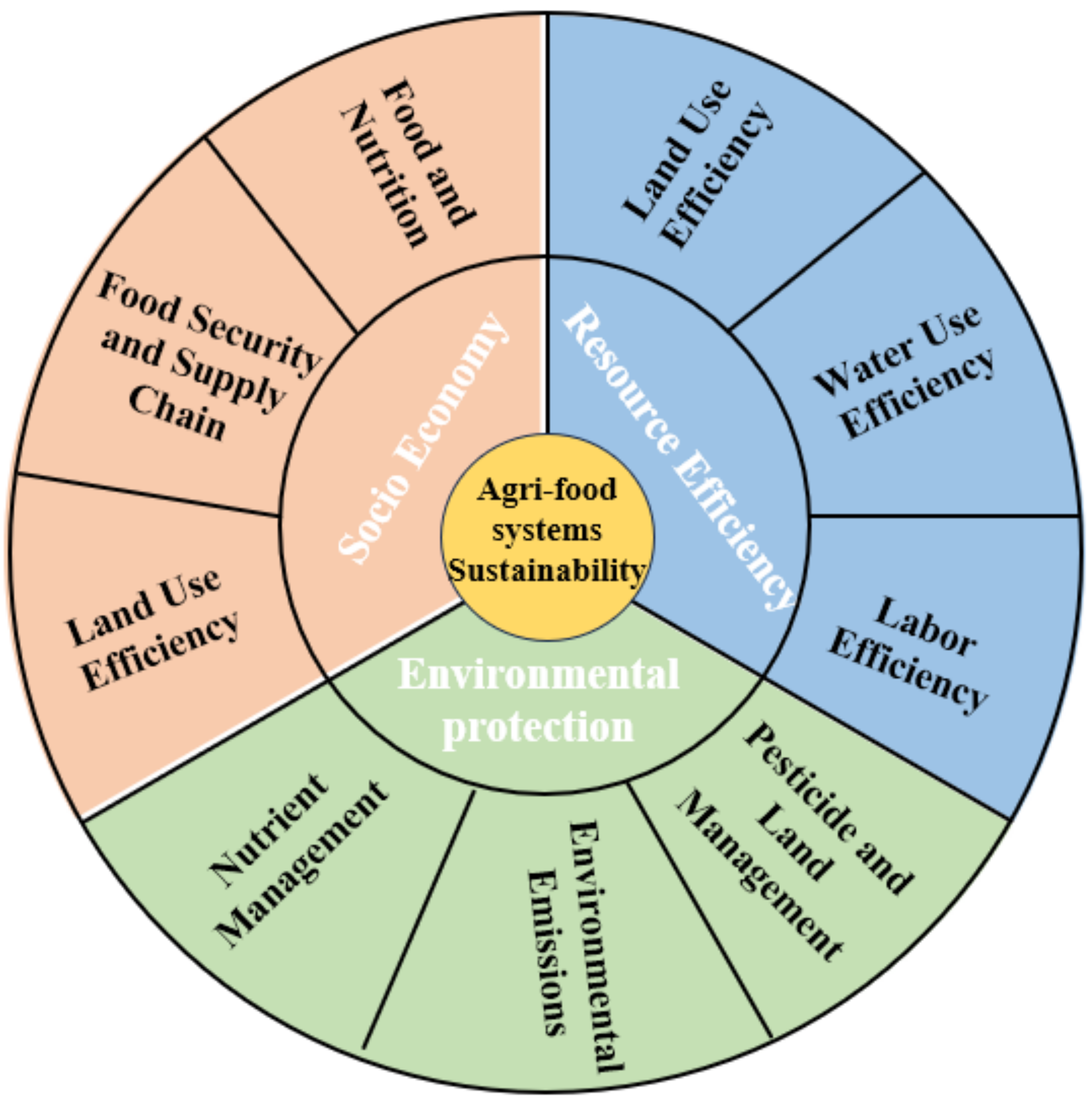
Supervisors: Qichao Zhu, Yong Hou, Fusuo Zhang, Xueqin Zhu , Hans-Peter Weikard

Background

- Agri-food systems, key to the global food supply, face major sustainability challenges such as resource overuse, climate impacts, and social and economic inequalities. Issues like land erosion, water scarcity, and extreme weather directly threaten agricultural production, while global disparities in resource distribution further weaken sustainability.
- This study develops a sustainability evaluation system for Agri-food systems based on the SDGs to assess their sustainability. This is crucial for improving system resilience, reducing environmental emissions, and achieving sustainable development.

System framework and the indicator system





- A sustainable Agri-food system balances Resource efficiency, socio-economy, and environmental protection. Efficient use of land, water, and labor enhances productivity while minimizing waste. A stable socio-economic structure ensures food security, equitable distribution, and a resilient supply chain. Meanwhile, environmental protection reduces emissions, manages nutrients, and preserves ecosystems. These three pillars interact to create a resilient, sustainable, and future-proof agri-food system.

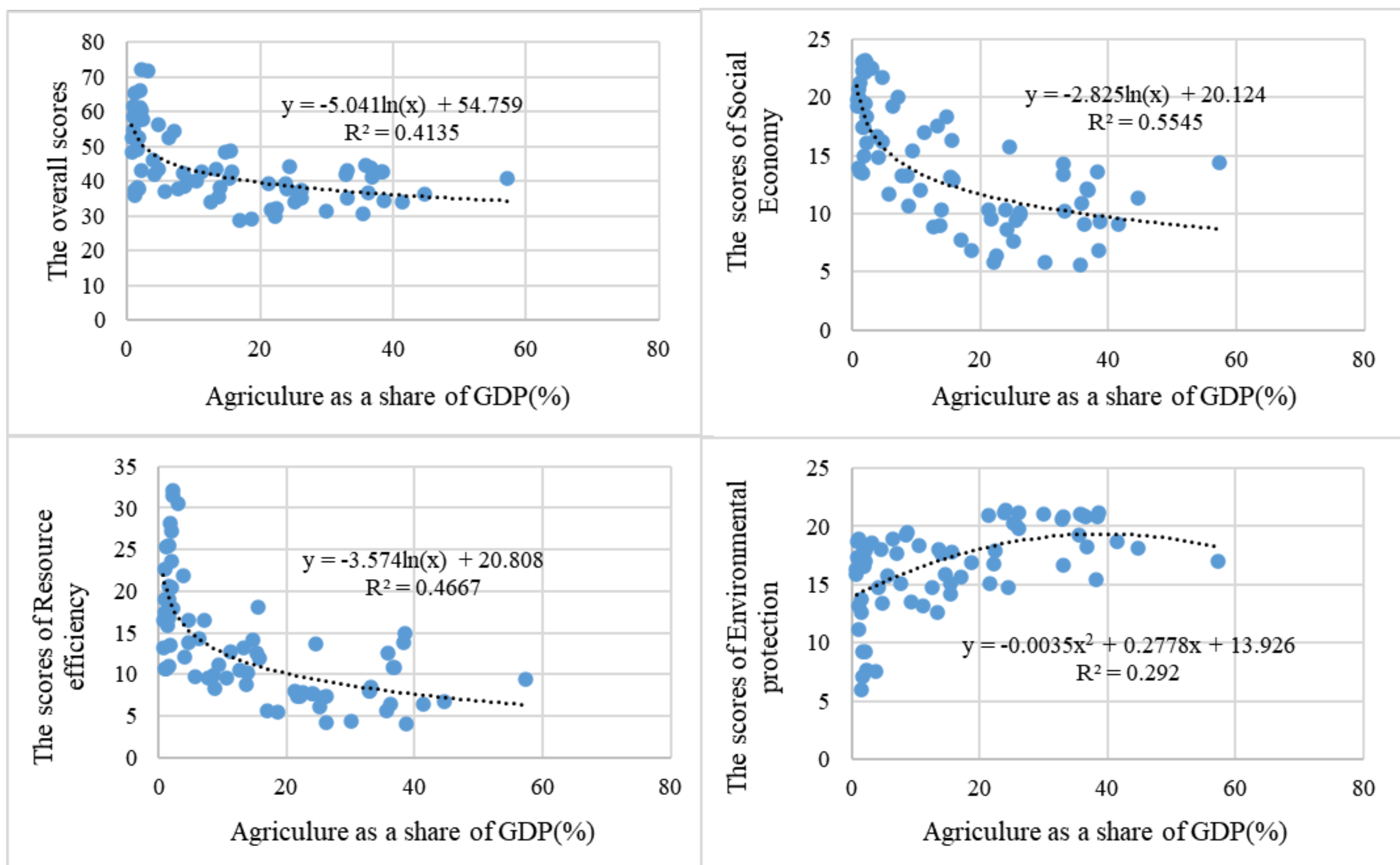
Mainly analysis methods

- Target value method
- Coupling coordination degree model
- Spearman correlation coefficient analysis
- Network analysis

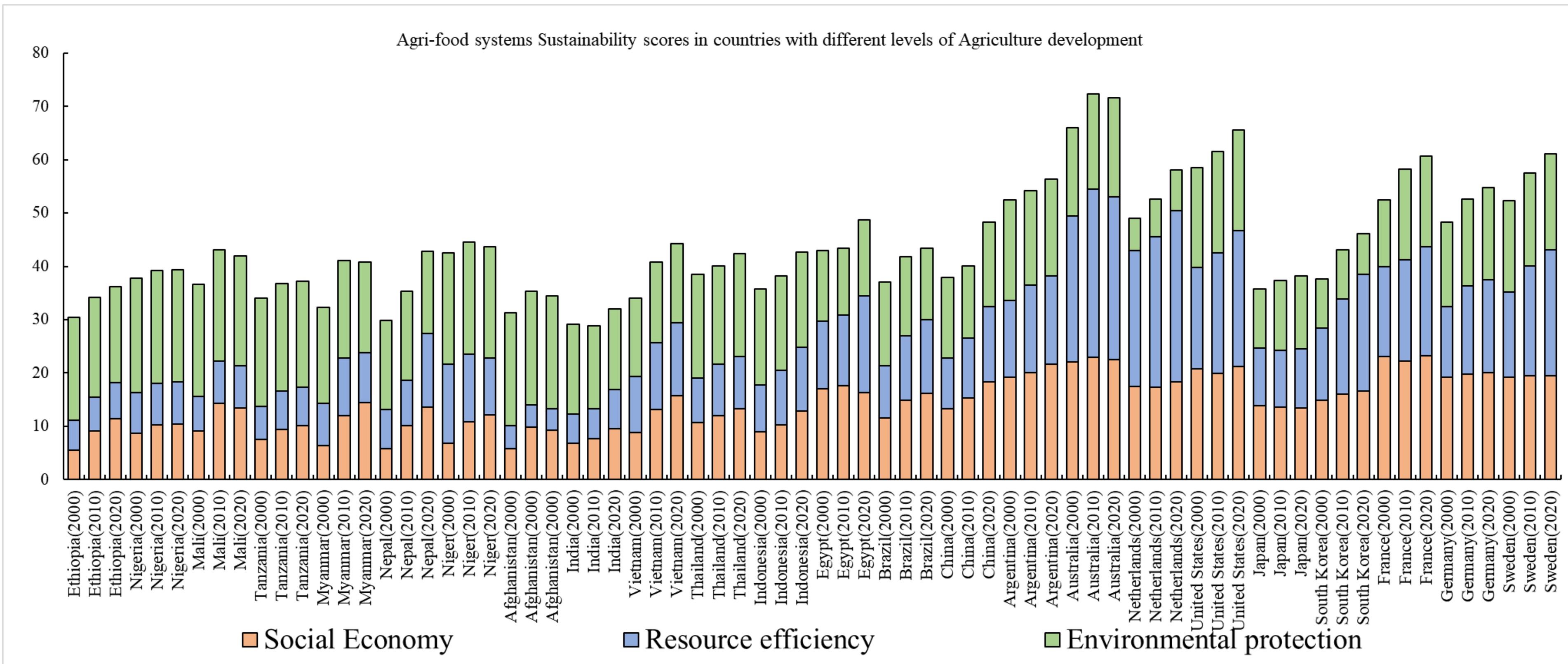
Acknowledgements

We gratefully acknowlege the sponsors of this research:China Scholarship Council (NO.201913043) and Hainan University.

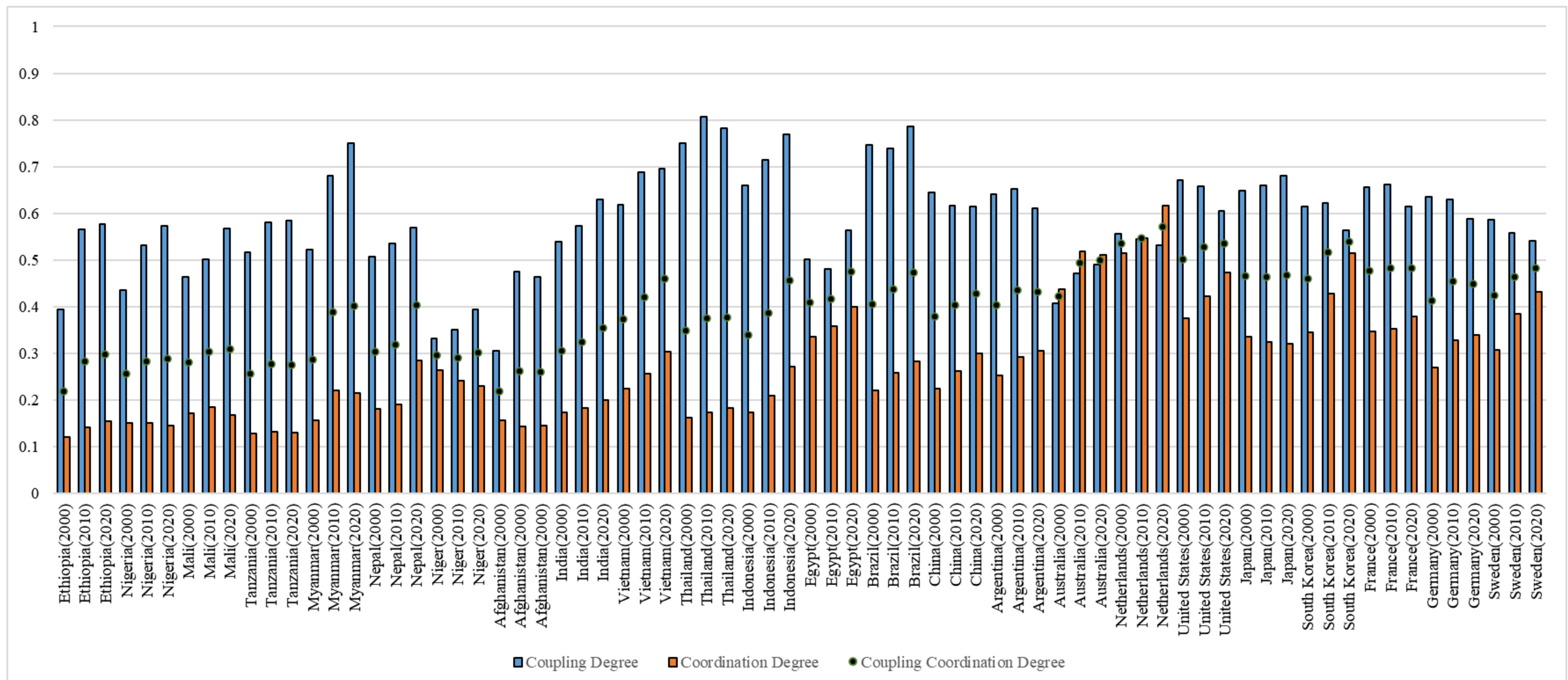
Results



The relationship of the sustainable scores and Agriculture as a share of GDP



Agri-food systems Sustainability scores in countries with different levels of Agriculture development



The Coupling Coordination Degree between three deminations

- The first chart shows that as agriculture's share of GDP increases, most scores (overall, social economy, and resource efficiency) tend to decrease, with moderate to weak correlations. However, environmental protection scores show a slight increase, though the relationship is weak and non-linear. In general, higher agricultural GDP share is associated with lower performance scores.
- This second chart shows the sustainability scores of agri-food systems in various countries, categorized into Social Economy, Resource Efficiency, and Environmental Protection. The countries are shown for three years, 2000 and 2020. Higher agricultural development countries, like the Netherlands and the United States, have higher scores, while countries with lower agricultural development, like Ethiopia and Afghanistan, have lower scores. Some countries show improvement from 2000 to 2020, especially in resource efficiency and environmental protection.
- This third chart shows the coupling degree, coordination degree, and coupling coordination degree for countries in 2000,2010 and 2020. Generally, countries like the Netherlands, the United States, and Sweden have higher values for all three measures, indicating stronger interactions and synchronization between systems. In contrast, less developed countries show lower values.

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Combining daily rumination time and milk yield for selecting more resilient dairy cows

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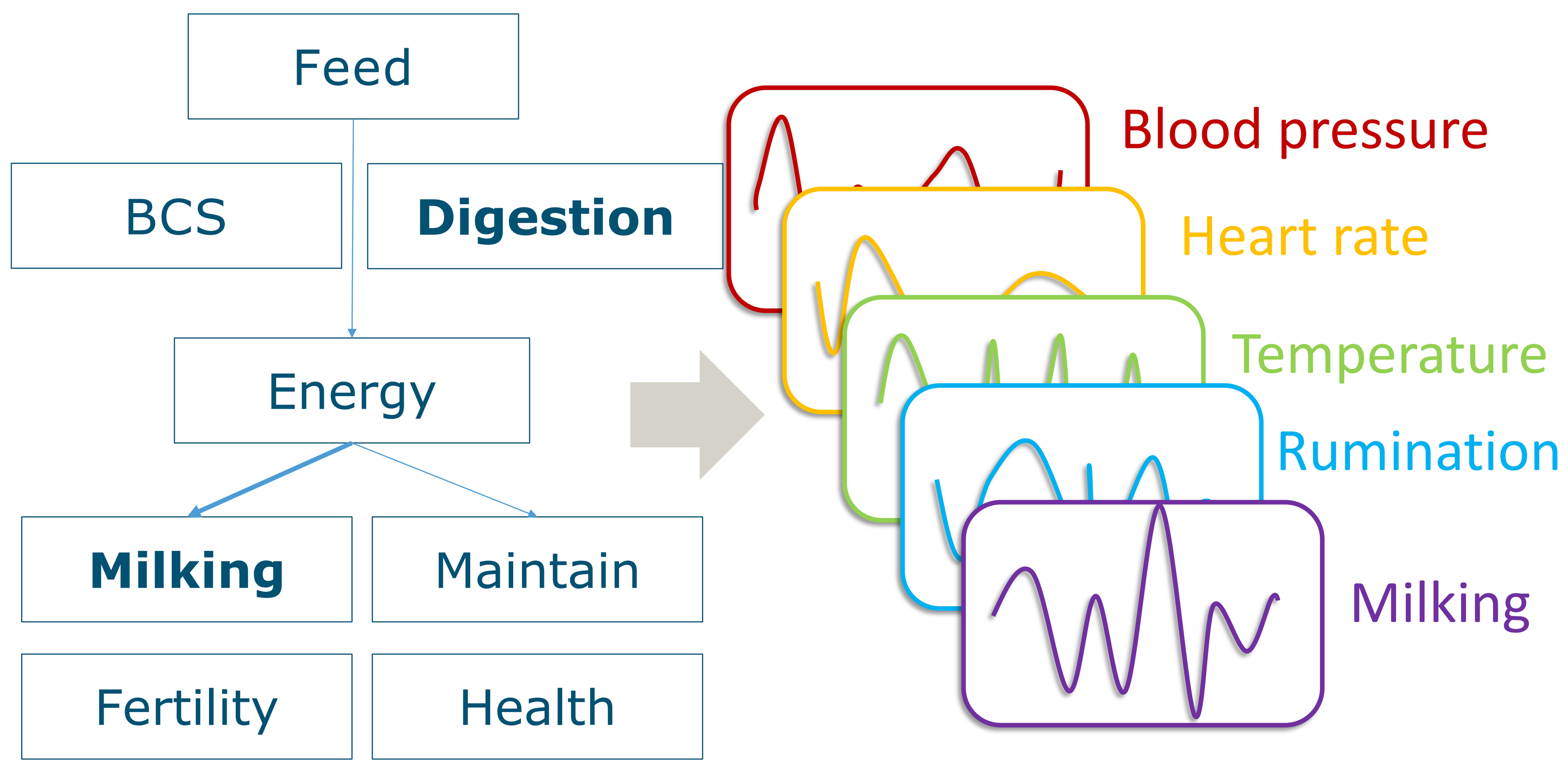
Background

- ➢ Resilience depends on subsystems in the body
- ➢ More information is better to be use



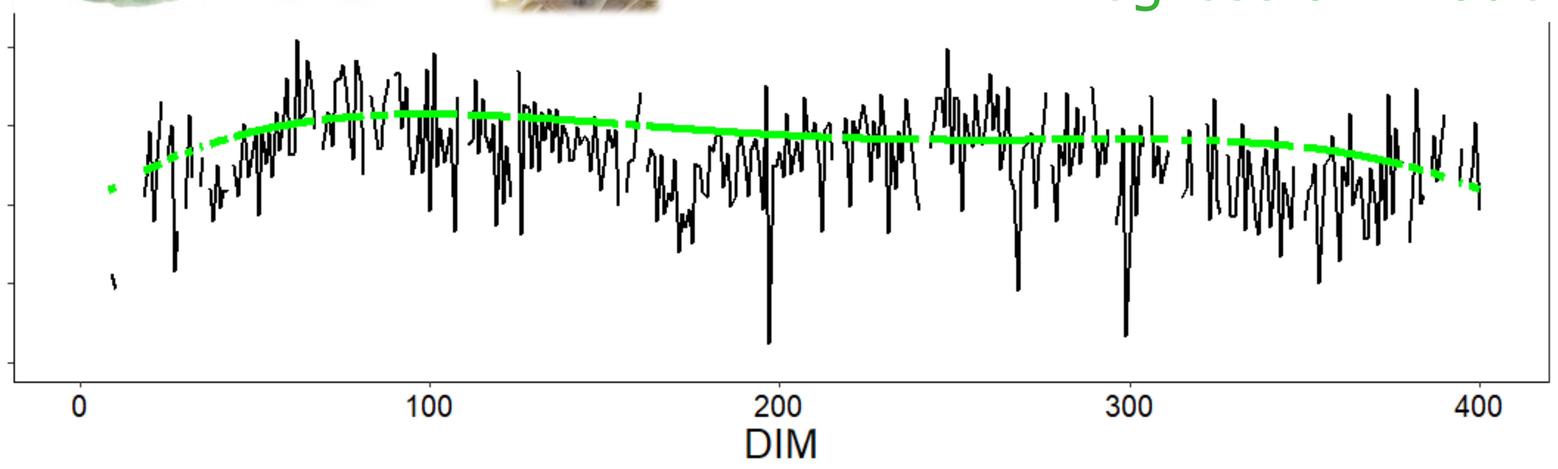
Objective

What is the selective effect for resilient cows with considering more information in breeding

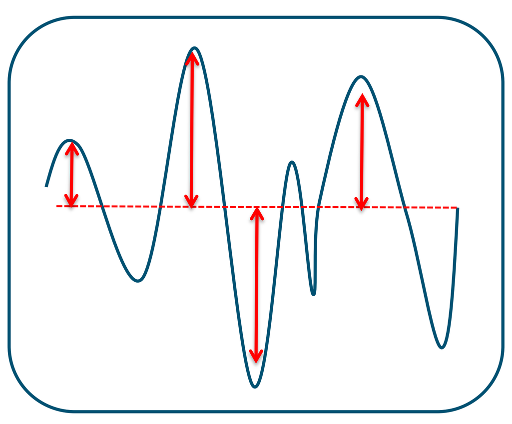
Methods

- Calculate undisturbed daily rumination time (DRT) and milk yield (DMY) in Holstein cows

Undisturbed DRT and DMY calculated from quantile regression model



- Define resilience indicators



- ✓ Variance of deviations (LnVar)
- ✓ Autocorrelation of deviations (Lag-1 Autocorr)
- ✓ Resilience: low LnVar and autocorr

- Genetic analysis
  - Univariate repeatability animal model
  - Uni- and bivariate animal models
  - Comparing four levels of resilience cows

Contact: (wenqi.lou@wur.nl)

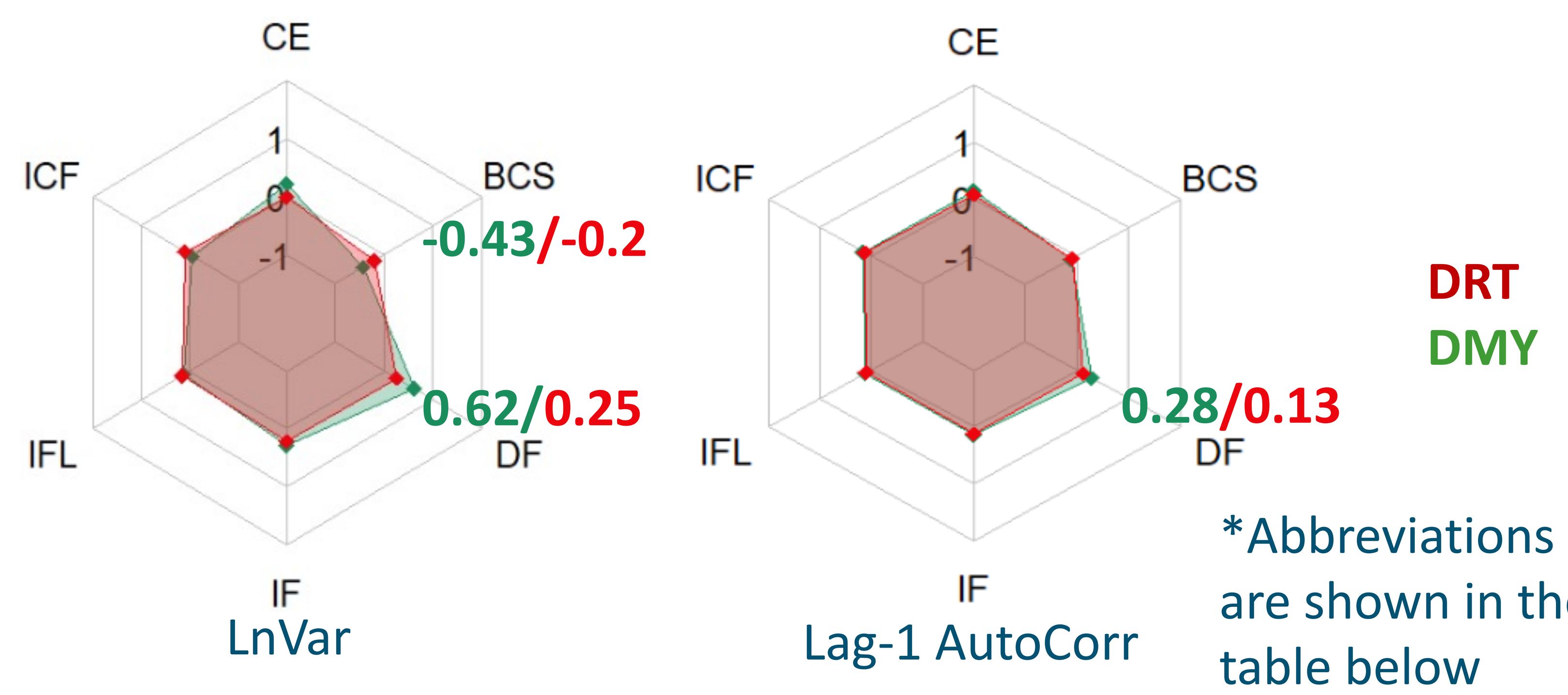
Conclusions

- DRT and DMY are difference in their phenotype and resilience indictors
- Combining DRT and DMY would be beneficial for selecting more resilient individuals

Results

1. Genetic parameters
   - ✓ Moderate heritability of LnVar and Autocorr
   - ✓ Stronger genetic relationship between DMY and other traits than that of DRT

Traits	Indicator	Heritability (SE)
DRT	LnVar	0.14±0.02
	Lag-1 Autocorr	0.07±0.01
DMY	LnVar	0.32±0.03
	Lag-1 Autocorr	0.10±0.02



*Abbreviations are shown in the table below

2. Selective effect in breeding for resilience
   - ✓ LL (stable DRT and DMY) is better than others

Traits	LL	LH	HL	HH
Calving easy (CE=1), %	87%^{a}	85%^{ab}	84%^{ab}	81%^{b}
Insemination frequency (IF=1), %	53%^{a}	44%^{b}	45%^{bc}	40%^{c}
Disease frequency (DF=0), %	76%^{a}	75%^{a}	62%^{b}	60%^{b}
Interval from calving to first insemination (ICF), d	30^{a}	40^{b}	40^{b}	48^{c}
Body condition score (BCS)	3.23^{a}	3.19^{b}	3.23^{a}	3.19^{b}

Acknowledgements

We gratefully acknowlege the sponsors of this research:China Scholarship Council (NO.201913043) and Hainan University.

A typology of farms and spatial patterns in the North China Plain to support crop-livestock integration

Yuhang Sun, Antonius G. T. Schut, Yong Hou, Martin K. van Ittersum

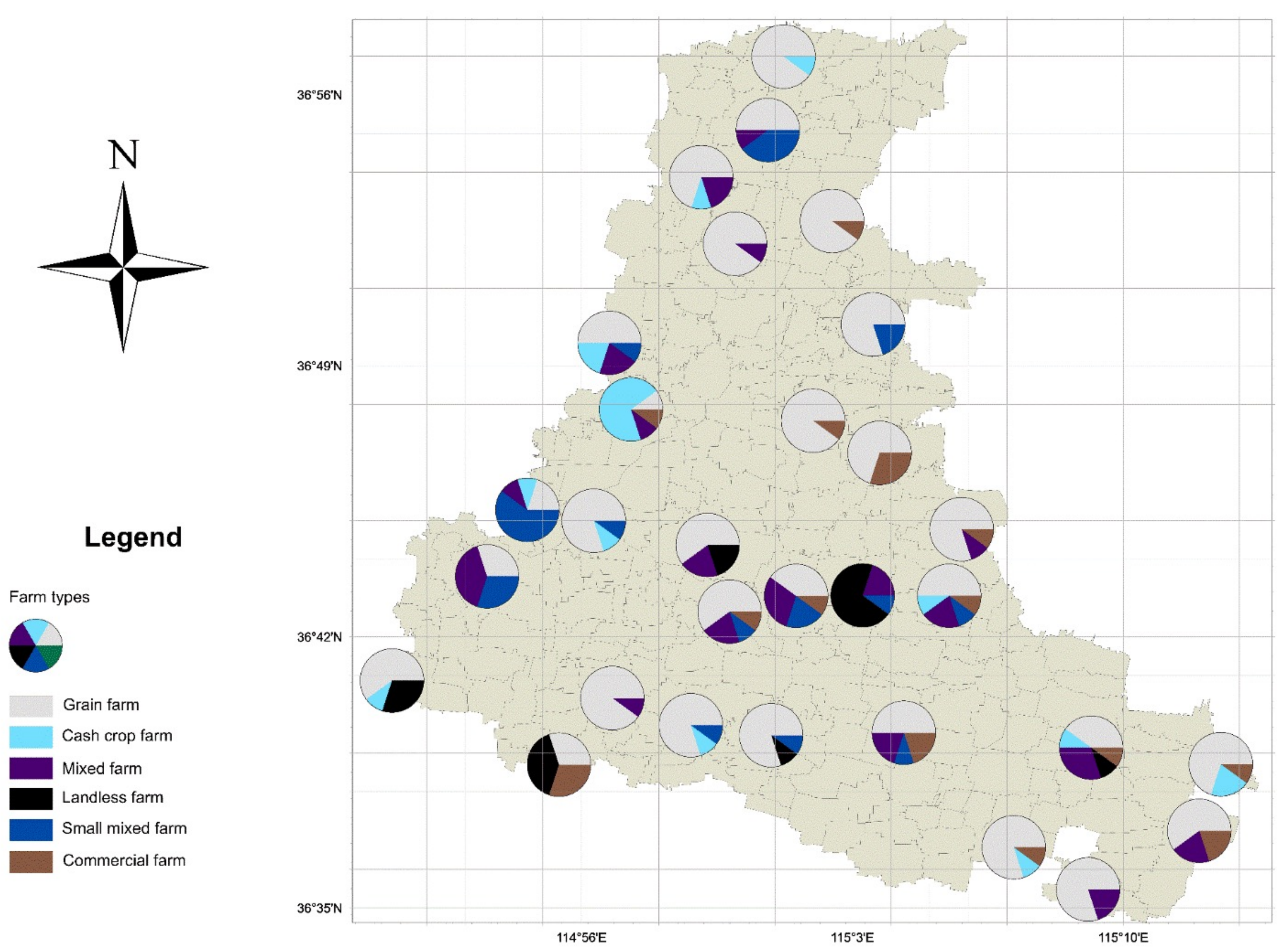
Backgroung

- In China, agriculture has intensified and specialised. In this process, crop and livestock production have been decoupled at household level. While the benefits of integrated crop-livestock systems (ICLS) have been widely discussed, their application remains limited.
- ICLS-studies predominantly focused on regions neglecting the farm level and also other stakeholders. They did not provide specific strategies tailored to particular regions. It is crucial to include the farm level, as key decision-making units, to understand drivers of specialisation in a regional analysis. There is a considerable heterogeneity across or within counties in terms of farm structure, management practices, farm assets, farm diversity and environmental characteristics. Quantifying the diversity of farming systems, their spatial distribution and farmers' characteristics is an essential step towards effective policies that enable ICLS.

Objectives

- Capture the diversity of farms by using farm-level data. We introduce a farm typology that is spatially explicit, data-driven, and oriented towards local farmers.
- Quantify regional farm diversity and map the distribution of identified farm types over the study area.
- Discuss how identifying farm types and their distribution may help to contextualize future ICLS designs to local conditions and how these findings can support agricultural transition policies in the North China Plain (NCP).

Key Results 1



- Grain farms were nearly evenly spread across the county and emerged as the dominant type in most surveyed villages, with proportions ranging from 0.3 to 1.0 (Figure 2). Cash crop farms were also evenly distributed but with much lower proportions, generally less than 0.2. Small mixed farms were concentrated in a few locations in the centre and north part of the county, with shares reaching up to 0.7. Landless farms featured mostly in the south in a few locations.
- The farm types were not evenly distributed across the region, indicating regional specialisation with a spatial decoupling of crop and livestock production.
- Using hierarchical cluster analysis, we identified six distinct farm types (Table 1) characterized by the degree of specialization, management, and farm size --- grain (66%), cash crop(2.7%), mixed (11%), commercial (7.3%), small mixed (8.3%), and landless farms (4.7%)
- Three features in these types were identified as being relevant in the context of ICLS, i.e. overuse of fertilizer, the decoupling of crop and livestock production and a strong dependence of specialized livestock farms on feed import (Table 2).

Conclusions

- Six major farm types featured in Quzhou county: grain, cash crop, mixed, commercial, small mixed, and landless farms. The farm types were not evenly distributed across the region, indicating regional specialisation with a spatial decoupling of crop and livestock production.
- Farm management strategies were suboptimal with an overuse of chemical fertilizer, a low proportion of recycled manure that is used on cropland, and a strong dependency of specialised livestock farms on feed imports.
- Our study suggests that in designing ICLS, having a balanced ratio of crop areas and livestock counts, as well as the number of crop and livestock farms and ensuring their even spatial distribution within the region are essential to efficiently recycle nutrients and enhance regional agricultural circularity.
- Driven by the Chinese dietary shift towards more animal-based products, the number and scale of livestock farms will likely increase. To minimize disruptions of circularity, the location of livestock farms matters as the capacity of surrounding croplands to produce feed and utilize manure is critical.
- We conclude that new guiding policies are needed to coordinate specialisation and facilitate ICLS to ensure a proper animal-to-cropland ratio at local level. This study can further complement model-based explorations to design, incentivize and develop locally adapted ICLS.

Materials and methods

- The case study focused on Quzhou county, located in the central part of the North China Plain (Figure 1 a-b). To establish a representative sample of farms from Quzhou county, a random selection process was employed using ArcGIS 10.8.
- Three villages from each of the ten townships were randomly chosen (Figure 1 c). Within each selected village, ten farm households were randomly chosen for the survey. In total, there were 300 households surveyed.
- We first developed a farm typology, based on farm-structure related variables. In a second step, we incorporated new stratifying variables related to farming practices and socio-economic information to further refine and categorize the initial farm typology, providing a more comprehensive understanding of the identified farm types. Finally, we used ArcGIS10.8 to map the distribution of each types.

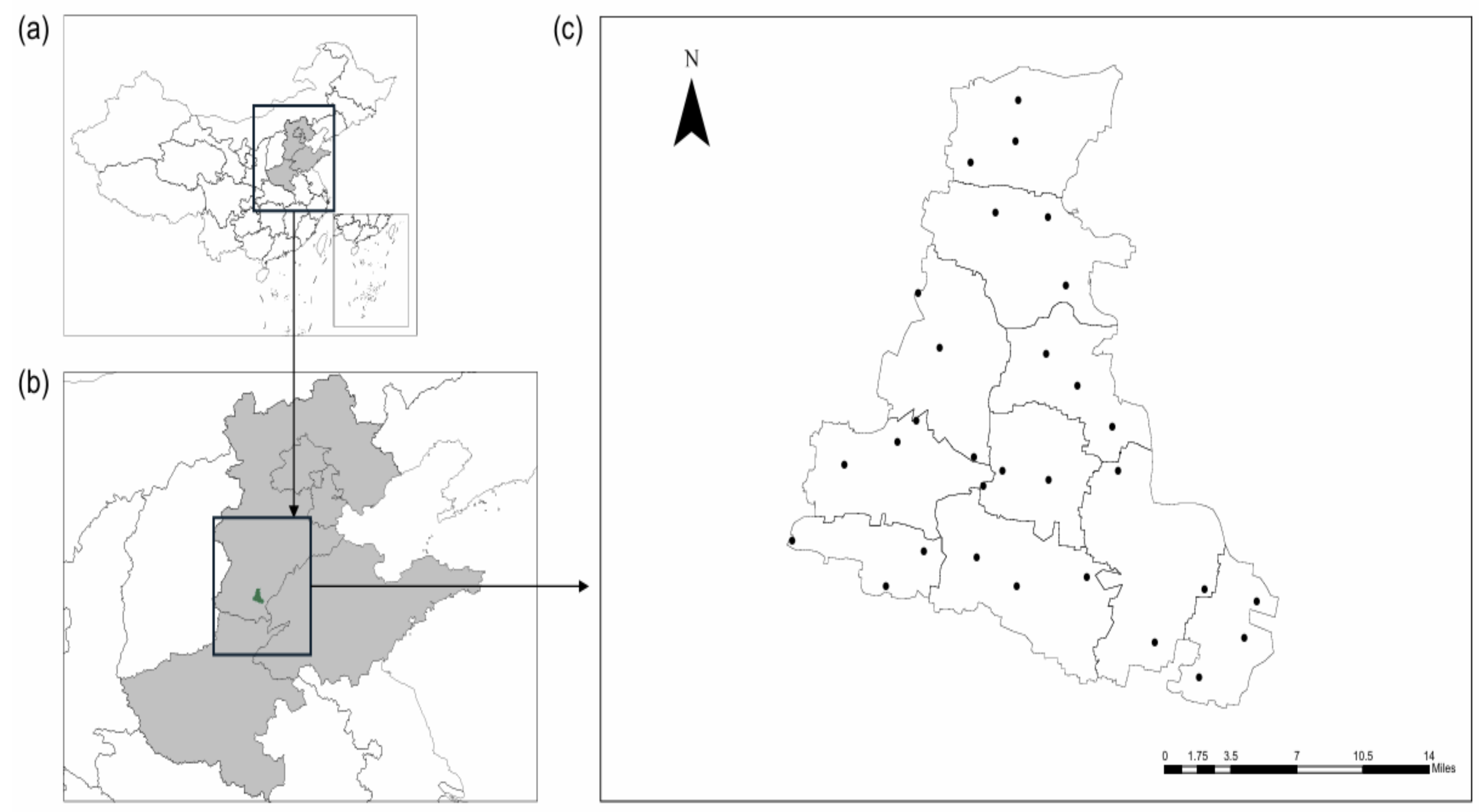


Fig.1 Geographic location of North China Plain (a), Quzhou county (b) and villages (c) randomly selected for farm survey.

Key results 2

Phosphorus	Farm type					
Farming practice variables	Grain (61%)	Cash crop (6.7%)	Mixed (11.3%)	Commercial(6.7%)	Small mixed (8.3%)	Landless (6%)
Mineral fertilizer management						
Mean P application (kg/ha/year)[1]	91.7^{b}	65.4^{a}	80.8^{ab}	69.8^{a}	80.5^{ab}	-
Feed management						
Mean P in purchased feed(kg/ha/year)[1]	-	-	1845^{b}	-	573.3^{a}	4881^{c}
Mean P in feed from neighbours (kg/ha/year)[1]	-	-	0	-	0	0
Manure management						
Mean organic fertilizer P on croplands (kg/ha/year)	45.7	46.2	11	35.2	137	-
Mean manure P production (kg/ha/year)	-	-	709	-	239.9	2059
Mean manure P export (kg/ha/year)	-	-	698	-	102.9	2059
Nitrogen	Farm type					
Farming practice variables	Grain	Cash crop	Mixed	Commercial	Small mixed	Landless
Mineral fertilizer management						
Mean N application (kg/ha/year)[1]	397.7^{b}	311^{a}	416^{b}	260^{a}	422^{b}	-
Feed management						
Mean N in purchased feed(kg/ha/year)[1]	-	-	13334^{b}	-	2498^{a}	30227^{c}
Mean N in feed from neighbours (kg/ha/year)[1]	-	-	0	-	0	0
Organic fertilizer management						
Mean organic fertilizer N on croplands(kg/ha/year)	126.5	150.4	59	120.4	97	-
Mean manure N production(kg/ha/year)	-	-	3501	-	1017	9226
Mean manure N export(kg/ha/year)	-	-	3442	-	920	9226

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Interventions to increase nitrogen circularity in food systems in the North China Plain

PhD candidate: Chuanlan Tang
Supervisors: P. J. Gerber, S. J. Oosting and O. van Hal (WUR-APS)，Y. Hou (CAU)

Background

- Chinese food systems need to enhance nitrogen (N) circularity urgently to mitigate the environmental and health impacts of N losses (Wang et al., 2020).
- While the principles of circular food systems have attracted interest, stakeholders lack strategic frameworks to guide the transition.
- Little research has been done to comprehensively assess the N circularity consequences of various strategies, especially the redesign of whole food system, using comprehensive indicators.

Research objectives

1. To explore how future regional circular food systems could be designed to meet local dietary requirements while minimizing domestic land use.
2. To examine N circularity trade-offs across various strategies scenarios

Material and methods

- Study area

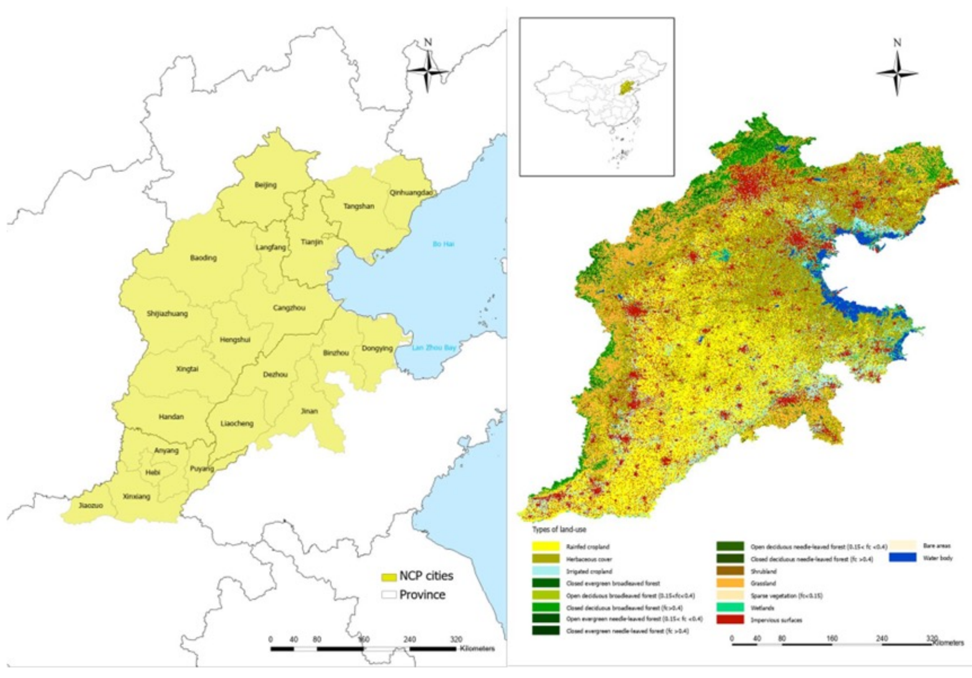


Figure 1. Geographical location and land use type of the North China Plain (NCP)

- Strategy framework

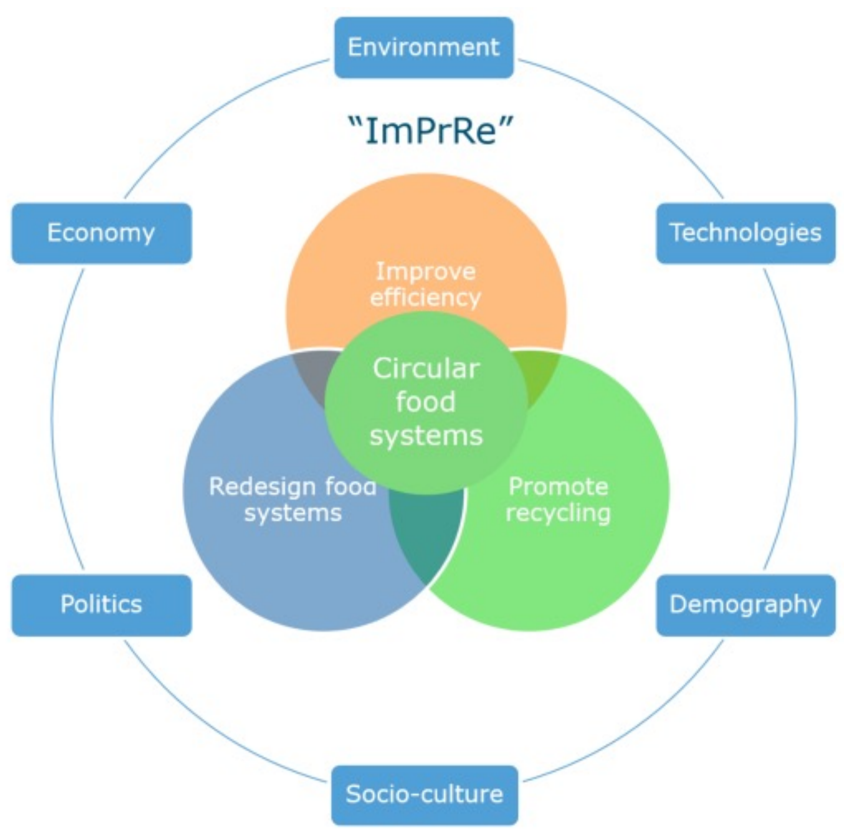


Figure 2. Proposed strategic framework of circular food systems

Scenarios

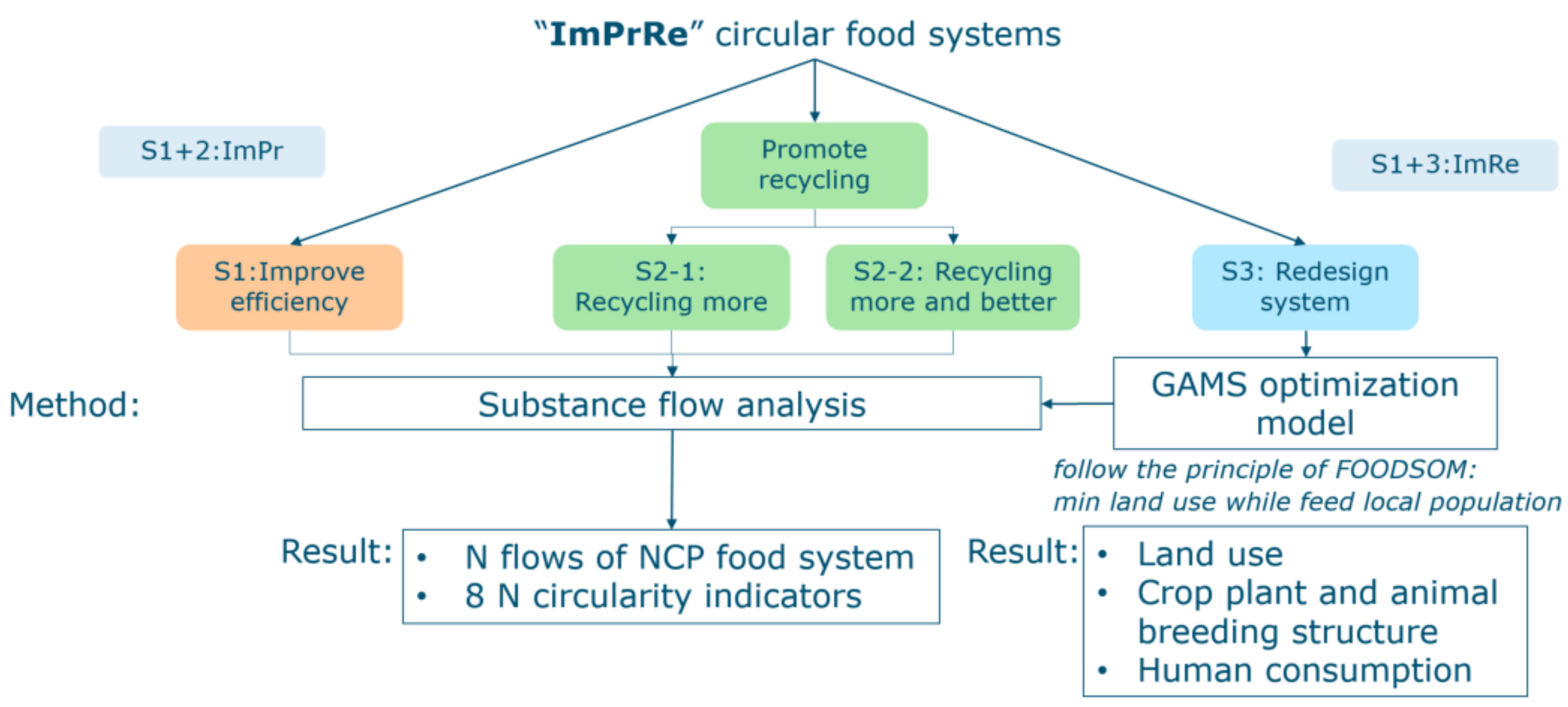
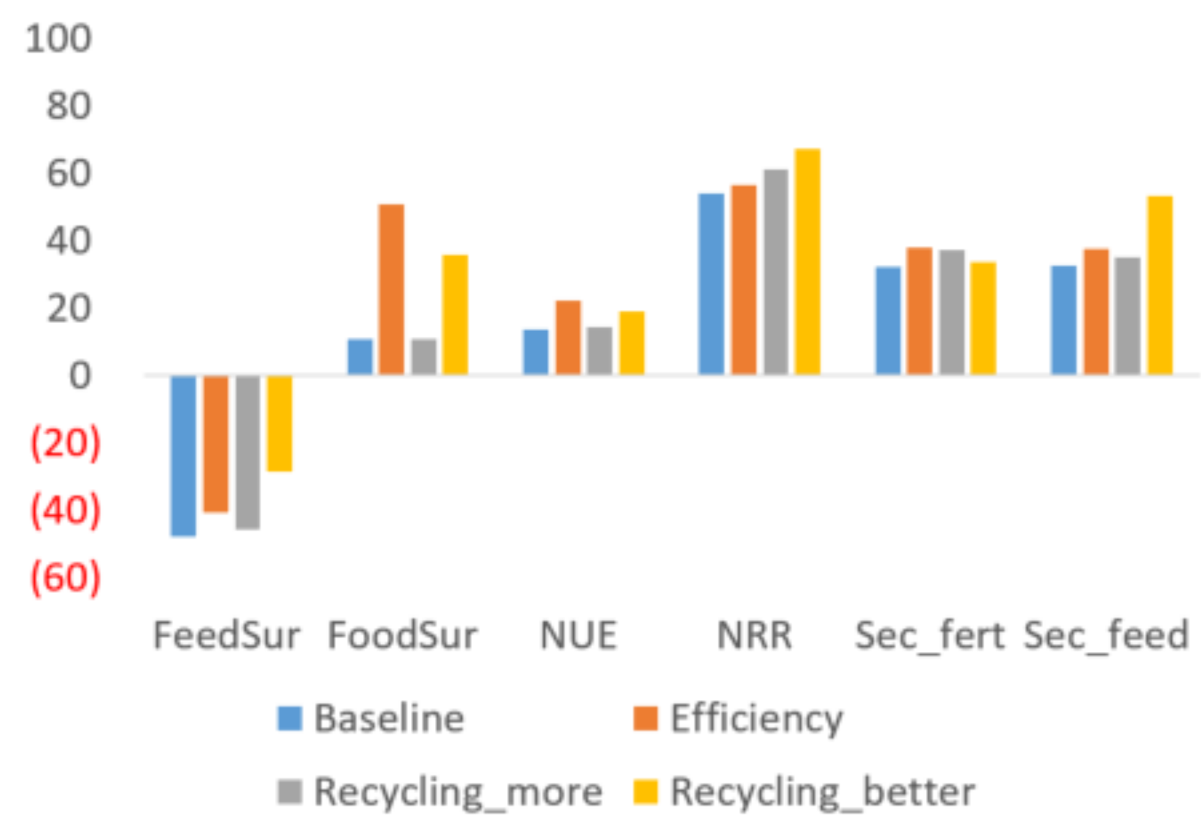


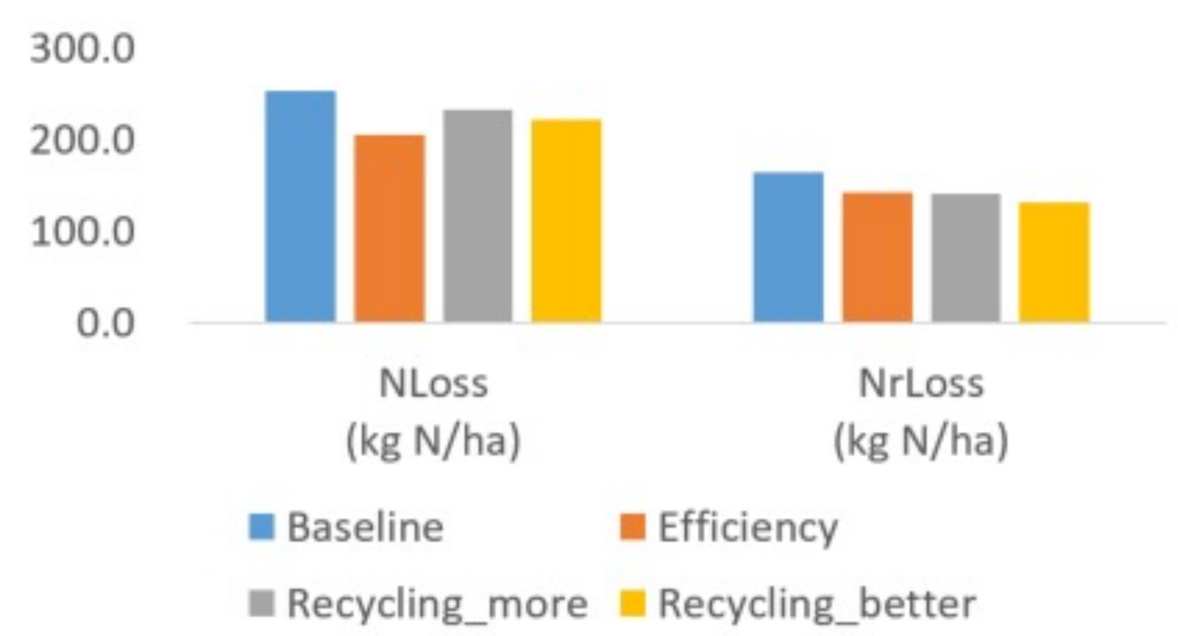
Figure 3. Scenarios and method

Preliminary results

- **N circularity performance in the NCP under some scenarios (%)**



- **N and Nr loss density in the NCP under scenarios (kg/ha)**



Potential conclusions

- "Recycling better " exhibited better circular performance than "recycling more"
- Improving efficiency, promoting better recycling and redesigning food systems simultaneously performed best N circularity performance in the NCP food systems

Reference

Wang, X., Bodirsky, B. L., Müller, C., Chen, K. Z., & Yuan, C. (2022). The triple benefits of slimming and greening the Chinese food system. Nature Food, 3(9), 686–693.

Acknowledgements

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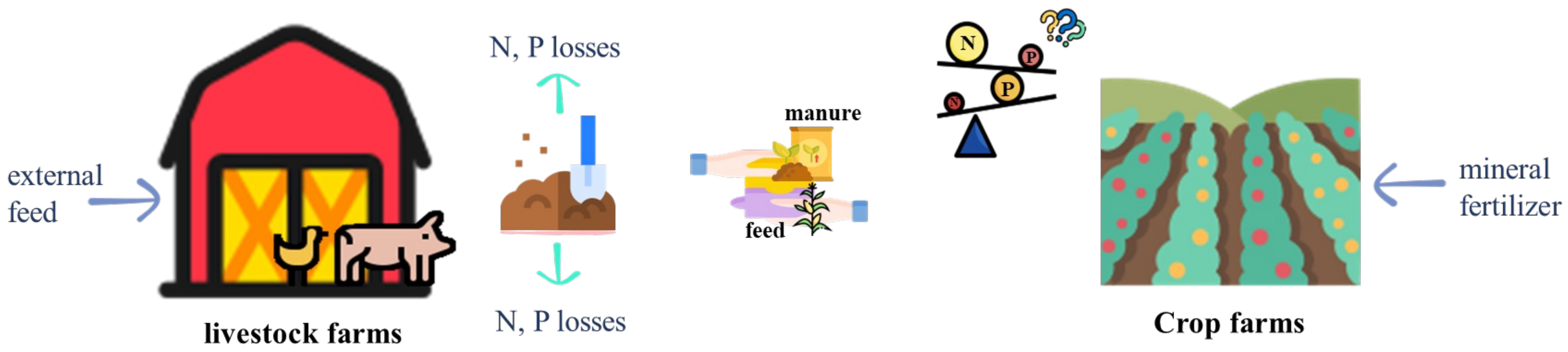
Mitigation of environment pollution by efficient recycling of nitrogen and phosphorus in regional integrated crop-livestock system

Xiaoying Zhang Supervisors: Y. Hou and HL. Wang (CAU)
M.K. van Ittersum and A.G.T. Schut (WUR-PPS)
P.J. Gerber and S.J. Oosting (WUR-APS)

Background

- The specialization of farming systems and limited cropland area increased nutrient losses to natural ecosystems. Design a new integrated crop-livestock system beyond farm (regional integrated crop-livestock system) level is needed.
- The integrated strategies of mitigation both nitrogen (N) and phosphorus (P) losses are needed to be developed in major agricultural production region.



Objectives

- The overall objective is to explore the integrated strategies on enhance N and P recycling efficiency and environmental reduction in regional integrated crop-livestock system.
  1) to quantify N and P flows and nutrient use efficiency on regional integrated crop-livestock system and three manure management subsystem;
  2) to explore the potential manure N and P collaborative mitigation strategies and improve associated use efficiency that enhance resources circularity of regional integrated crop-livestock system;

Methods

- Quantitative evaluation; Material flow analysis); Scenario analysis;

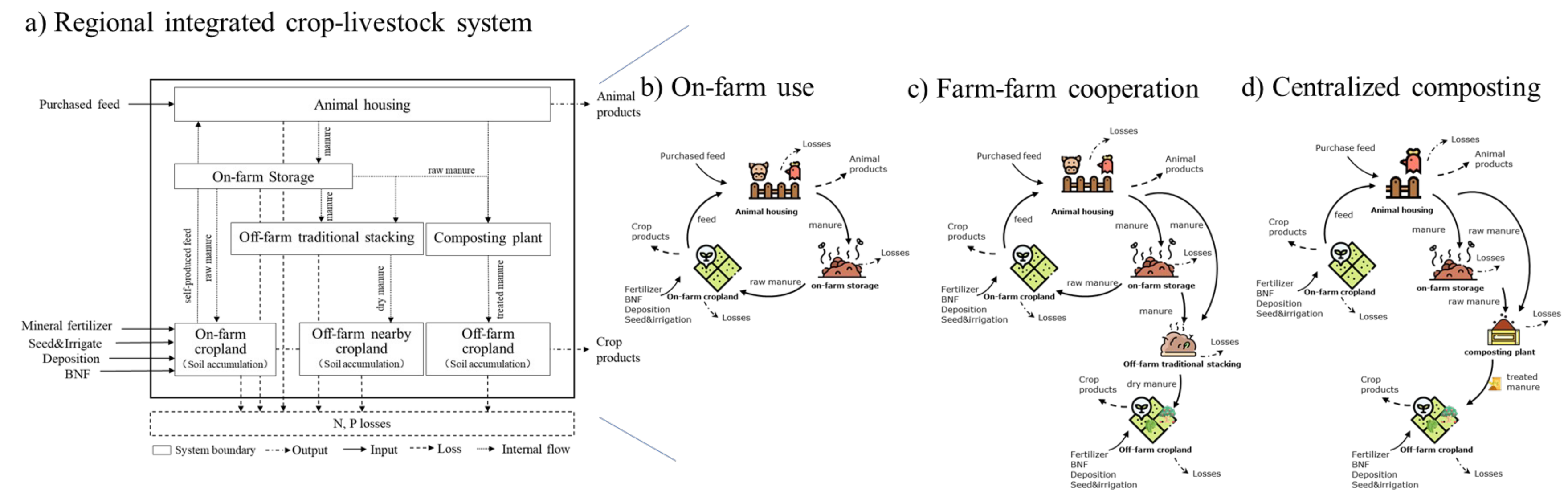


Figure 1. Schematic representation of integrated crop-livestock systems and three manure management subsystem in Quzhou.

Results

1) At the regional level, i.e., total external N input was 1129 kg N·ha^{-1}·yr^{-1}, mostly in the form of livestock purchased feed (61%) and mineral fertilizer (33%). This N was not used efficiently: the NUE and NRR of the system was only 29% and 37%,.
2) Total external P input to country was 190 kg P·ha^{-1}·yr^{-1}, mostly from livestock purchased feed (54%). The PUE and PRR were 26% and 91%, respectively. A large P was accumulation in cropland (66%, 125 kg P· ha^{-1}·yr^{-1}).
3) Majority N was losses from different stages, especially during storage. Overall, NH3 was the major form of N emissions in all systems, followed by losses to water (e.g., discharge, leaching, erosion, runoff).

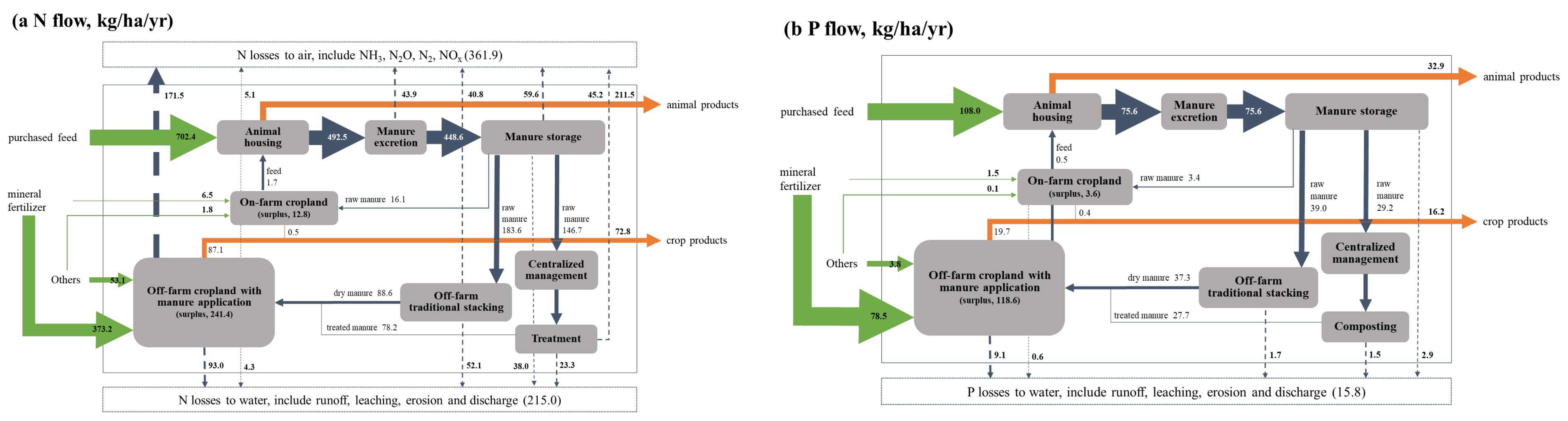


Figure 2. The nitrogen (a-N, kg/ha) and phosphorus (b-P, kg/ha) flows in current regional-integrated crop-livestock system (BAU) of Quzhou. The inputs (green arrow) include feed, mineral fertilizer, others (BNF, deposition, seed and irrigation). Outputs (orange arrow) are animal (live weight), crop products (total grain and straw harvested from cropland, not include the straw returned to the cropland); Surplus mean the soil nutrient surplus, which calculate by total nutrient input minus output, losses (gray dotted arrow); the losses are distinguished with stages (housing, storage, treatment, cropland, gray square) and destinations (air and water). The gray solid arrows mean inner cycle of regional crop-livestock system.

Table 1. Nitrogen (N) and Phosphorus (P) losses (%) of total external input in systems.

Indicators	Integrated system	On-farm use	Farm-farm cooperation	Centralized composting
Total N losses (%)	49.6	57.5	54.7	41.9
Total P losses (%)	7.9	49.3	8.6	5.9
Housing				
NH_3 loss to air	3.8	7.4	4.1	3.4
Storage & Treatment				
NH_3 loss to air	9.0	6.5	8.5	9.9
N_2O	1.6	0.2	1.7	1.4
Others to air	2.1	2.1	1.6	2.8
N loss to water	9.3	3.2	10.7	7.3
N discharge	0.6	29.1	0.6	0.0
P losses to water	2.2	1.3	2.2	2.3
P discharge	0.7	43.5	0.5	0.0
Cropland				
NH_3 loss to air	6.1	2.2	6.7	5.2
N_2O	0.8	0.1	0.5	1.3
Others to air	7.8	2.4	8.4	7.1
N loss to water	8.5	4.2	11.9	3.5
P losses to water	4.9	4.5	5.9	3.5

4) Scenario S1 (Improved technology of whole system) decreased external input (N: -29%; P: -26%), loss (N: -49%; P: -55%), P surplus (-21%), but increased N surplus (+24%) in system. Although the nutrient recycling rates were improved, the nutrient use efficiency decreased slightly.
5) Scenario S2 (S1+ Redistribute manure) decreased external N import to 354 kg N· ha^{-1}·yr^{-1}, especially reduced mineral N fertilizer from 305 to 131 kg N· ha^{-1}·yr^{-1}, along with significantly decreased total N loss and surplus by 78% and 61%, respectively. These gains translated into an increase in NUE from 29 to 51%. For P, the total external P input decreased by 57%. Total P loss and surplus dramatically decreased by 79% and 66%, raised the PUE to 45%.

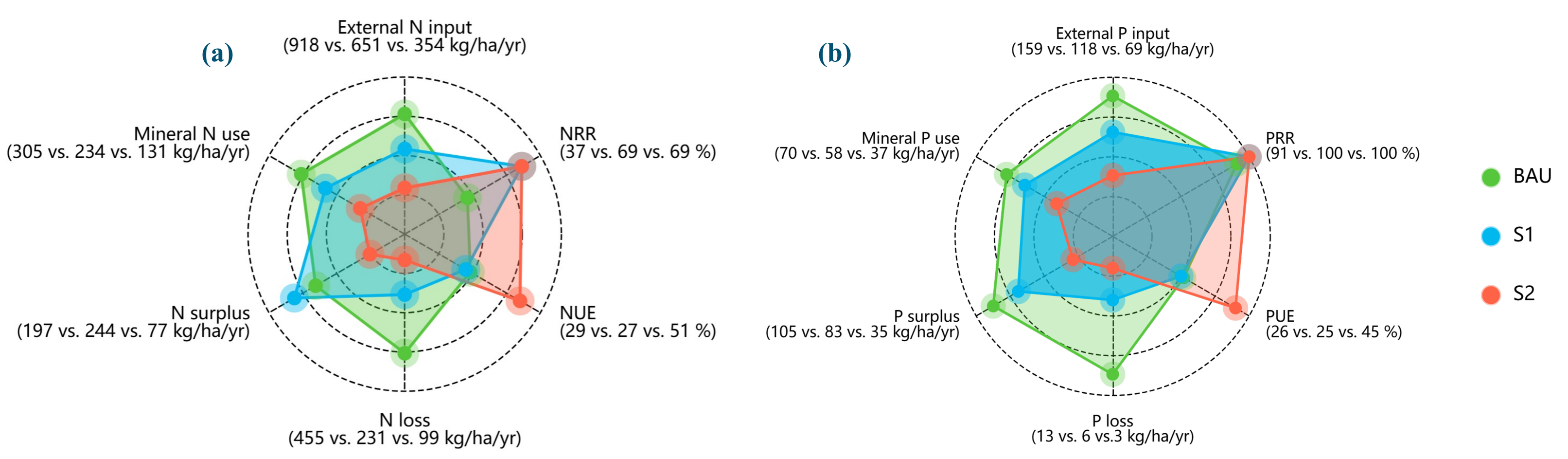


Figure 3. Comparison of indicators between BAU and S1, S2: radar chart (a) for N; and radar chart (b) for P. Higher indicator values on NUE, PUE, NRR, PRR are indicative of better environmental performance (i.e. high efficiency) whereas higher indicator values on external input, loss, surplus and mineral use are indicative of poorer environmental performance (i.e. less self-sufficient in inputs and greater pollution risk). The value for each indicator's axis of BAU (left), S1 (middle) and S2 (right) are provided in brackets after the indicator label.

Conclusion

1)The integrated crop-livestock system, when extended beyond the farm scale, suffers from high external nutrient import and low nutrient use efficiency and high nutrient losses. Significant nutrient losses occur during storage and treatment stages, as well as from excess manure returned to cropland.
2)Implementing a centralized manure composting system can help reduce nutrient loss during storage. A higher nutrient loss during treatment and surplus on cropland were happened. To prevent further nutrient loss on cropland, a more efficient strategy for manure return should be optimized, and the area of manure application should be expanded while regulating the amount of manure applied.

Acknowledgements

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Optimization of manure management options in view of crop nutrient demands, environmental benefits and costs

PhD student: Weikang Sun
WUR supervisors: Wim de Vries, Gerard H. Ros
CAU supervisors:Qichao Zhu, Yong Hou

Background

China's agricultural intensification, driven by the rising food demand, relies heavily on nitrogen (N) and phosphorus (P) fertilizers, causing soil acidification, ammonia (NH_3) and nitrous oxide (N_2O) emissions to air and leaching/runoff of nutrients to water, all of which threaten agricultural sustainability. Livestock production, which nearly tripled between 1980 and 2010, has worsened these impacts through ineffective manure management. Enhanced manure recycling and appropriate use offers a sustainable solution by reducing soil acidification, improving soil fertility, decreasing fertilizer dependence and mitigating environmental impacts. Logistical, economic and technical barriers, such as transportation and treatment costs, along with mismatched N:P ratios compared to crop demand, limit effective manure use in agriculture.

Objectives

The study aims to evaluate the effectiveness of manure management options to use nutrients efficiently by matching manure volume and composition with crop nutrient demands, while balancing manure management costs and environmental benefits.

Methods

The potential of manure management options to optimize N and P use was evaluated for a typical livestock production city Quzhou in China. Eleven manure management options were assessed using combinations of housing systems, storage and treatment techniques. Their impact on nutrient use and investment and maintenance costs were determined. The ratio of excreted manure nutrients, corrected for losses during the processing, to crop demands was calculated to evaluate regional nutrient self-sufficiency, and. An optimization model was developed to find economically feasible and sustainable manure management options.

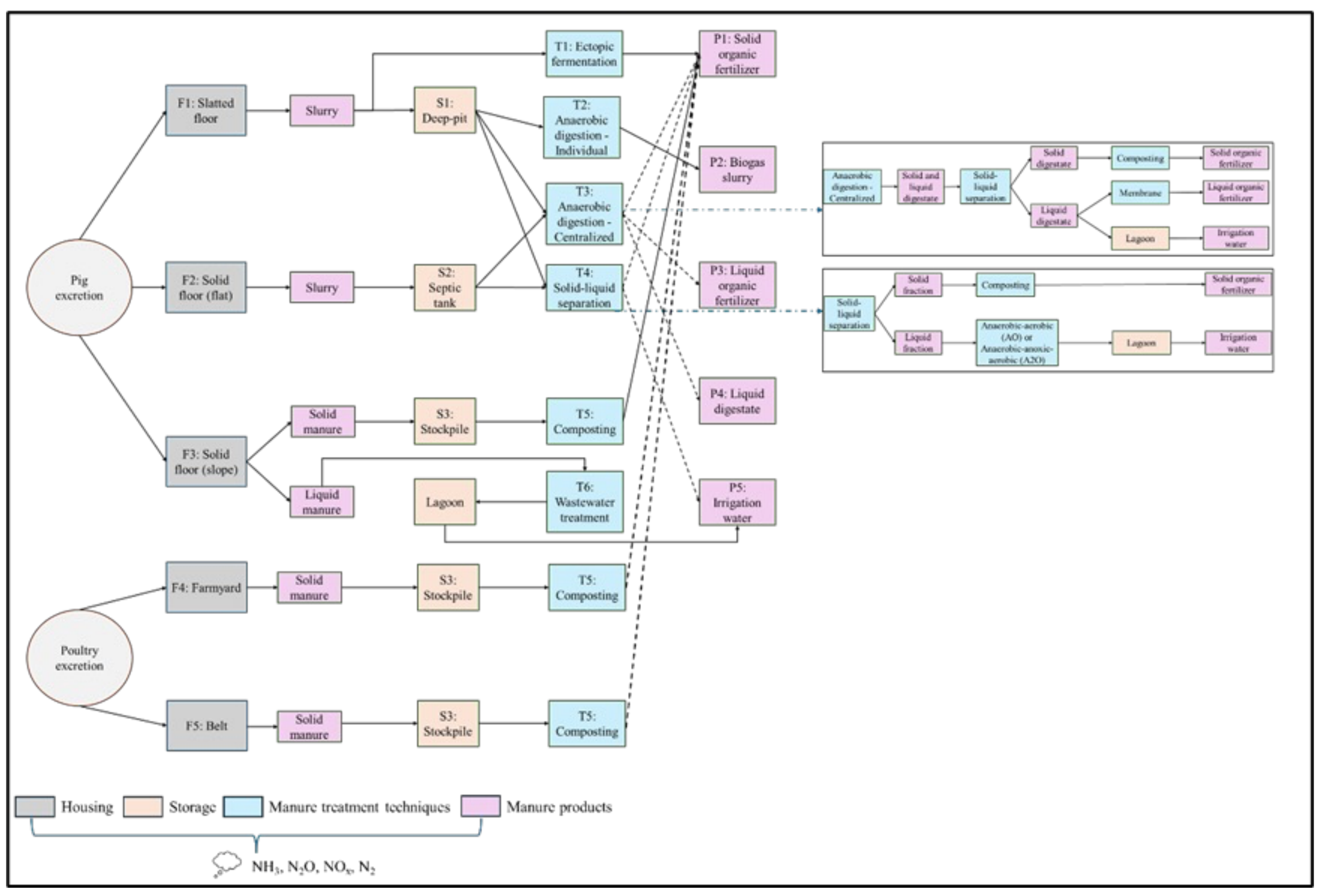

Fig. 1. Schematic representation of the manure management chain with manure treatment technologies discussed in this study. The arrows indicate the flows of manure. The codes stand for F = floor type, S = storage type, T = manure treatment and P = manure product.

Results

Manure inputs under current and crop demand driven manure allocation

The crop-manure balance index (ratio of demand versus manure supply) of P was 2 before allocation and reached 1 after manure products were distributed to crops. The initial crop-manure N balance index was 0.33. After allocation, 47% of the N demand for vegetables was met via manure, while only 28% for citrus and as low as c.a. 10% for oil crops, other cash crops, and rice.

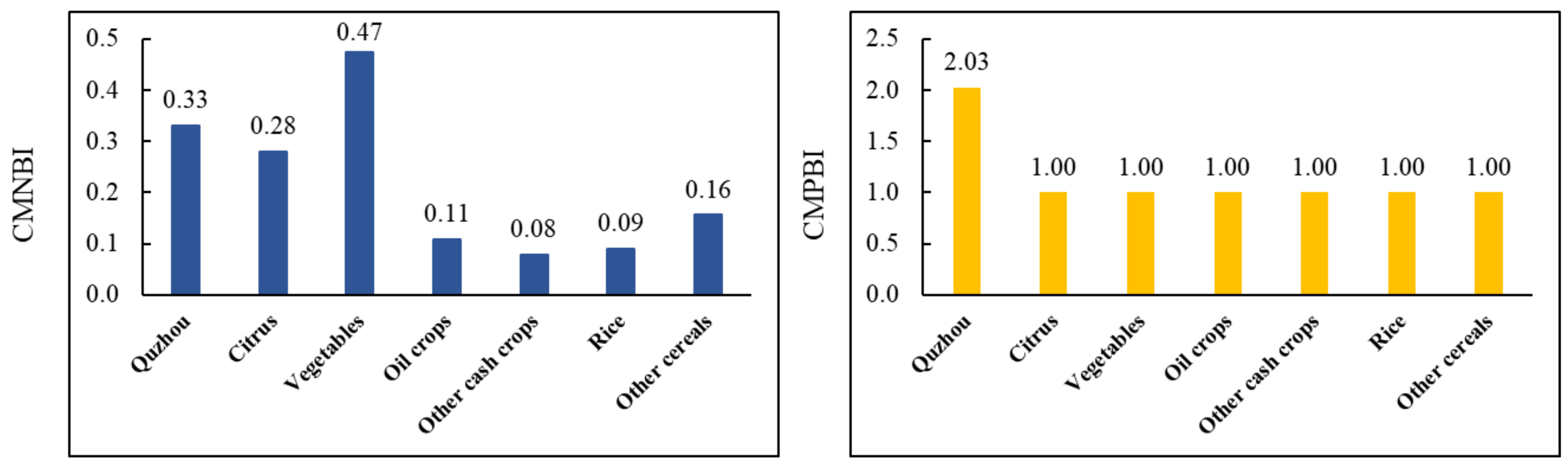

Fig. 2. Crop-manure N and P balance index (CMNBI and CMPBI) under current and crop demand driven manure allocation options,

All pig manure products were fully utilized during the allocation process. The solid manure product from smallholder poultry farming was 96% consumed, while the solid manure product from industrial poultry farming was not used because P demands were already satisfied.

Environmental impacts for manure management options

Nutrient retention across the 11 manure management options varied from 14% to 60%, with most losses, and related environmental impacts, caused by emissions during the housing and treatment stage.

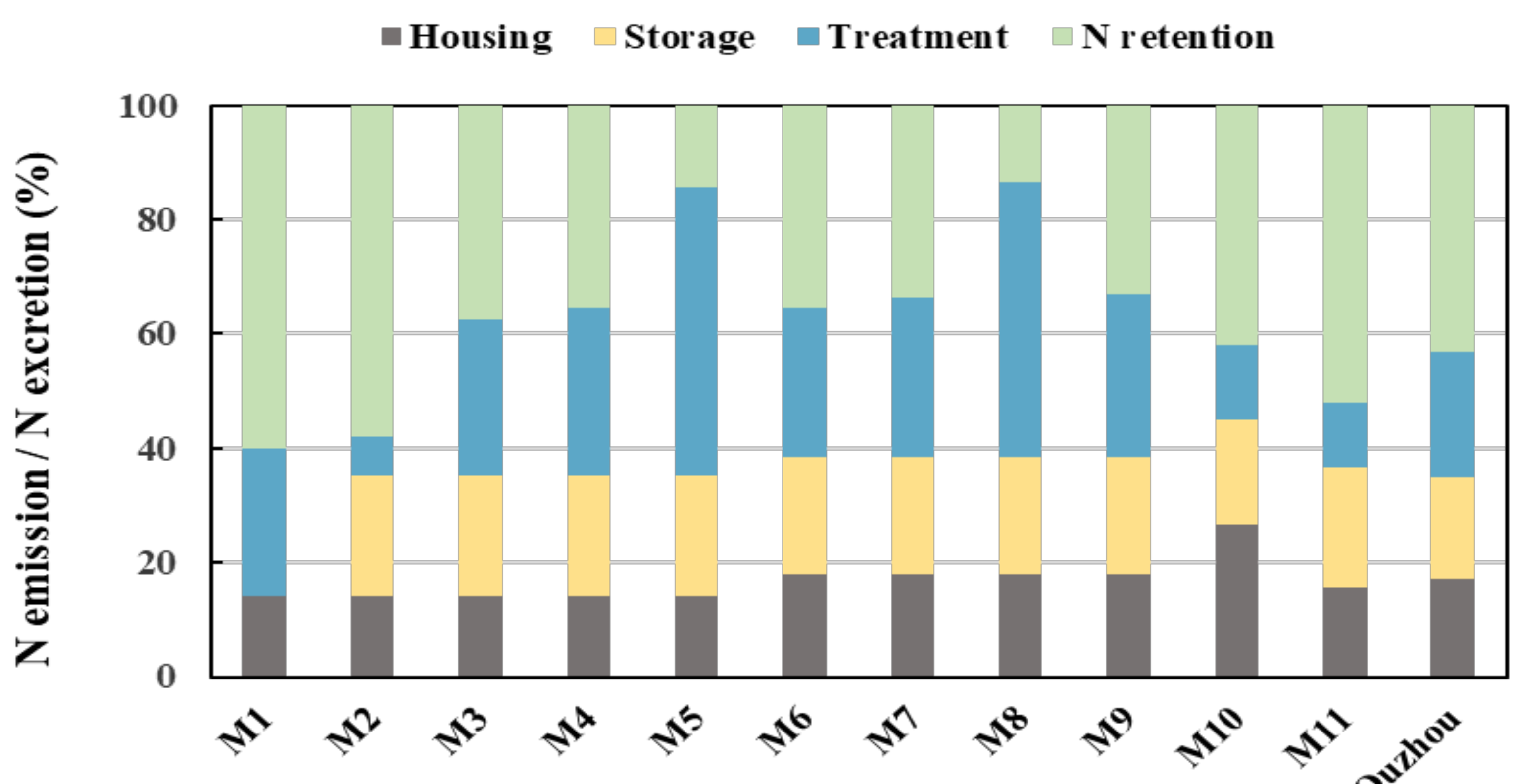

Fig. 3. Comparison of the ratio of N emission over N excretion from different manure management options

Conclusion

The crop-manure balance index reveals a regional N deficit and P surplus. Manure management could reconcile agronomic and environmental challenges. Currently only 14% to 60% of excreted nutrients are used, with significant NH_3 emissions. Optimizing manure management increased manure use, and reduced N losses substantially.

Acknowledgements

We gratefully acknowledge the sponsors of this research: China Scholarship Council (NO.201913043) and Hainan University

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Sunstainable development of China’s agriculture driven by the nutrient management policy

PhD student: Ling Zhang

Supervisors: Qichao Zhu, Yong Hou, Nico Heerink, Marrit van der Berg, Wim de Vries, Gerard H. Ros

Background

On 5 September 2015, the 193 members states of the United Nations (UN) adopted a new 2030 Agenda for Sustainable Development. The 2030 Agenda succeeds the UN’s Millennium Development Goals (MDGs), and features 17 Sustainable Development Goals (SDGs) with 169 targets, which UN member states have committed to implement by 2030. Synthetic fertilizer production and its agricultural use plays an important role to the achievement of 17 SDGs. The effects of fertilizer could exert different effects on different SDGs, may promote and prohibit. For example, the widespread use synthetic fertilizer has played a crucial role in boosting agricultural productivity and fulfilling the food demands of the growing world population (SDG2.1), while their extensive use has resulted in serious environmental issues, including soil acidification (SDG 15.2), water eutrophication (SDG 14.1), and air pollution (SDG 2.4).

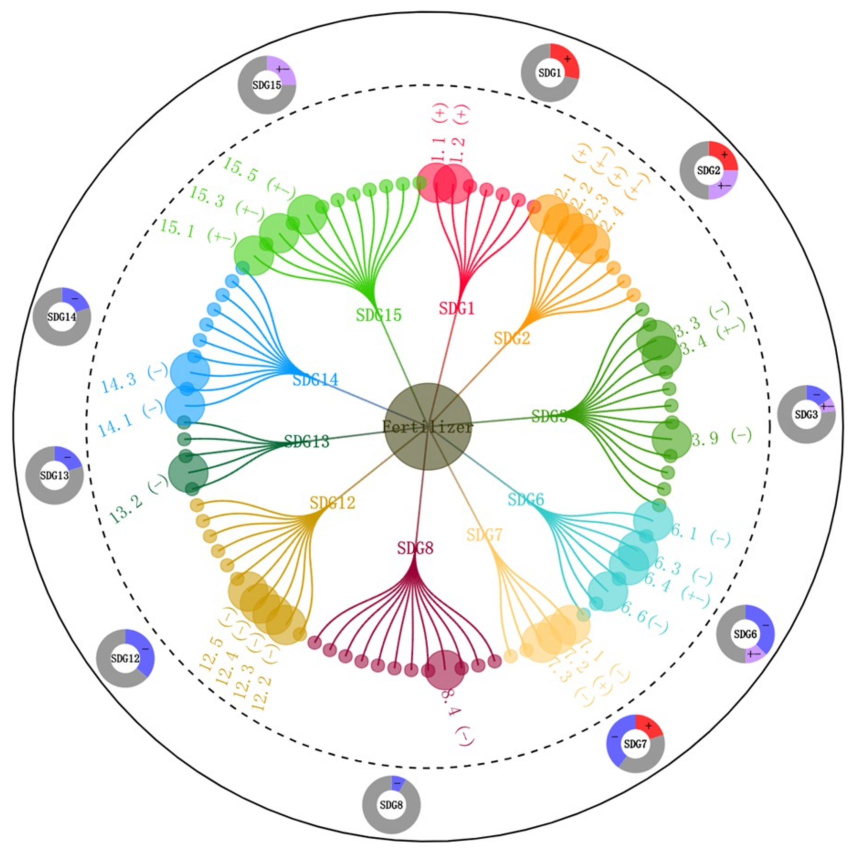
By understanding the complex links between the SDGs and their constituent targets, researchers can better support policymakers to think systematically about interactions between the different SDGs, including how actions to achieve each goal affect each other within and between sectors.

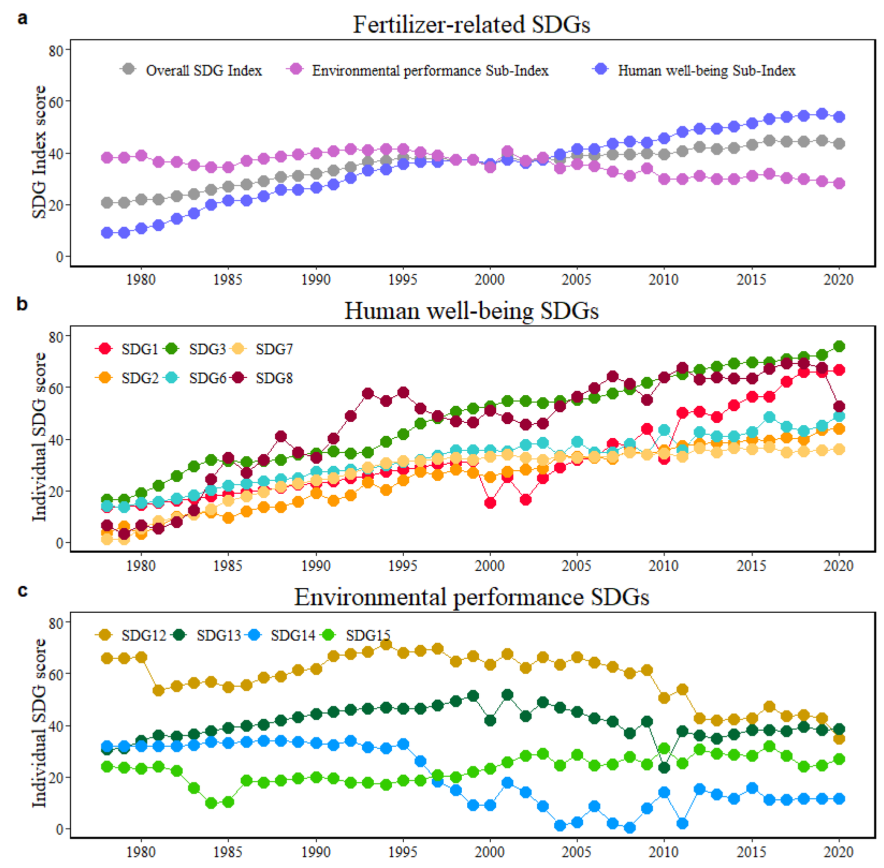
Method

1. Based on qualitative analysis supported by the published literature, we classify the relationship between SDG targets and fertilizer production and application as positive relevance, negative relevance, or bidirectional relevance.
2. Develop an indicator system to assess the changes in relevant SDGs between 1978 and 2020 in China.
3. Using the moving-window method, examine how changes in fertilizer N and P inputs affect SDG progress. In each window, treat fertilizer N and P input as the independent variable and average SDG Index as the dependent variable to analyze changes in marginal benefits.

Result 1

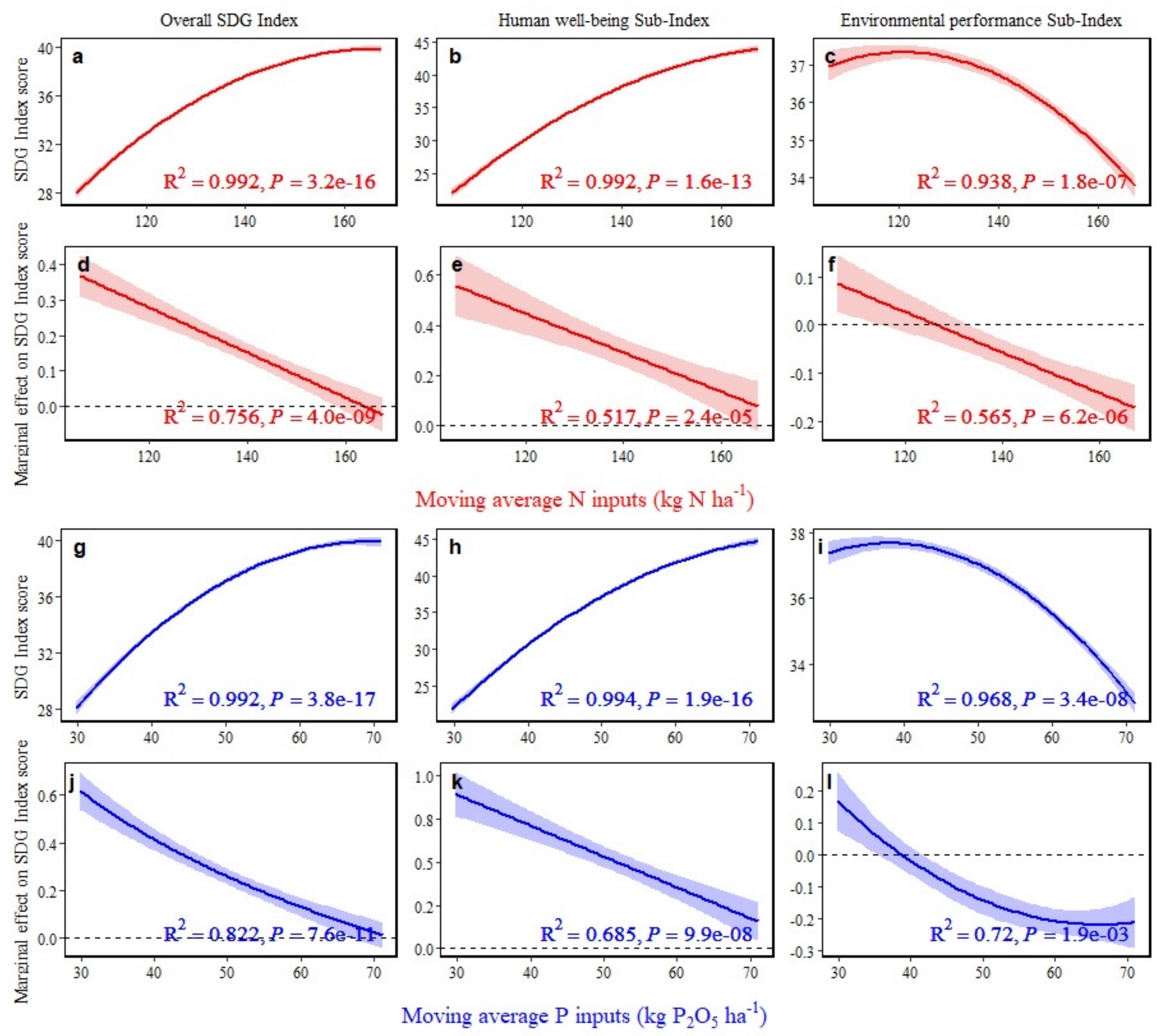
- 10 SDGs (out of 17), and 27 SDG targets (out of 169) are related to fertilizer production and application. Among them, 5 are positive relevance, 15 are negative relevance, and 6 are bidirectional relevance.
- From 1978 to 2020, China's 10 fertilizer-related SDGs showed an overall upward trend, increasing by 22.8 points. Among them, human welfare indicators increased by 44.8 points, while environmental indicators decreased by 10.2 points.





Results 2

- The overall SDG Index score and the human well-being sub-index with increasing trends following the increasing fertilizer N and P inputs, while environmental performance sub-index initially increase and rapidly declining.
- When the marginal effect reaches 0, the promoting effect is at its maximum, with fertilizer NP inputs of 164.0 kg N ha^{-1} and 69.2 kg P_2O_5 ha^{-1}.
- The marginal effect of fertilizer NP input on environmental SDG scores becomes 0 when fertilizer NP inputs are 126.4 kg N ha^{-1} and 38.8 kg P_2O_5 ha^{-1}, after which the marginal effect turns negative.



Acknowledgements

We gratefully acknowlege the sponsors of this research:China Scholarship Council (NO.201913043) and Hainan University.

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Assessment of the spatial variation in the gap between current and critical ammonia emissions for ecosystems in China

PhD student: Rong Cao
WUR / CAU Supervisors: Wim de Vries, Gerard H. Ros, Wen Xu
Cooperation with PhD student Xiaodong Ge

Background

Chinese agricultural sector emits large amounts of ammonia (NH_3) due to intensive livestock breeding and large-scale application of fertilizer and manure. The resulting high atmospheric NH_3 concentrations and deposition has adverse impacts on ecosystems via eutrophication and acidification, and also on human health by increasing particulate matter exposure. Spatially explicit information on (the gap between) current and critical ammonia emissions is crucial to optimize agricultural management strategies minimizing this gap. However, reliable spatial explicit information on the gap in current and critical NH_3 emissions is still limited in China

Objectives

1) Improve spatial variation of NH_3 emissions based on bottom-up modelling methods
2) Assess spatial variation in critical NH_3 emission, and the gap with current emissions, based on critical N loads

Research methods

- Improve methods to assess the spatial variation in livestock numbers in China
- Develop meta-regression models to improve spatial patterns of NH_3 emission factors
- Assess the spatial variation in NH_3 emission, and derive insights in the gap between current (Figure 2) and critical N emissions (Figure 3)

Figure 1. Mechanism of fertilizer NH3 volatilization

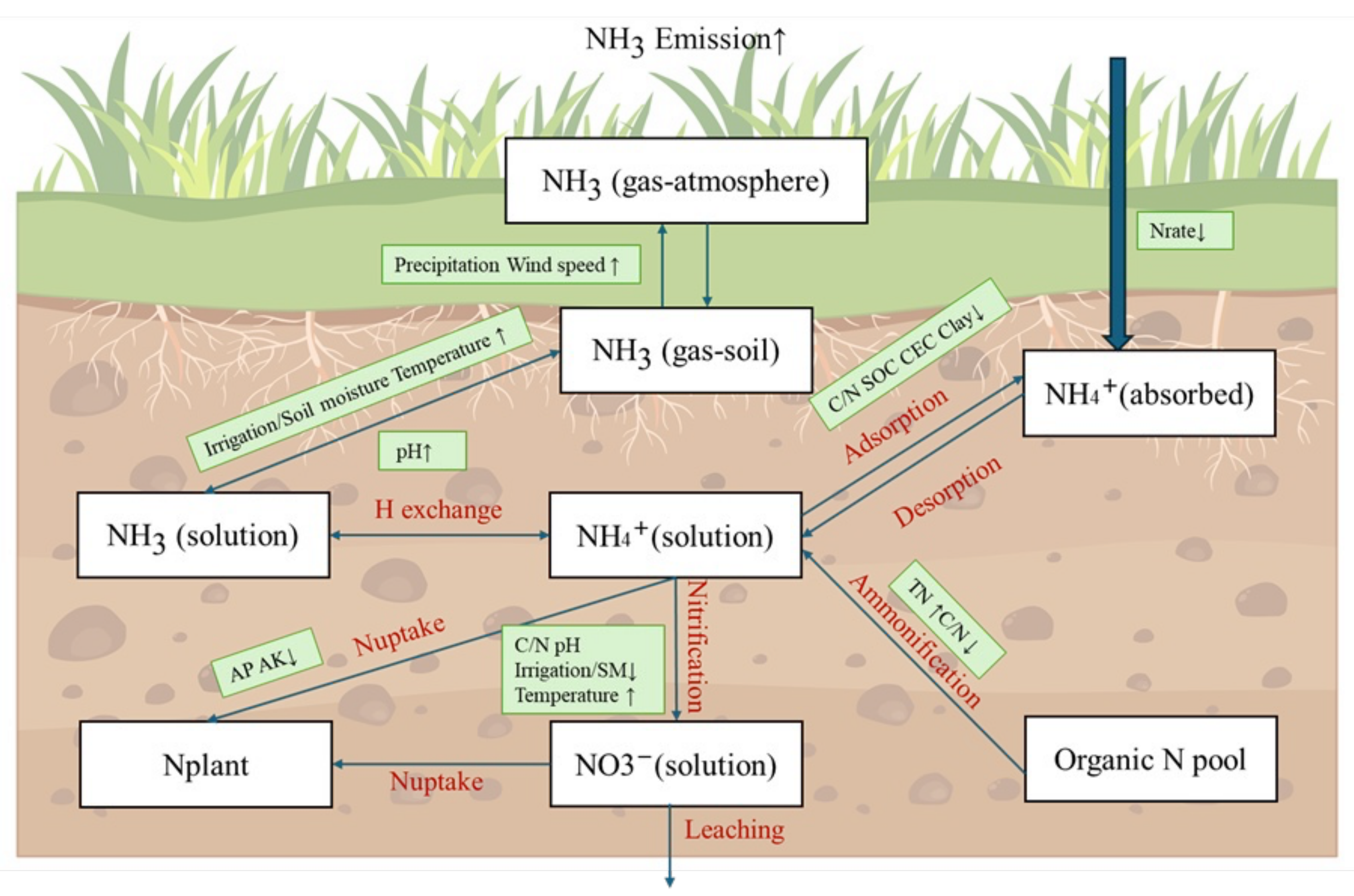

Figure 1. Factors influencing NH3 volatilization.

Results

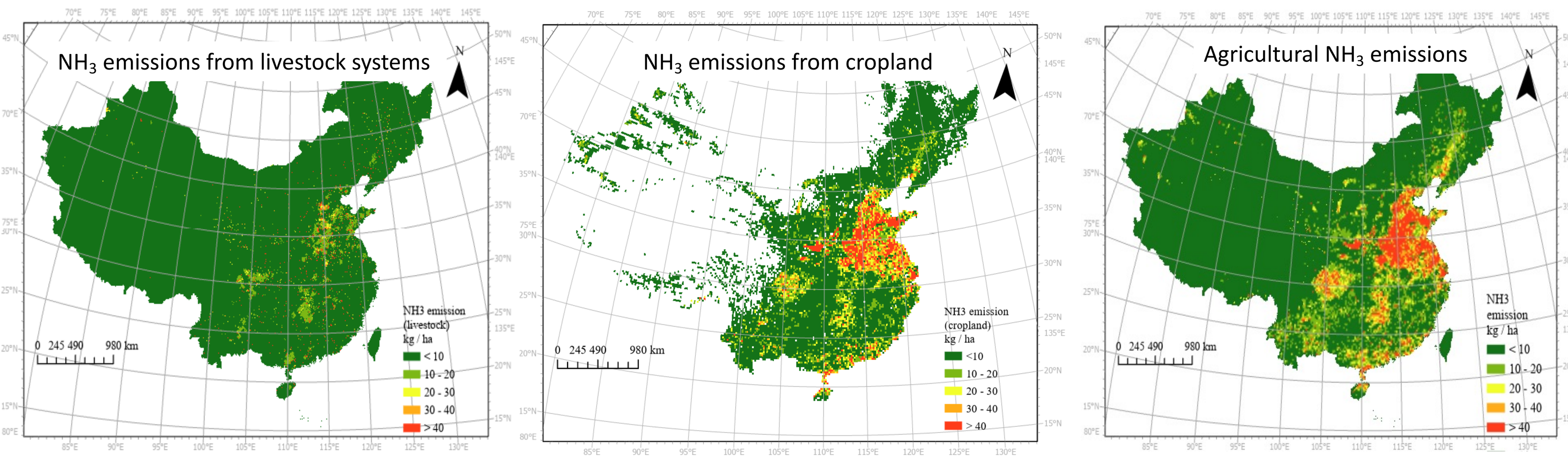

Figure 2. Predicted spatial distribution of NH_3 emissions from livestock systems (kg N-NH_3 ha^{-1}) housing and manure storage systems and grazing animals) and cropland (manure and mineral fertilizer application) and the combination (Cao et al., 2025).

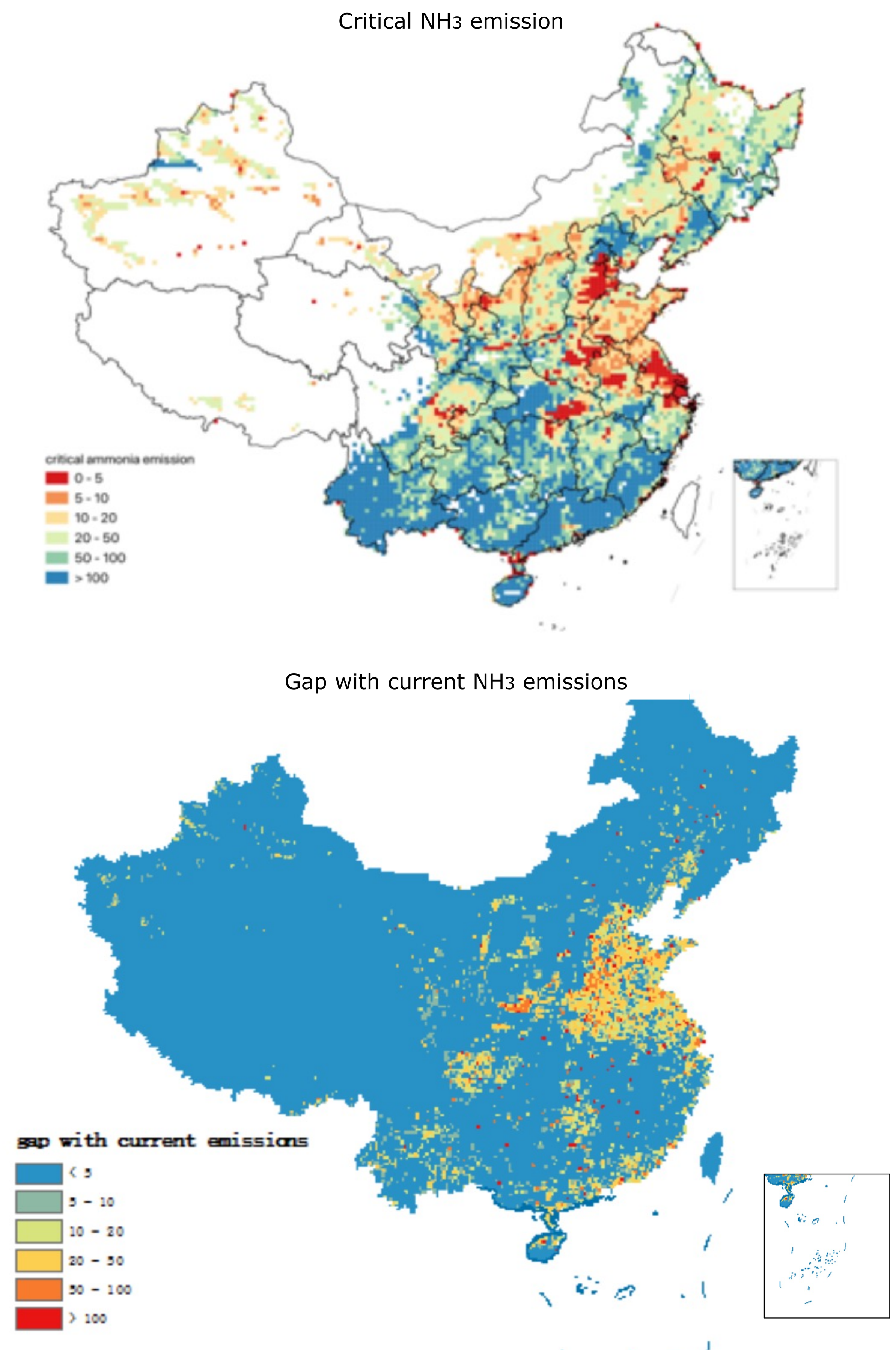

Figure 3. Critical ammonia emission (kg N-NH_3 ha^{-1} $year^{-1}$) for cropland and the gap with current NH_3 emissions (Ge et al., 2025).

References

Cao R, Xu W, Ros GH, De Vries W, (2025) Spatial patterns of current ammonia emissions from agriculture using a newly developed bottom-up method in China. (to be submitted).
Ge XD, R. Cao, Xu W, Ros GH, De Vries W, (2025) Spatial variation in the gap between critical and current ammonia emissions over China. (to be submitted).

Acknowledgements

We gratefully acknowlege the sponsors of this research:China Scholarship Council (NO.201913043)

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Estimation of ammonia emissions over China using IASI satellite-derived surface observations

PhD: Jianan Chen (CAU/WUR)

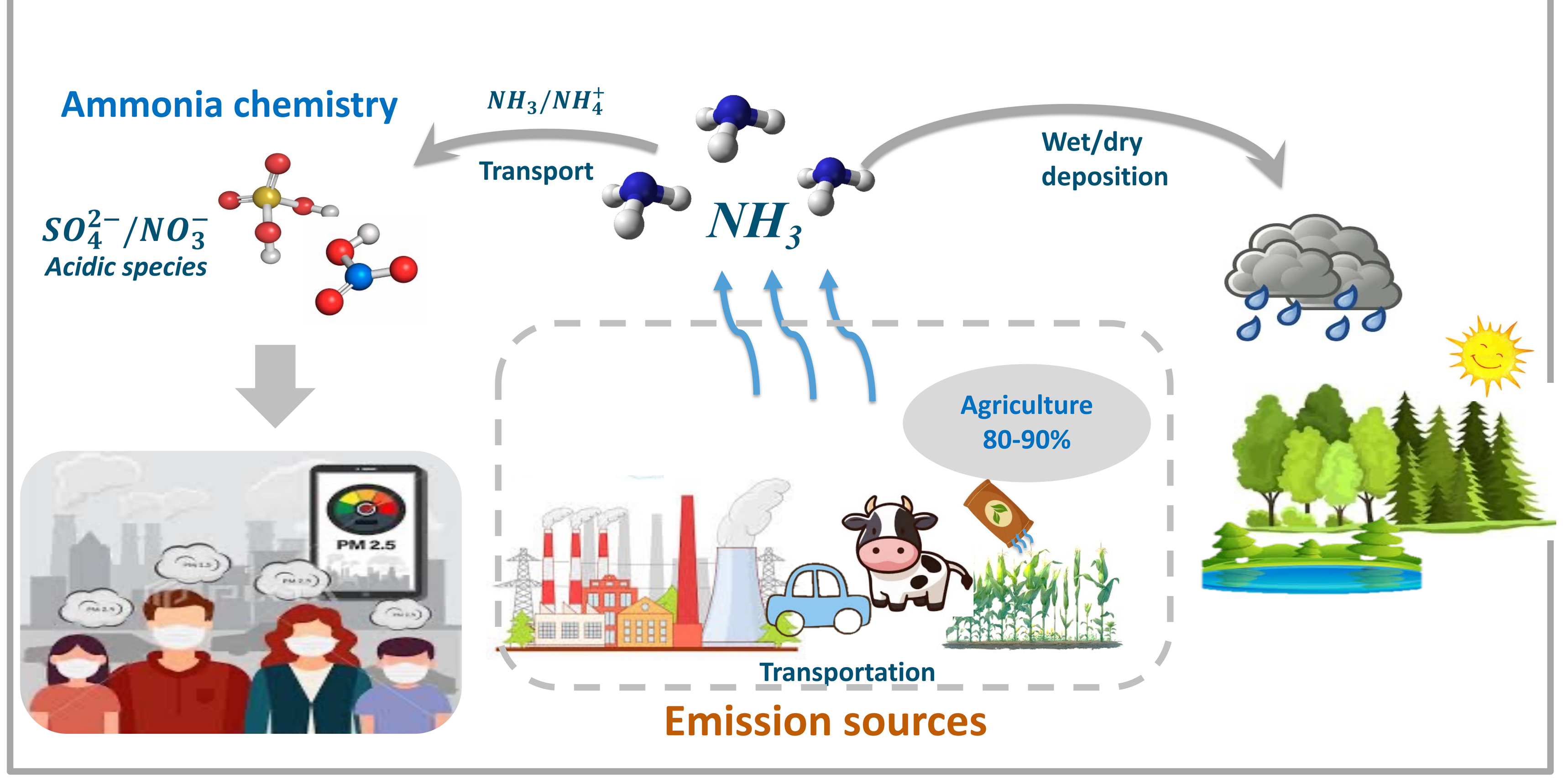
Supervisor: Wen Xu (CAU); Maarten Krol (WUR/UU)

Background

Ammonia (NH_3)

- Reactive nitrogen (Nr) loss
- Precursor of $PM_{2.5}$
- Excessive N deposition

Large uncertainties exist in NH_3 emissions over China



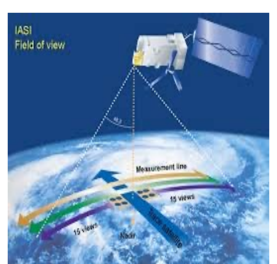
Objectives

- **Optimizing monthly NH_3 emissions over China**
- **Appling satellite-derived surface concentration data**
- **Figure out how the effect of error configuration on inversion**

Methods --- "Top-down"

Observations

IASI satellite product NH_3 column



NNDMN surface measurements — *validate* → IASI-derived surface NH_3 concentration

Prior

Emission inventory
- China
- 2020
- 36 km grid

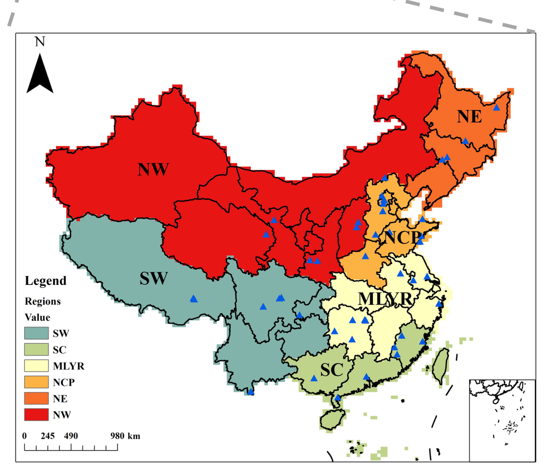
MEICModel Tracking Anthropogenic Emissions

input

CAMx Ozone Particulates Toxics

The sensitivity of surface NH_3 concentration to NH_3 emissions over 6 regions

"Big region" inversion

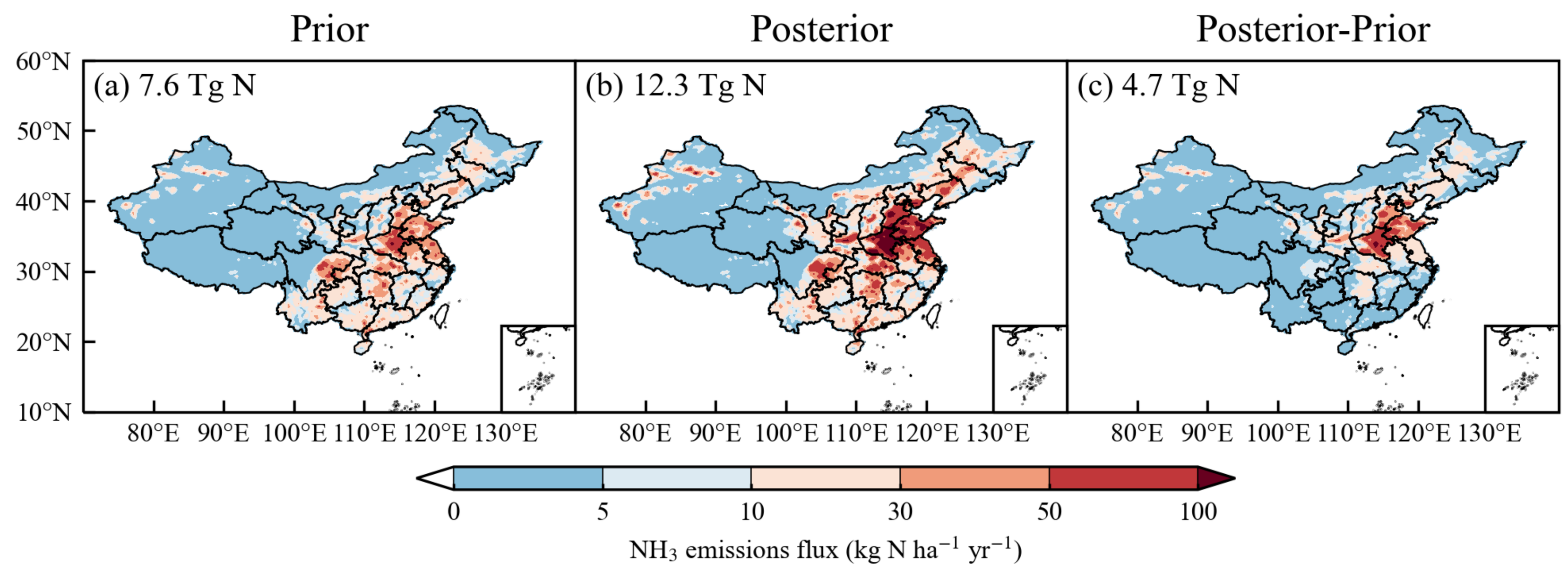


The optimized NH_3 emissions
- Monthly
- Regional

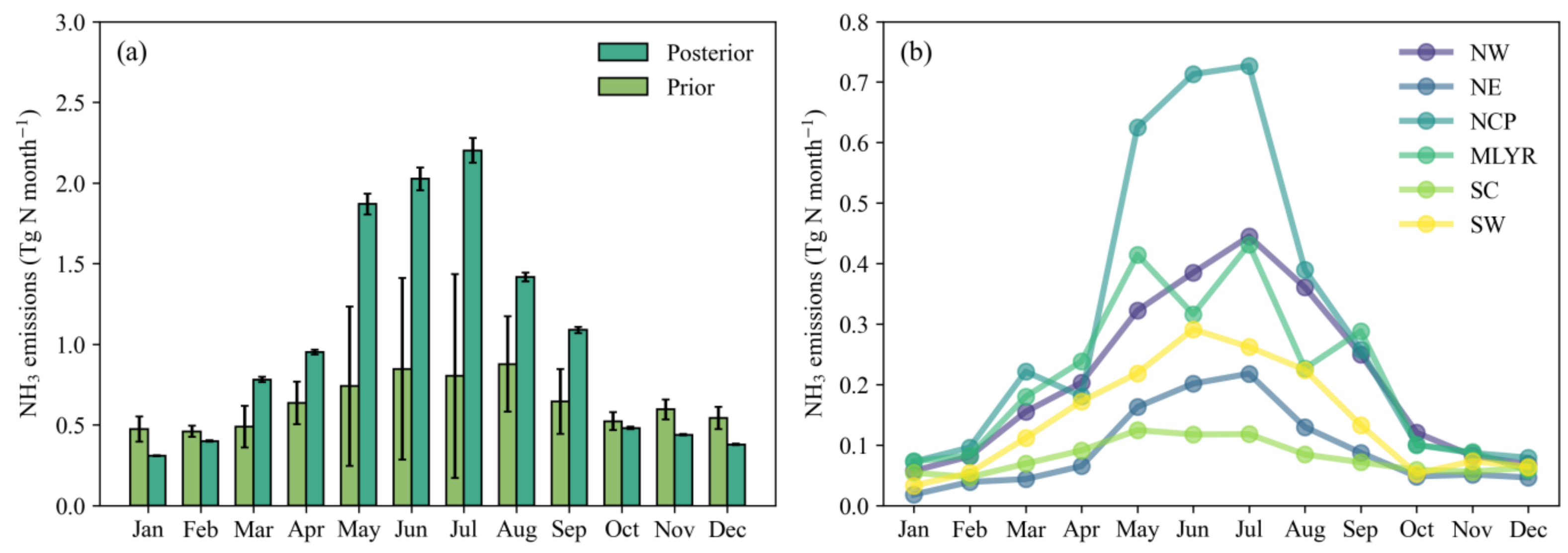
Posterior

Results

Optimizing emissions

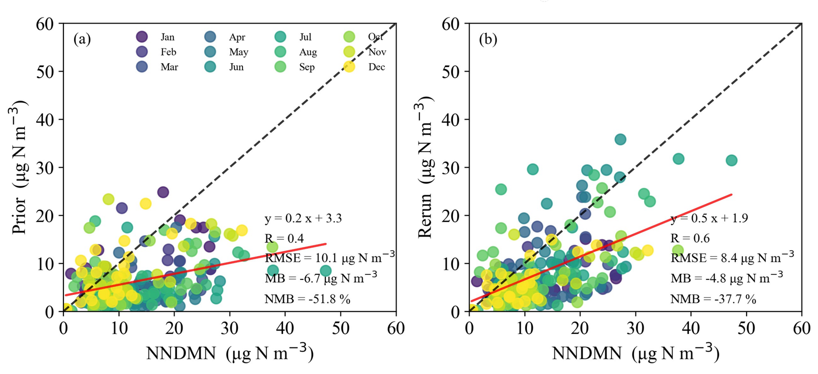


Monthly variations

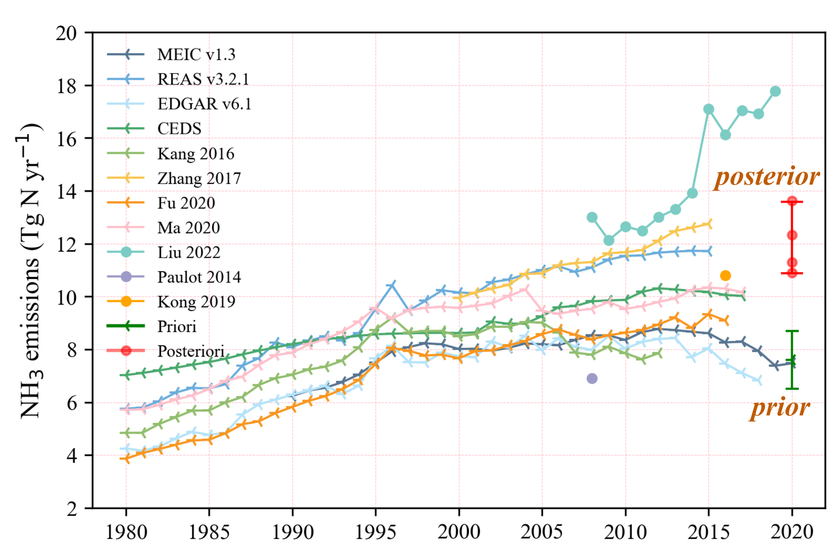


Posterior validation

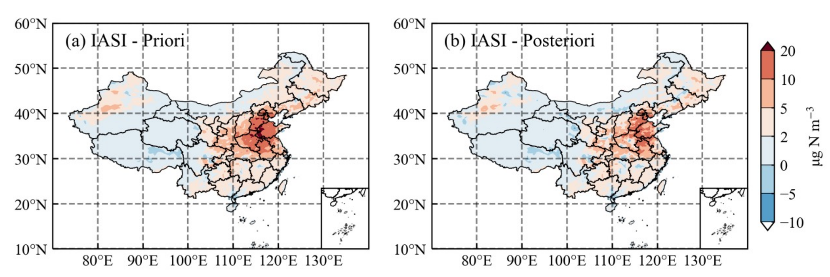
Compare with surface measurements



Compare with other studies



Compare with satellite observations



Conclusions

The surface measured NH_3 concentrations were broadly captured by IASI observations but poorly represented in winter.

NH_3 emissions over China are underestimated in many bottom-up inventories, particularly, in summer, over areas with high emissions.

Evaluation of inversion shows overall improvements.

- The lack of flexibility to change the emission pattern within a region.
- High temporal emissions, like daily or weekly, can not be identified.

Acknowledgements

We gratefully acknowlege the sponsors of this research:China Scholarship Council (NO.201913043)

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The impacts of soil and water conservation on streamflow and sediment discharge

Presenter: Yinan Ning

Supervisors: Xuejun Liu, Lihua Ma, Xinping Chen

Joao Nunes, Jantiene Baartman, Coen Ritsema

Background

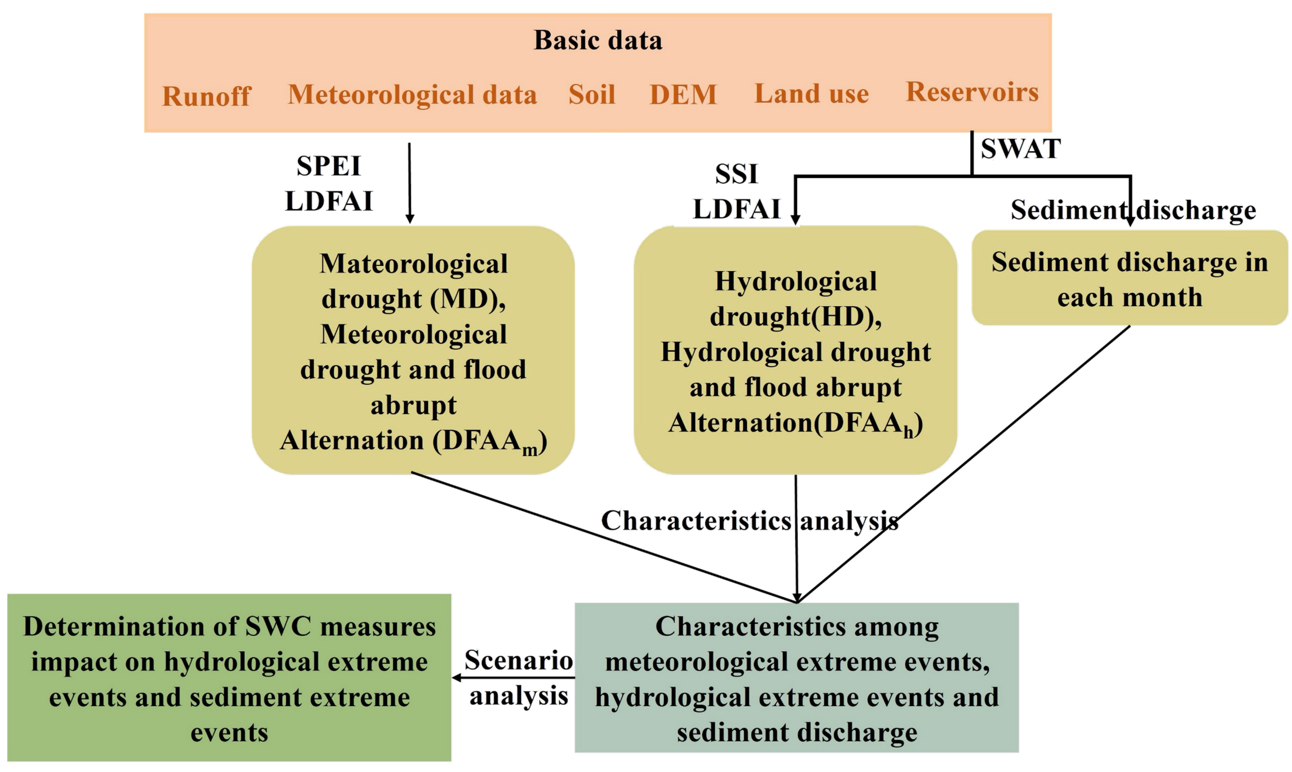
The Yangtze River, ranked as the third-longest river in the world, despite a large amount of investment in soil and water conservation (SWC) measures at the national and regional levels since the 1950s, while the soil erosion and nutrients runoff (with erosion) have not been significantly reduced in all areas. Therefore, quantifying the impact of SWC measures on streamflow and sediment discharge is of vital importance to determine the best management measures for the basin. However, the effect of individual SWC measures or their combination on water quantity and quality (nutrients and yield) at the catchment scale has rarely been evaluated.

Objectives

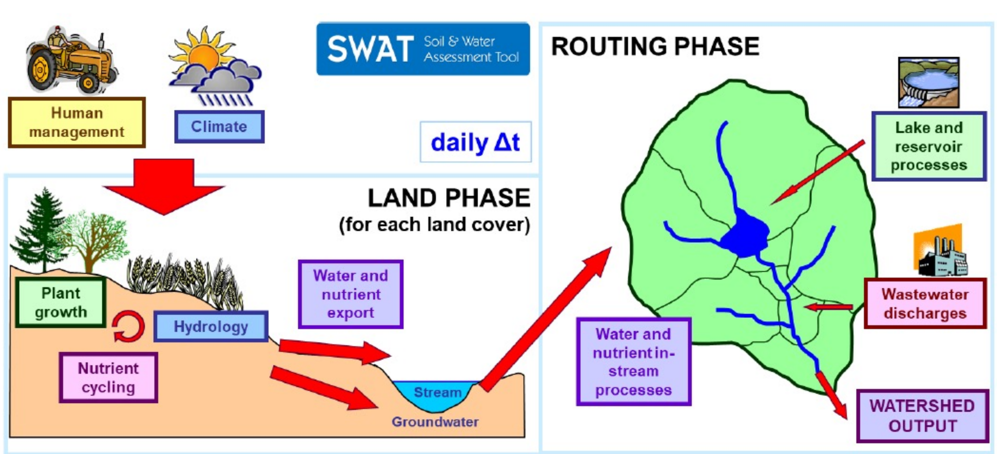
1. Analyzing the evolution, characteristics of monthly streamflow and sediment discharge in the YRB since 1980.
2. Identify the characteristics of monthly meteorological and hydrological events and the resulting changing sediment discharge characteristics.
3. Quantifying the impact of SWC measures on these characteristics;

Methods

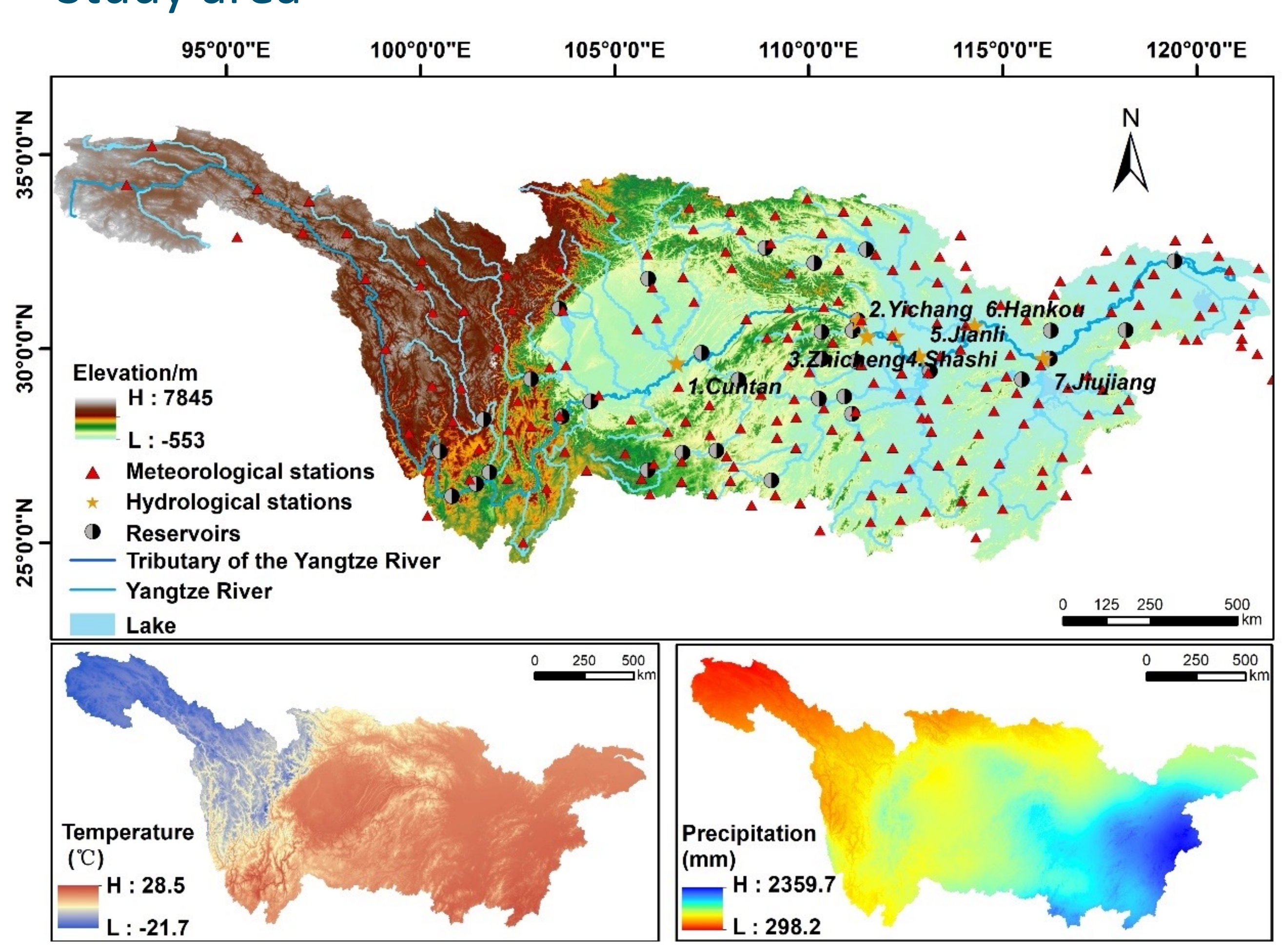
- Research framework



- SWAT model



- Study area



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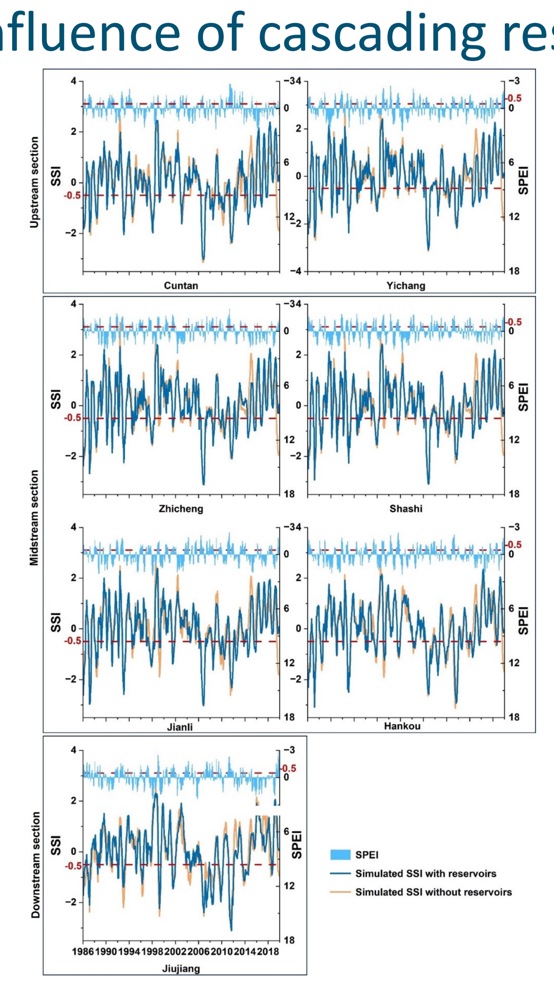
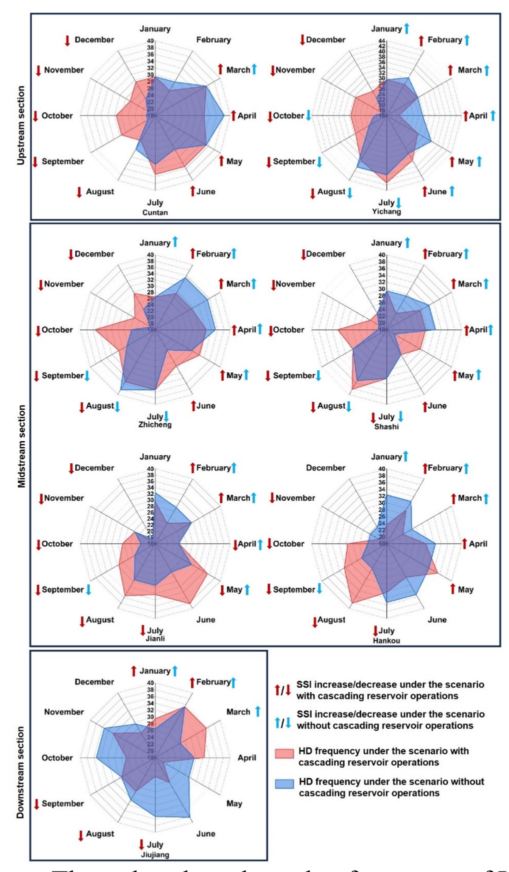
Results

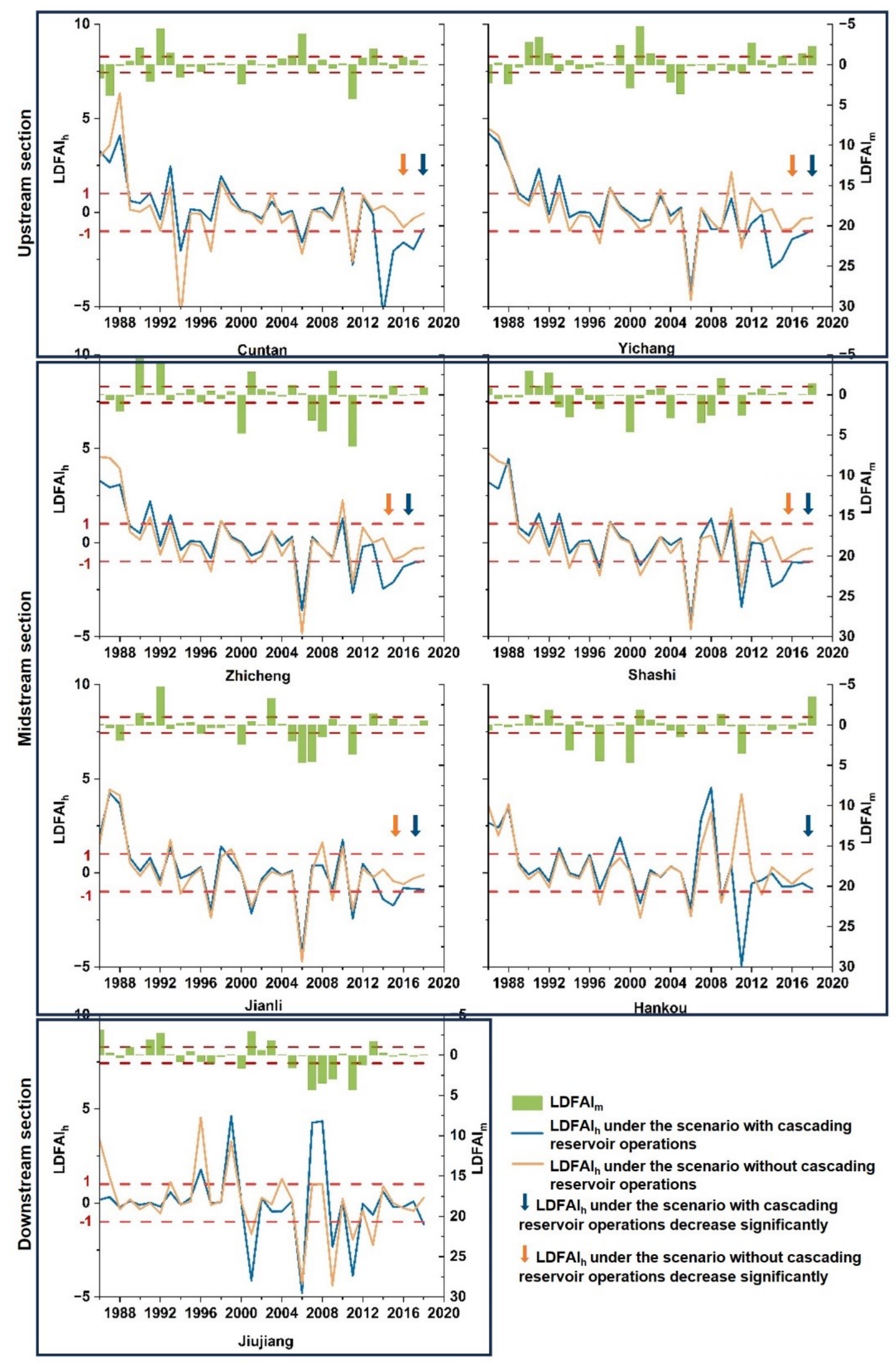
- Influence of cascading reservoirs on hydrological drought events



Monthly SPEI and SSI with and without reservoirs at 7 stations from 1986–2020

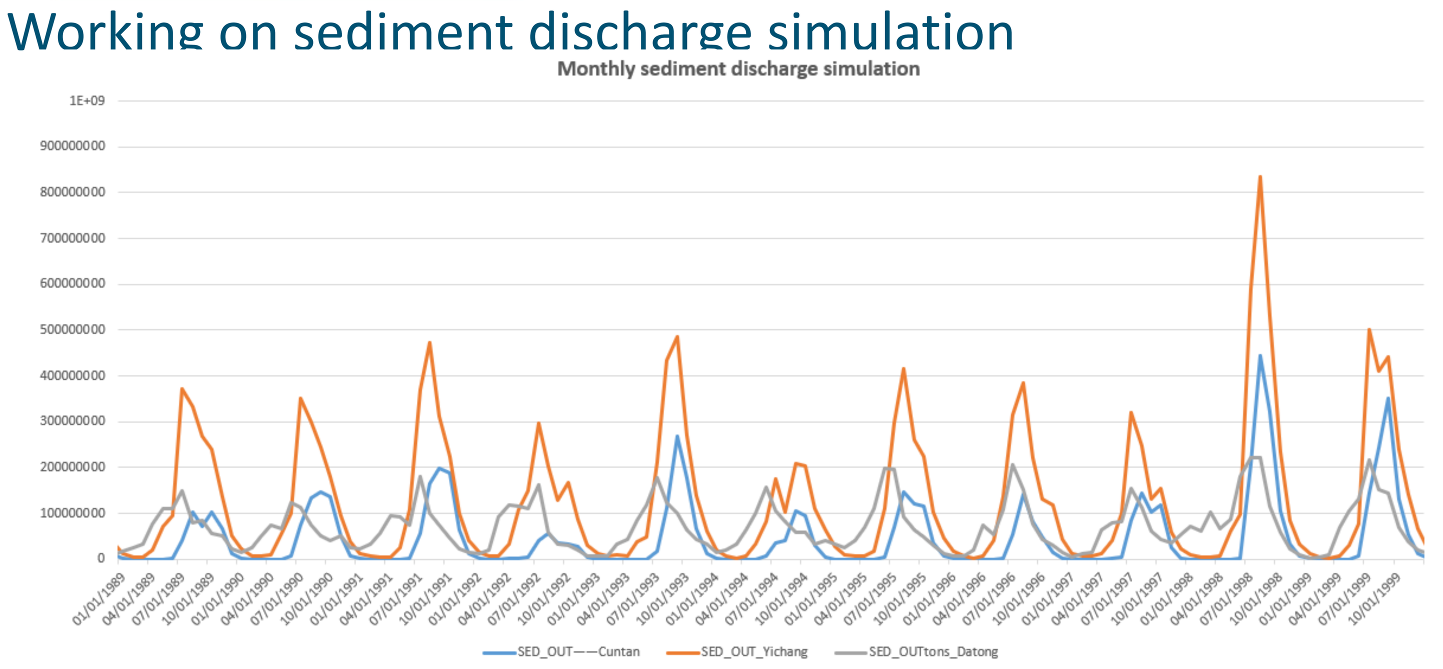


The radar plots show the frequency of HD under the two scenarios within each month at 7 stations.



LDFAI$_m$, LDFAI$_h$ under the scenario with cascading reservoir operations, and LDFAI$_h$ under the scenario without cascading reservoir operations for 7 stations

- Working on sediment discharge simulation



Conclusions

1)Monthly statistics revealed that MD were most prevalent in the autumn (August to November), while HD were predominantly concentrated in the summer (May to August).

2)The operation of cascading reservoirs increased the frequency and duration of HD events during the year while decreased their intensity.

3)The LDFAI$_h$ in the YRB exhibited a significant declining trend, indicating an overall shift from flood to drought conditions.

Acknowledgements

We gratefully acknowlege the sponsors of this research:China Scholarship Council (NO.201913043) and Hainan University.

Quantifying above-ground biomass, SOC and erosion with a detailed crop map and PESERA model in the Yangtze River Basin

Author : Jichen Zhou

Supervisor: Xuejun Liu, Lihua Ma, Jantiene E. M. Baartman, Joao Carvalho Nunes, Coen Ritsema

Background

Soil erosion represents a primary threat to soil systems with adverse implications for ecosystem services, crop production, potable water and carbon storage. While numerous studies have quantified the spatial distribution of Above-Ground Biomass (AGB), soil erosion and Soil Organic Carbon (SOC) in the Yangtze River Basin (YRB), limited attention has been given to assessing the contributions of different land use types and especially crop types to AGB, soil erosion and SOC. In most studies, cropland is taken as a land use class, while detailed crop types and rotation patterns, and their effect on soil erosion and SOC, vary significantly.

Objectives

Seven single crop types and seven common crop rotation types were incorporated into the land use map using the Metronamica model to create a detailed crop map.

Using this new land use and crop distribution map, the revised Pan-European Soil Erosion Risk Assessment (PESERA) model was applied to spatially quantify soil erosion, SOC, and soil biomass patterns in the YRB.

Study site

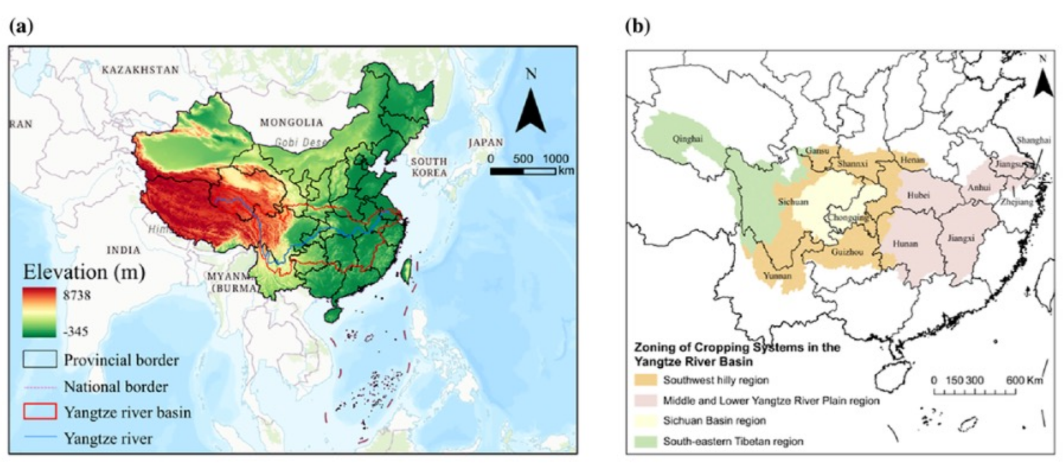


Fig. 1 Elevation for Yangtze River Basin, for China, with the Yangtze River Basin highlighted by the red frame (a). Climate zones as used for Yangtze River Basin to vary crop calendars by agroclimatic zone (b).

Methods

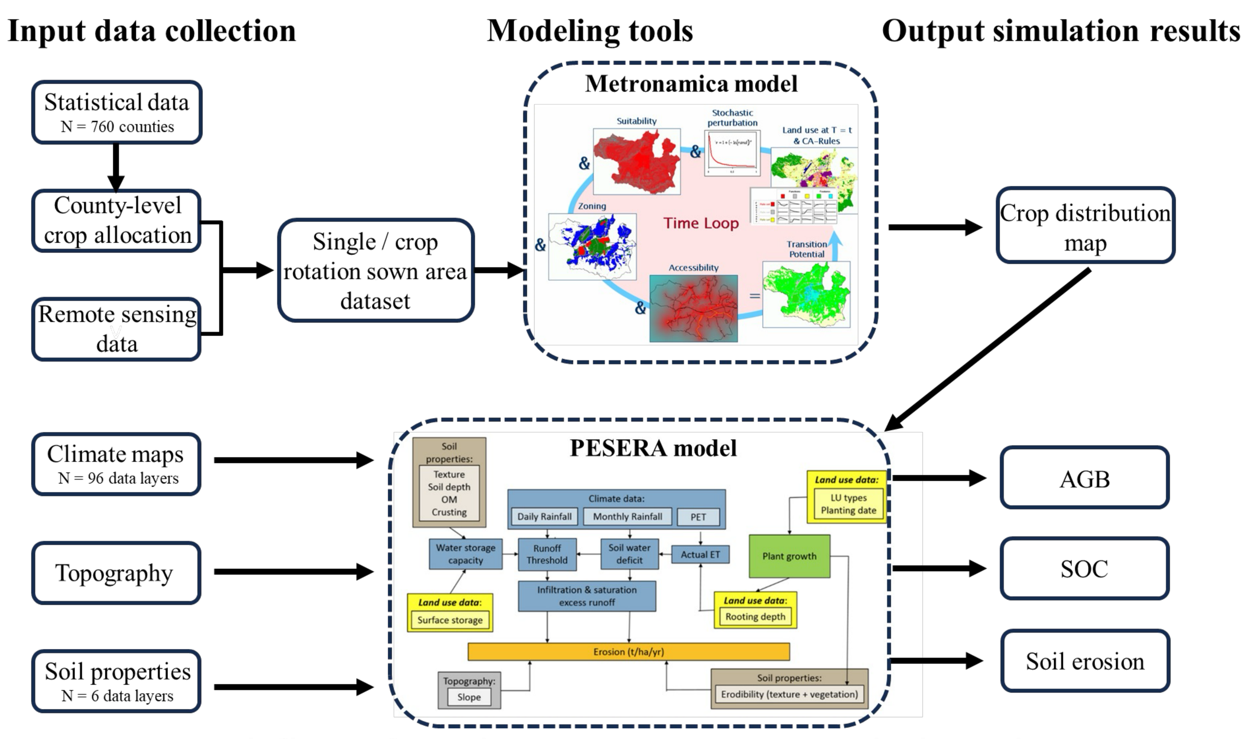


Fig. 2 A schematic workflow for the spatiotemporal distribution assessment of soil erosion, soil organic matter and biomass using the Metronamica and Pan-European Soil Erosion Risk Assessment (PESERA) models.

Results

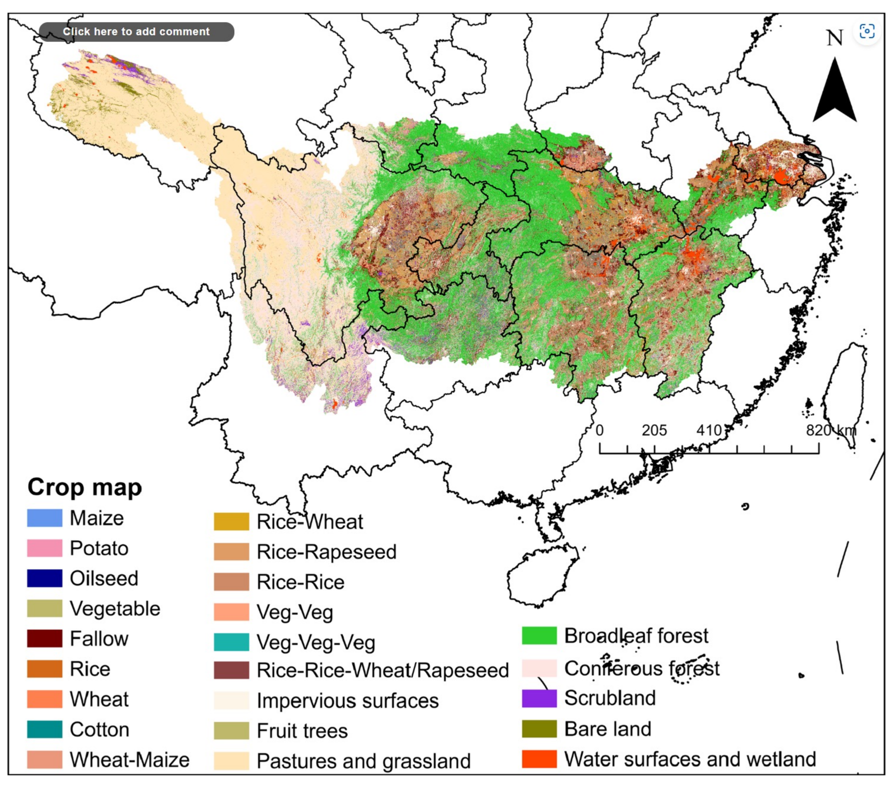


Fig. 3 Land use and crop map for Yangtze River Basin.

Within cropland, across the entire YRB, the most prevalent cropping patterns, excluding fallow lands, are rice-rice (16.3%), rice-rapeseed (10.9%), wheat-maize (10.6%) and rice-wheat (7.6%). Monoculture crops such as rice (3.3%), maize (1.3%) and wheat (1.1%) constitute a smaller proportion.

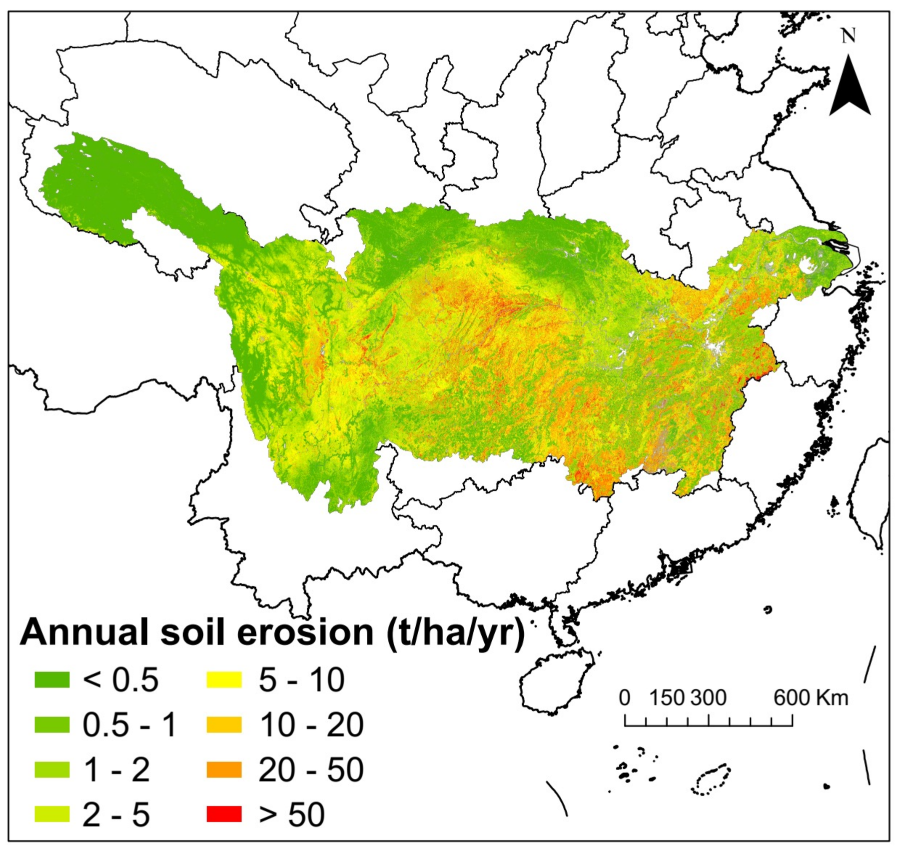


Fig. 4 Simulated long-term average erosion rates across Yangtze River Basin using the PESERA model.

Overall average erosion for the entire YRB was simulated at 8 t/ha. Hotspots of soil erosion were concentrated in the Sichuan Basin and the Central-southern region while lower rates of soil erosion were found in the Northwestern region and the Yangtze River Delta.

Table. 1 The amount of SOC/soil erosion/AGB for each land use type.

Land use/ crop	SOC (g/kg)	Soil erosion (t/ha)	Soil erosion (%)	AGB (t/ha)
Artificial	-	1.62	0.56	-
Fruit trees and berry plantations	16.27	9.07	2.24	37.23
Pastures	21.33	2.64	6.93	1.25
Forest - broadleave	23.86	5.22	19.06	93.76
Forest - coniferous	26.28	3.54	8.09	171.78
Shrubland	16.59	5.86	1.38	14.20
Bare land	0.00	2.17	0.20	-
Arable land	9.04	17.61	61.79	4.91

Artificial land, bare land and pastures showed the lowest erosion rate, while arable land and fruit trees showed the highest erosion rate. Forests had the highest AGB and SOC, while pasture had the lowest AGB.

Table. 2 The amount of SOC/soil erosion/AGB for each crop type.

Land use/ crop	Soil erosion (t/ha)	Soil erosion (%)	biomass (t/ha)
Maize	21.41	1.02	5.64
Potato	29.33	2.32	0.97
Oilseed	22.24	1.63	3.03
Vegetable	13.27	3.32	1.84
Fallow	32.48	26.63	0.01
Rice	12.06	1.39	5.36
Wheat	12.64	0.50	4.15
Cotton	8.84	1.20	3.29
Wheat-Maize	17.86	6.70	7.98
Rice-Wheat	7.10	1.90	10.14
Rice-Rapeseed	10.00	3.84	6.30
Rice-Rice	12.58	7.25	8.47
Veg-Veg	12.72	1.32	3.06
Veg-Veg-Veg	13.46	1.04	4.15
Rice-Rice-Wheat/Rapeseed	8.81	1.48	8.55

Within the arable land, the highest erosion rates and the lowest AGB were simulated in fallow land and potato land, while the lowest erosion rate and highest AGB were simulated in rice-wheat rotation land.

Conclusions

Crop distribution map on the YRB was built using Metronamica model.

Soil erosion, SOC and AGB were simulated by PESERA model.

Erosion hotspots concentrated in the Sichuan Basin and the Central-southern region.

Our findings enable a better understanding of the spatial-temporal distribution of SOC, AGB and soil erosion, as well as the contributions of different land use and crop types to them.

Acknowledgements

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Modelling antibiotic concentrations in rivers in China: hotspots, sources and risk assessment

PhD candidate: Songtao Mei
CAU supervisor: Kai Wang
WUR supervisor: Nynke Hofstra
External supervisor: Heike Schmitt (RIVM and TU Delft)

Background

Antibiotics are widely used in the therapeutic and preventive treatment of diseases for humans and livestock. However, misused antibiotics can lead to serious water pollution. The presence of non-lethal and sub-inhibitory concentrations of antibiotics could generate genetic and phenotypic variability and develop antibiotic resistance (AR). There is a lack of data on concentrations of antibiotics in rivers in many regions in China due to the difficulty of monitoring. To better understand antibiotics pollution in rivers in China and the associated risk, a water quality model simulating the antibiotics load to rivers and the concentrations in rivers in China is developed.

Research objective

To quantify antibiotic emission to rivers and concentration in rivers, identify important sources and assess the risk of antibiotic resistance selection in rivers in China

Methdology

The Global Waterborne Pathogen (GloWPa) model (Vermeulen et al., 2019) is adapted for the simulation of antibiotics. The modelled antibiotics include 10 sulfonamides, 4 tetracyclines, 10 fluoroquinolones, 5 macrolides, 1 lincosamide and 3 β-lactams. The model is developed with a spatial resolution of 0.5°×0.5° on a monthly time step and represent 2020.

Results

- Antibiotic emission to rivers in 2020 is 1313.1 tons.
- Yangtze River Basin has the highest antibiotic discharge.
- Tetracycline and fluoroquinolone have the highest discharge, while macrolide, lincosamide and β-lactam antibiotics have lower discharge.
- Main antibiotic sources are direct discharge of livestock manure is the (73.8%), discharge from WWTPs (14.4%), diffuse emission from livestock (9.6%)
- Pigs, broilers, and laying hens contribute the highest emission.
- Smallholder farms exhibit the highest discharge, while medium farms contribute the least.

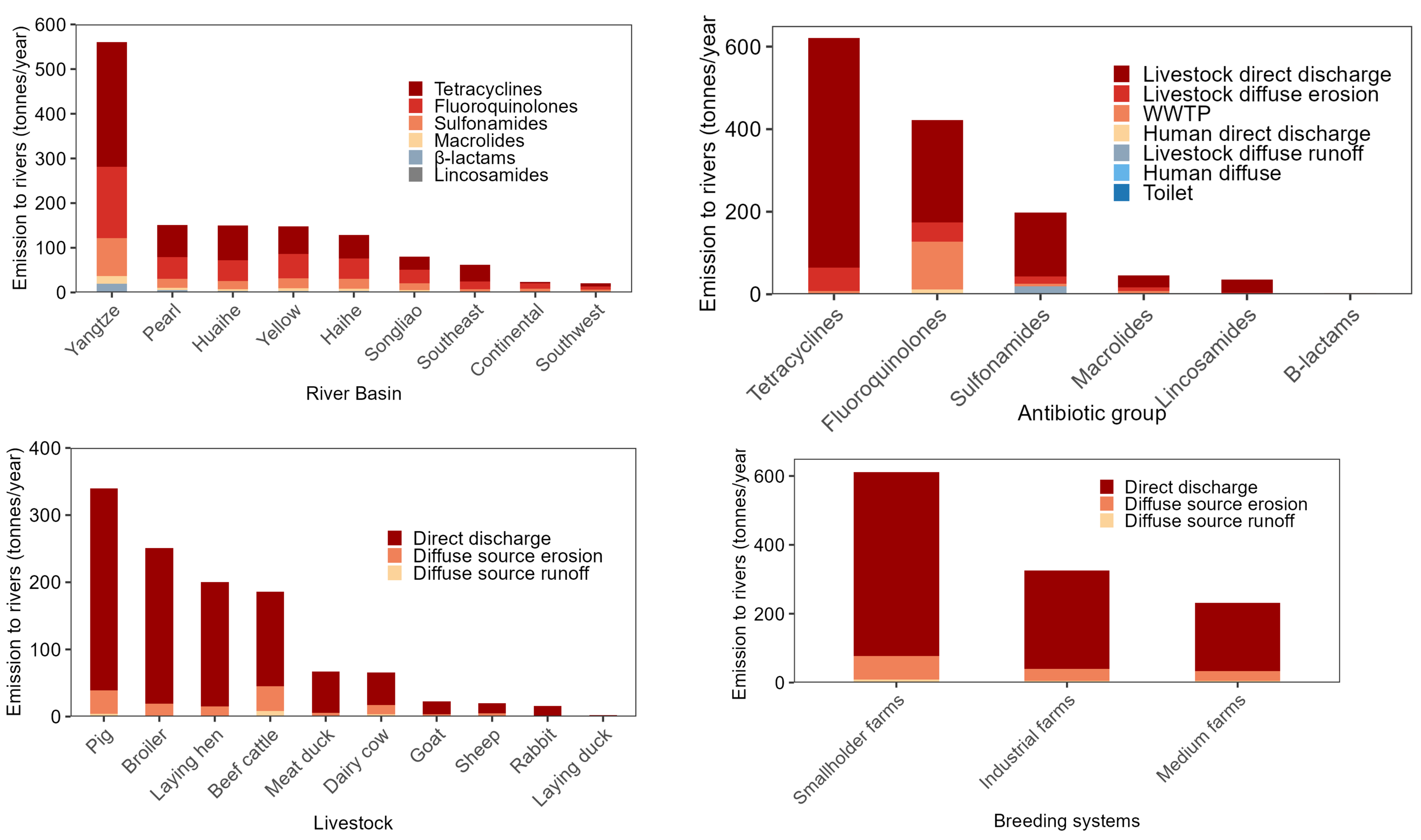

Figure 1. Antibiotics emission from various river basins, antibiotic classes, livestock species and breeding systems.

- Hotspots of elevated antibiotic concentrations are Huaihe, Haihe, Pearl, middle and downstream of Yellow and Yangtze, south of Songliao River basins.

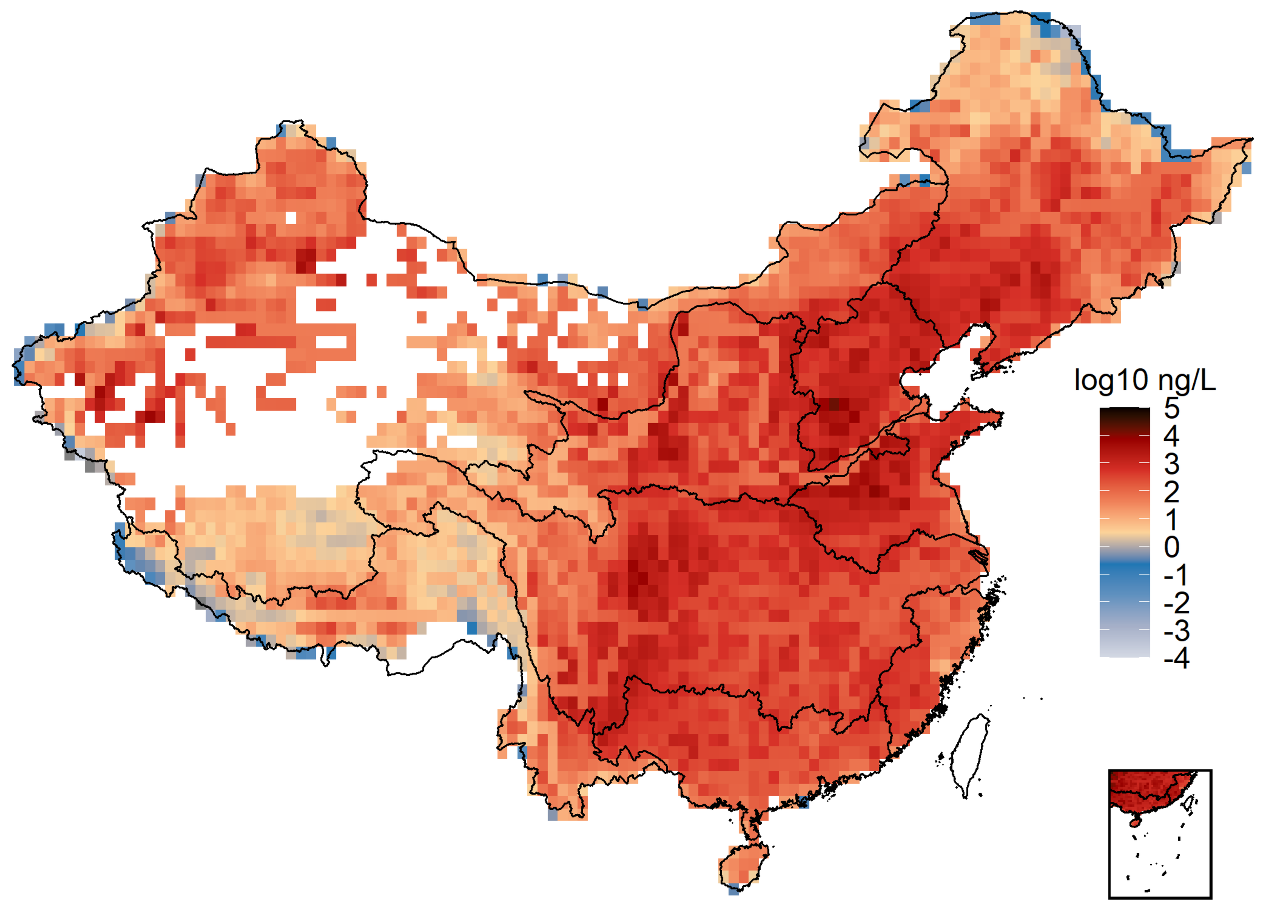

Figure 2. Antibiotic concentration distribution in rivers in China.

- Fluoroquinolone antibiotics pose the highest risk of antibiotic resistance selection.

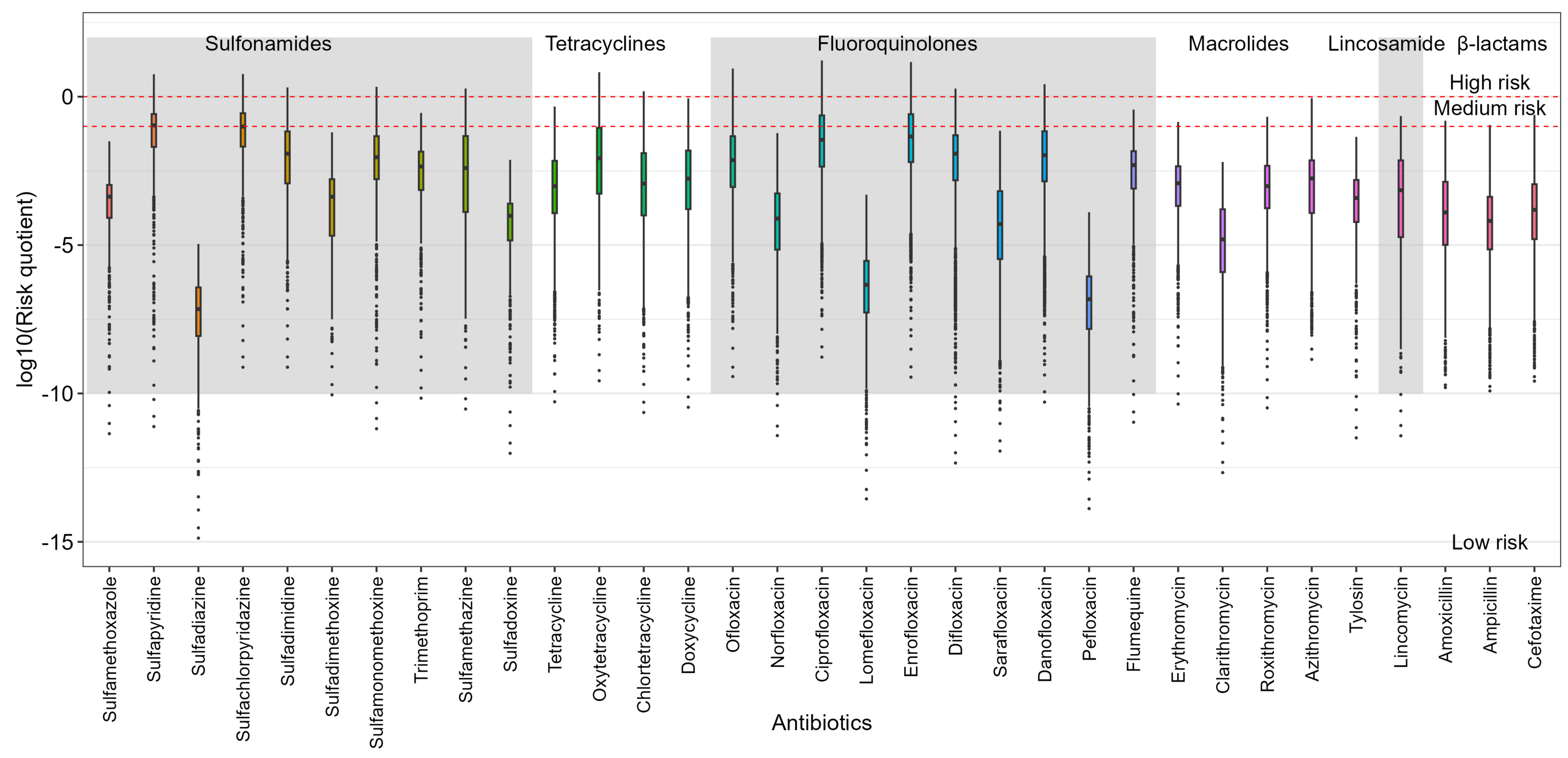

Figure 3. Distribution of risk quotient of antibiotic resistance selection.

Conclusion

- Antibiotic pollution hotspots are Huaihe, Haihe, Pearl, middle and downstream of Yellow and Yangtze, south of Songliao River basins.
- Direct discharge of livestock manure, discharge from WWTPs and diffuse emission from livestock are the main sources.
- Antibiotics in rivers in China pose medium to high risk of antibiotic development.
- Fluoroquinolones, especially ciprofloxacin and ofloxacin are the priority antibiotics to be managed.

References

Vermeulen, L. C., van Hengel, M., Kroeze, C., Medema, G., Spanier, J. E., van Vliet, M. T., & Hofstra, N. (2019). Cryptosporidium concentrations in rivers worldwide. *Water research*, *149*, 202-214.

Acknowledgements

We gratefully acknowlege the sponsors of this research:China Scholarship Council (NO.201913043) and Hainan University

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UV exposure and tillage abrasion on macro/micro-plastic fragmentation

Hanyue Zhang, Kai Wang, Xuejun Liu, Violette Geissen, Xiaomei Yang

Background

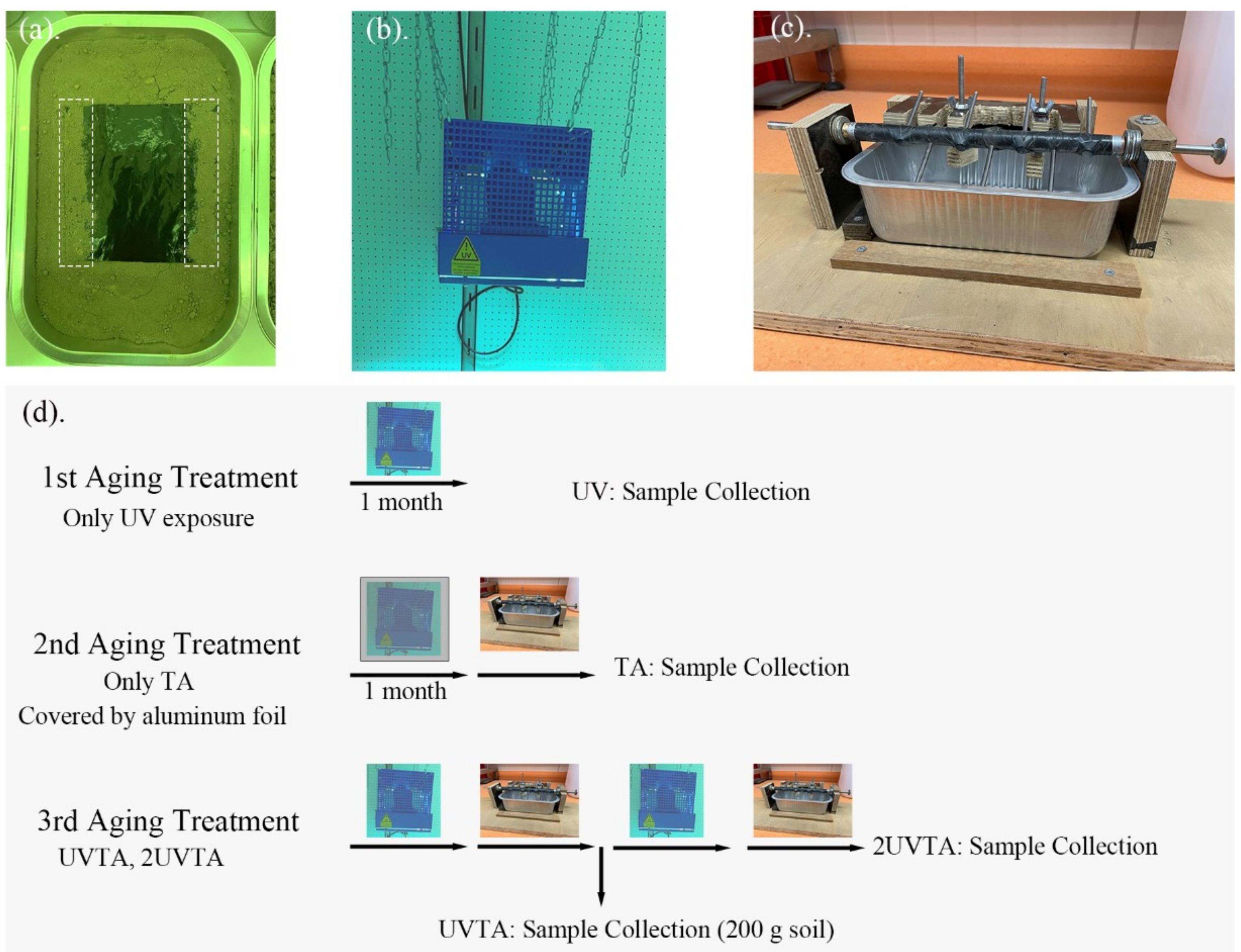
Plastic mulch films have become integral to global agricultural production due to their various advantages, yet their widespread use has resulted in the accumulation of significant amounts of agricultural plastic waste. Once applied to fields, these films undergo progressive fragmentation, influenced by multiple factors such as UV radiation, mechanical abrasion, and hydrolysis, producing numerous macroplastics (MaPs) and microplastics (MiPs).

Objectives

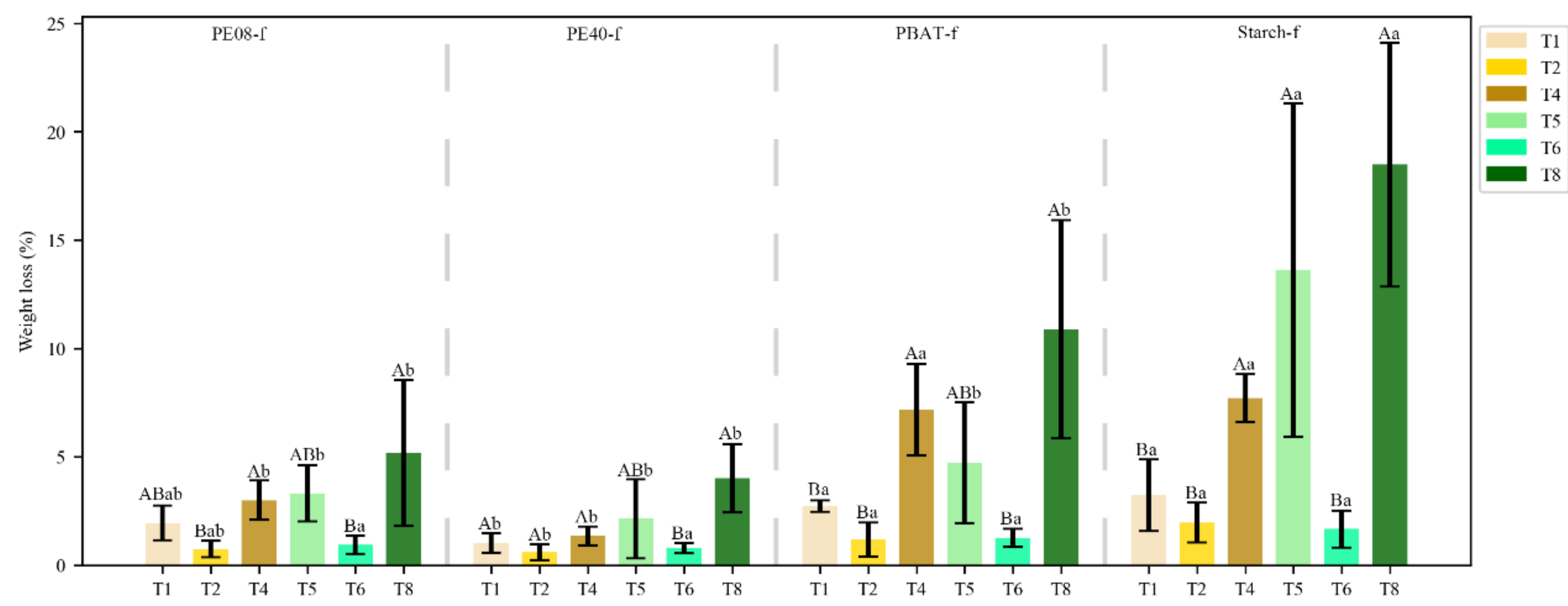
The experiment investigated the fragmentation behavior of conventional and biodegradable plastic mulch films in an accelerated weathering chamber with UV lights with different soil humidity. Tillage practice(TA) was applied after UV exposure and the procedures were followed as famers doing in the field. We hypothesized that plastic fragmentation processes can be influenced by aging treatments, polymer characteristics, and soil conditions. Accordingly, this study aimed to: (a) quantify the generation of MaPs and MiPs from different plastic films under different treatments; (b) compare the fragmentation behavior across aging factors, including UV exposure, TA, and their combination; (c) assess the influence of plastic polymer type, film thickness, and soil humidity on plastic fragmentation.

Methods

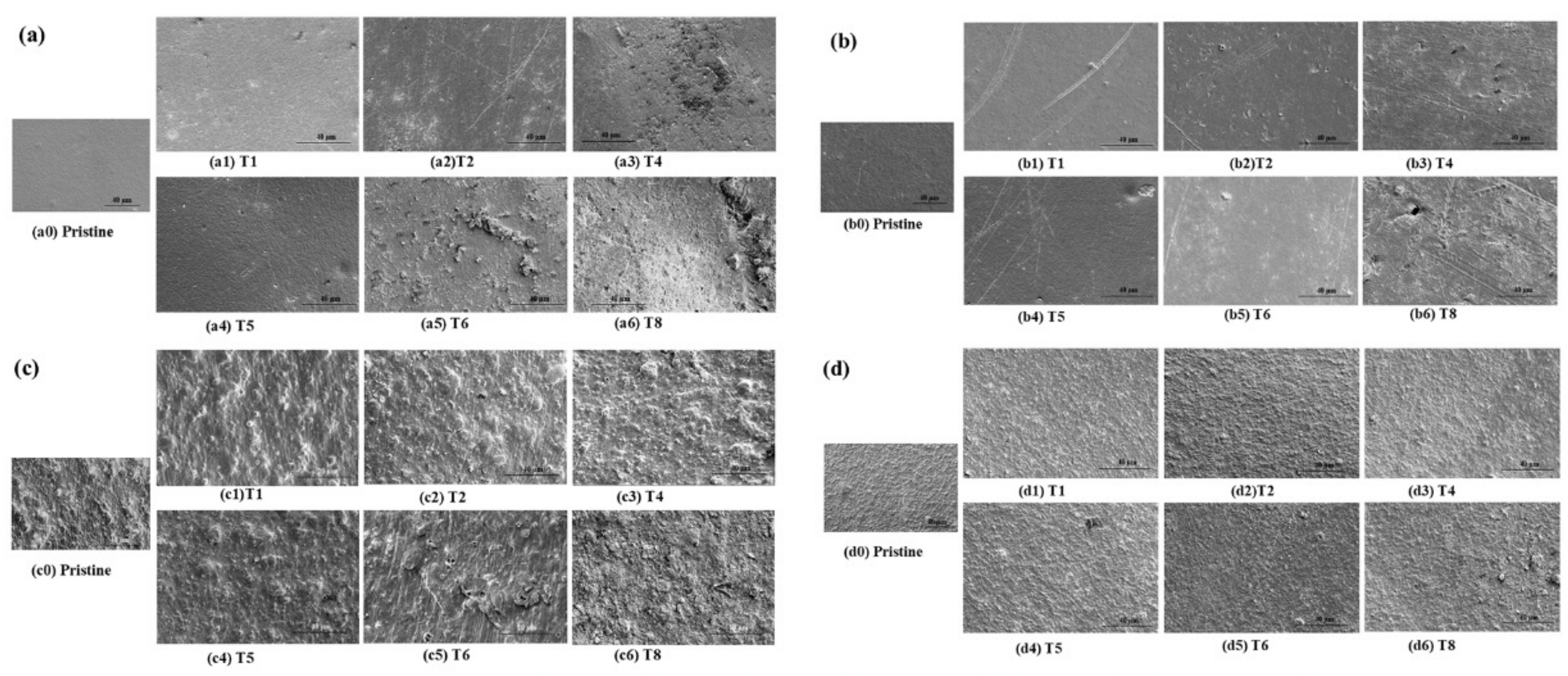
- Polymers:
  - 8 μm polyethylene (PE) film (PE08-f)
  - 40 μm PE film (PE40-f)
  - 15 μm polybutylene adipate terephthalate-based film (PBAT-f)
  - 15 μm Starch-based film (Starch-f)
- Soil condition:
  - Dry condition (20% FC)
  - Wet condition (60% FC)
- Soil pot: Contains 1.3 kg of soil covered with a 10 cm × 10 cm mulch film.
- High-intensity UV light: UV intensity four times that of natural sunlight to simulate accelerated aging.
- Mechanical abrasion instrument: A scaled-down rotary tiller used to simulate mechanical abrasion, mimicking the wear experienced during tillage.



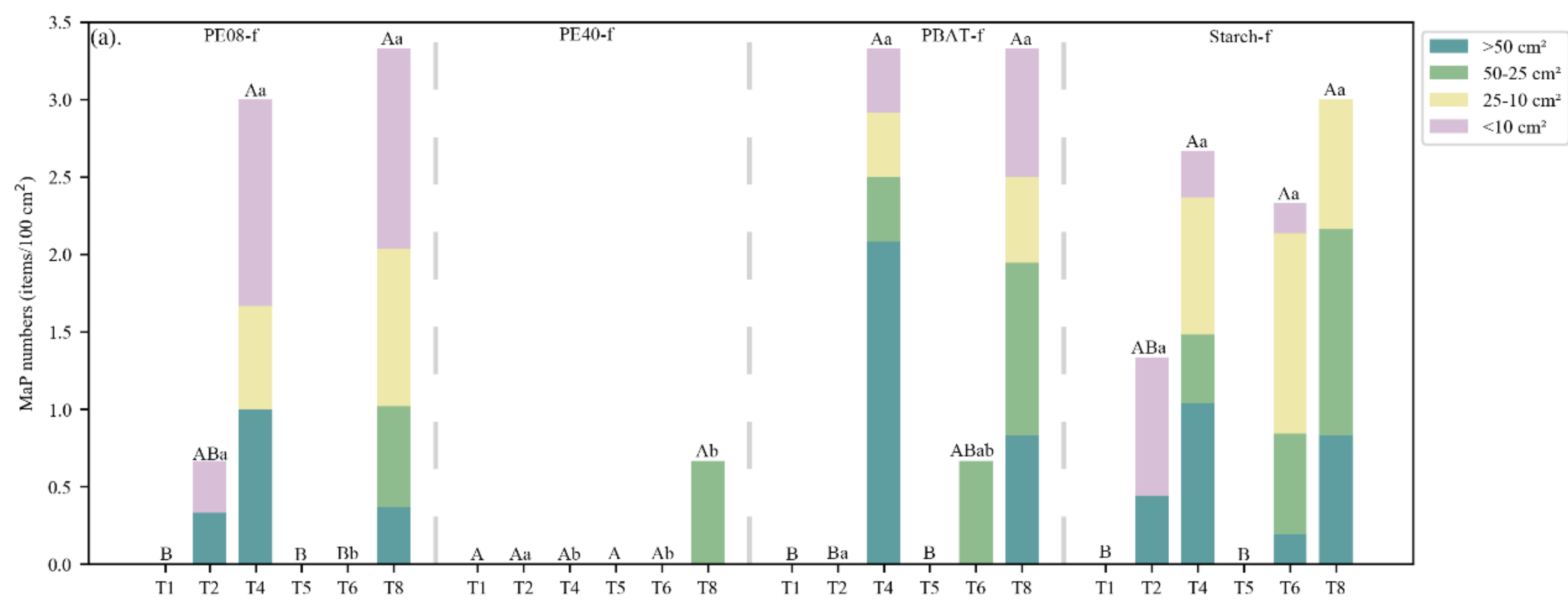
Results



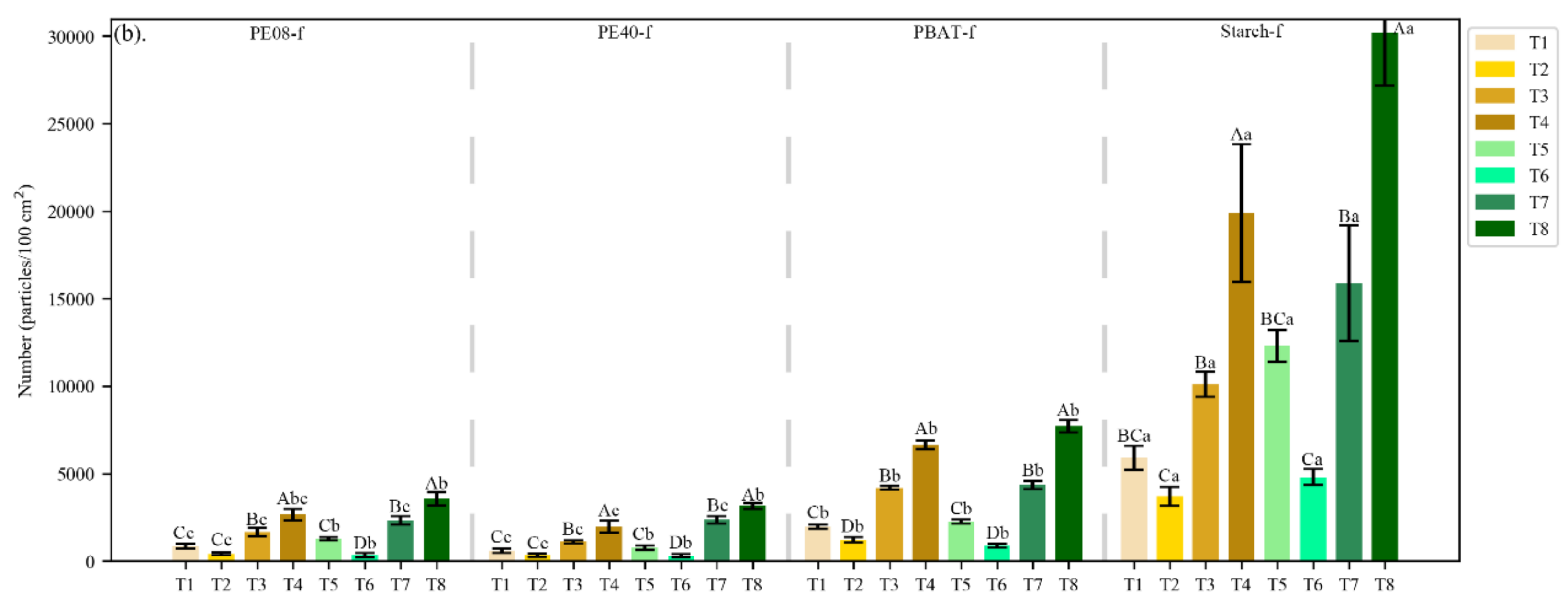
Weight loss of plastic films.



SEM images of plastic films with PE08-f (a), PE40-f (b), PBAT-f (c), or Starch-f (d).



MaP generation (items 100 cm^{-2}) from different treatments.



Different capital letters represent significant differences in MaP, MiP numbers or weight loss between different aging treatments, while different lowercase letters indicate significant differences between different plastic types (p<0.05). T1, T2, T3, and T4 represent UV, TA, UVTA, and 2UVTA treatments under dry conditions, while T5, T6, T7, and T8 correspond to the same treatments under wet conditions.

Conclusions

- Our findings indicate that the combination of UV and TA significantly accelerated fragmentation, resulting in the highest plastic weight loss and MaP/MiP generation.
- Starch-f exhibited the highest weight loss and MaP/MiP generation, followed by PBAT-f and PE08-f.
- Higher soil moisture levels enhanced plastic fragmentation, emphasizing the role of environmental conditions in the degradation process.

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Acknowledgements

We gratefully acknowlege the sponsors of this research:China Scholarship Council (NO.201913043)

Fate and risk of atmospheric pesticides in the North China Plain

Mingyu Zhao, Kai Wang, Daniel Figueiredo, Coen Ritsema

Background

The widespread distribution of pesticides in the global atmosphere has been well-documented, posing significant threats to ecosystems and human health, particularly from highly hazardous pesticides (HHPs) characterized by elevated toxicity and/or persistence. Recent studies suggest that certain environmental transformation products of pesticides may be even more hazardous than their precursors. However, related knowledge remains limited currently, hindering our comprehensive assessment and effective response.

Objectives

- Develop a pseudo-target analysis framework to quantify pesticides and their transformation products in the air.
- Investigate the occurrence and distribution of pesticides in the atmosphere across the North China Plain.
- Assess the health risks of atmospheric pesticides to local residents and animals.
- Simulate potential long-range transport of pesticides based on back-trajectory analysis.

Methods

- Sampling was conducted during the period from November 2022 to October 2023 across the North China Plain.

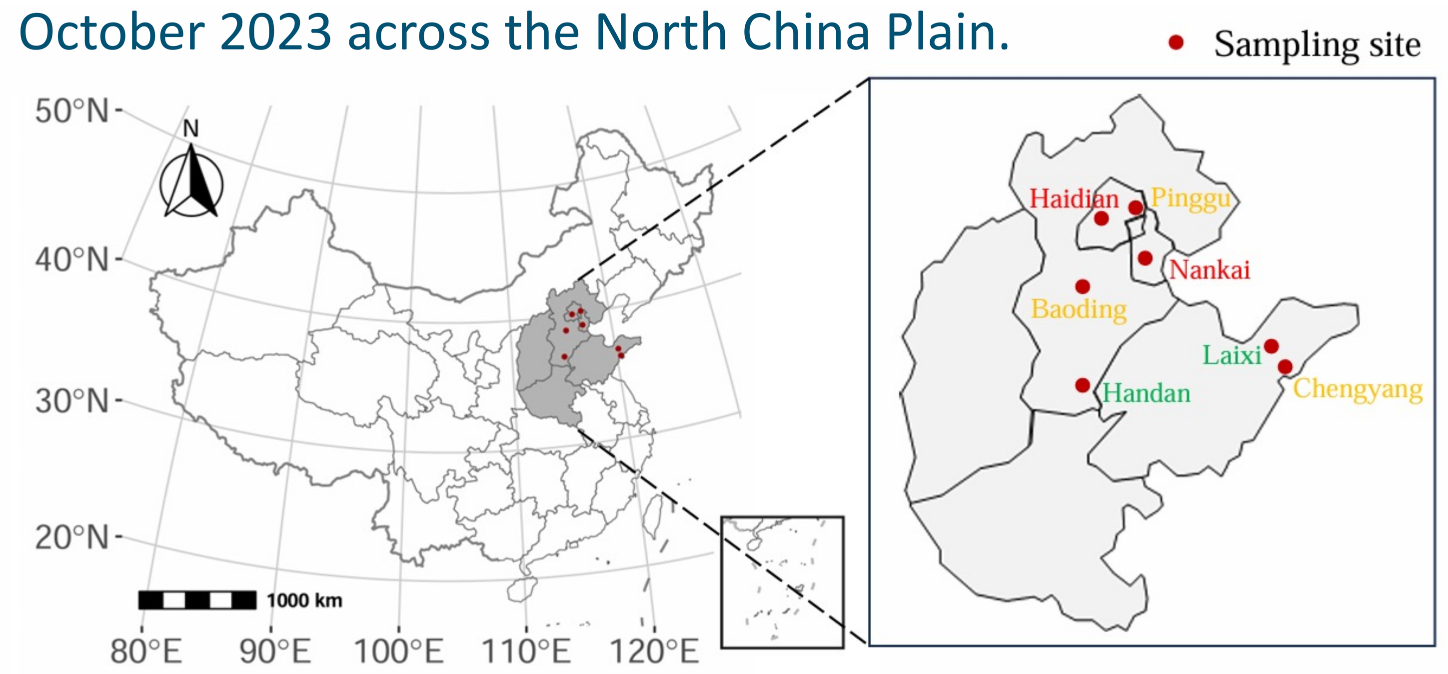

Fig. 1 Locations of sampling sites in the North China Plain.

- Targeted and non-targeted analysis of more than 1400 pesticides.

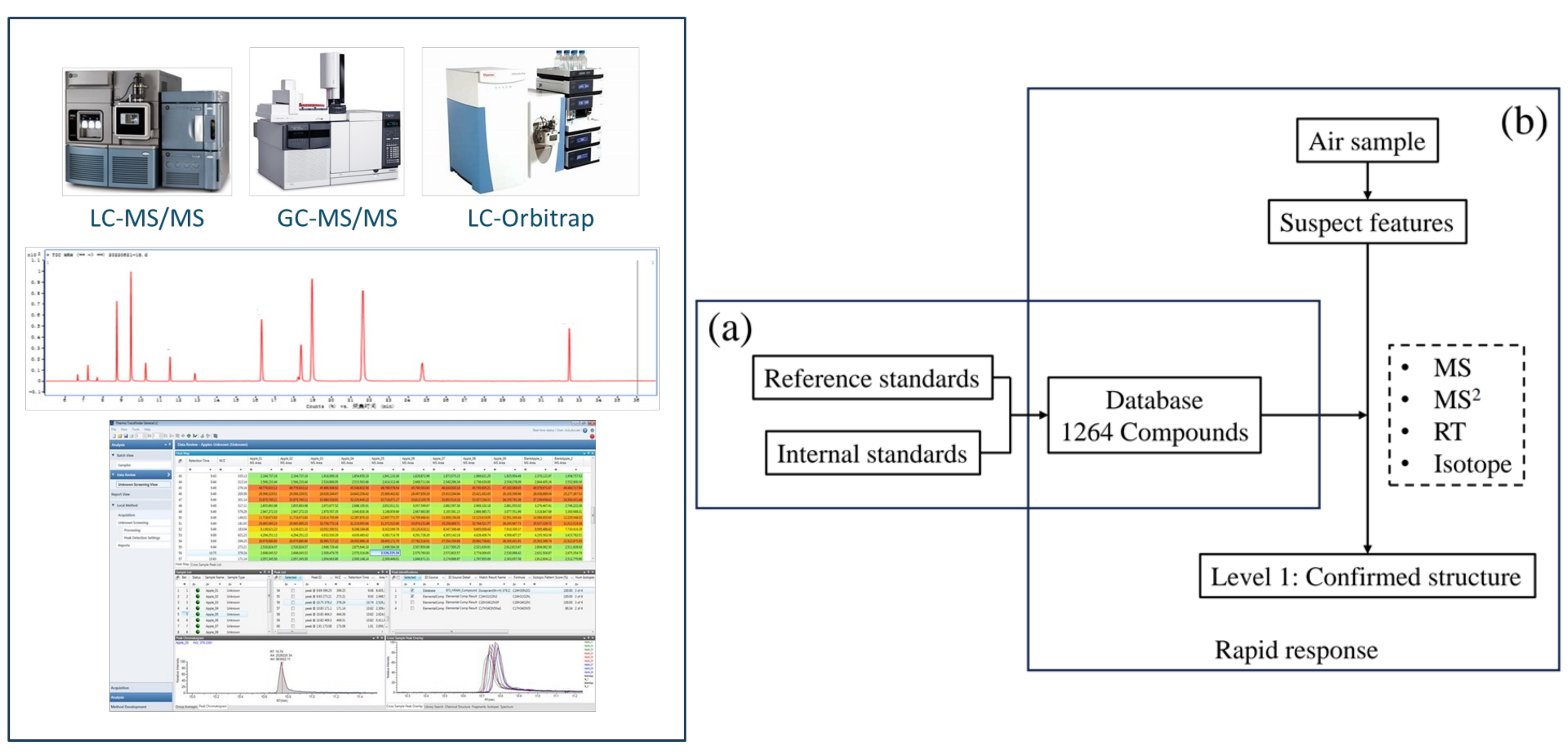

Fig.2 Analytical framework for the rapid identification of atmospheric pesticides and transformation product.

- Exposure and risk of atmospheric pesticides in the North China Plain.

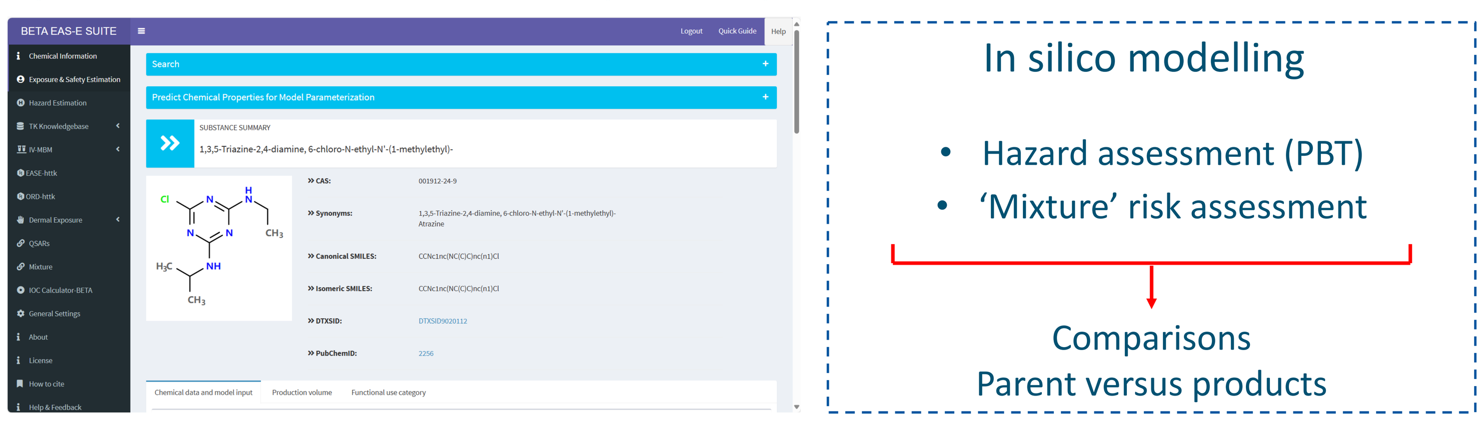

Fig. 3 Risk assessment of atmospheric pesticides based on the EAS-E model.

Results

- A total of 127 pesticides were quantified in the ambient air samples, with detection frequencies ranging from 1.2% to 97.6%.
- The atmospheric residues consisted of 61.2% insecticides, 31.7% fungicides, and 7.1% herbicides.
- Concentrations of parent pesticides ranging from 3122.9 to 7023 pg m^{-3}, which were 4.8 to 15.3 times higher than those of transformation products (303.9–1273.9 pg m^{-3}).

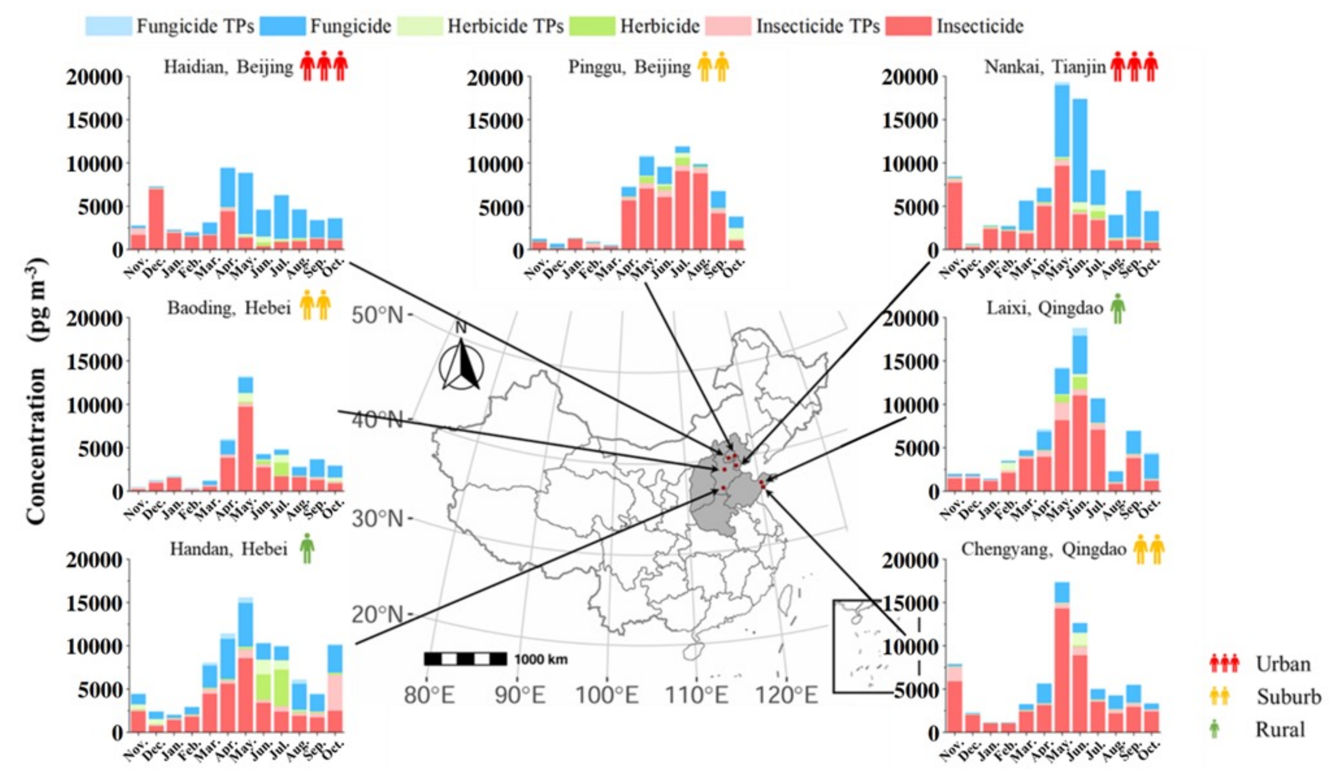

Fig.4 Distribution of atmospheric pesticides in the North China Plain.

- The cumulative risk of atmospheric pesticides to human health in the North China Plain ranges from 0.03 to 3.09.
- The North China Plain is influenced by both external inputs and intercity transport of atmospheric pesticides.

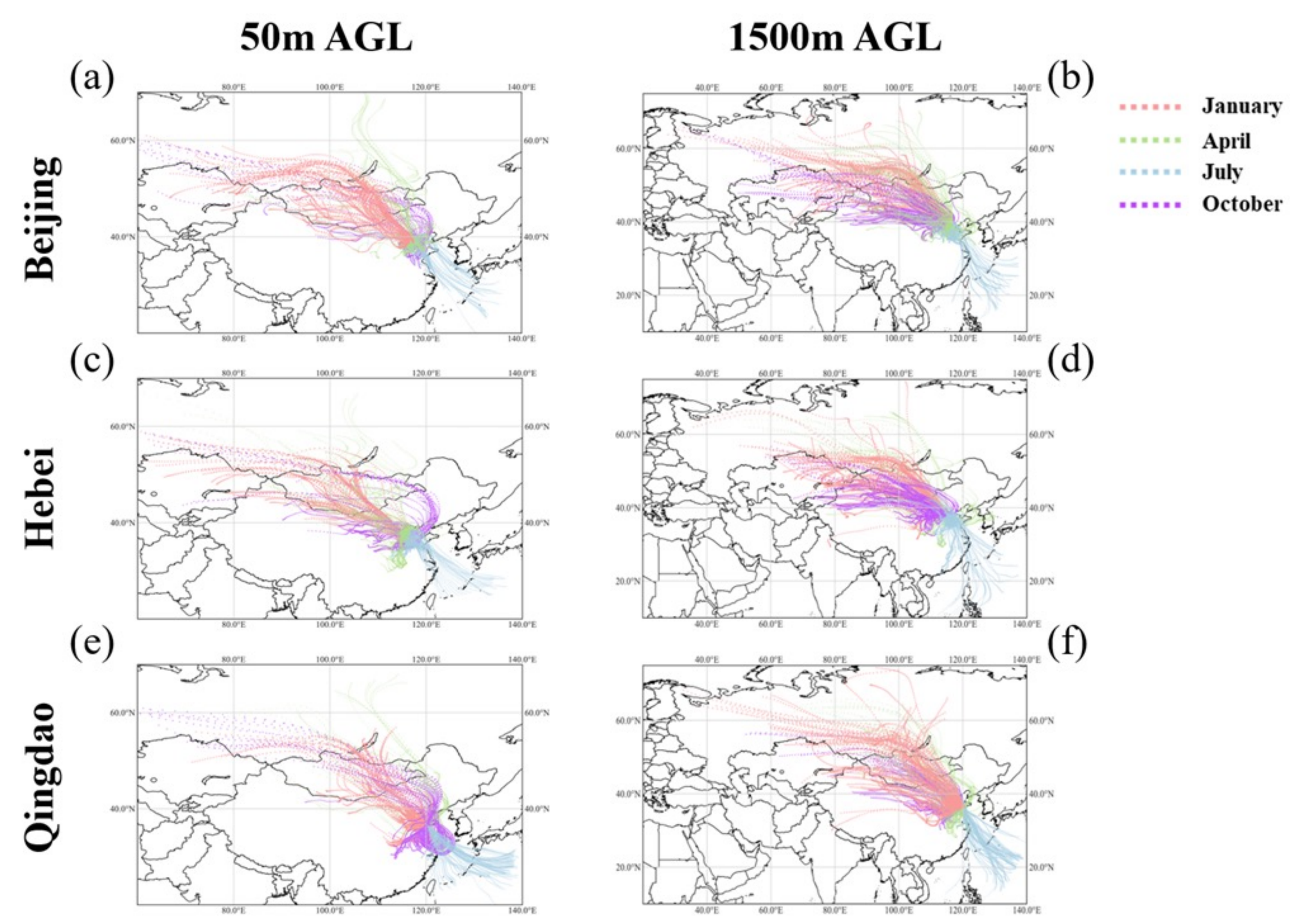

Fig.5 The 168-h backward trajectory tracking analysis for the North China Plain.

Conclusions

Here, we developed a rapid pseudo-targeted high-resolution mass spectrometry method to screen thousands of pesticide-related compounds in air samples. In the North China Plain, our year-long monthly sampling identified 127 pesticides and transformation products, with clear seasonal and spatial trends linked to agricultural activities. Risk assessments based on environmental and toxicological data revealed unacceptable human and animal risks in some cases, dominated by HHPs. HYSPLIT analysis further indicated that both external inputs and intercity migration contribute to atmospheric pesticide levels, with Eurasia and the Pacific Ocean as potential sources.

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Pursuing China's Sustainable Food Security through Strategic Cropland Productivity Improvement

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Supervisors: Dr. Jie Zhang, Prof. Fusuo Zhang, Dr. Luuk Fleskens, Prof. Coen Ritsema

Background

Feeding an increasingly affluent population is a great challenge for global agriculture, particularly in developing economies with low cropland productivity. The UN has identified improving agricultural productivity as a key strategy in SDG 2.4 to achieve sustainable food production and food security (UN, 2020). Strategic cropland productivity improvement is therefore key to enhance agricultural productivity. China has launched a portfolio of national programs to improve cropland productivity while increasing resource use efficiency and environmental sustainability. Understanding the driving factors controlling the agronomic and environmental impacts of national programs implemented is key to increase the sustainability of farming systems across China in view of the global and regional boundaries crossed, to promote healthy soils, ensure food security and to minimize adverse environmental impacts of farming.

Objectives

- Analyze the spatiotemporal change of cropland productivity across China from 1980 to 2020;
- Quantify the contribution of the national program from 1980 to 2020 on the cropland productivity improvement based on ensemble learning approach;
- Analyze driving factors controlling the agronomic and environmental impacts of national programs implemented.

Results

China's Cropland Productivity Improvement

From 1980 to 2020, China doubled its cropland productivity (from 2.86 to 5.73 t/ha) and reduced the variability in cropland productivity, with the coefficient of variation decreasing from 37% in 1980 to 21% in 2020 (Fig. 1). In the 1980s, China's cropland productivity improved by 37% over one decade (equaling to 1.23 t/ha), with a remarkable growth in the Northeast region. In the 1990s and 2000s, the cropland productivity improved by 15% (0.60 t/ha) and 16% (0.74 t/ha) on average, respectively. In the 1990s, cropland productivity increased more in the Northwest region and the North China Plain. In the 2000s, the improvement in cropland productivity was more balanced across China.

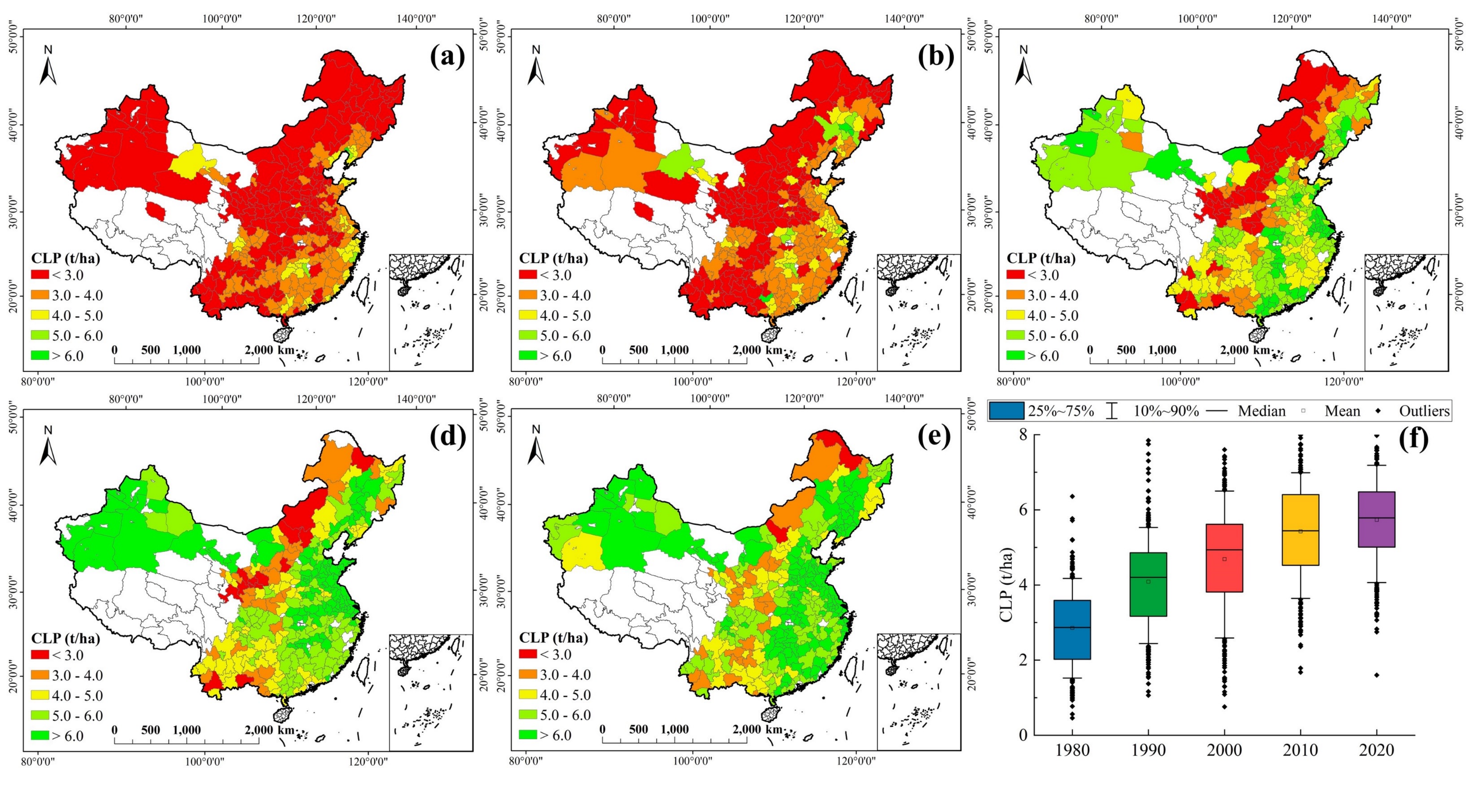

Fig. 1. Spatiotemporal changes in cropland productivity (ton/ha) from 1980 to 2020. (a) 1980, (b) 1990, (c) 2000, (d) 2010, (e) 2020, (f) temporal change of country averaged cropland productivity.

Contributions of National Programs on Cropland Productivity Improvement

From 1980 to 2020, the national programs contributed up to 53% to the improvement in cropland productivity from 1980 to 2020 (Fig. 2). In the first two decades, the programs even contributed more than 60% of the cropland productivity improvement. After 2000, their contributions gradually decreased down to 41% in the 2000s and to 8.8% in the 2010s.

The increase in agricultural inputs (fertilizer inputs) was the dominant factor in cropland productivity improvement in the 1980s (0.43 t/ha), 1990s (0.20 t/ha), and 2000s (0.15 t/ha). The negative effect of agricultural inputs in the 2010s was mainly due to the stimulated reduction in fertilizer inputs. The effects of improved agricultural infrastructure gradually decreased over time, from 0.19 t/ha in the 1980s to 0.014 t/ha in the 2010s. After 1990, the improvement of cropland soil fertility became an important factor in increasing cropland productivity (0.16 t/ha, 0.09 t/ha, and 0.05 t/ha in the 1990s, the 2000s, and the 2010s, respectively).

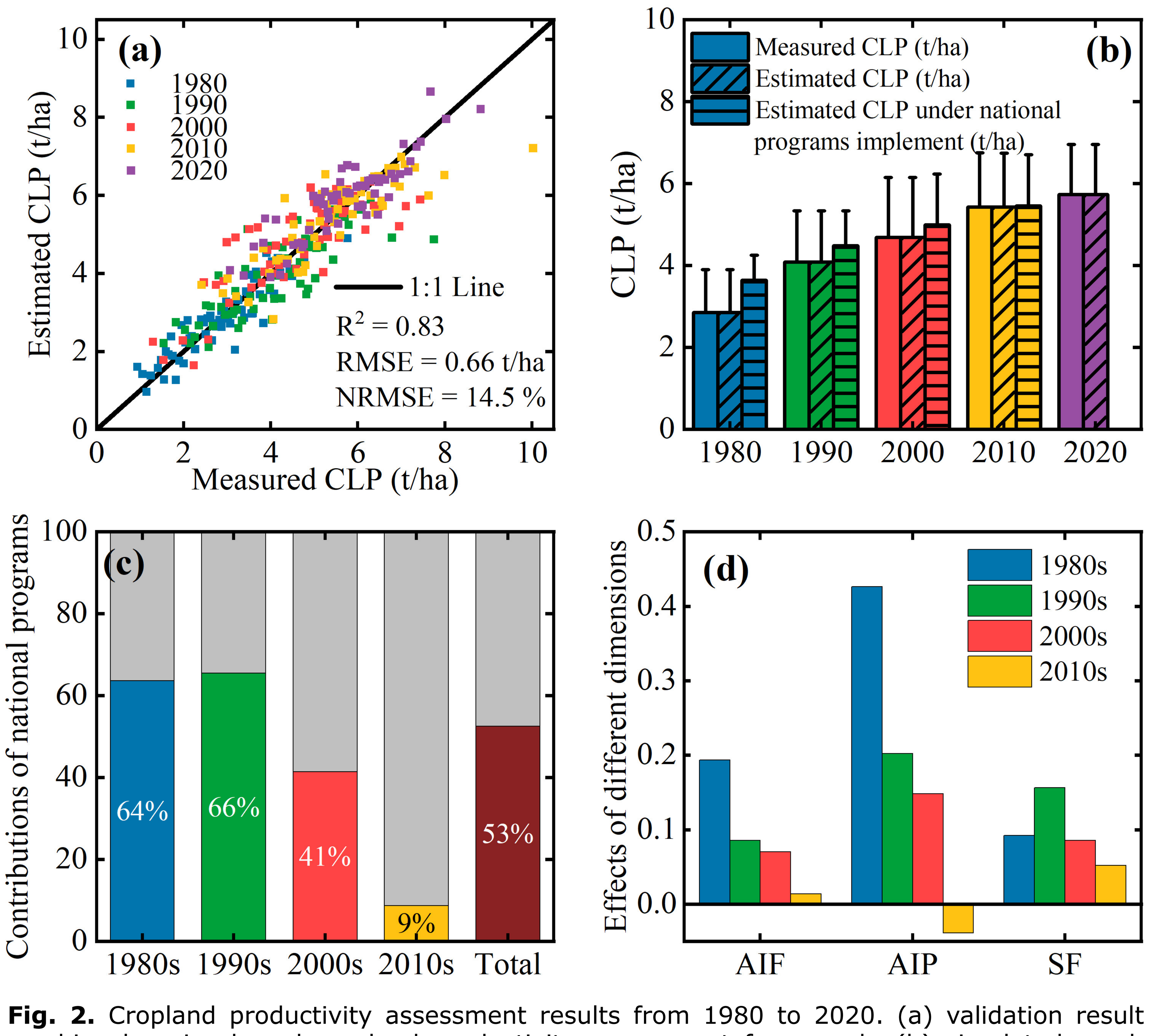

Fig. 2. Cropland productivity assessment results from 1980 to 2020. (a) validation result of machine learning-based cropland productivity assessment framework, (b) simulated cropland productivity with or without the impact of national programs, (c) contributions of the nation programs, (d) effects of the national programs on different dimensions, AIF is agricultural infrastructure, AIP is agricultural inputs, SF is soil fertility.

Summary

This study used a multi-source data and machine learning-based framework to quantify the contribution of national programs. From 1980 to 2020, China has doubled its average cropland productivity (from 2.86 to 5.73 t/ha), and the national programs contributed to 53% of the total growth. In the 1980s and 1990s, the contribution exceeded 60%, and agricultural inputs were the dominant factors. After 2010, the dominant factor has gradually shifted to soil fertility and agricultural infrastructure in most regions.

Acknowledgements

We gratefully acknowlege the sponsors of this research:China Scholarship Council (NO.201913043)) and Hainan University.

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Predicting Rhizosphere-Competence-Related Catabolic Gene Clusters with RhizoSMASH

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Scan to Check **rhizoSMASH** on WUR GitLab

Abstract

- Develop **rhizoSMASH**, a bioinformatic tools to analyze catabolic capacity to utilize root exudate compounds *in silico* based on bacterial genomic sequences.
- Characterize **r**hizosphere-**c**ompetence-related catabolic **g**ene **c**lusters (**rCGCs**) identified by rhizoSMASH and demonstrate their power in prediction of rhizosphere competence.

Introduction

- The capability of a soil microorganism to colonize the rhizosphere of a plant, known as **rhizosphere competence**, significantly influences the benefits a host plant could receive from their interaction.
- The ability of **catabolizing the compounds in root exudates** is one of most important determinants of rhizosphere competence.
- The diversity of catabolic pathways and the redundancy of catabolic genes have made it challenging to interpret catabolism from a (meta)genomic perspective.

Methods

Rule based detection of rCGCs is done by capturing enzyme domains with profile hidden Markov models and limiting the combination of these domains with a set of logical rules (detection rules). (Fig 1A)

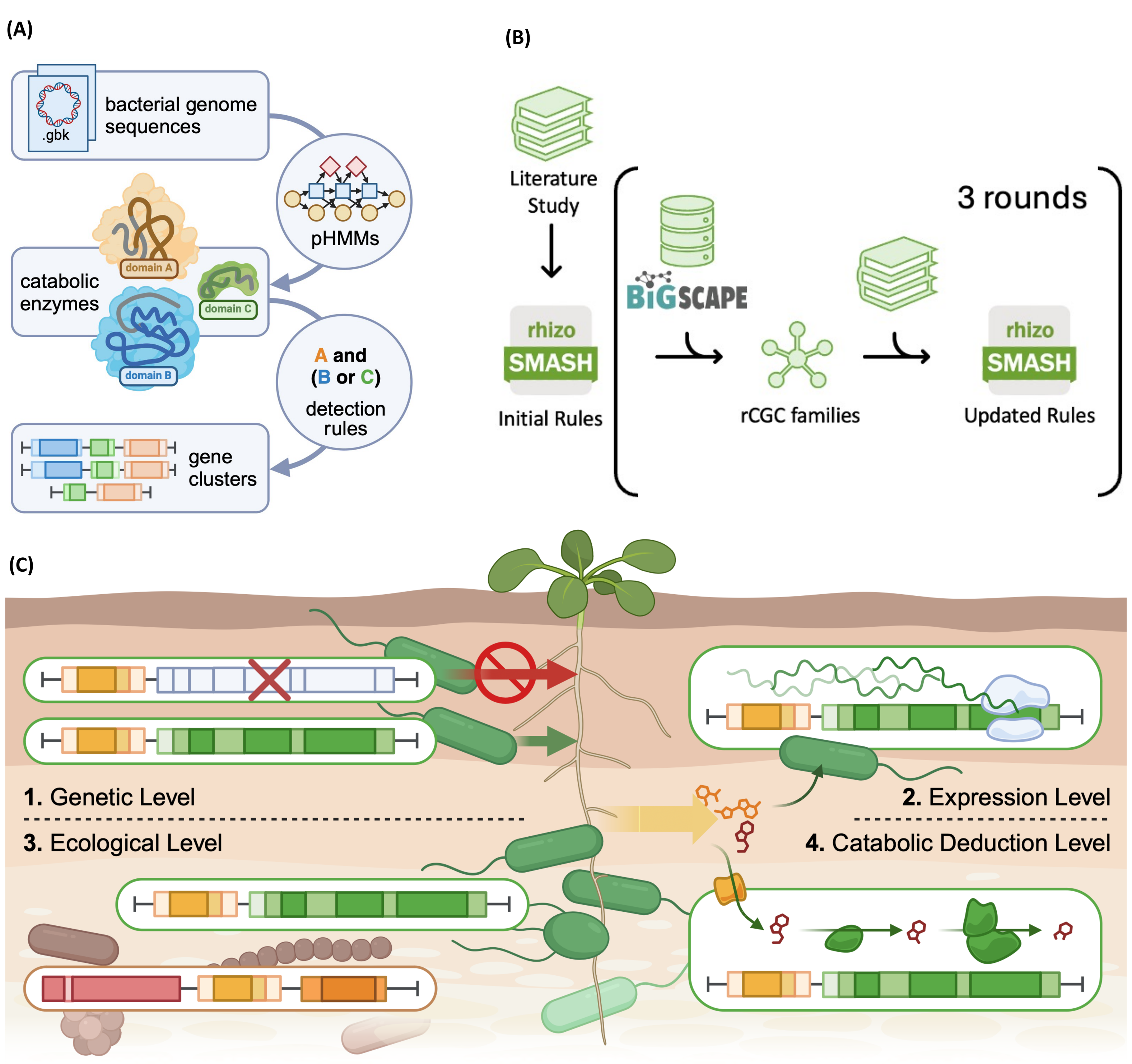

Fig 1. **(A)** a workflow of rhizoSMASH. **(B)** Detection rule calibration loops. **(C)** Four levels of known rCGC evidence:
1. interruption of gene cluster causes rhizosphere incompetence;
2. treatment of root exudate (components) triggers expression of the gene cluster;
3. the gene cluster were more often found in rhizosphere-dwelling bacteria;
4. the gene cluster encodes a pathway utilizing a major root exudate component

To design the gene cluster detection rules for rhizoSMASH, we ran a comprehensive literature study and collected known gene clusters that have 4 levels of confidence on their relation to rhizosphere competence. (Fig 1C)

Calibration of detection rules is undergoing to improve prediction accuracy. We first ran rhizoSMASH on a collection of soil and rhizosphere bacterial genomes. The detected rCGC calls were summarized with Big-SCAPE. False rCGCs calls were manually excluded based on visual inspection of the genomic context in each cluster family and public research articles by adjusting detection rules. (Fig 1B)

Conclusions

RhizoSMASH provides an extensible bioinformatic framework to study catabolism in rhizosphere bacteria, offering new possibilities in agriculture green development via designing of more rhizosphere-accessible synthetic microbiomes or through rhizobacteria-targeted plant breeding.

Results

The Working Version of rhizoSMASH contains 58 detection rules covering catabolic pathways of carbohydrates, organic acids, amino acids, amines, phytohormones and aromatic metabolites found in root exudates.

Taxonomic distribution of rhizoSMASH-predicted rCGCs.

We characterized rCGCs detected by rhizoSMASH from all bacterial genomes in 1229 soil or rhizosphere isolated bacterial genomes. Rhizosphere-abundant bactaia families *Pseudomonadaceae* and *Burkholderiaceae* show the highest abundance and diversity in rCGC types. (Fig 2A)

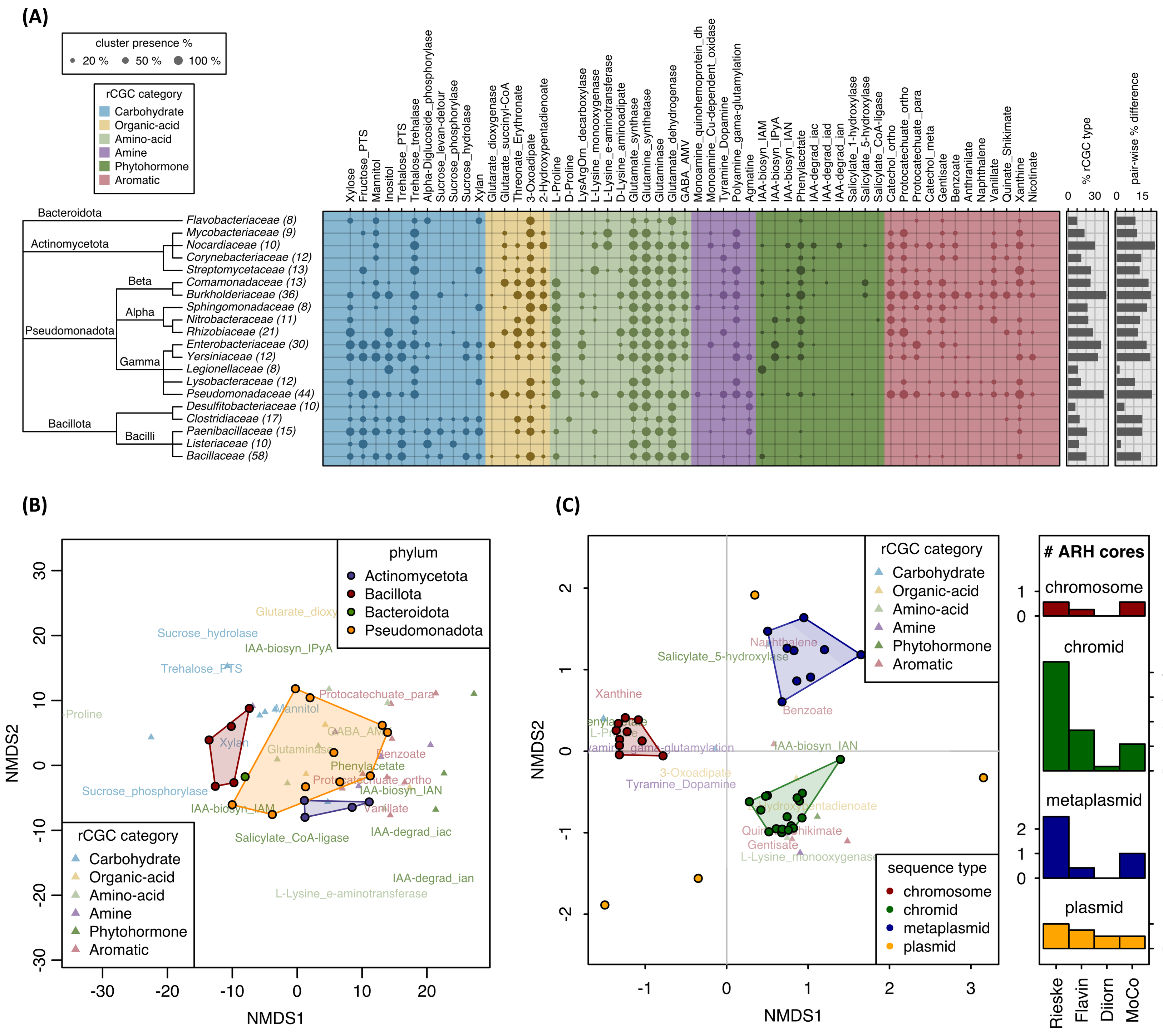

Fig 2. Distribution of rCGCs in soil and rhizosphere bacteria genomes. **(A)** Prevalence of each rCGC type, abundance and diversity of rCGCs in bacteria families. **(B)** NMDS of bacteria families according to rCGC prevalence. Families are colored based on phyla. **(C)** NMDS of chromids in *Burkholderia* spp. according to rCGC presence/absence profiles. Chromids are colored based on their rank of sizes in each genome.

rhizoSMASH rCGCs predicts rhizosphere competence.

We trained random forest models to predict the rhizosphere competence of these *Pseudomonas* strains reported by Zboralski *et al.* in 2020 using either rhizoSMASH-predicted rCGC presence/absence profiles or catabolism data. Cross validation showed that the genome based rCGCs have comparable prediction power as catabolism profiles in rhizosphere competence (Fig 3).

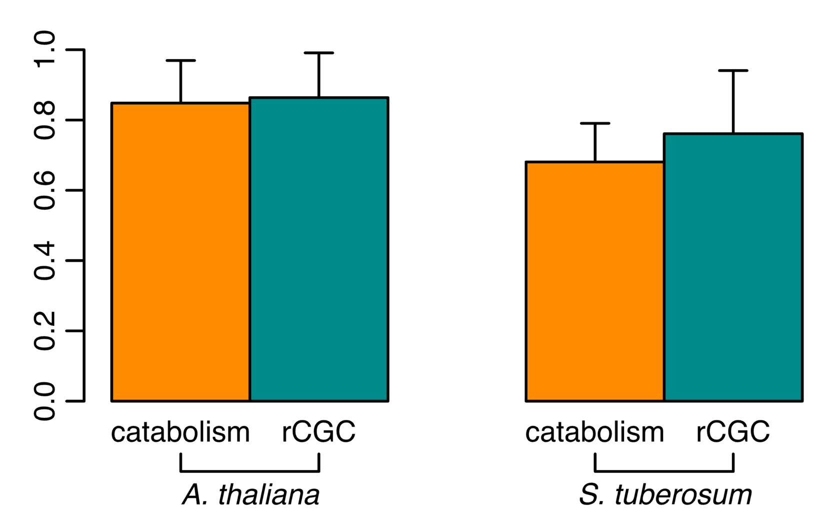

Fig 3. Random forest prediction accuracies of bacterial rhizosphere competence in *A. thaliana* and potato with either experimental catabolism data or rhizoSMASH-predicted rCGC presence/absence profile data.

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Unveiling the influence of domestication on taxonomic and functional microbiome composition in foxtail millet

PhD Candidate: Mingxue Sun

Supervisors: Chunxu Song (CAU); Marnix Medema; Liesje Mommer (WUR); Jos Raaijmakers (NIOO-KNAW; Leiden University)

Background

Plant domestication alters microbiome composition and functions, with "missing microbes" potentially reinstating beneficial plant-microbe associations to boost crop productivity. Foxtail millet (*Setaria italica*) was domesticated from its wild relative, green foxtail (*Setaria viridis*), over 16,000 years ago in northern China (Doust & Diao, 2017). Recent studies reveal significant findings in millet improvement genes and intricate microbe-agronomic trait relationships through pan-genome and mGWAS analysis (Wang et al., 2022; He et al., 2023). However, the influence of foxtail millet domestication on root-associated microbiomes, including connections between root exudates, developmental traits, and microbiome functions, remains unclear.

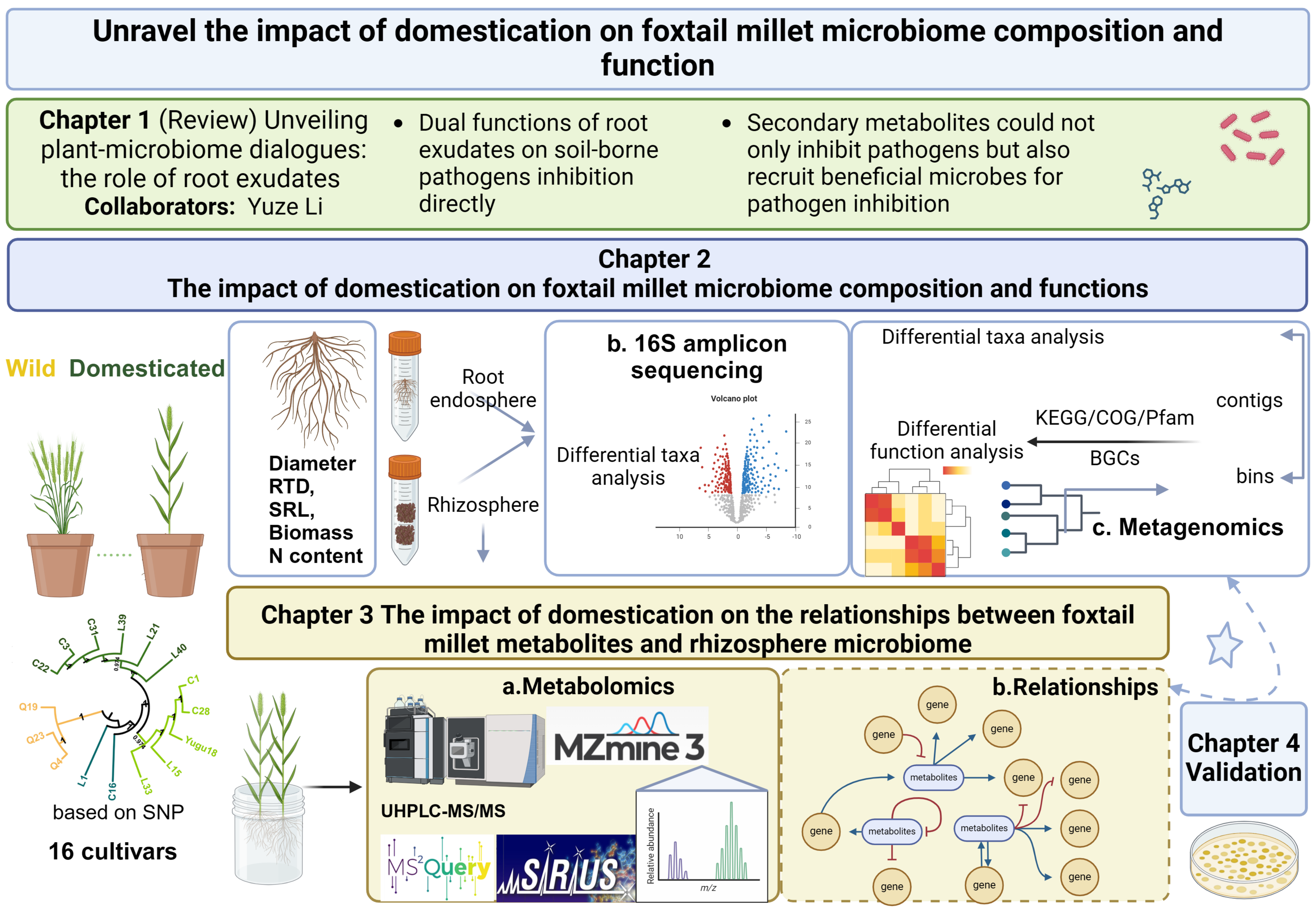
Objectives

I. Investigate the evolutionary changes in root phenotypes of foxtail millet during domestication.

II. Decipher the molecular and chemical signaling mechanisms underlying foxtail millet-microbiome interactions during domestication.

III. Uncover the potential contributions of "missing microbes" to plant growth and health.

Experimental Workflow



Results

- Wild cultivars with higher SRL (Specific Root Length) and smaller RTD (Root Tissue Density) exhibited significant associations with specific ASVs of *Devosia*, *Nocardioides*, *Allorhizobium-Neorhizobium-Pararhizobium-Rhizobium* and the fungal symbiont *Funneliformis*.

Fig.1

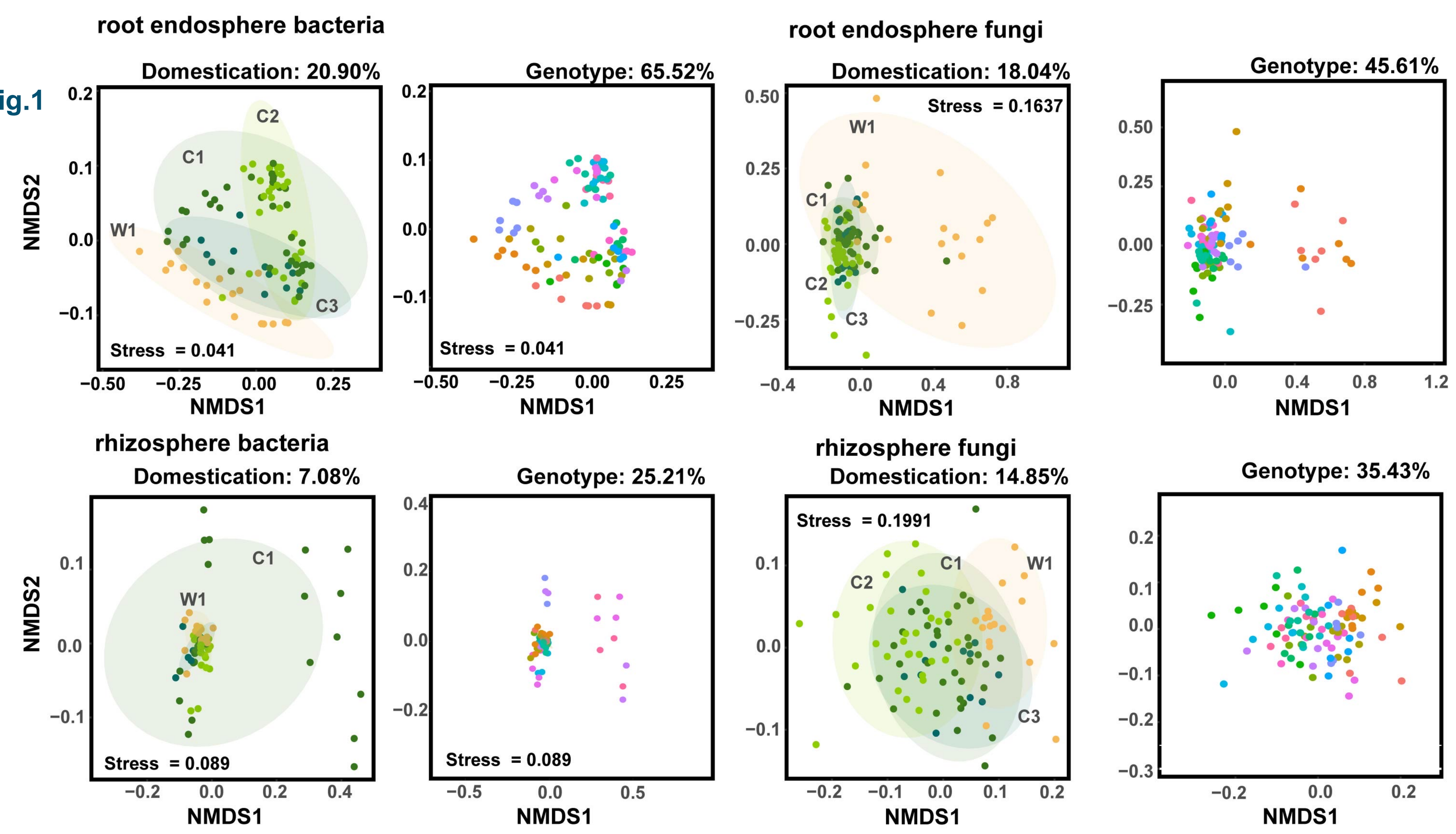


Fig.2

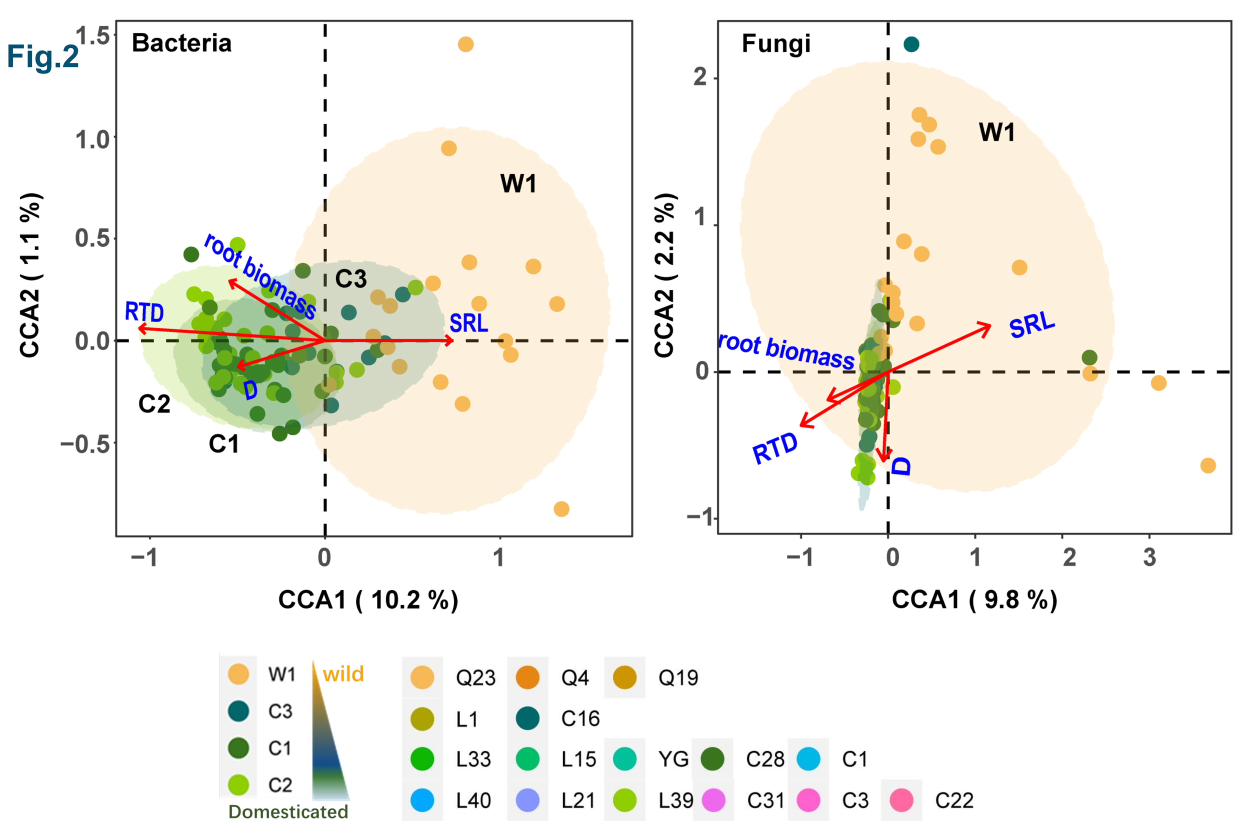


Figure 1. Variation of bacterial and fungal communities constrained by domestication status and genome types. All Non-metric Multi-Dimensional Scaling (NMDS) analyses yielded significant results (PERMANOVA, $p < 0.05$).

Figure 2. Canonical Correspondence Analysis of Amplicon sequencing data and root morphological traits

- Plant domestication shapes rhizosphere microbiome assembly and metabolic functions. "Transcription," Carbohydrate transport and metabolism", "amino acid transport and metabolism" functional categories were significantly enriched in the wild green foxtail. Besides, more multi-type BGCs were detected in wild varieties rhizosphere microbiome.

Fig.3

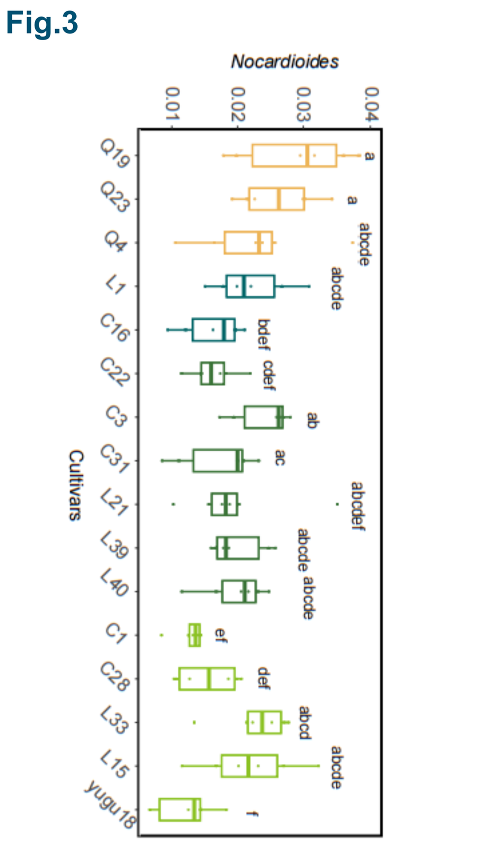


Fig.4

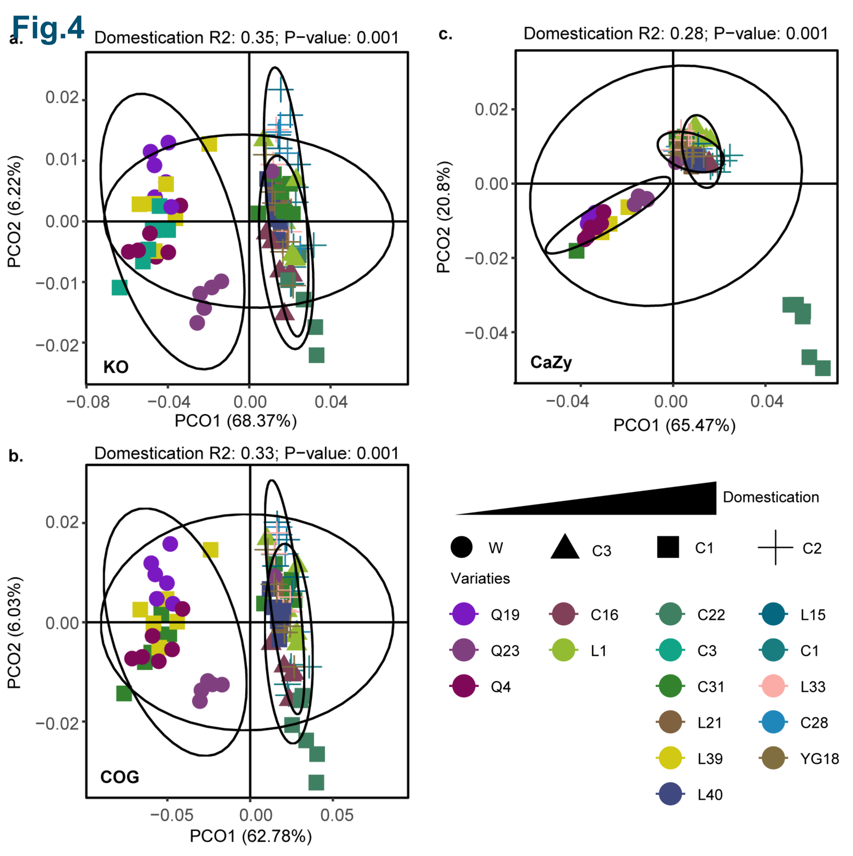


Fig.5

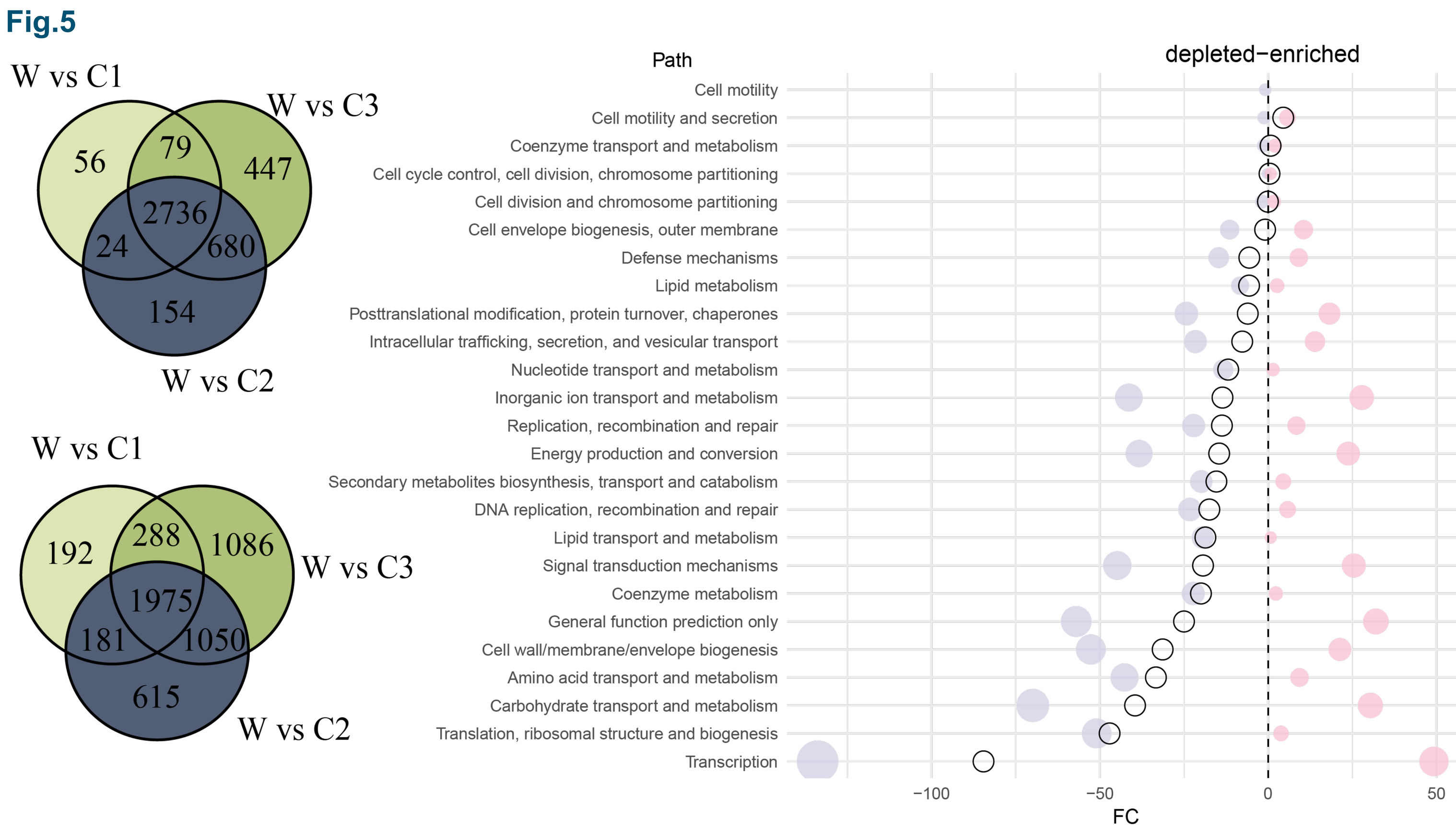


Figure 3. Statistical analysis results of *Nocardioides* relative abundance based on metagenome among sixteen cultivars.

Figure 4. Variance of KOs, COGs, CaZymes profiles during domestication.

Figure 5. The categories of significant depleted and enriched COGs during domestication.

Conclusions

We found domestication exerted strong selection power on the root microbiome assembly and functions. Besides, there were significant associations between the root-associated microbes and specific root phenotypic traits.

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Optimizing crop supply chains for healthy diets in China

PhD candidate: Yijun Li

WUR supervisors: Joke van Lemmen-Gerdessen, Anneleen Kuijsten, Tjeerdjan Stomph, Wopke van der Werf, Sander de Leeuw, Edith Feskens

CAU supervisors: Wenfeng Cong, Shenggen Fan, Mo Li, Fusuo Zhang

Background

Shifting towards more plant-based diets is crucial for health and environmental benefits[1,2,3,4], yet the potential of plant-based foods to sustainably fill the micronutrient supply-demand gap remains underexplored. This research investigates how plant-based foods can alleviate the gap between food supply and malnutrition in a sufficient, diverse, and sustainable way in China.

Objectives

- ☐ Assessing the role and potential of plant-based food supply in fulfilling nutrient needs for energy and 17 nutrients in China.
- ☐ Analyzing possible measures across crop supply chain stages to contribute to nutrition security and sustainability in China and other countries.
- ☐ Exploring the potential of reallocating rice and wheat cultivated areas to underutilized cereals and beans (UCBs) for better nutrition and environmental outcomes in China.

Methods

- ☐ Bipartite network linking crops and nutrients
- ☐ Quantifying coverage (supply/demand ratio), source diversity (exponentiated Shannon entropy) of nutrient sources
- ☐ Linear programming + multi-objective optimization

Results

- ☐ The current food supply primarily based on plant sources has limitations in meeting the micronutrient intake needs of the Chinese population, including insufficient calcium, selenium, vitamin A, and vitamin B2, along with a lack of diversity in vitamin C sources (Fig. 1).
- ☐ Addressing these limitations requires an integrated food system approach, including reducing nutrient losses, reallocating crop use, and dietary pattern transformation.

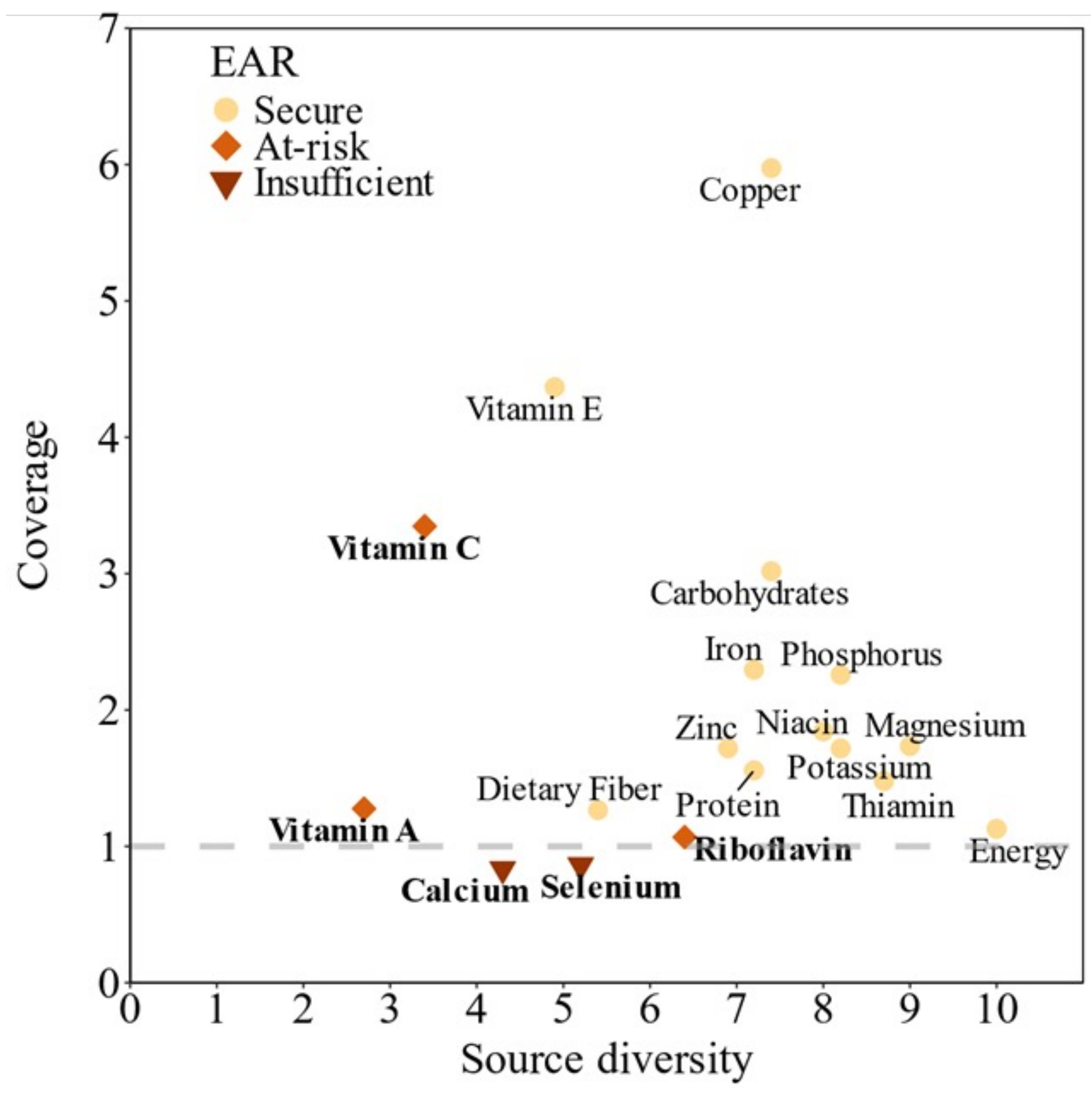

Fig. 1 | Coverage and source diversity from plant- and animal-based food sources in 2018 in China. EAR (Estimated Average Requirement), RNI (Recommended Nutrient Intake). Each nutrient supply was classified as secure (supply>RNI), at-risk (EAR<supply<RNI, or supply>RNI but source diversity is low), insufficient (supply<EAR).

- ☐ Reallocating rice and wheat areas to underutilized cereals and beans (UCBs) substantially increase the supply of iron and dietary fiber, but the improvement in selenium is limited (Fig. 2).
- ☐ To achieve these benefits: reallocate 7 million ha (24% of current areas) of rice, 0.7 million ha (3% of current) of wheat to Sorghum (+4.7 million ha), millet: +2.3 million ha, beans: +0.7 million ha. The major change is in Northeast China and Inner Mongolia.

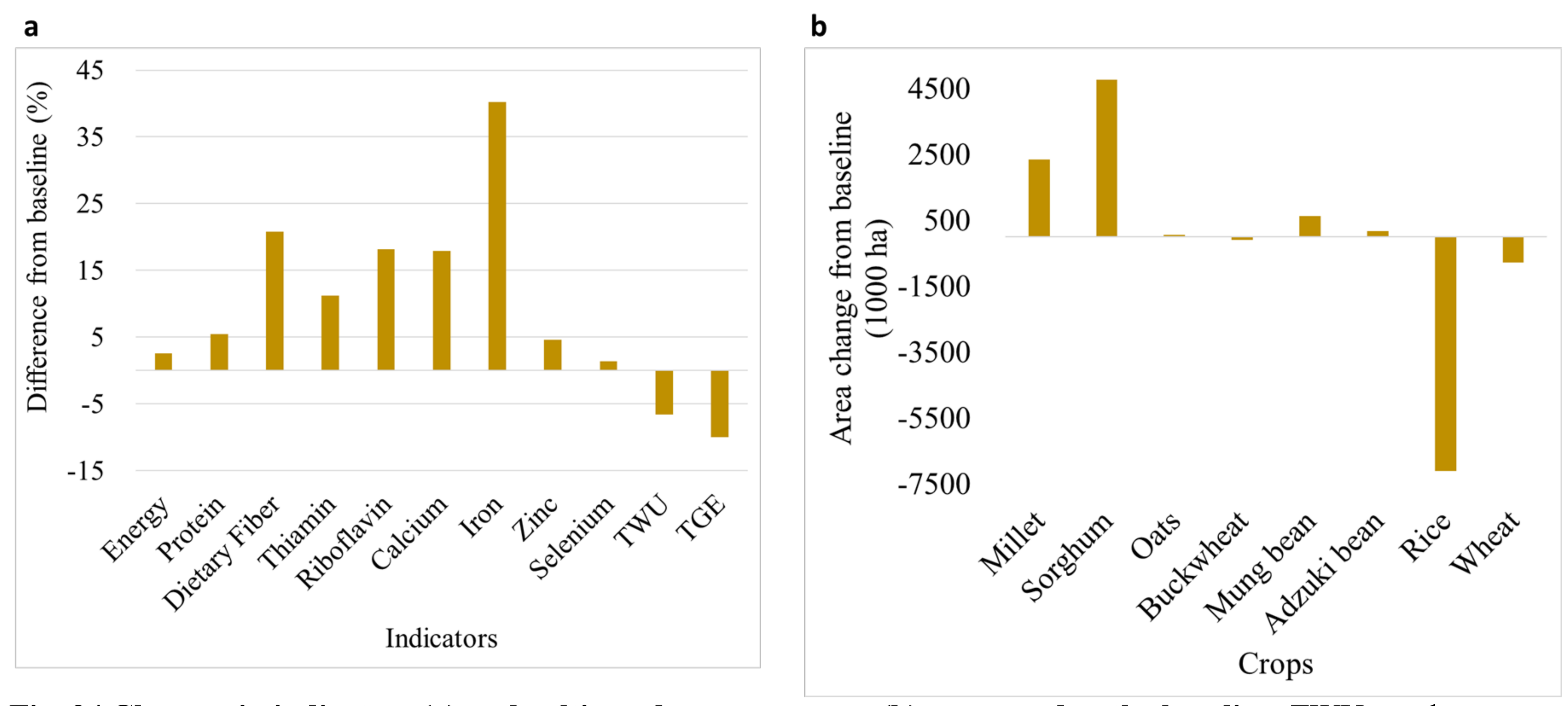

Fig. 2 | Changes in indicators (a) and cultivated areas per crop (b) compared to the baseline. TWU, total water use. TGE, total GHG emissions during cropland and transportation. We compare the improvement for each indicator when reallocating rice and wheat areas to underutilized cereals and beans with area constraints per province and do not maintain energy and selenium supply at the baseline level.

Conclusions

The current plant-based food supply in China cannot meet all the nutrient needs of the population. Transformations like reducing avoidable losses, repurposing feed to food by reducing red meat intake, and reallocating crop use offer a great chance to replace feed and energy-dense crops with nutrient-dense crops that have lower environmental impact while improving self-sufficiency.

Reallocating areas of energy-dense major crops (rice, wheat) to nutrient-dense minor crops increases supply for seven micronutrients by 5-40% while decreasing total water use and GHGE by over 7-10% compared to the baseline. Achieving this requires primarily reallocating rice areas in Northeast China and Inner Mongolia to sorghum and millet, alongside shifting diets richer in underutilized cereals, beans, and whole grains.

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Acknowledgements

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Consumers' preferences for whole grain foods: A discrete choice experiment with directional information interventions

Reporter: Xin Zhang (2+2 PhD)
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College of Economics and Management, China Agricultural University; Global Nutrition, Wageningen University and Research;

Background

- Diets low in whole grains were the second leading diet-related cause of death behind high sodium (GBD 2019). Low whole-grain intakes contributed to approximately 0.6 million deaths of Chinese in 2016.
- Whole grains provide numerous health benefits, such as reducing the risk of cardiovascular disease, type 2 diabetes, and colon cancer. Additionally, due to their higher "extraction rate" and reduced energy consumption during processing, whole grains are a more sustainable option compared to refined grains.
- Chinese consumers mostly consume refined grains,with an average whole grains intake of only 20.1g/d,far below the recommended range of 50-150g/d.
- However, few studies shed light on the preferences and willingness to pay of Chinese consumers towards whole-grain foods.

Objectives

- Analyzing Chinese consumers' preferences and WTP for different attributes of whole-grain foods,and the heterogeneity of consumers' preference for whole-grain foods attributes.
- Analyzing the impact of different information interventions on consumers' preference for different attributes.

Methods

Survey and data

- Discrete choice experiment
Five attributes, including whole wheat, green food label, taste, portion size and price per kg was considered.
- An online survey was conducted via a professional online survey company (PowerCX) across China urban areas during May 2023.
- T1 represents the control group, while T2 provided health information, T3 provided sustainable information, and T4 provided both health and sustainable information.

		I would buy neither option1 nor option 2
Taste: Soft	Taste: Corse	
Portion size: Large (5kg/bag)	Portion size: Small (1kg/bag)	
Unit Price: 8 yuan/kg	Unit Price: 6 yuan/kg	
Option 1	Option 2	Option 3

Fig. 1. Example of a choice set.

Economic Model

The DCE is based on the random utility theory,and the utility of consumer is defined as follow:

$$U_{ijt} = \beta_{ijt} X + \varepsilon_{ijt}$$

The probability of alternative i is chosen can express as follow:

$$P(y_{ijt} = j | x_{ijt}) = \frac{\exp(x_{ijt}\beta_j)}{\sum_{k=1}^{j} \exp(x_{ijt}\beta_k)}$$

Consumer's WTP is estimated as follow:

$$WTP_i = -\frac{\beta_i}{\beta_p}$$

Results

❑ **Consumer's preference of whole wheat**

- Whole wheat flour did not show statistical significance in the control group, whereas it showed a significant effect in all intervention groups (T2-T4).

❑ **WTP across treatment**

- Providing information on the benefits of whole grain foods significantly increases consumers' WTP values of whole wheat flour compared to the control group.

❑ **Heterogeneity analysis**

- Consumers over 35 and those with a bachelor's degree prefer products with whole wheat labels in both the control group and the combined health and sustainability information group.

Table 4. Mixed logit models across treatments

	T1		T2		T3		T4=T
VARIABLES	Mean	SD	Mean	SD	Mean	SD	Mean
Price/kg	-0.181***		-0.166***		-0.287***		-0.110***
	(-5.29)		(-5.14)		(-8.46)		(-3.49)
Whole wheat	0.076	-0.409	0.394***	0.741***	0.575***	-0.292	0.334***
	(0.61)	(-0.86)	(3.11)	(3.61)	(4.60)	(-0.88)	(2.79)
Green label	1.314***	2.037***	1.109***	1.637***	1.435***	2.036***	0.936***
	(6.16)	(8.10)	(6.10)	(8.83)	(6.89)	(9.32)	(5.37)
Taste soft	1.167***	2.404***	1.288***	1.403***	0.944***	1.337***	0.729***
	(4.96)	(9.68)	(7.35)	(7.25)	(5.59)	(7.22)	(3.98)
Small size	-0.589***	0.824***	-0.441***	0.789***	-0.522***	0.427**	-0.451***
	(-5.13)	(5.05)	(-4.11)	(5.13)	(-5.28)	(2.23)	(-4.52)
Large size	0.049	1.130***	-0.249	1.111***	-0.081	1.112***	-0.081
	(0.28)	(5.74)	(-1.50)	(5.64)	(-0.47)	(5.91)	(-0.52)
ASC	-4.545***	3.486***	-4.346***	2.890***	-5.817***	3.506***	-4.067***
	(-8.57)	(9.27)	(-8.59)	(7.34)	(-8.44)	(7.00)	(-8.29)
Observations	5,049	5,049	5,103	5,103	5,049	5,049	5,103
AIC	2675.81		2667.65		2471.94		2712.99
Log-likelihood	-1324.91		-1320.83		-1222.97		-1343.49

Note: In parentheses is the stand error, z-statistics in parentheses, *** p<0.01, ** p<0.05, * p<0.1; T1 is the contrc does not provide any information; T2 provides health information; T3 provides sustainability information; and T4 both health and sustainability information interventions.

Conclusions

❑ The results showed that consumers were willing to pay more for wheat flour products with whole grain label, green food label, soft texture, and medium size.

❑ Whole grain label and green food label have a complementary impact on consumer perception of wheat flour.

❑ Both types of information intervention could increase consumers' WTP for whole grain foods, and the health benefits information intervention group showed a higher WTP for whole wheat flour than the environmental benefits information intervention group.

❑ Respondents received the combined information intervention demonstrated the highest WTP across treatments.

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Why do smallholders grow intercrops – a case study in Hangjinhou county, China

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Background

Intercropping is seen as a promising pathway towards sustainable agricultural practices. But there are few studies on the actual practices of intercrops on smallholder farms and the factors driving farmers to adopt intercrops.

Highlights

- ◆We did field research on intercrops (IC) practices in China
- ◆Intercrops increased gross margin but also labour per unit area
- ◆Labour increases were recorded for sowing, harvesting and weeding
- ◆Subsidies were a key driver for adopting maize/soybean IC, a novel system
- ◆Traditional IC systems were adopted because of gross margin

Survey site and intercropping systems

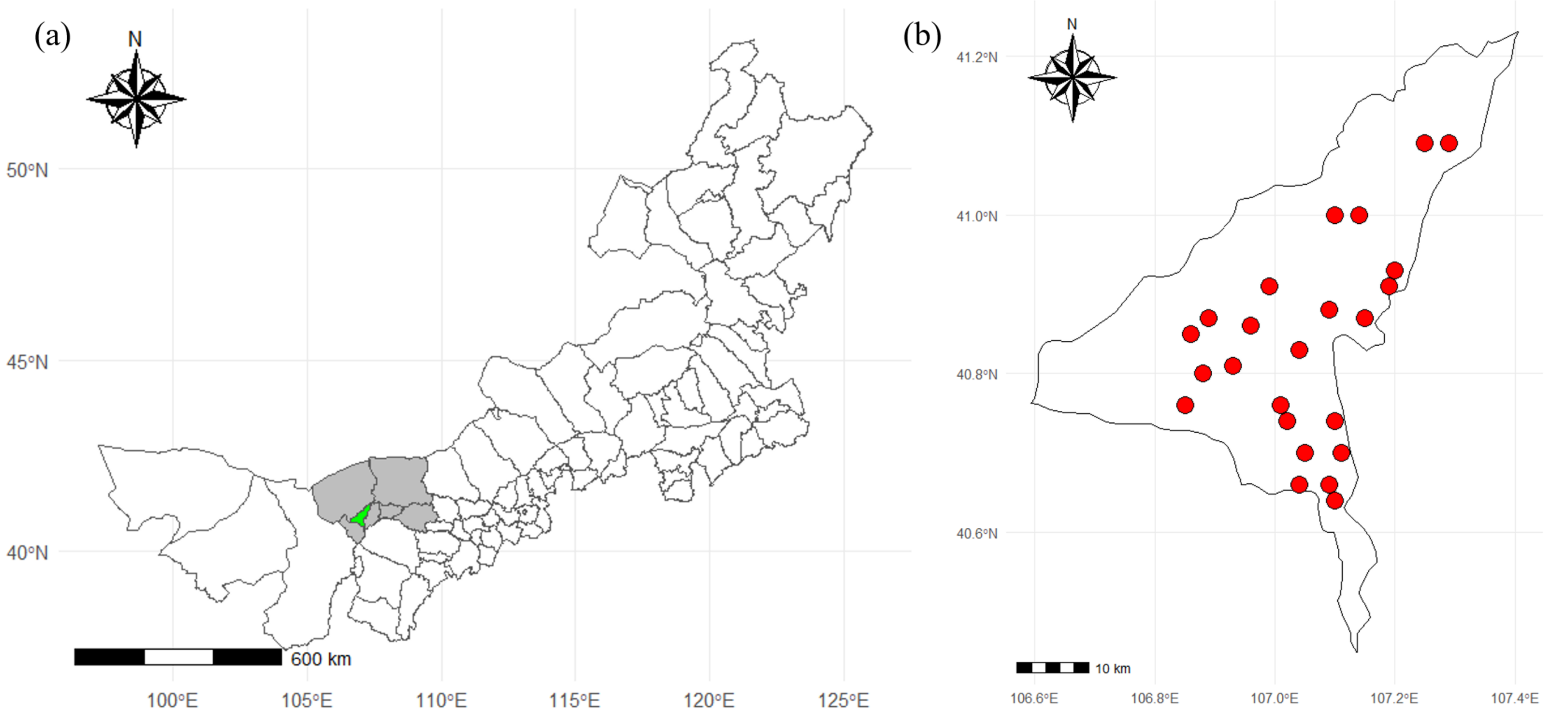
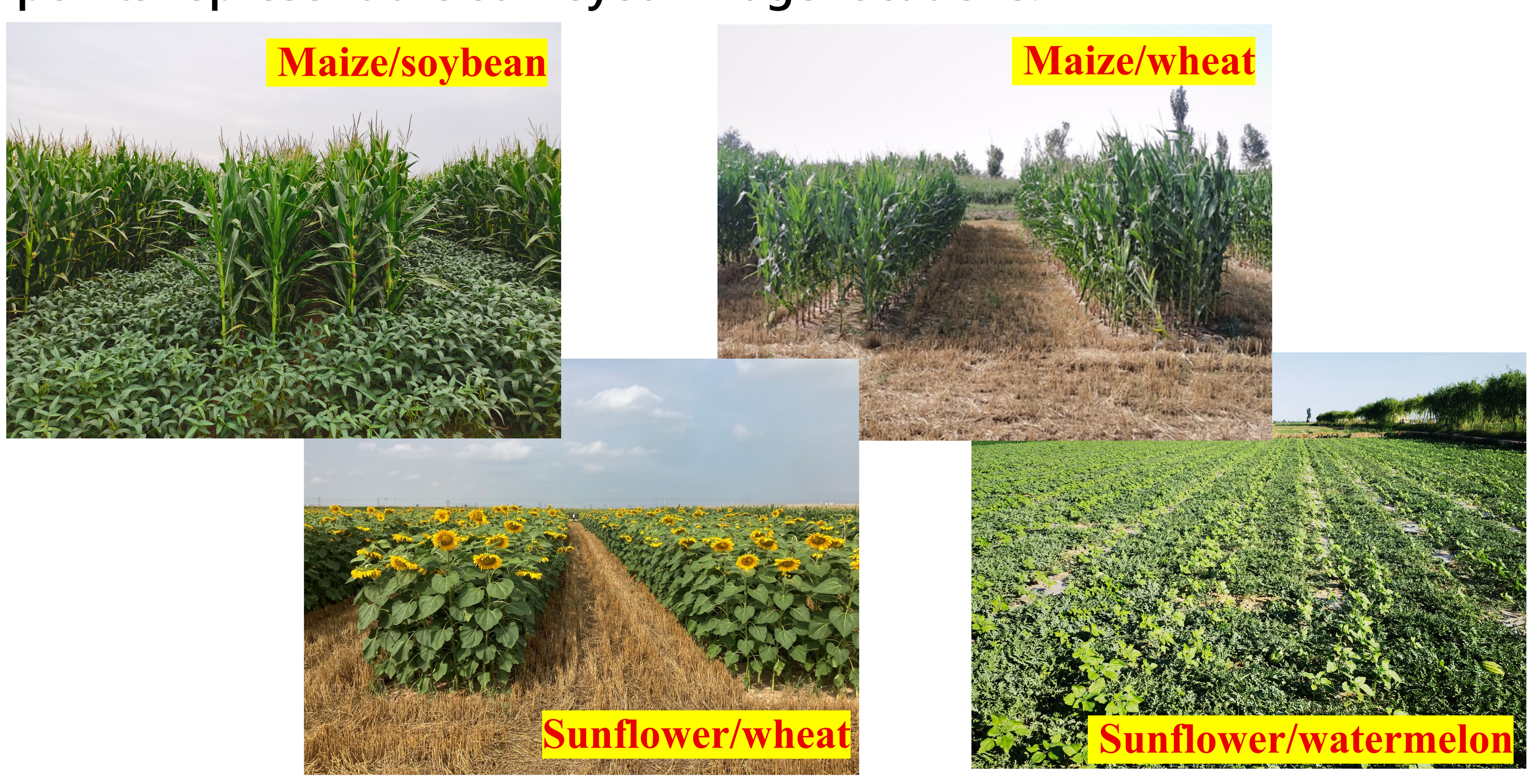


Fig.1 (a) Map of Inner Mongolia Autonomous Region including county borders, with Bayannur City area marked in grey and Hangjinhou county marked in green; (b) Map of Hangjinhou county, located in the arid Yellow River irrigation area. The red points represent the surveyed village locations.



In July 2022, we interviewed 315 farmers from 24 villages in Hangjinhou County in Northwest China and collected information on inputs and outputs of sole crops and intercrops.

Results

Fig. 2 Plots numbers, growing periods, and sowing and harvest methods in surveyed cropping systems.

Unit	Δ Gross margin Thousand CNY/ha	Δ Costs Thousand CNY/ha	Δ Total labour hours Hours/ha	Relative labour income CNY / hour
Maize/soybean	-1.99±1.31 (91%)	1.2±0.32 (113%)	43.87±6.03 (135%)	68%
Maize/wheat	2.17±1.26 (112%)	6.245±0.46 (176%)	50.9±5.89 (145%)	82%
Sunflower/wheat	8.6±1.18 (148%)	4.79±0.48 (177%)	83.93±4.85 (176%)	86.5%
Sunflower/watermelon	40.7±5.95 (291%)	6.2±0.45 (219%)	96.08±11.17 (178%)	176%
Δ Overall*	9.49±1.58 (148%)	4.64±0.22 (170%)	69.89±3.70 (161%)	94%

Table 1 Differences in overall performance between intercrop and monocrop. The values are presented as the mean ± SE. The percentage in parentheses represents the relative value compared to the reference monocrop. *The weights for the weighted averages are based on the frequency of each cropping system. 1 CNY (¥) = 0.13 (€).

What drove you to adopt intercropping?	Maize/ Soybean n=39	Maize/ Wheat n=48	Sunflower/ Wheat n=85	Sunflower/ Watermelon n=28	Total number
Good soil	6	2	7	1	16
Subsidies	29	15	14	0	58
Habit	6	26	47	22	101
Increase income	16	30	52	20	118
Benefit for next crop	4	18	27	11	60

Table 2 Answers to open question from farmers (n=167) who adopt intercrop

Conclusions

- ◆ Greater gross margin per unit area was the most important factor driving smallholders to adopt intercropping.
- ◆Other drivers include subsidies and proximity to markets for fresh produce (watermelon) grown in intercrops.

Acknowledgements

We acknowledge Hangjinhou Science and Technology Backyard (STB), Hangjinhou County Agriculture Department and who participated in the household survey and data entry. This study was financially supported by the National Key Research and Development Project of China (2022YFD1900300) and the China Scholarship Council (No.201913043) and Hainan University. We also thank Yue Hou, Wopke van der werf, Ming Yang and Nan Yang for providing the intercropping photos.

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Root exudates driven root-soil microsite interactions to improve soil nutrient retention and supply capacity for sustainable crop production

phD: Mengxue Mao
Supervisor: Kemo Jin, Liping Weng, Walter schenkeveld

Background

- ◆ Phosphate fertilizer is widely applied in agriculture to maintain crop yield. When applied to soil, the efficiency of P fertilizers is greatly reduced due to fixation in soils as a result of strong adsorption and formation of precipitates with metal ions
- ◆ Plants have developed P acquisition strategies in order to make soil P more bioavailable. One of these strategies involves root exudation of low molecular weight organic acids (LMWOAs) like citric and malic acid.
- ◆ In any soil, P is present in multiple species varying in solubility and P releasing kinetics. So far, it is unclear how the P speciation changes with the P fertilization in soils with different pH, from which species P is mobilized by LMWOAs and how LMWOAs enhance P bioavailability in compacted soils.

Objectives

- ◆ To establish P speciation in soils covering a wide pH range which have received long-term P fertilization at different levels.
- ◆ To determine which P species are mobilized from calcareous and red soils by LMWOAs, thereby enhancing P availability.

Chemical mechanism of root soil interface regulating soil phosphorus supply capacity through root secretion of organic acids

Methods

- ◆ A red soil from China (pH=4.2) and a Chinese calcareous soil (pH=7.5) are selected, on which long-term (about 10 years) P fertilization experiments have been conducted, involving 4 different P application rates. Through sequential extraction we have attempted to determine P speciation in the soils. However, the selectivity of extractants for specific P species is limited. the Beijing Synchrotron Radiation Facility (BSRF) analysis will help to verify the results from the extraction and to better identify the change of P speciations.
- ◆ The above soils will be extracted with LMWOAs (oxalic acid, citric acid, malic acid and trans-aconitic acid). The concentration of P, Fe, Al and Ca dissolved in these extractions will be measured. The solid phase will be analyzed by BSRF and the results will be compared to those of the original soils to establish the change in P speciation due to LMWOAs extraction.

Results

Table 1. Physical and chemical properties of soil samples

Soil type	Fertiliser treatment (kg P_2O_5 ha^{-1})	pH_{water}	pH_{CaCl2}	TN (g kg^{-1})	TOC (g kg^{-1})	C/N ratio	Fe-ox (g Fe kg^{-1})	Al-ox (g Al kg^{-1})	P-ox (g P kg^{-1})	Fe-DCB (g Fe kg^{-1})	Al-DCB (g Fe kg^{-1})	P-DCB (g P kg^{-1})	$CaCl_2$-P (mg kg^{-1})	Olsen-P (mg kg^{-1})	Total-P (g kg^{-1})
Calcareous soil	0	8.15^{a}	7.41^{a}	1.08	7.70	7.13	1.32^{b}	0.05^{c}	0.33^{d}	9.26^{b}	0.51^{a}	0.72^{d}	0.41^{d}	6.78^{d}	0.71^{c}
Calcareous soil	75	8.12^{ab}	7.33^{b}	1.26	8.40	6.69	1.34^{ab}	0.05^{b}	0.48^{c}	9.63^{a}	0.57^{b}	0.86^{c}	0.48^{c}	20.17^{c}	0.93^{b}
Calcareous soil	150	8.10^{b}	7.23^{c}	1.11	7.69	6.95	1.30^{b}	0.05^{c}	0.54^{b}	8.94^{c}	0.51^{a}	0.91^{b}	0.62^{b}	30.46^{b}	0.99^{b}
Calcareous soil	300	7.97^{c}	7.16^{d}	1.17	8.71	7.58	1.41^{a}	0.06^{a}	0.82^{a}	9.71^{a}	0.62^{a}	1.21^{a}	0.70^{a}	68.01^{a}	1.28^{a}
Red soil	0	4.74^{c}	4.13^{d}	0.53	3.16	5.98^{b}	2.8	0.22^{a}	0.01^{d}	76.59^{a}	4.75^{a}	0.64	0.35^{b}	0.16^{d}	0.28^{c}
Red soil	60	5.11^{b}	4.28^{c}	0.64	5.00	7.85^{a}	2.3	0.17^{b}	0.03^{c}	73.77^{ab}	4.68^{ab}	0.64	0.34^{b}	0.35^{c}	0.30^{c}
Red soil	90	5.25^{a}	4.45^{a}	0.57	4.15	7.30^{ab}	2.34	0.19^{ab}	0.05^{b}	71.34^{b}	4.69^{ab}	0.62	0.41^{a}	0.50^{b}	0.33^{b}
Red soil	120	5.16^{b}	4.31^{b}	0.55	3.54	6.51^{ab}	2.47	0.22^{a}	0.08^{a}	72.63^{ab}	4.40^{b}	0.66	0.41^{a}	0.99^{a}	0.38^{a}

Note: Fe-DCB, Al-DCB, P-DCB: concentration of Fe, Al or P in the extraction of sodium citrate bisulfite; Fe-ox, Al-ox, P-ox: concentration of Fe, Al or P in ammonium oxalate extraction

Results

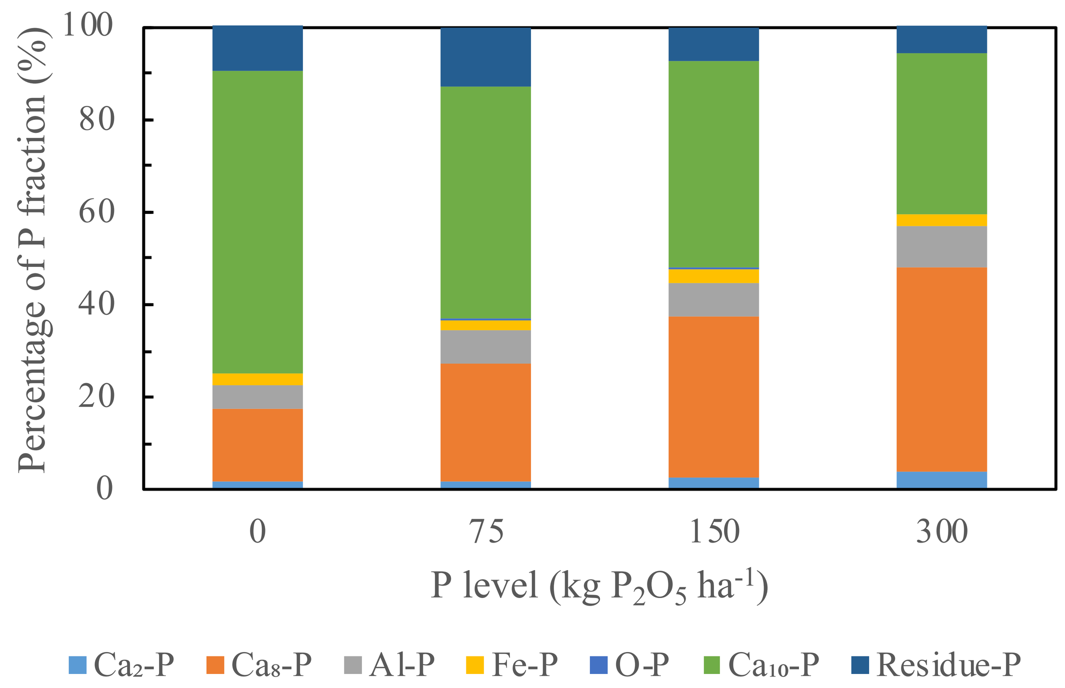

Fig 1. Proportion of phosphorus forms in calcareous soil extracted by Jianggu continuous extraction method.

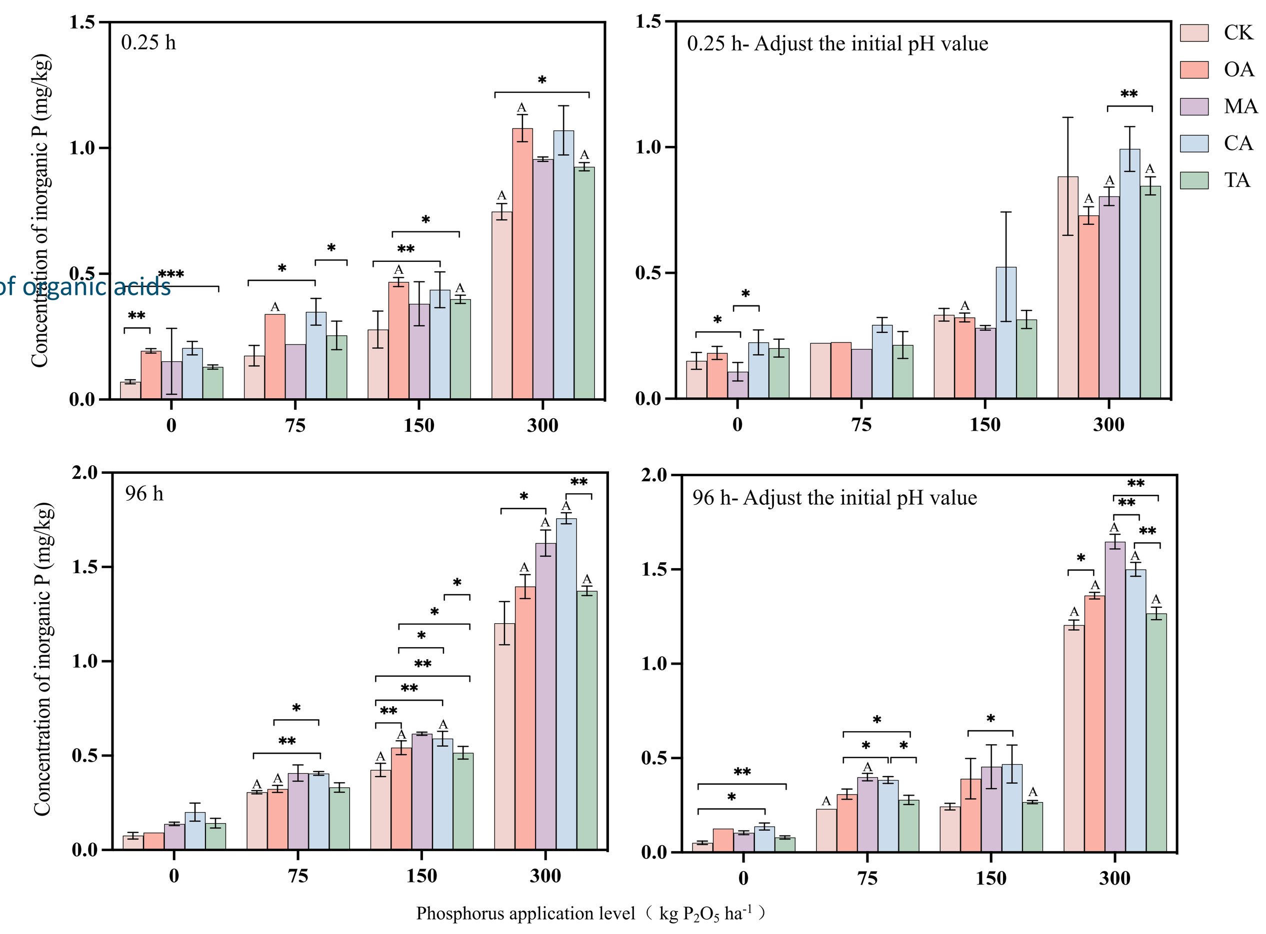

Fig 2. Phosphorus concentration of calcareous soil (phosphorus application level is 0, 75, 150, 300 kg P_2O_5 ha^{-1}) extracted by organic acid at 0.25 and 96 hours with or without adjusting the initial organic acid pH value.

Conclusions

- ◆ The study found that different phosphorus application rates significantly affected the pH, iron, aluminum and phosphorus contents of calcareous soil and red soil, but had little effect on total nitrogen and total carbon.
- ◆ The results of Jiang-Gu inorganic phosphorus grading showed that the phosphorus forms in calcareous soil were significantly affected by different phosphorus application rates, mainly Ca_8-P and Ca_{10}-P, and Ca_2-P, Ca_8-P, Al-P and Fe-P increased significantly with the increase of phosphorus application rates. There was a correlation between the phosphorus forms.
- ◆ The activation of organic acids on phosphorus varies in soils with different phosphorus application rates. The change of initial pH and different reaction time will also affect the activation of different kinds of organic acids on phosphorus.

Acknowledgements

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Geochemical mechanisms of enhancing the phosphorus bioavailability by maize root exudates

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Chair group: Soil Chemistry and Chemical Soil Quality, Wageningen University and Research
Department of Plant Nutrition, Chines Agricultural University, China

Background

- Phosphorus (P) is an essential macronutrient critical for plant growth, playing a key role in energy transfer, photosynthesis, and nutrient metabolism. However, its availability in soils is often limited due to its strong adsorption onto metal (hydr)oxides, such as goethite, which renders it immobile and inaccessible to plants.
- To enhance P mobilization, plants have evolved adaptive strategies, such as the release of low molecular weight organic acids (LMWOAs), including citric acid and malic acid. These LMWOAs compete with P for adsorption sites on metal (hydr)oxide surfaces, thereby mobilizing P and increasing its bioavailability in the rhizosphere.
- Despite the effectiveness of LMWOAs in enhancing P availability, their interactions are further complicated by the presence of humic substances (HS), such as fulvic acid (FA) and humic acid (HA), which are ubiquitous in natural soils. HS not only competes with P for adsorption sites on Fe (hydr)oxides but also interacts with LMWOAs, potentially reducing their efficiency in mobilizing P.
- While the adsorption mechanisms of individual adsorbates (e.g., phosphate (PO_4), HA, FA) onto Fe (hydr)oxides have been extensively studied, the complex interplay between P, LMWOAs, and HS in competitive adsorption systems remains poorly understood.
- Furthermore, the influence of soil solution chemistry, such as variations in pH and IS, on the efficiency of LMWOAs in mobilizing P in the presence of HS has not been thoroughly investigated. This knowledge gap hinders a comprehensive understanding of nutrient dynamics in natural soil environments and limits the development of strategies to optimize P availability for agricultural productivity.

Objectives

The aim of this study is to quantitatively investigate the geochemical mechanisms by which LMWOAs (citric acid and malic acid) mobilize P in the presence of HS (including HA and FA) on goethite surfaces. This study focuses on elucidating the effects of varying solution conditions, such as LMWOAs concentration, P concentration, HS concentration, pH and ionic strength (IS), on the competitive adsorption and mobilization processes.

Methods

- In this study, the competitive interactions between humic substances (HS), specifically humic acid (HA) and fulvic acid (FA), and low molecular weight organic acids (LMWOAs), namely citric acid and malic acid, were investigated under varying solution conditions using batch adsorption experiments. The experiments were designed to systematically examine the effects of different concentrations of HA, FA, citric acid, malic acid, and phosphorus (P), as well as the influence of pH and ionic strength (IS).
- The experimental data were analyzed and interpreted using surface complexation modeling, specifically the Charge Distribution of Natural Organic Matter (NOM-CD) model, to elucidate the underlying geochemical mechanisms.

Results

- The presence of citric acid and FA significantly affects P availability. The available P increases as the pH increases, indicating that citric acid and FA enhance P mobilization, particularly at lower pH levels.
- Increasing the concentration of FA to 150 mg/L further influences P adsorption.
- The addition of malic acid and HA shows a similar trend, with available P increasing as pH increases. Malic acid, like citric acid, competes with P for adsorption sites, and the presence of HA further enhances this effect, particularly at lower pH levels.
- At the highest concentration of HA (450 mg/L), the competition for adsorption sites is even more pronounced.

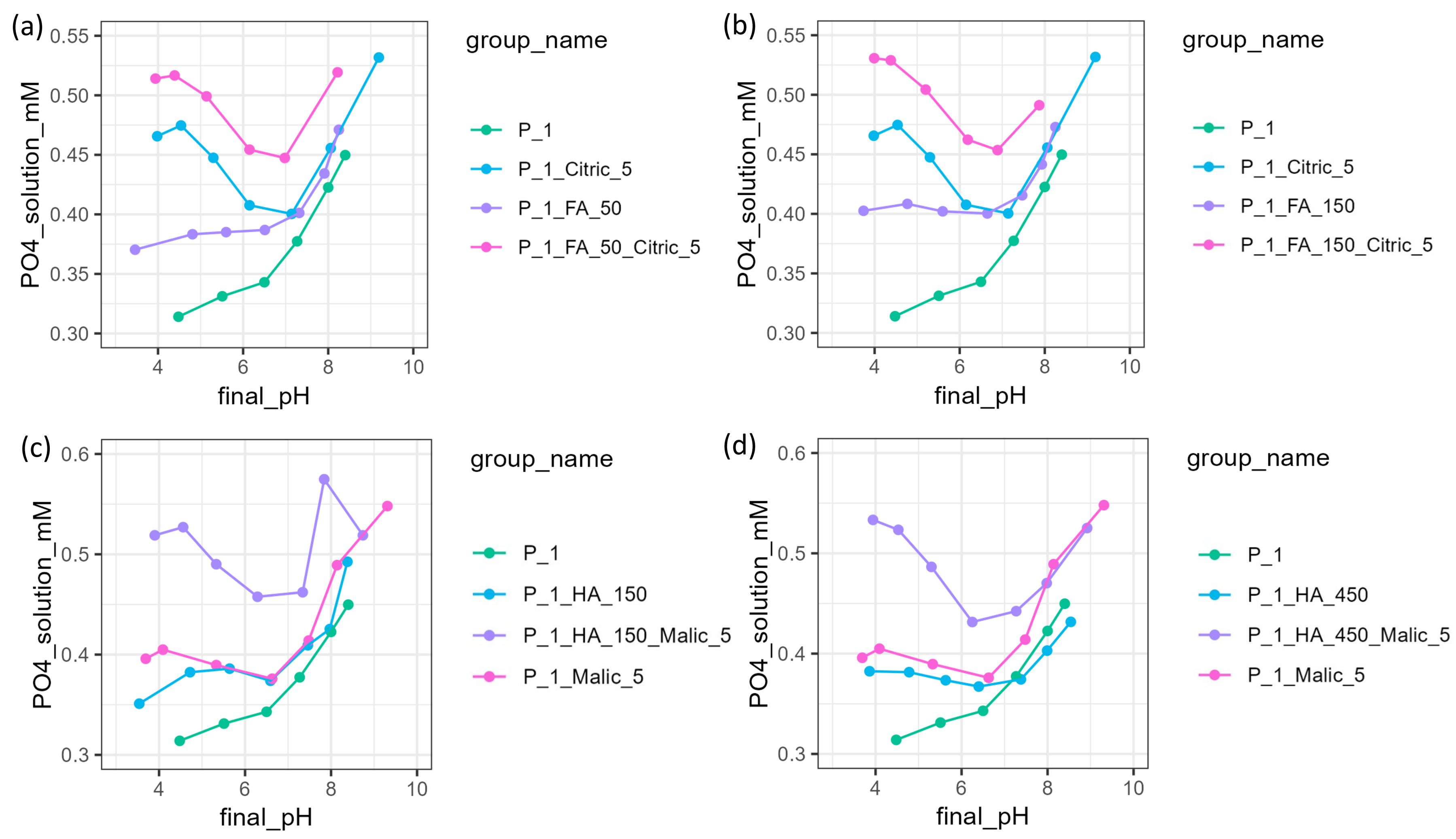

Figure 1. Adsorption envelopes of available P in solution for competitive model systems. The experiments were conducted with an initial P concentration of 1 mM and IS of 1 mM, combined with: (a) 5 mM citric acid and 50 mg/L FA; (b) 5 mM citric acid and 150 mg/L FA; (c) 5 mM malic acid and 150 mg/L HA; and (d) 5 mM malic acid and 450 mg/L HA. The results illustrate the influence of varying concentrations of low molecular weight organic acids (citric acid, malic acid) and humic substances (HA, FA) on P availability under different solution conditions.

Conclusions

- The results demonstrate that both citric acid and malic acid effectively compete with P for adsorption sites on goethite, enhancing P availability in solution.
- The presence of FA and HA further amplifies this effect, with higher concentrations of HS leading to greater P mobilization.
- The efficiency of P mobilization is pH-dependent, with greater effects observed at lower pH levels, likely due to changes in surface charge and competitive adsorption dynamics.

Acknowledgements

We gratefully acknowlege the sponsors of this research:China Scholarship Council (NO.201913043)

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Plant-arbuscular mycorrhizal fungi-bacteria tripartite interaction

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Supervisors: Erik Limpens (WUR), Xu Cheng (WUR), Lin Zhang (CAU), Gu Feng (CAU)

Background

Arbuscular mycorrhizal (AM) fungi can colonize over 80% of terrestrial plants. Similar to the rhizosphere microbiome, the microbiome closely associated with AM fungi plays a critical role in the biogeochemical cycling of various mineral elements. These processes significantly affect the nutrition and overall performance of the plant-AM fungi symbiosis. Simultaneously, different AM fungal taxa colonize a single plant root, each fostering a distinct microbiota.

We aim to investigate whether different host plants recruit unique hyphosphere bacteria and what functions these bacteria perform. It is also essential to address why different host plants recruit specific hyphosphere bacteria and the mechanisms underlying these selections.

Results

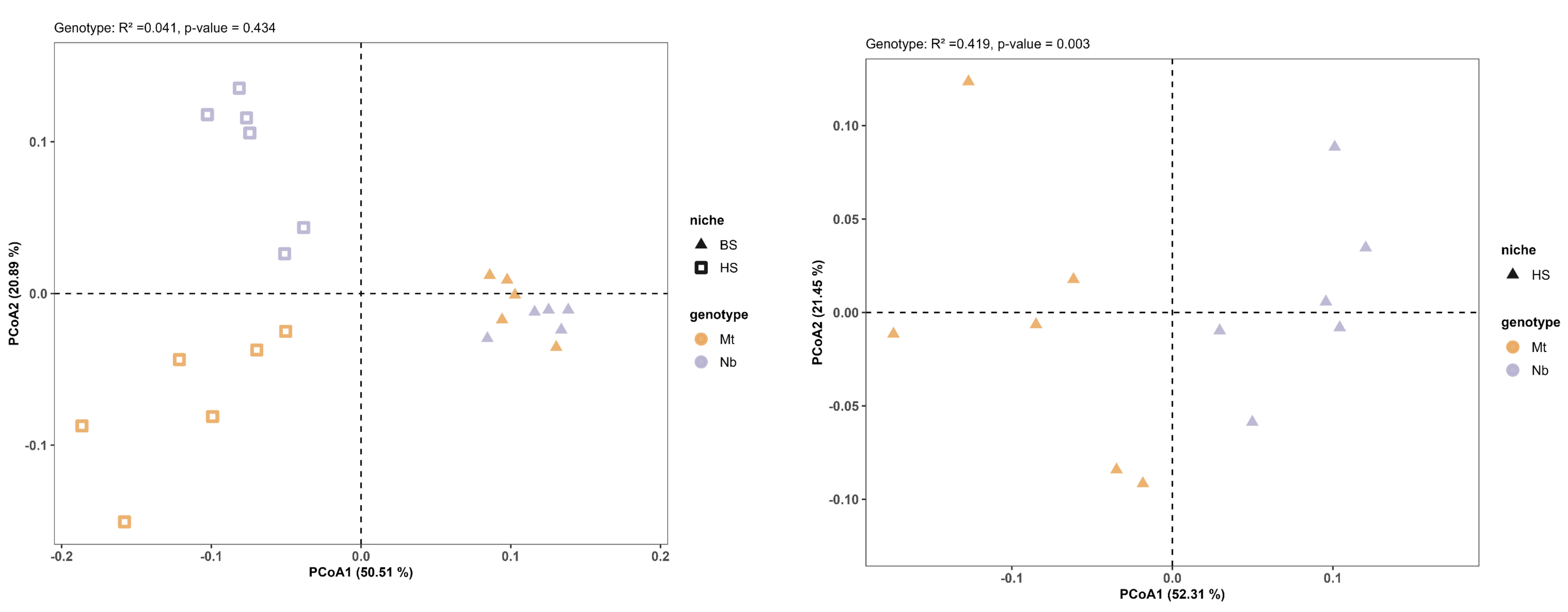

Fig 1. Different host plants shape different bacterial community in hyphosphere

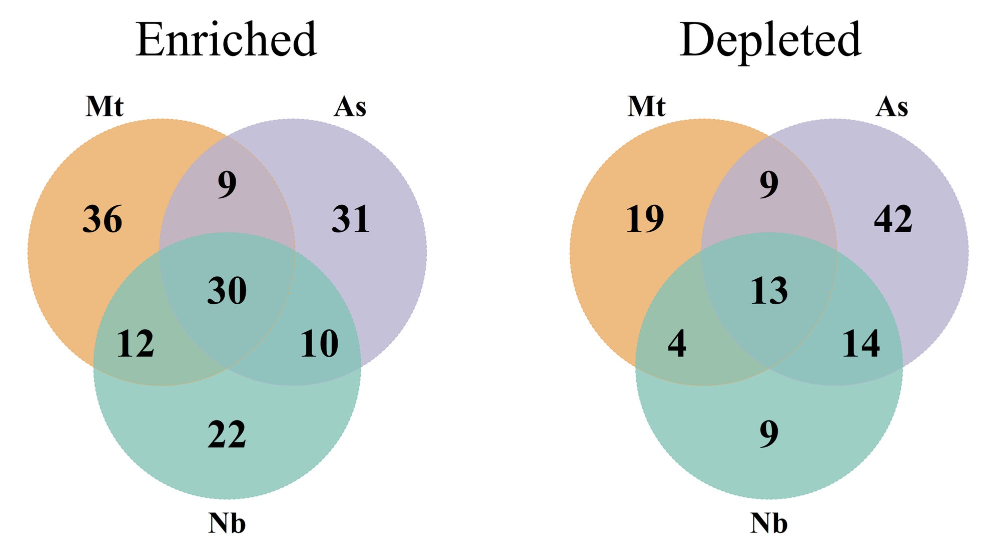

Fig 2. Bacterial enrichment and exclusion in the hyphosphere of AM fungus associated with different host plants compared with bulk soil

Fig 3. Pcyc gene co-occurrence networks visualizing significant correlations (ρ > 0.65, P < 0.01) in Mt hyphosphere (a) and in Nb hyphosphere (b) of Rhizophagus irregularis MUCL 43194. Lines of different colors represent different functional categories.

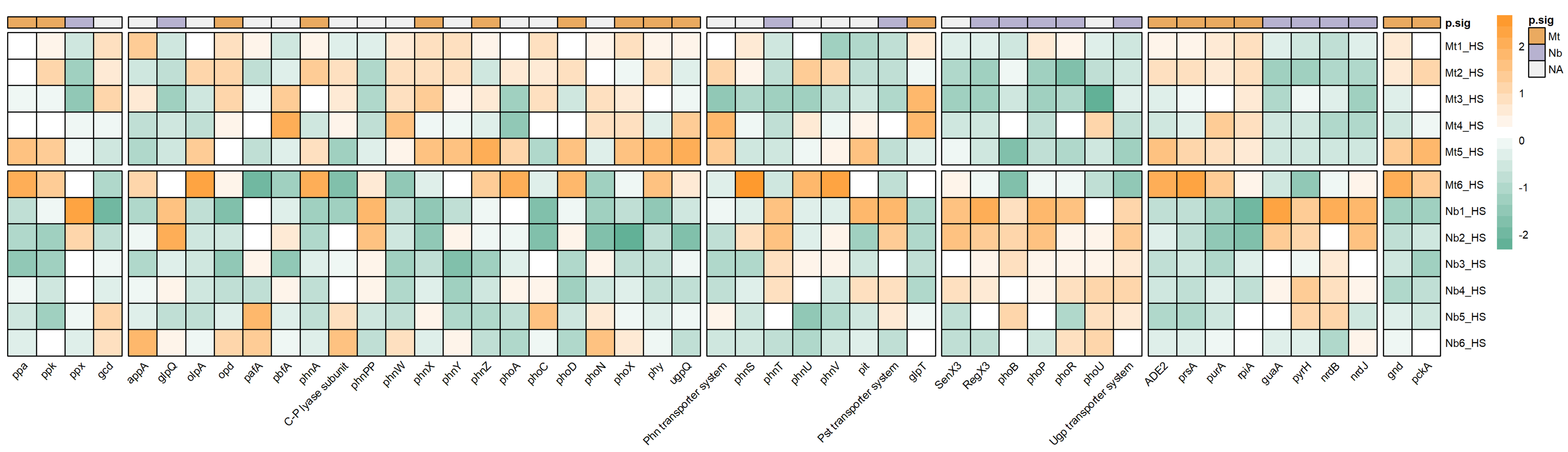

Fig 4. Relative abundance of microbial P-cycling genes characterized at each site.

Conclusions

- ❑The bacterial community structure of the hyphosphere is significantly different from that of the bulk soil, indicate the strong influence of AM fungi.
- ❑Different host plants recruit different bacteria to the mycorrhizal hypha.
- ❑Bacteria enriched in the hyphosphere of the AM fungi associated with different host have different functional preferences.

Acknowledgements

We gratefully acknowlege the sponsors of this research:China Scholarship Council (NO.201913043) and Hainan University.

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Unraveling mechanisms for arbuscular mycorrhizal fungi recruit and activate hyphosphere bacteria to improve plant phosphorus uptake

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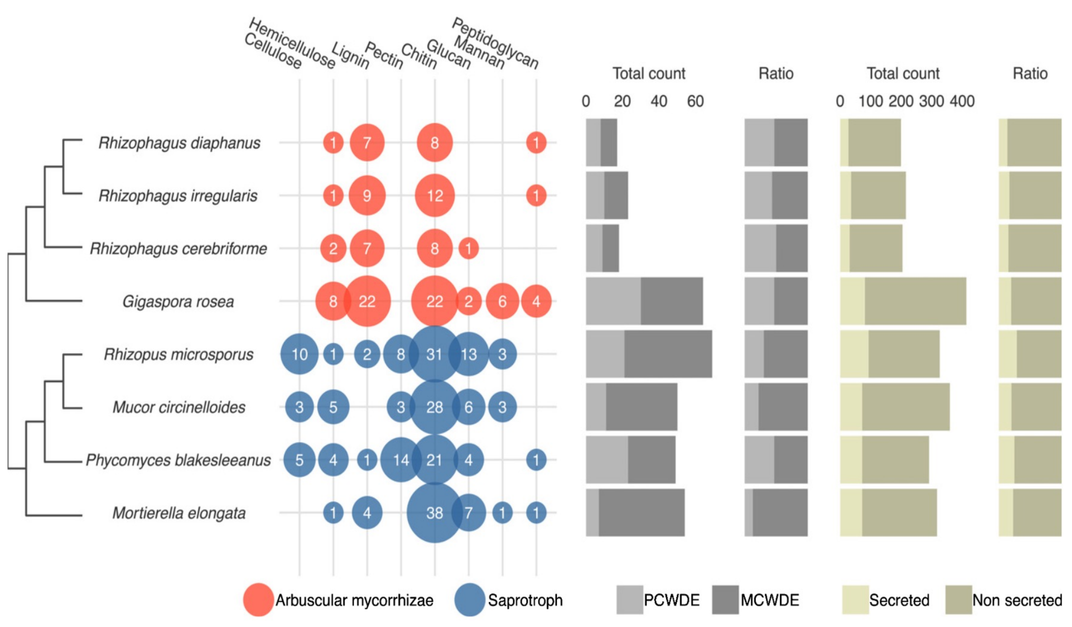
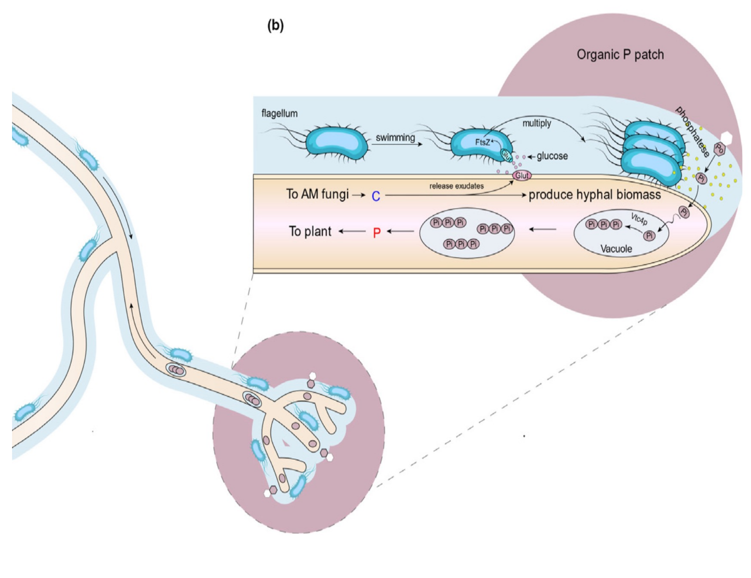
Supervisor：Lin Zhang, Gu Feng, Erik Limpens, Cheng Xu

Background

More than two-thirds of terrestrial plants acquire nutrients by forming a symbiosis with arbuscular mycorrhizal (AM) fungi (Smith and Read, 2008). AM fungi produce extensive extraradical hyphae in the soil, not only enlarging the area to acquire nutrients and water but also creating a habitat for other soil microbes to colonize (Artursson et al., 2006). During the co-evolution with plants, AM fungi have lost some saprophytic function genes compared with other filamentous fungi, such as genes encoding plant cell degrading enzymes and phytase (Tisserant et al., 2013; Morin et al., 2019).



(Morin et al., New Phytologist, 2019)



(Jiang et al., New Phytologist, 2021)

This suggests that AM fungi have relatively weak abilities to directly mobilize soil organic nutrients compared with other kinds of fungi (Zhang et al., 2021). By colonizing the hyphosphere of AM fungi, soil microbes may significantly increase the turnover of soil organic nutrients (Falkowski et al., 2008), which complement the capabilities of AM fungi. Recently research found that AM fungi can recruit bacteria to mobilize organic phosphorus to improve plant phosphorus uptake AM fungi's spores and hyphae contain multiple nuclei in a common cytoplasm (Tisserant et al., 2013). Thus, genetically manipulating AM fungi is extremely difficult. In this study, we want to use host-induced gene silencing technology to achieve fungi function gene silencing to reveal the recruiting mechanism at the gene level.

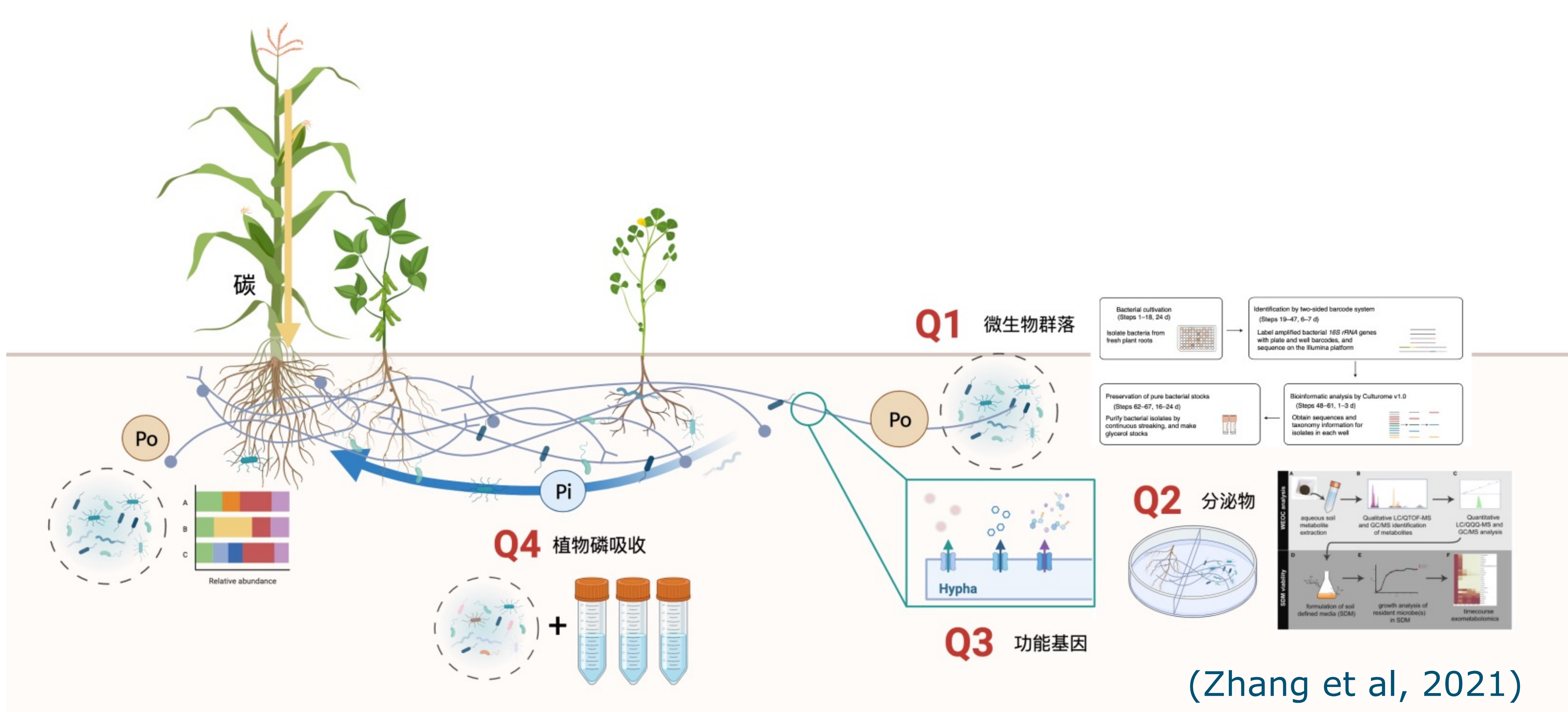
? The mechanisms by which hyphosphere bacteria are recruited and activated to improve plant phosphorus uptake are still less understood.

Objectives

- Identify the biotic effects on the hyphosphere microbiome and confirm the member of the library of hyphosphere bacteria.
- Reveal the recruitment mechanisms of hyphosphere bacteria by AM fungi
- Attempts the genetic manipulation of AM fungi and uncover its influence on the hyphosphere microbiome.

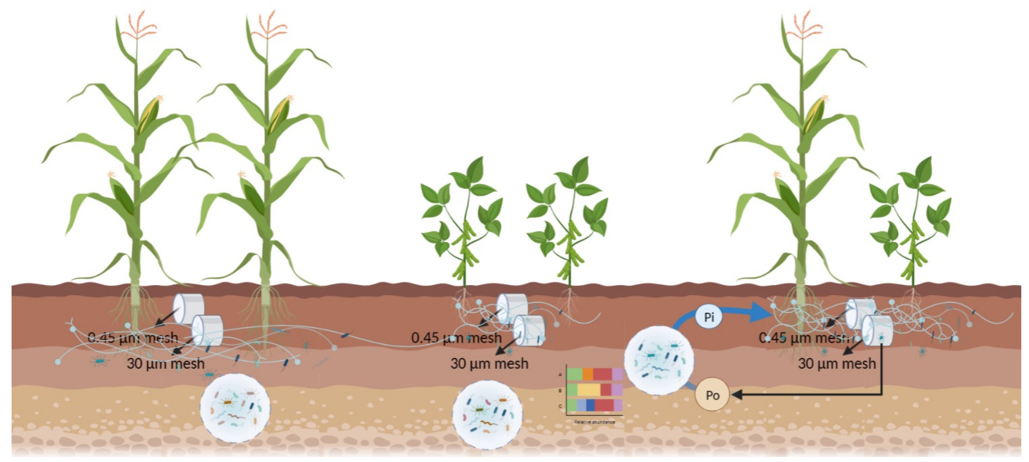
Framework

Q1: Which hyphosphere core microorganisms are recruited by AM fungi to improve plant phosphorus nutrition?
Q2: What are the essential substances for AM fungi to recruit functional hyphal bacteria?
Q3: What genes control the synthesis/secretion of essential substances in AM fungi?
Q4: How to targeted regulate the function of mycelia microorganisms to improve plant phosphorus nutrition?

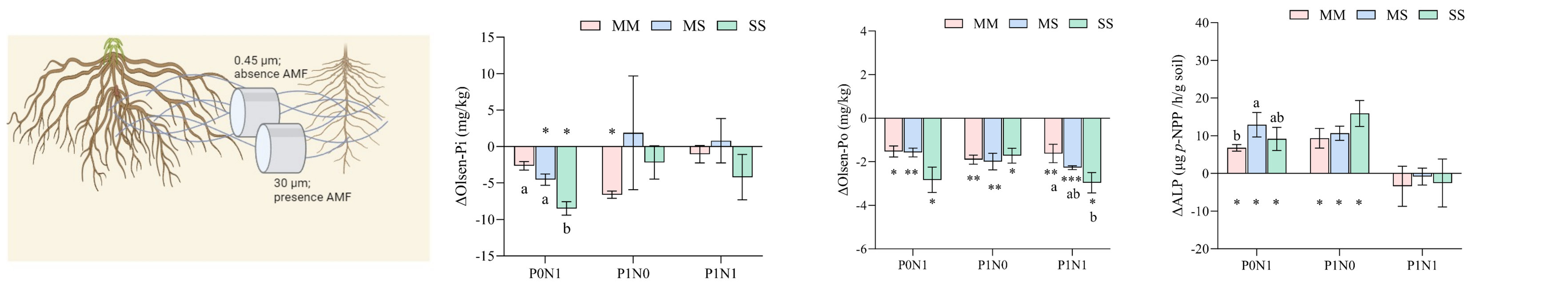


(Zhang et al, 2021)

Chapter 1: Mechanism of organic-P mineralization in the interaction between AM fungi and hyphosphere bacteria under different cropping systems and nutrient supply conditions



☐ The interaction between AM fungi and microbiome promoted the mobilization of soil organic P

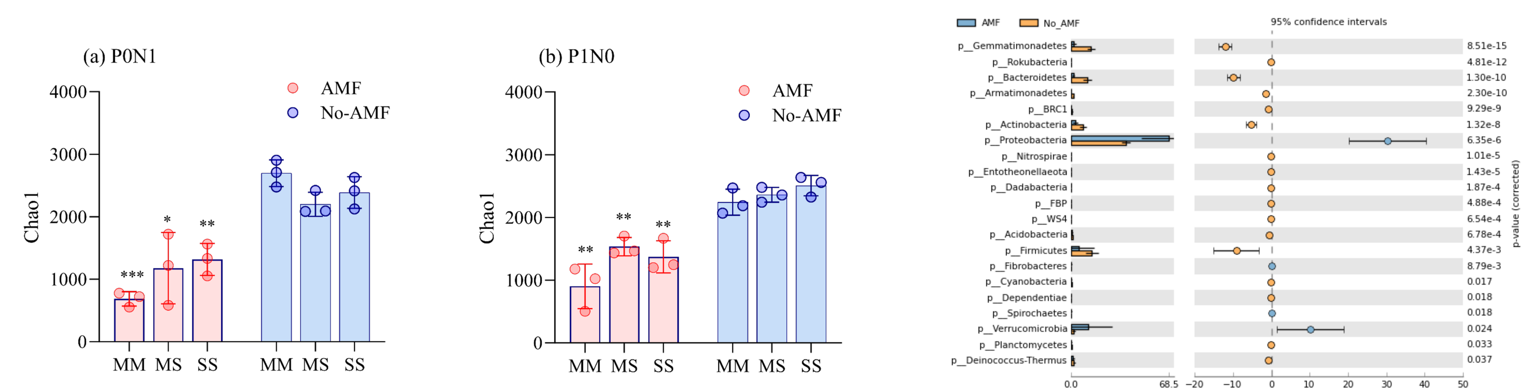


ΔOlsen-P＝AMF treatment Olsen P－No_AMF treatment Olsen P
ΔALP activity＝presence AMF soil ALP activity－absence AMF soil ALP activity

Asterisks indicate significant differences between with and without AMF. Lowercase letters indicate significance between different planting systems.

- AM fungal–bacterial interactions strengthened phosphatase activity and stimulated organic P mineralization

☐ AM fungi hyphosphere selectively enriched bacterial communities distinct from bulk soil

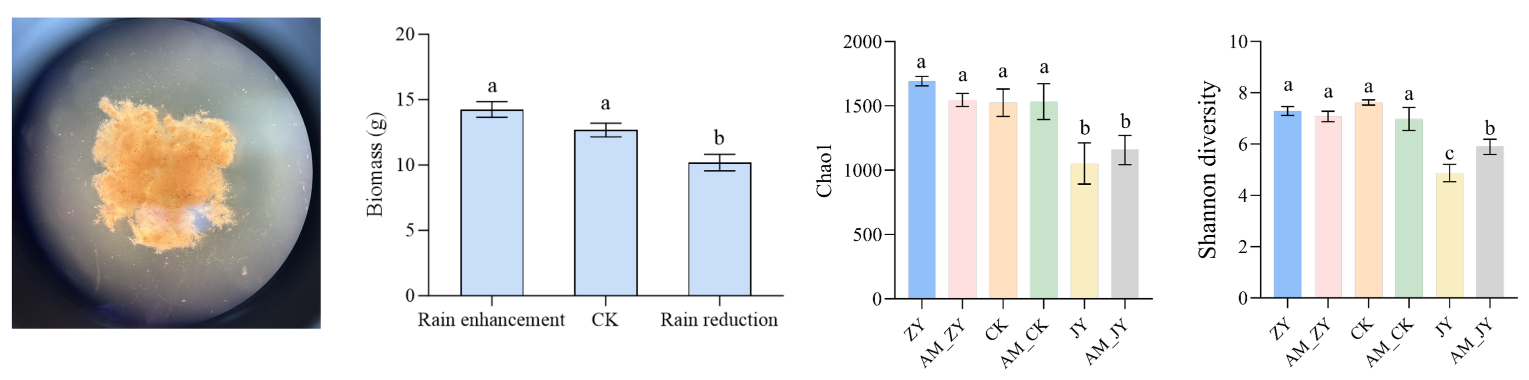


- Proteobacteria; Verricomicrobia; Fibrobacterer; Spirochartes were significantly enriched in hyphosphere.

Chapter2： Effects of precipitation gradient on the interaction between AMF and hyphosphere bacteria in soil organic phosphorus mineralization in grassland ecosystems

Rain enhancement　　CK　　Rain reduction

☐ Reduced precipitation decreases grassland biomass, reduces species richness, and lowers community diversity and evenness



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Finding adaptations of symbiosis signalling cascade:

from mycorrhizal symbiosis to nitrogen-fixing symbiosis

Wenying Huo
Supervisors: Prof. Jianbo Shen, Prof. Bin Ni, Dr. Rene Geurts, Dr. Rik Huisman

Background

Plants can establish mutualistic symbioses with soil microbes. The most ancient and wide-spread symbiosis is the cooperation between plants and arbuscular mycorrhizal (AM) fungi[1]. Some plant species, especially legumes, evolved symbiosis with rhizobia. AM fungi and rhizobia produce signal molecules with similar structures, thereby activating the same signalling network in plants, named the **common symbiosis signalling pathway** (**CSSP**)[2].

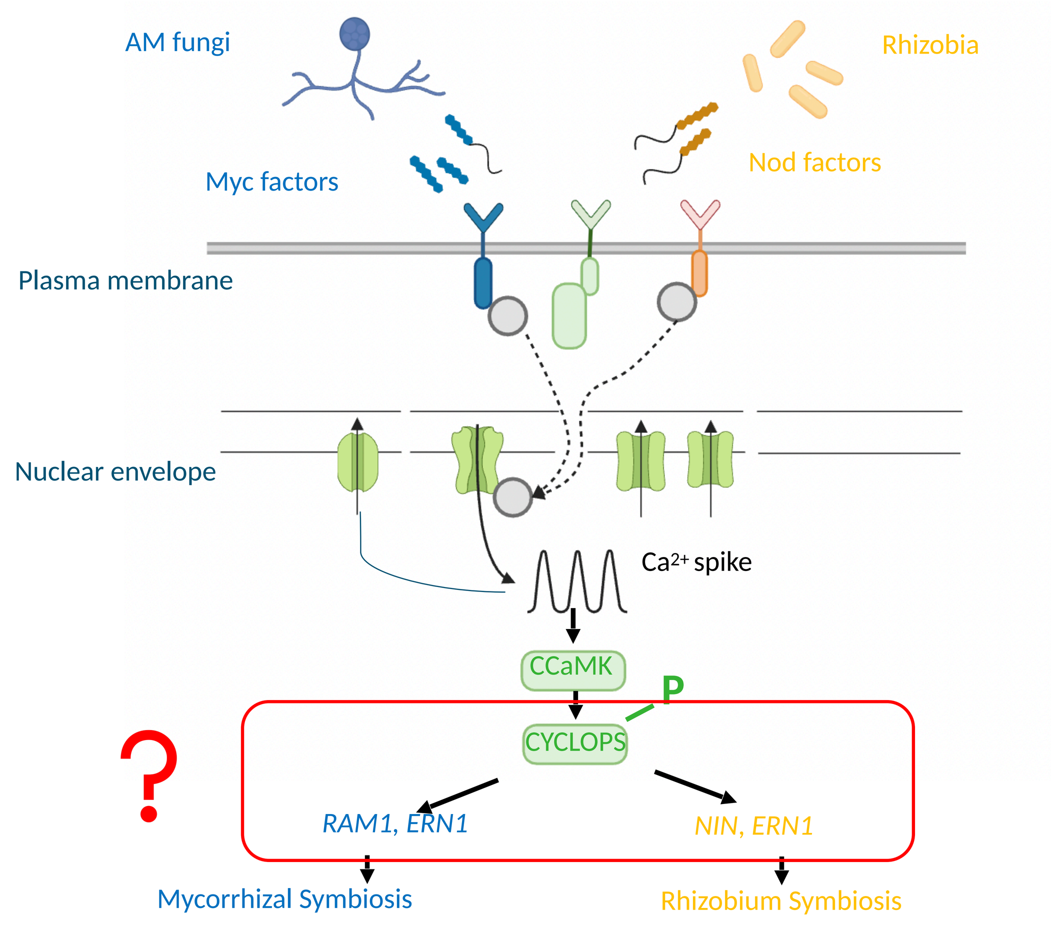

Figure 1. Common symbiosis signalling pathway

Both microbes trigger the activation of transcription factor CYCLOPS. However, During AM symbiosis CYCLOPS activates the transcription factor *RAM1*[3], whereas during nodulation CYCLOPS activates transcription factors *NIN* and *ERN1*[4,5]. As a result, the gene expression triggered by AM fungi and rhizobia shows little overlap[6-8]. it leads to the main research question of this project: How can plants discriminate between AMF and rhizobia with the same signalling pathway?

In this research, the non-legume *Parasponia andersonii* is used as research system.

Objectives

- Description of CYCLOPS-responsive elements (CYC-REs) activity.
- Confirmation of CYC-Res by transactivation assay.
- Identification of the molecular mechanism that determines which genes are activated by the common symbiotic signalling pathway.

Methods

- Transactivation assay in *Nicotiana benthamiana* leaves.
- Co-immunoprecipitation and/or Turbo-ID.

Results

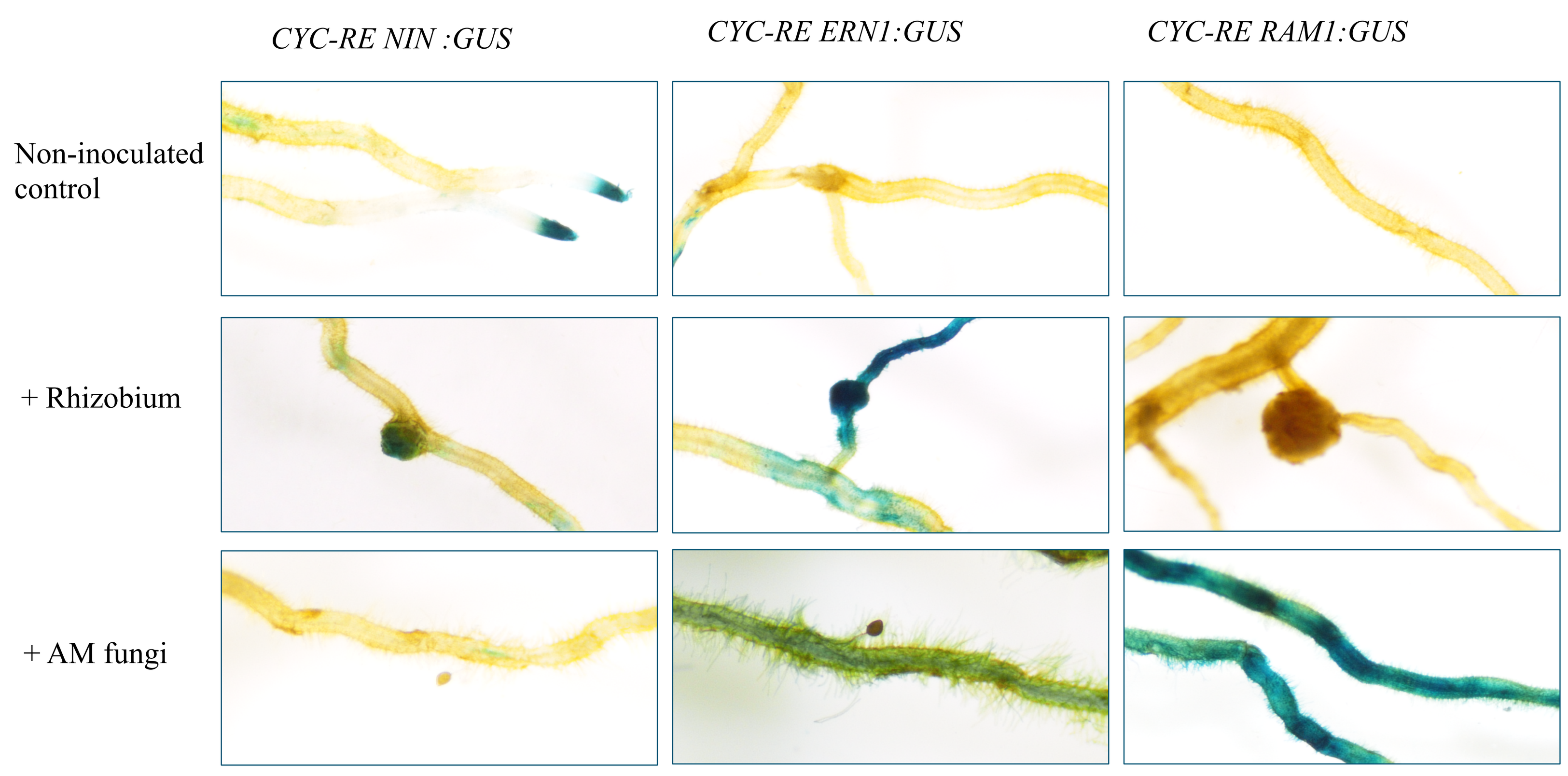

Figure 2. *CYC-REs* of *NIN* and *RAM1* specifically respond to rhizobium or AM fungi respectively, and *CYC-RE ERN1* is activated by both rhizobium and AM fungi in *Parasponia andersonii*. Wild-type parasponia were stably transformed with 5×*PanCYC-REs*:*GUS*. *CYC-REs* are 52bp cis-elements from parasponia covering the published *LjCYC-REs*. Roots were harvested and stained 4 wpi.

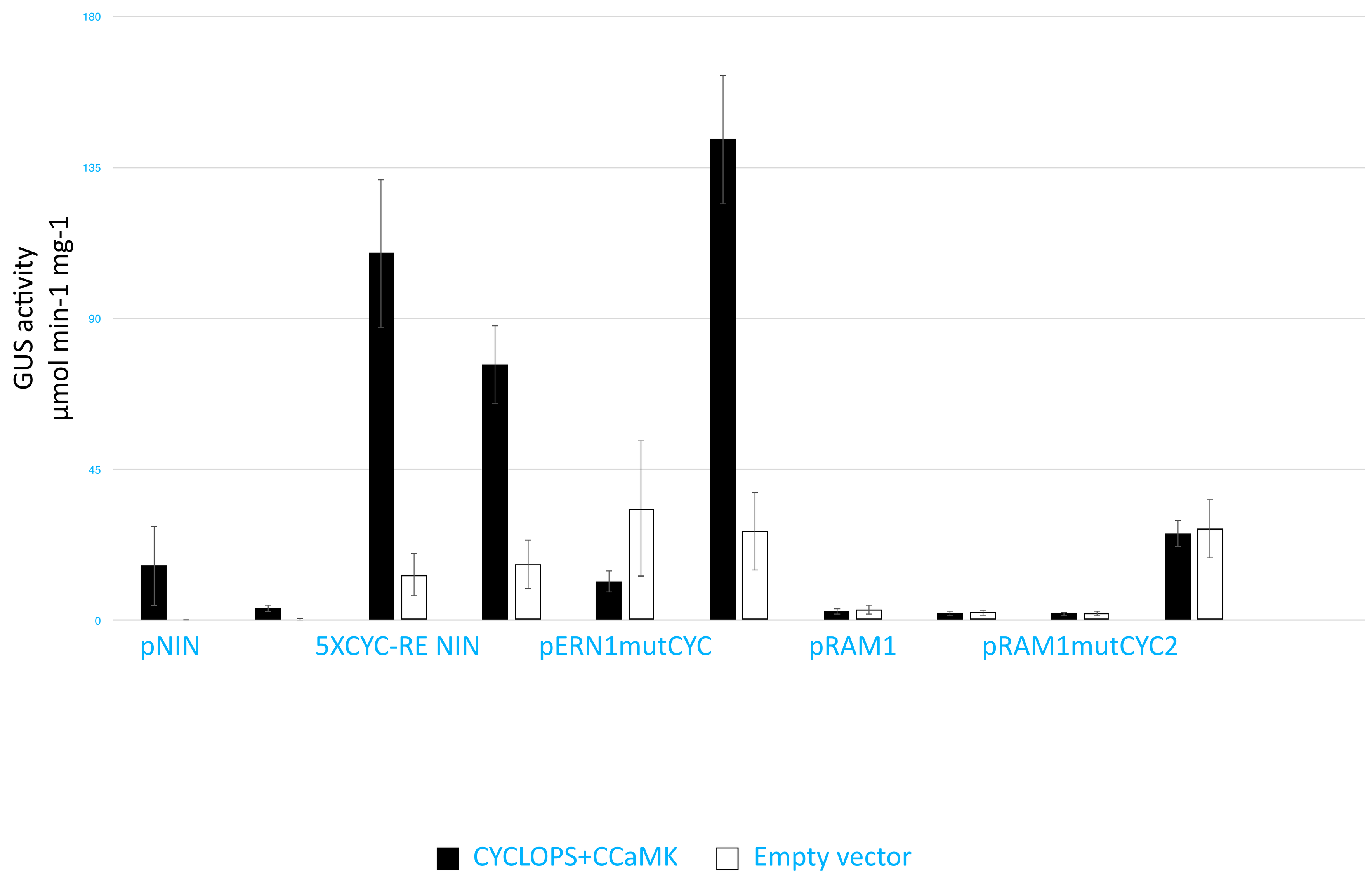

Figure 3. Promoters and *CYC-REs* of *NIN* and *ERN1* are transcriptionally activated by CYCLOPS in *Nicotiana benthamiana* leaves. The *N. benthamiana* leaves were cotransformed with GUS reporter driven by wild-type full promoters, full promoters with mutated *CYC-REs*, or 5×*CYC-REs* of *NIN*, *ERN1* and *RAM1*, together with CYCLOPS and autoactive CCaMK, or empty vector control. *NIN* and *ERN1* promoters are transactivated by CCaMK + CYCLOPS, depending on CYCLOPS and CCaMK. However RAM1 promoter does not respond to CYCLOPS. GUS activity was determined by histochemical quantification after 3 days of infiltration. Mean values were determined from 11-14 replications, and the error bars indicate standard deviation.

Future plans

- Test the specificity of *CYC-REs* in the model legume *Medicago truncatula*.
- Identify of the upstream activator of *RAM1*.
- Describe the phenotype of *Pancyclops*, *Panern1*, *Panram1* mutants.

Conclusions

- The specific activation of *NIN* (nodule specific) and *RAM1* (mycorrhiza specific) is encoded in their *CYC-REs*.
- The activation of CYCLOPS is not sufficient for the activation of the *RAM1* or *NIN CYC-RE*.
- *PanCYC-RE RAM1* cannot be activated by CYCLOPS in *N. benthamiana leaves.*

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We gratefully acknowlege the sponsors of this research:China Scholarship Council (NO.201913043) and Hainan University.

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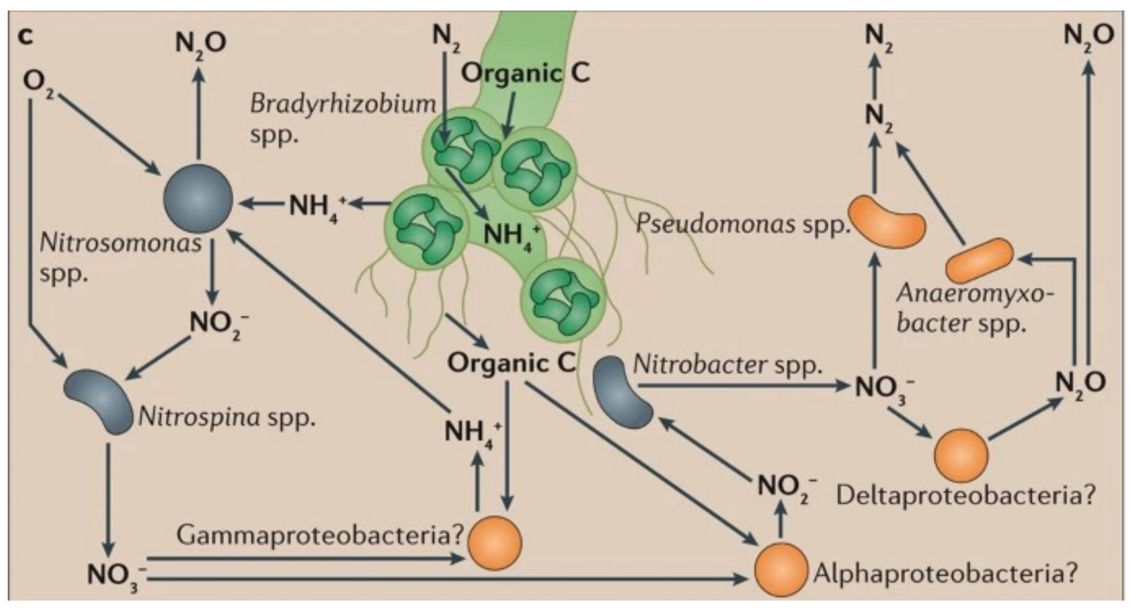
Uncovering the coordination mechanisms between plant and rhizosphere microbiome under different nitrogen levels

PhD student: Pugang Yu
Supervisors:Prof. Jianbo Shen, Prof. Bin Ni, Dr. Rene Geurts

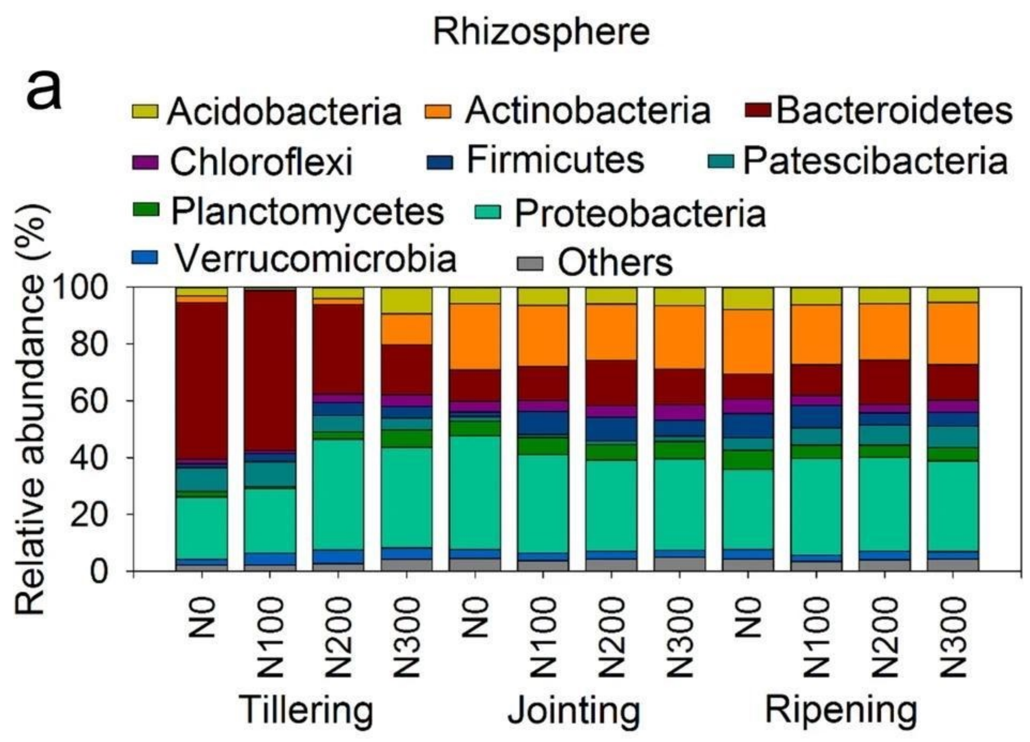
Background

- ✓ Microbiome drive nitrogen cycle processes including nitrogen fixation, nitrification, denitrification in farmland.



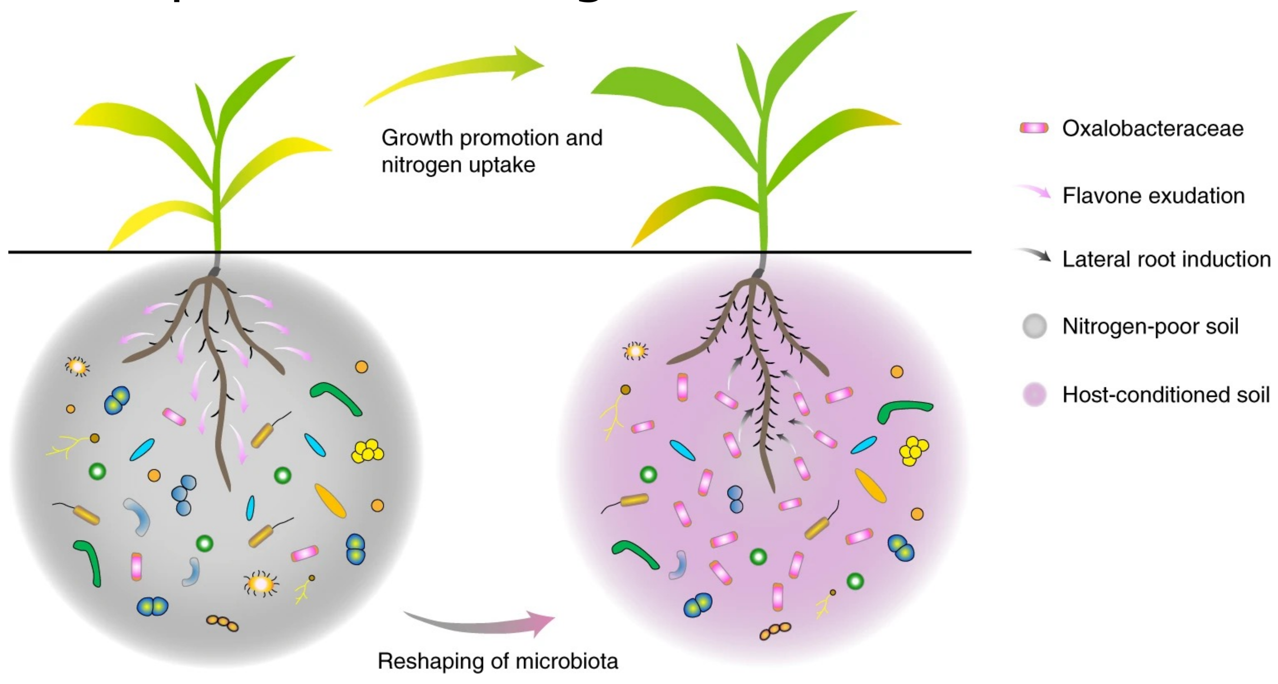
[1]

- ✓ Rhizosphere microbiome can response to different nitrogen input levels.



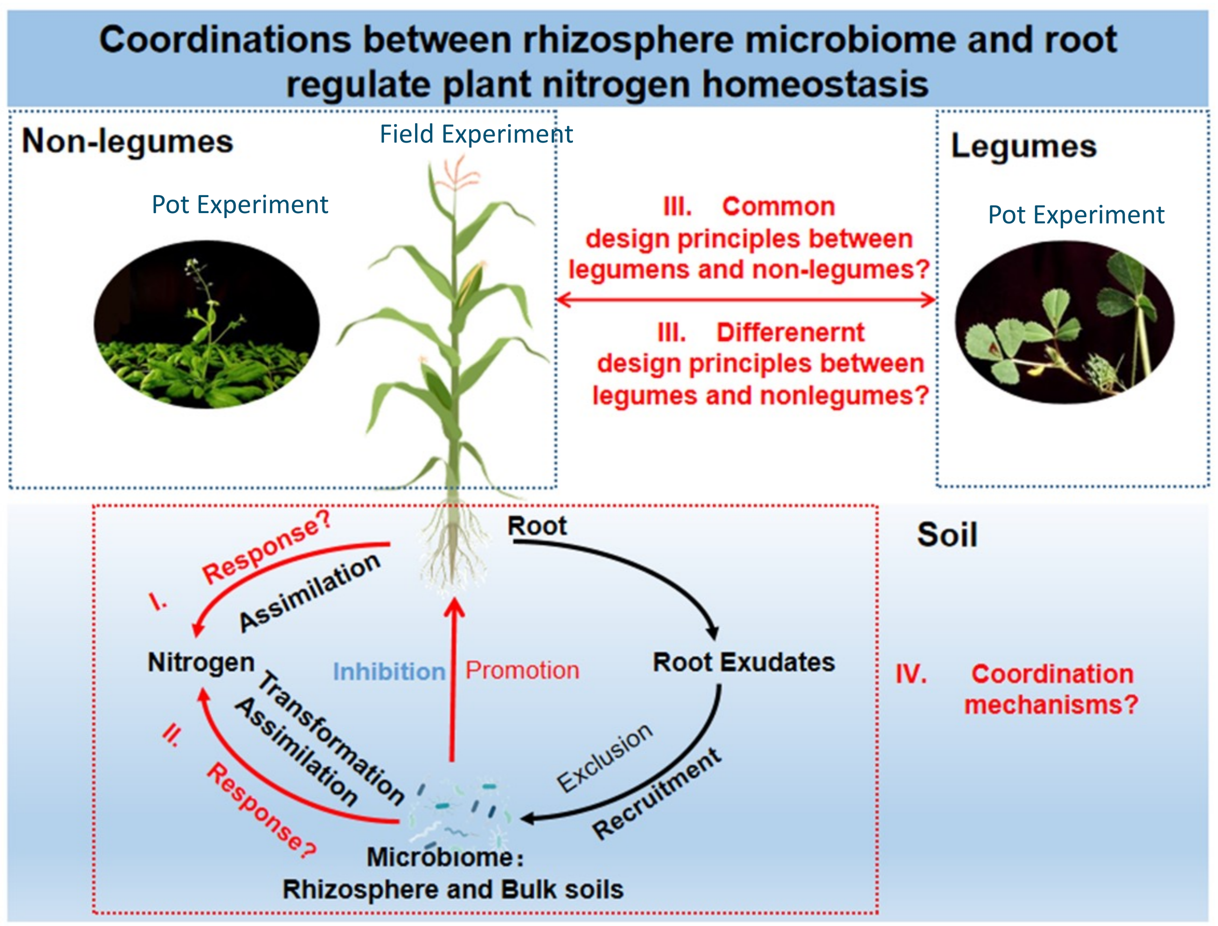
[2]

- ✓ For maize, inbred line 787 can secret flavones to recruit *Oxalobacteraceae* to adapt to low nitrogen soils.

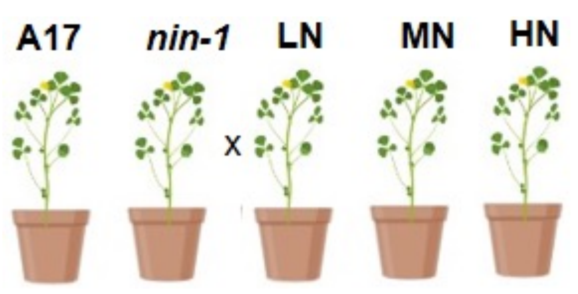


[3]

Research framework

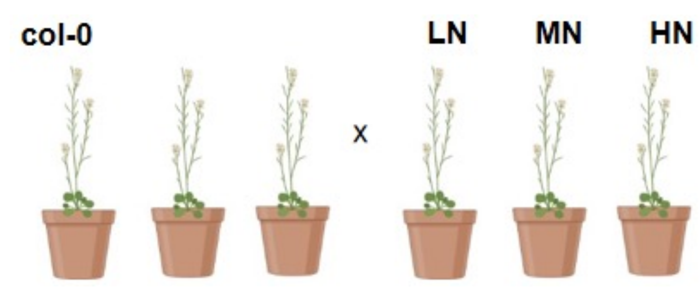


Pot Experiments 1



2 genotypes x 3 nitrogen levels
Medicago truncatula

Pot Experiments 2



3 genotypes x 3 nitrogen levels
Arabidopsis thaliana

Fields Experiments : 6 Nitrogen input levels (from N0 to N300), 2 maize Varieties

Objectives

01 To explore the changes of root gene expression level in response to different nitrogen levels.

02 To explore the changes of rhizosphere microbiome to get adapted to different nitrogen levels.

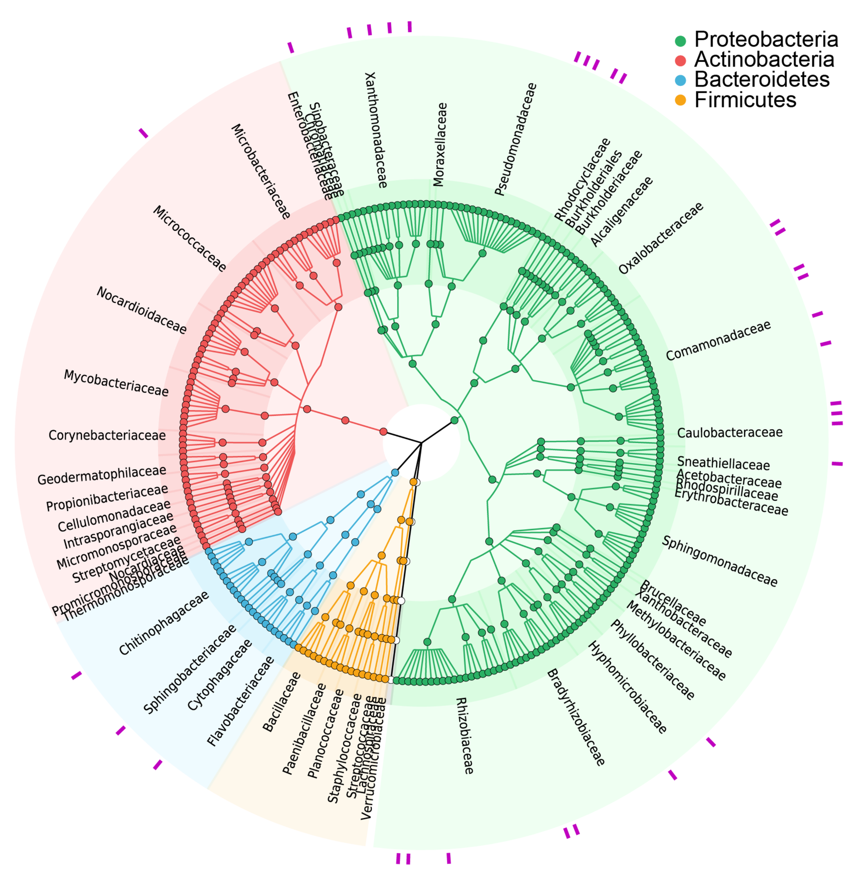
03 To explore the coordinations between rhizosphere microbiome and plant roots.

04 To find common design principles in shaping these plant-rhizosphere microbiome interactions between legumes and non-legumes?

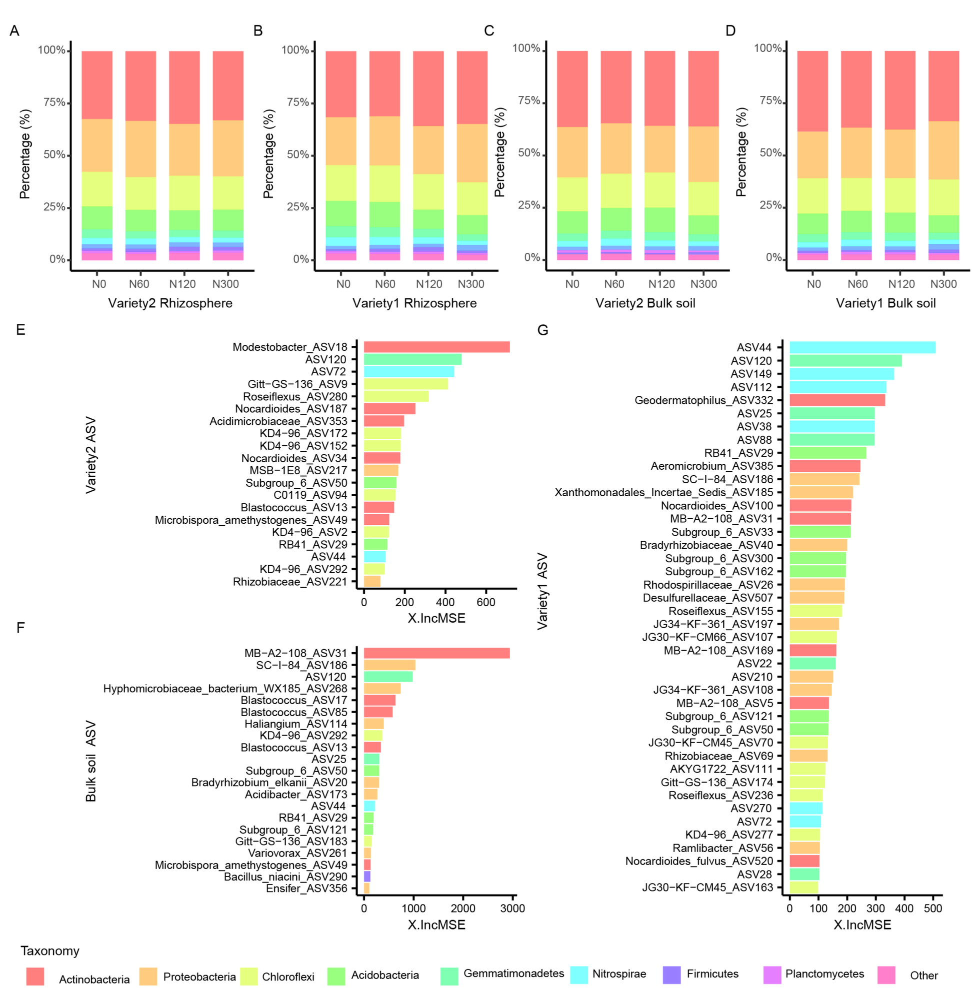
Research prospect

1. Based on the research, the coordinations between rhizosphere microbiome and plant roots under different nitrogen levels will be partly clarified.
2. To develop new crops systems: maximize the coordinations between plants and microbiome.

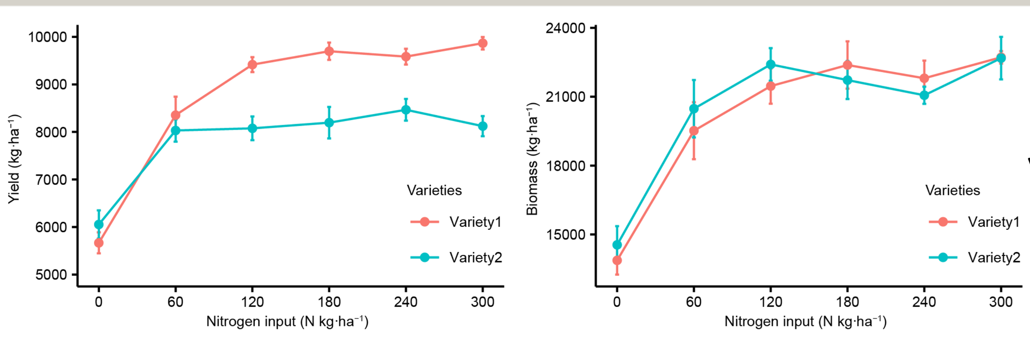
Results



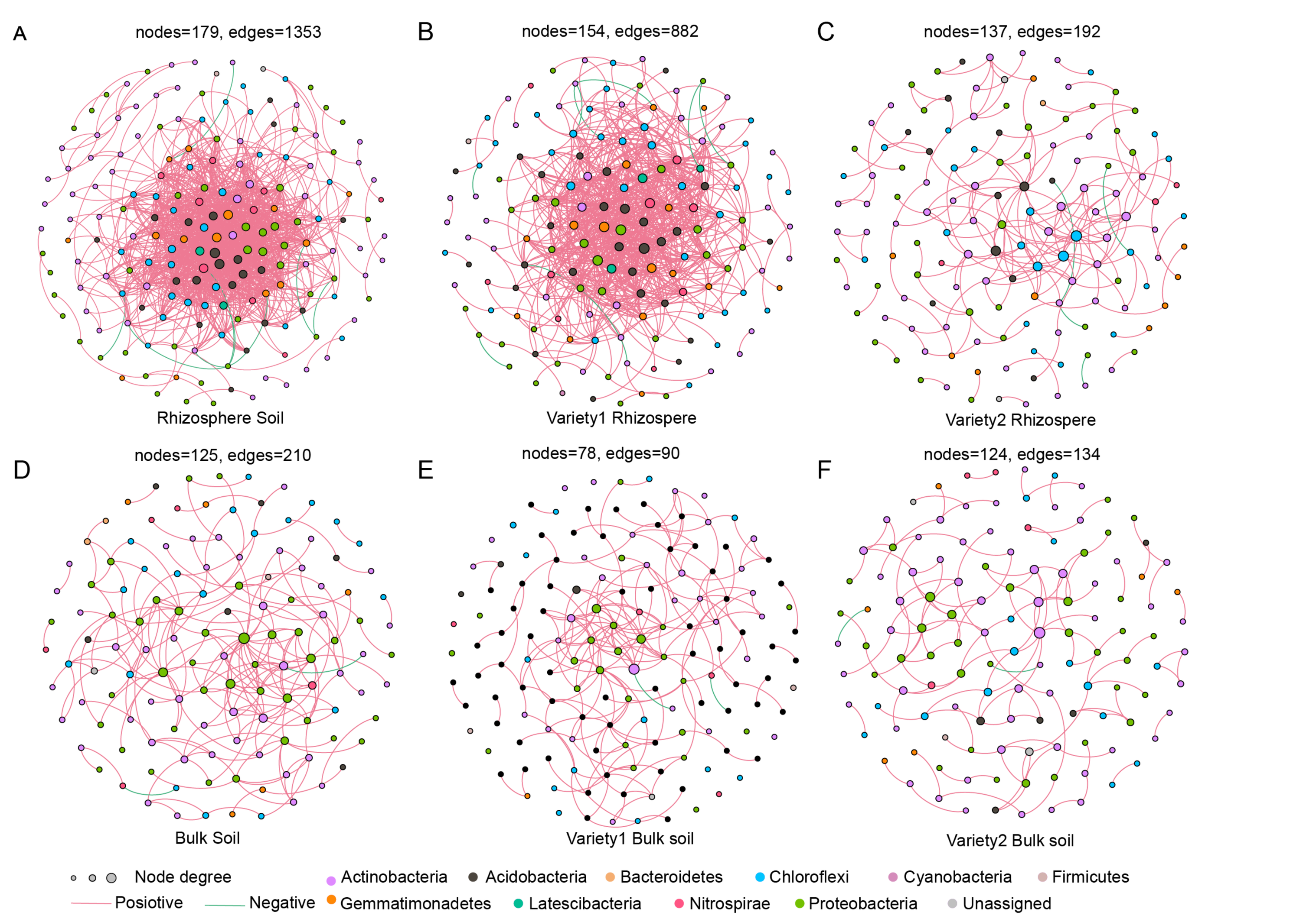
Bacteria culturome of 8 weeks maize root from pot experiments used soils of Quzhou. All the bacteria belonged to *Proteobacteria*, *Actinobacteria*, *Bacteroidetes*, *Firmicutes*.



Nitrogen response ASVs identified by random forest regressions in rhizosphere soils and bulk soils. Variety1 rhizosphere had a stronger N response than variety2 in the field experiment.



Nitrogen input significantly changed yields and biomass of 2 maize varieties.



Maize rhizosphere soils had a more complex and stable networks than bulk soils, and variety1 had a more complex network than variety2.

Reference

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Soil N index enhancement by organic fertilizer application depends on aggregate size

Candidate: Zewen Hei Supervisor: Yongliang Chen; Stefan Geisen; Jan Kammenga

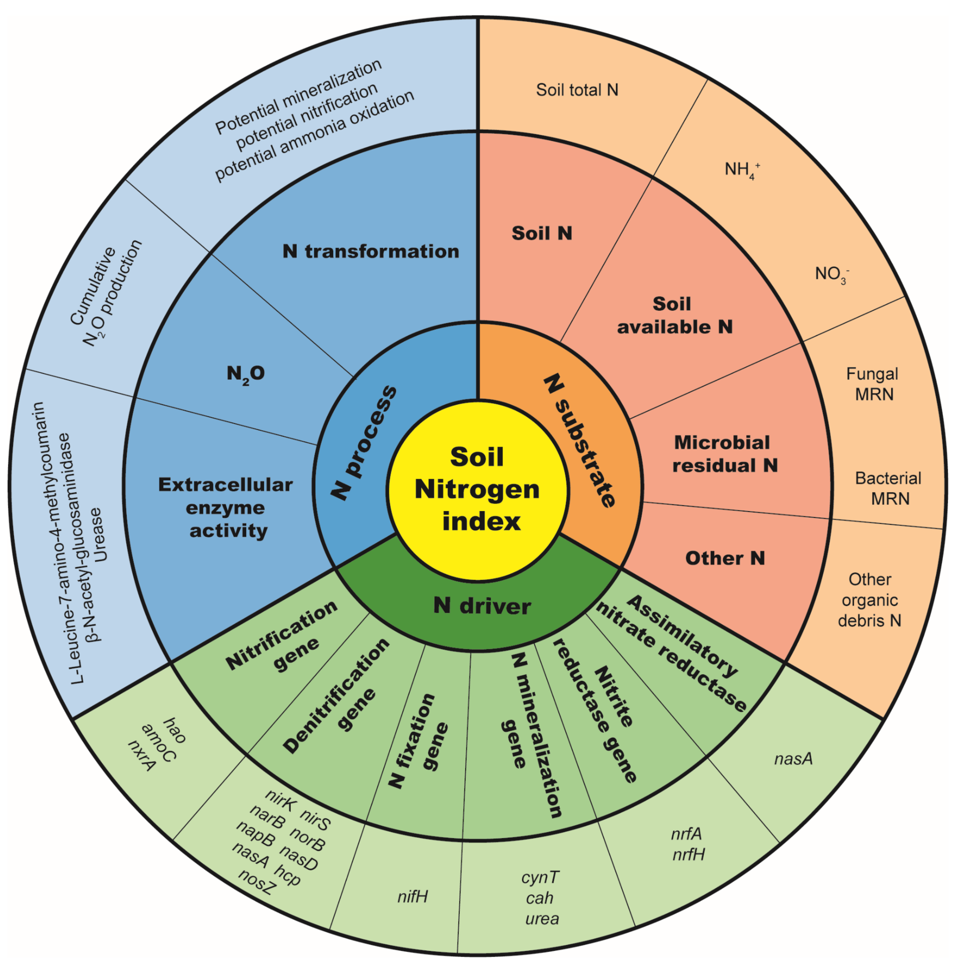
Background

Nitrogen (N) is the major limiting nutrient determining yield and quality of crops. Many factors related to the N cycle jointly determine its overall functioning and plant uptake, which farmers aim to manipulate with different fertilization types (e.g., organic versus mineral) and fertilizer application rates. Most N is stored in differently sized aggregates. However, the effects of fertilizer types on the soil N cycle in different soil aggregate fractions remain elusive.

Objectives

In this study, we investigated how changes in fertilization regimes (two application rates each of organic and mineral fertilizers, with identical NPK concentrations) influence the comprehensive soil N cycle across three aggregate fractions. We tested the following three hypotheses: (1) organic fertilizer increases the soil N index compared to mineral fertilizer across all aggregate fractions; (2) the soil N index increases with fertilizer application rates in all aggregate fractions; and (3) microaggregates have the highest soil N index among the three aggregate fractions.

Methods



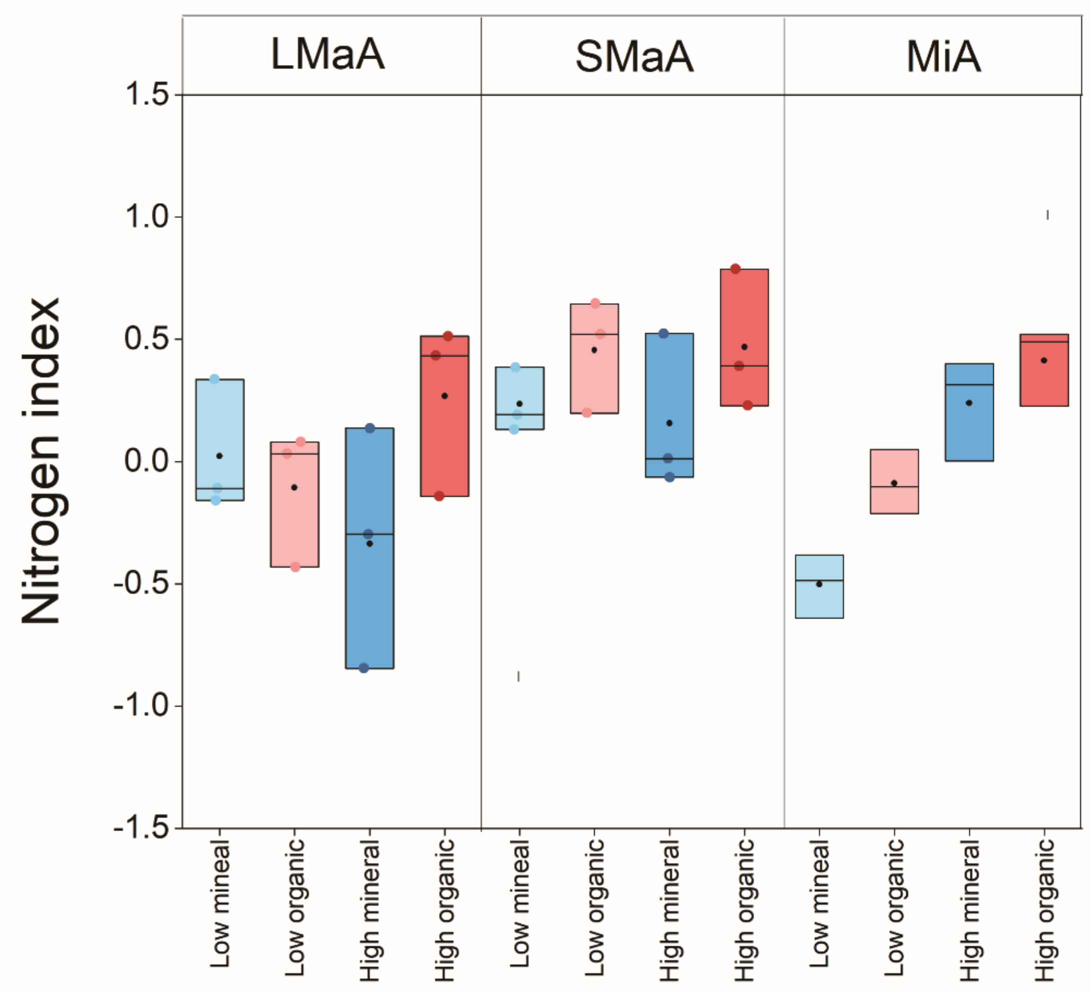
We first established a soil N index to summarize N-related soil functions. The soil N index was determined by averaging all nitrogen-related soil functions using the z-transformation method. The soil N index was calculated from soil N substrates (physiochemical property and microbial residual N), N drivers (functional gene abundance and diversity) and N processes (N transformation rate and extracellular enzyme activity) in large and small macroaggregates, and microaggregates.

Results

(a) **Table**. General mixed effect model

	χ^2	df	P value	Significance
Fertilizer type	9.0045	1	0.003	**
Fertilizer rate	5.0629	1	0.024	*
Aggregate	13.456	2	0.001	**
Fertilizer type * Aggregate	0.0687	2	0.966	-
Fertilizer rate * Aggregate	11.435	2	0.003	**
Fertilizer type * Fertilizer rate	1.2159	1	0.270	-
Fertilizer type * Fertilizer rate * Aggregate	5.2119	2	0.074	-
Blocking factor	3.1188	2	0.210	-

(b)



The general mixed effects model of the soil N index showed that there was a marginally significant interactive effect of fertilizer type and rate, and aggregate fraction (Fig. 2a, $\chi^2 = 5.21$, $P = 0.074$). There was also an interactive effect of fertilizer rate and aggregate fraction on the soil N index (Fig. 2a, $\chi^2 = 11.44$, $P < 0.01$).

Conclusions

We conclude that organic fertilizer application boosts the soil N index mostly in microaggregates. The usefulness of the soil N index lies in its capacity to offer a comprehensive representation of the intricate N functions, encompassing N substrates, drivers and processes. While further studies with different soils and varying fertilizer practices are needed, our research suggests that examining soil within microaggregates may be crucial for tracking functional changes in the soil N cycle.

Acknowledgements

This study was supported by the National Key Research and Development Program of China (2023YFD1902603 and 2021YFD1700900), the 2115 Talent Development of China Agricultural University, China Scholarship Council (No.201913043) and Hainan University.

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Dynamics and functions of rhizobiomes during plant maturation

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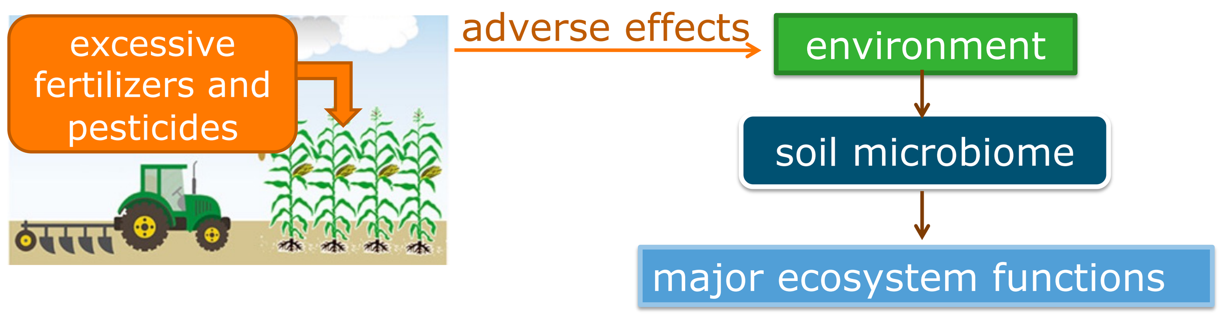
[1] : Laboratory of Nematology, Wageningen University, 6708PB Wageningen, The Netherlands

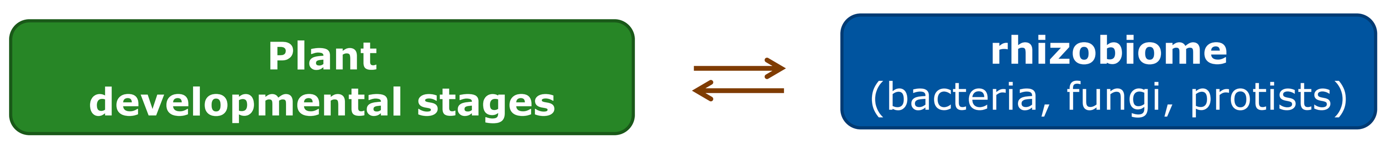
[2] : College of Resources and Environmental Sciences, China Agricultural University, Beijing 100193, China

Background

- Wheat-maize rotation: the most common cropping system in North China



- Plant developmental stages --- rhizobiome diversity and community composition
- Tight link between plant performance and rhizobiome
- Rhizobiome functioning on plant performance remains unknown



Objectives

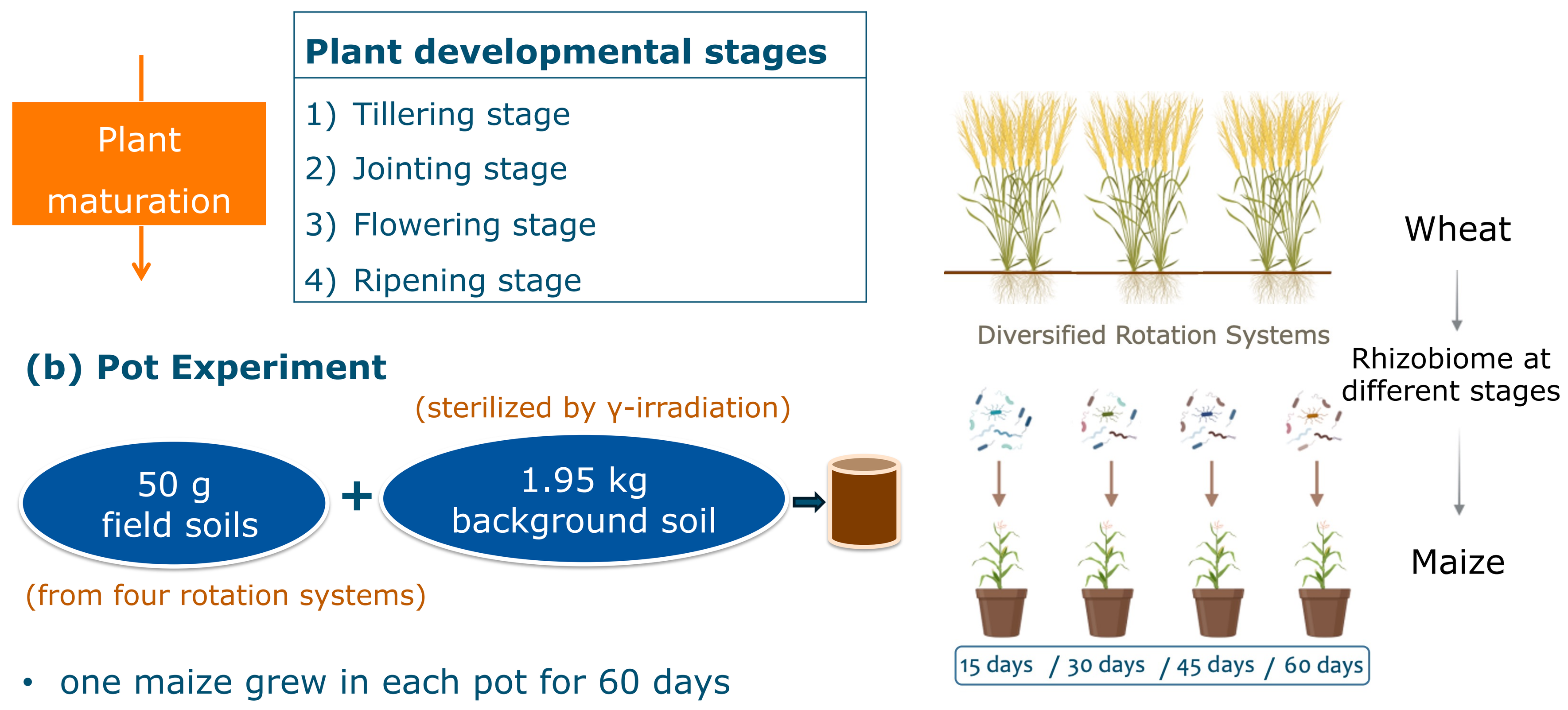
Understand the temporal dynamics of rhizobiomes (bacteria, fungi, and protists) during plant maturation and the influences of resulting functional shifts on plant performance.

Methods

(a) Field Study

- samples from long-term field study with four diversified crop rotation systems.

(b) Pot Experiment



- one maize grew in each pot for 60 days
- harvested every 15 days to measure: chlorophyll content (SPAD); height; leaf area; shoot and root biomass; C and N in plant
- N_2O and CO_2 measurements

Results

(a) Field Study

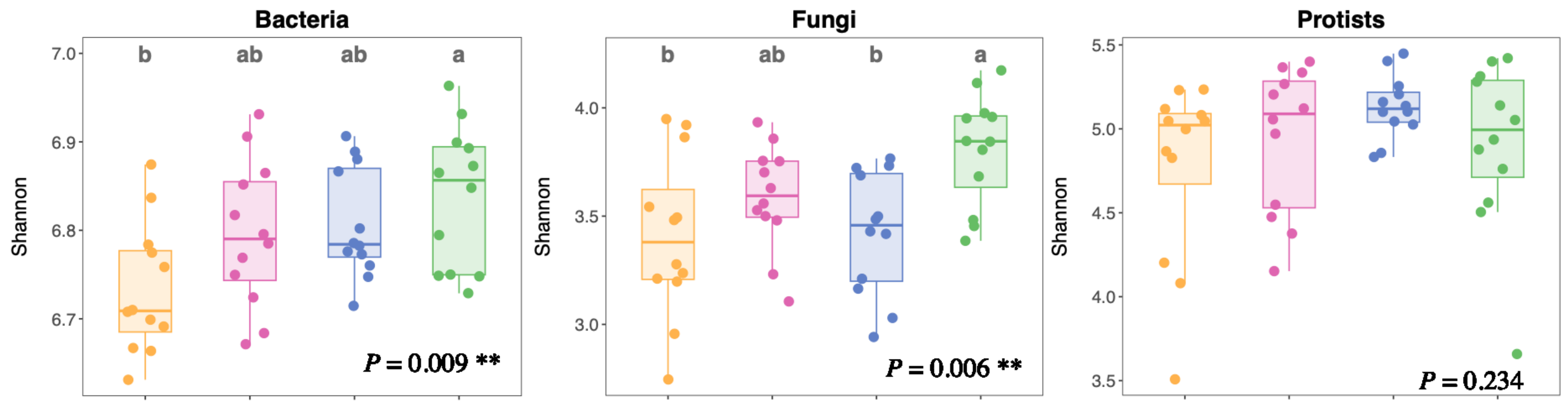


Fig.1: Bacterial and fungal diversity increased and community composition changed during plant maturation, but protist community was not affected.

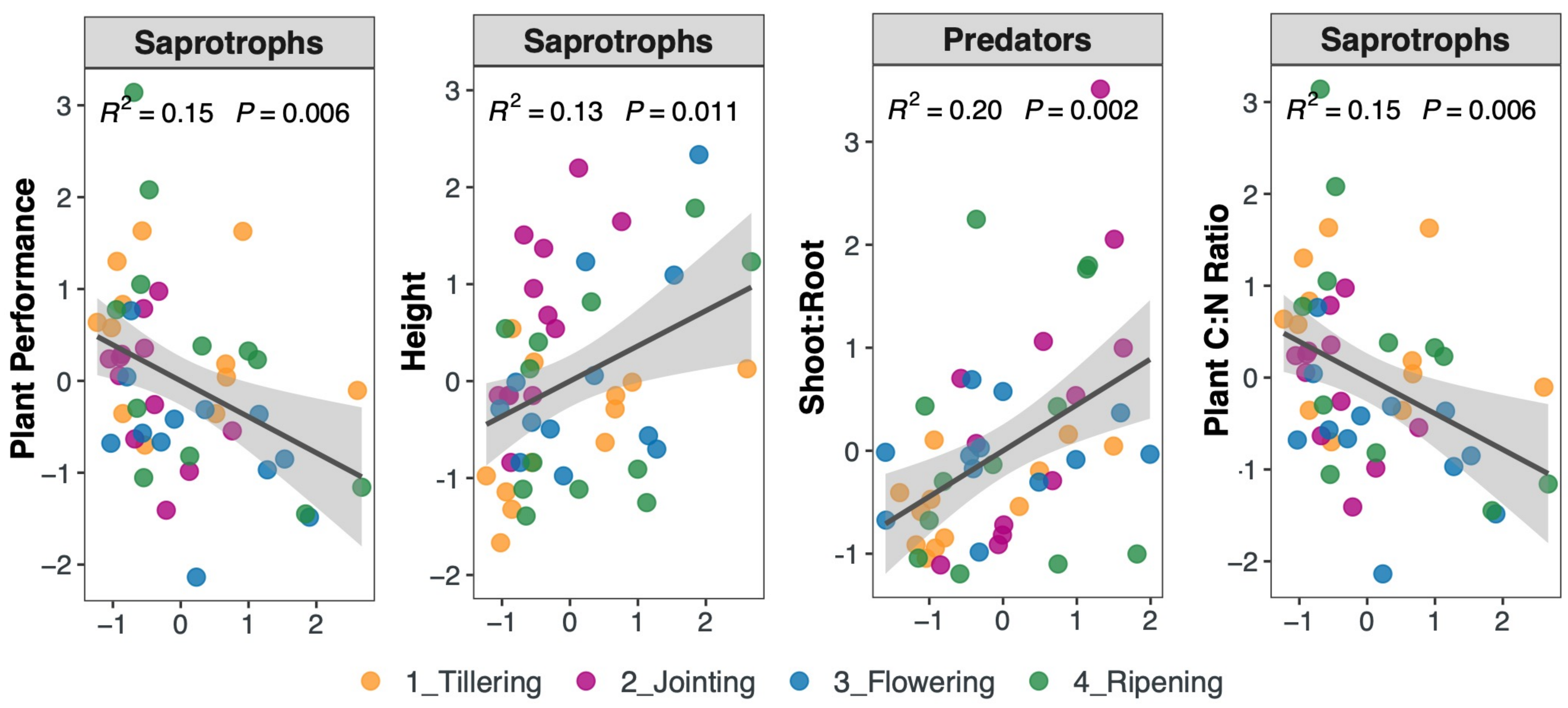


Fig.4: Plant performance negatively correlated with saprotrophs; especially saprotrophs positively correlated with plant height and negatively correlated with plant C:N ratio; the ratio of shoot:root biomass positively correlated with predators.

(b) Pot Experiment

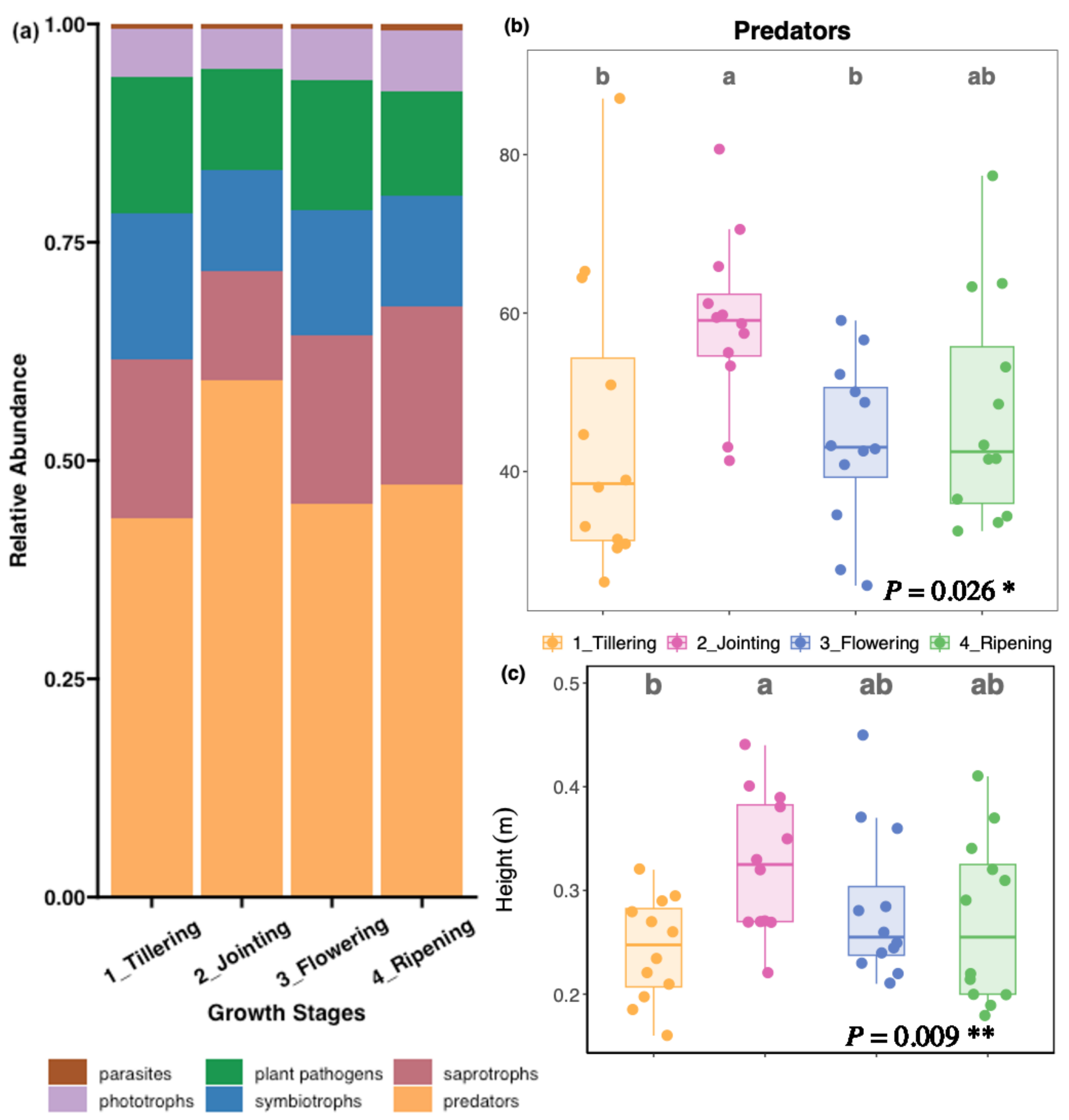


Fig.2: Rhizobiome functional groups across four plant developmental stages. Higher abundance of predators at jointing stage led to enhanced plant height in the pot experiment.

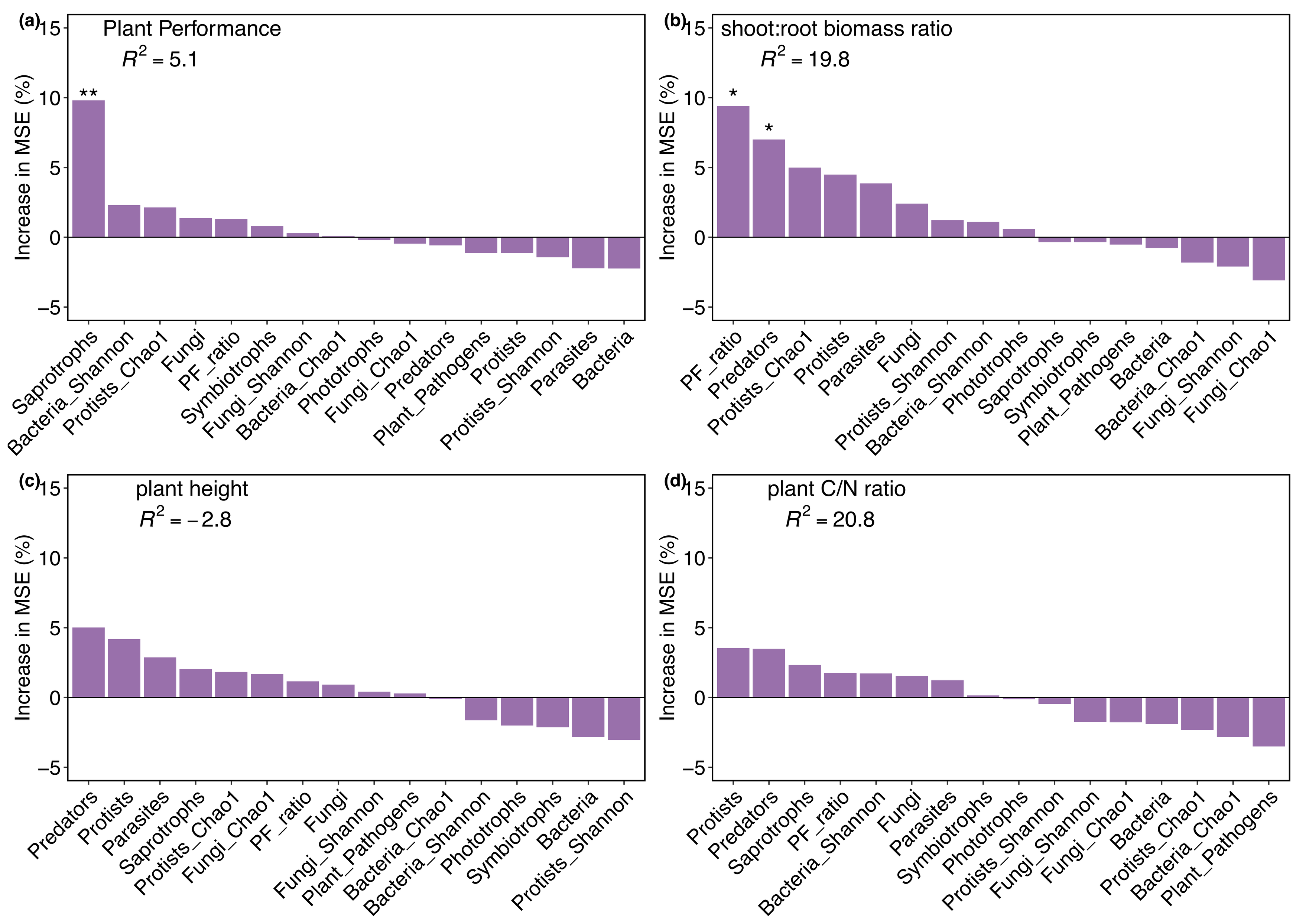


Fig.5: The microbial drivers of plant growth in the pot experiment. Plant performance was affected by saprotrophs, while the ratio of plant shoot/root biomass was affected by the ratio of protists/fungi and predators

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Conclusions

1) Plant maturation increased rhizobiome diversity and altered community composition
2) Not a higher abundance of saprotrophs or PBRMs is necessary, but the distinct rhizobiomes that could support the different growth needs of plants must be considered

We gratefully acknowlege the sponsors of this research: China Scholarship Council (NO.201913043) and Hainan University.

Overview PhD projects – starting year 2023 & 2024
Posters, March 2025

Starting 2023

Name	*Model**	*Project*
1. Yuxiang Ren	1+3	Non-point Source Pollution Control: Residue and Transport of Fertilizers and Pesticides in the Erhai Lake Watershed.
2. Chen Zheng	1+3	Agricultural Green Development Strategies for Nutrient Pollution Control: A New Integrated Approach for Decision Support
3. Xin Wang	2+1+1	Analysis of the Current Situation and Potential of Non-point Source Pollution Control Technologies in Typical Areas of the Erhai Lake Basin
4. Peiyu Tian	2+1+1	Nitrogen Losses and Reduction Control Potential during Manure Fertilization Process in China

Starting 2024

Name	*Model**	*Project*
5. Lidong Qi	2+1+1	Developing site specific sustainable P management in China based on P legacy and soil properties
6. Chengran Zhao	2+1+1	Productive performance and ecological benefits of intercropping adopted by smallholder farmers in China —— A case study in Gansu
7. Jiayin Feng	2+1+1	The distinction of hyphosphere microbiome diversity and phosphorus activation ability of different Arbuscular Mycorrhizal (AM) Fungi
8. Peiying Lv	2+1+1	Modelling and optimization of agri-food system towards coupled food supply and environment conservation in China
9. Yue Hou	2+1+1	Organic-inorganic nutrient management in farmland in China: regional differences and optimization strategies
10. Xuhao Chen	2+1+1	Innovating precision management frameworks for carbon, nitrogen and phosphorus in livestock slurry: from STB upscaling to regional application
11. Jiayu Lu	2+1+1	Optimizing nutrient management in integrated livestock-crop systems to enhance soil health
12. Dongmei Wang	2+1+1	The impact and scale-up strategy of the “Science and Technology Backyard + Market” Model in empowering smallholders for Green and High-Value Cultivation
13. Jiyang Lv	2+1+1	Modelling the effects of strategies for enhancing food production and clean water availability in China

Model*: There are two different types of PhD candidates, hence 2 models.
2+1+1 model: Graduates at CAU; project starts and ends in China; stays for one consecutive years in Wageningen.
1+3 model: Graduates at WU; project starts in China; stays for three consecutive years in Wageningen.

Non-point Source Pollution Control: Residue and Transport of Fertilizers and Pesticides in the Erhai Lake Watershed.

PhD candidate: Yuxiang Ren (1+3), Soil Physics and Land Management Group(WUR)

CAU supervisors: Prof. Yong Hou; Dr. Kai Wang

WUR supervisors: Prof. Coen J Ritsema; Dr. Lingtong Gai

Background

Agricultural non-point source pollution (ANSP) significantly impacts the water quality of the Erhai Lake. Although agriculture in the Erhai Lake region has shifted from high-value and high-pollution to sustainable practices, emissions still exceed the standards, particularly on rainy days. Although many studies have been conducted on source analysis of non-point source pollution in the watershed, the transport processes of pollutants through soil and water bodies remain unclear. To address ANSP issue effectively, this project aims to assess the current state of ANSP, simulate its transport pathways through soil and sediment into waterways feeding the lake, and evaluate the impact of sustainable agricultural practices on mitigating these pollutants in the Erhai Lake watershed. Ultimately, this project will analyze the feasibility of BMPs based on local conditions and provide relevant policy recommendations..

Objectives

1. To assess the current status of pollution caused by fertilizers and pesticides application in the region and to identify the pollution source areas.
2. To apply and improve a robust model capable of accurately simulating the diffusion and transport of ANSP in the Erhai Lake Basin.
3. To evaluate the effectiveness of sustainable agriculture practices in mitigating ANSP within the Erhai Lake watershed.
4. To identify the best management practices (BMPs) for sustainable agriculture practices in the Erhai Lake watershed based on a comprehensive environmental, economic, and social evaluation criteria.

Methods

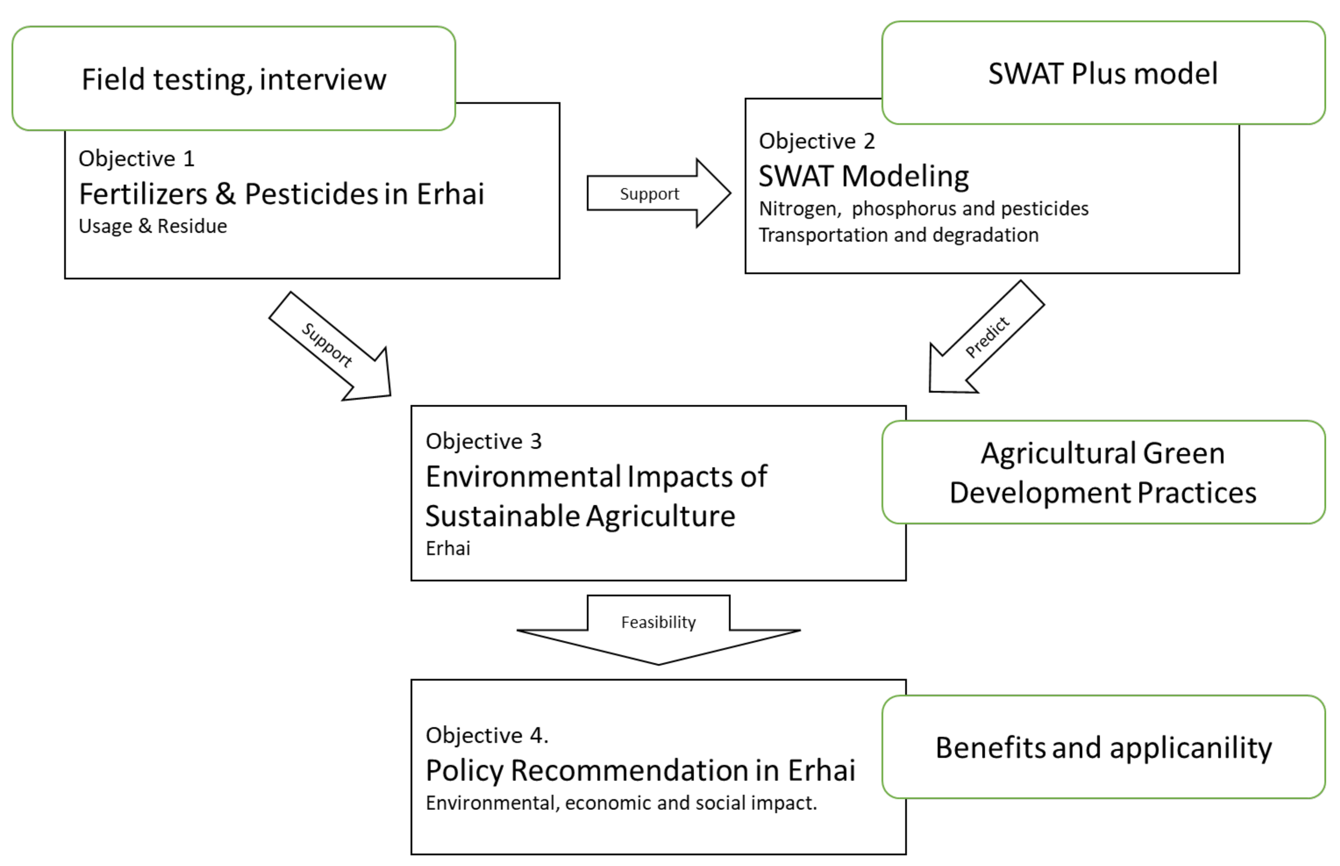


Figure 1. Framework of the project (Black) with method (Green).

This project will begin by assessing the current status of pesticide and fertilizer use in the Erhai Lake Basin, along with conducting field measurements to quantify the ANSP levels in the natural environment. It will then focus on applying the SWATPlus model to simulate the transport of pesticides and fertilizers from soil to the lake system. Furthermore, through developing scenarios based on the upscaling of various locally feasible sustainable agricultural practices, the project aims to simulate the process of pollution mitigation by these practices and subsequently quantify their potential for pollutant reduction in the long-term. Ultimately, the project will assess the environmental, economic, and social benefits of these sustainable practices, identify the best management practices (BMP) for policy recommendation purposess (Figure 1) under the local context.

Results

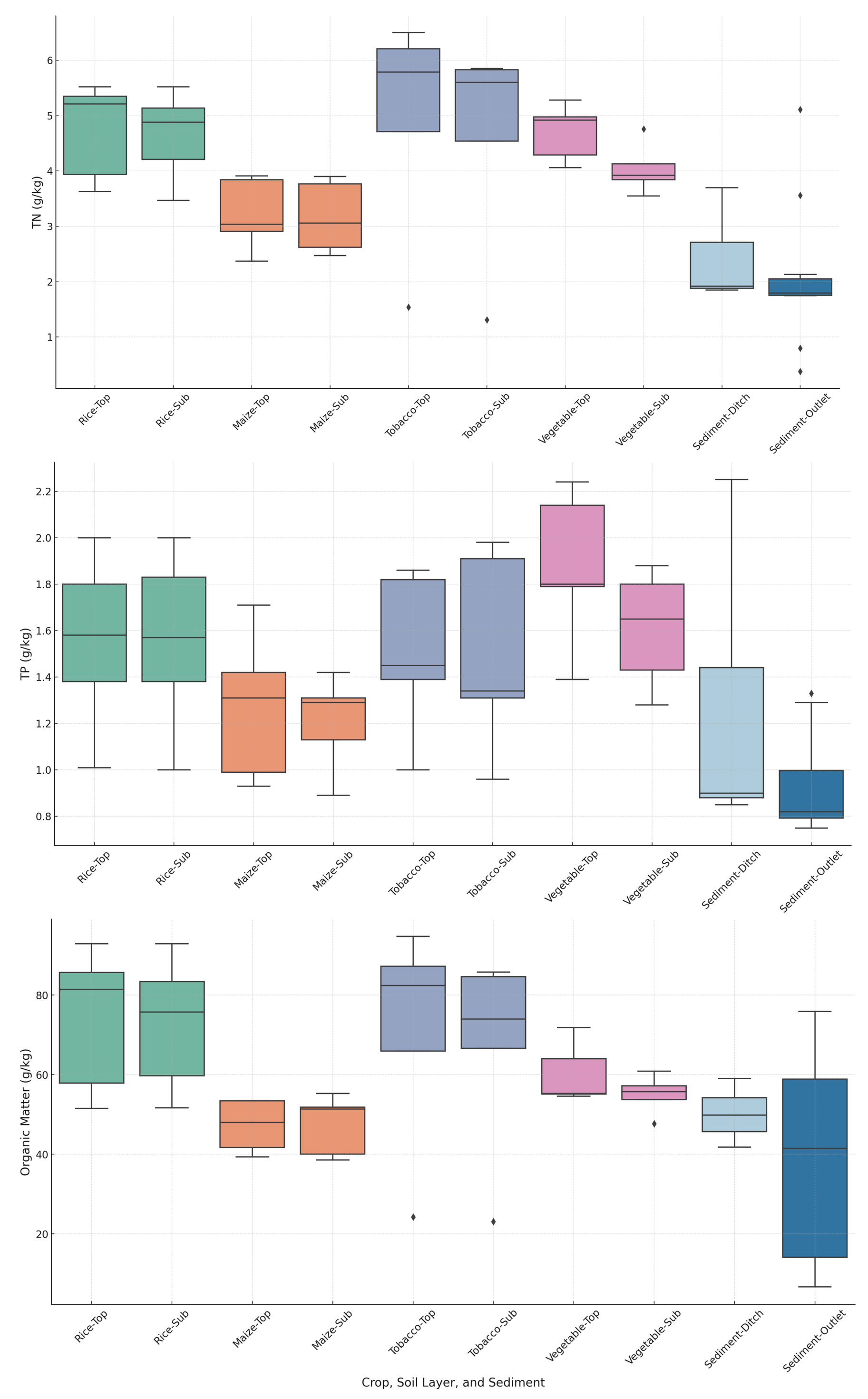
Table 1. Pesticide Bans and Recommendations in Erhai Basin (Partial)

Name	CAS	2019	2021	2022	2023
demeton	8065-48-3	1	0	1	1
phosfolan	947-02-4	1	0	1	1
isazophos	42509-80-8	1	0	1	1
flocoumafen	90035-08-8	0	1	1	1
brodifacoum	56073-10-0	0	1	1	1
bromadiolone	28772-56-7	0	1	1	1
aluminum_phosphide	20859-73-8	0	1	0	0
trichloronitromethane	76-06-2	0	1	0	0
thiodicarb	59669-26-0	0	0	1	1
pirmicarb	23103-98-2	0	0	1	1
isoprocarb	2631-40-5	0	0	1	1
metolcarb	1129-41-5	0	0	1	1
lividomycin_a_sulfate_salt	36441-41-5	0	0	2	0
beta_1_3_d_glucan	232-739-1	0	0	2	0
2_allylphenol	1745-81-9	0	0	2	0
bacillus_thuringiensis	68038-71-1	0	0	2	2
matrine	519-02-8	0	0	2	2
azadirachtin	11141-17-6	0	0	2	2
nicotine	54-11-5	0	0	2	2

Banned
Not mentioned
Recommended

Red indicates banned (1), green indicates recommended (2), and 0 indicates not mentioned. Full list includes 185 pesticide types. Data sourced from local government.

Figure 2. Total Nitrogen (a) , Total Phosphorus (b), and Organic Matter (c) in different crops soils and sediments of ditches and rivers in the Erhai basin.



Four land types: Rice fields, Maize fields, Tobacco fields, and Vegetable fields. Each type has two layers: Top (0–2 cm) and Sub (2–20 cm), e.g., Rice-Top represents the top layer of rice fields. Each soil-crop-layer type includes 5 samples. There are two sediment sampling locations: Sediment-Ditch, collected from ditches beside farmland with 4 sampling points; and Sediment-Outlet, collected from river inlets near the lake with 6 sampling points.

Conclusions

1. Local government has established comprehensive pesticide regulations, with relevant policies implemented for years, including detailed banned and recommended lists. However, the recommended list includes pesticides banned in Europe, such as *triadimenol, triadimefon, and matrine*. The residues and usage of these pesticides warrant attention.
2. In local agricultural soils, the N and P contents are relatively high in rice, tobacco, and vegetable fields. Additionally, the N and P contents in the surrounding river sediments are not low. The total N and P transported into the lake through sediment deposition also warrants attention.

Acknowledgements

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Agricultural Green Development Strategies for Nutrient Pollution Control: A New Integrated Approach for Decision Support.

PhD candidate: Chen Zheng
CAU supervisor: Prof. Zhenling Cui
WUR supervisors: Dr. Maryna Strokal, Dr. Mengru Wang
Advisor: Prof. Yulong Yin

Background

- **Agricultural activities** in China often release excess nutrients into rivers and air, causing eutrophication and air quality problems;
- **Agricultural Green Development** (AGD) strategies aim to avoid these problems but without a clear understanding of their trade-offs and co-benefits for food production and nutrient pollution control;
- **Decision Support Tools (DSTs)** are platforms designed to support stakeholders in decision-making by providing options to address certain issues;
- However, rarely DSTs used in **Erhai Lake basin** taking trade-offs and co-benefits into account.

Objectives

To develop an integrated decision-support tool that assesses the trade-offs and co-benefits of AGD strategies for air and water pollution control to support decision-making in the Erhai Lake Basin.

Research question

- **RQ1:** What are the impacts of crop and livestock production activities on air and water pollution in the Erhai Lake Basin?
- **RQ2:** What are the trade-offs and co-benefits of the AGD strategies between food production and pollution control for air and water in the Erhai Lake Basin?
- **RQ3**: What are the effective AGD strategies to reduce air and water pollution considering their trade-offs, co-benefits, and stakeholder perspectives in the Erhai Lake Basin?
- **RQ4:** What are the lessons for supporting decision-making in future pollution control when considering global change?

Research method

Erhai Lake Basin (Fig.1)

- Located in Dali Bai Autonomous Prefecture, Yunnan province;
- The second-largest freshwater lake in Yunnan province;
- Important part of the Cangshan Erhai National Nature Reserve and serves as a crucial drinking water resource for Dali City.

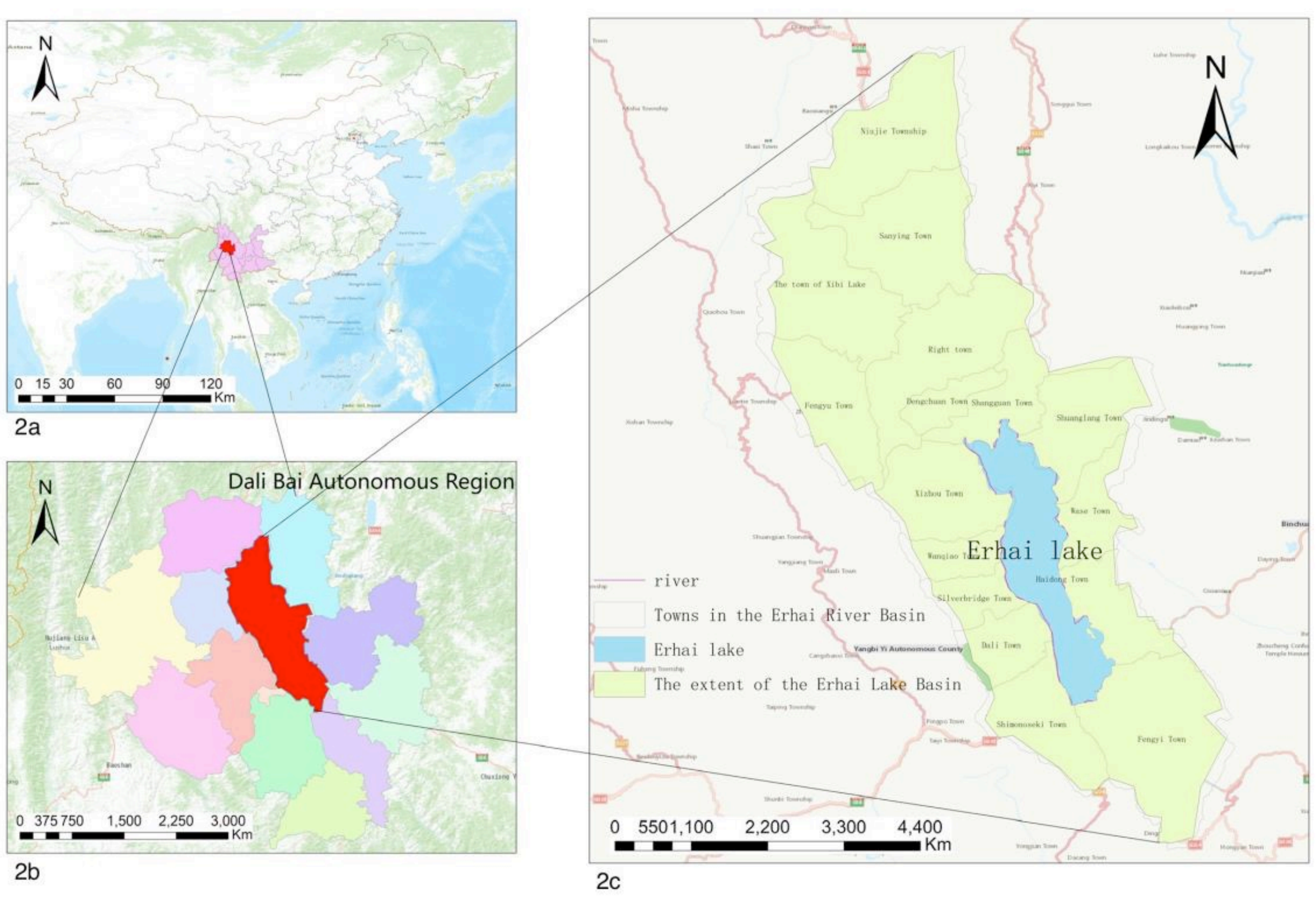

Figure 1. The study area of this PhD research project

Research framework (Fig.2)

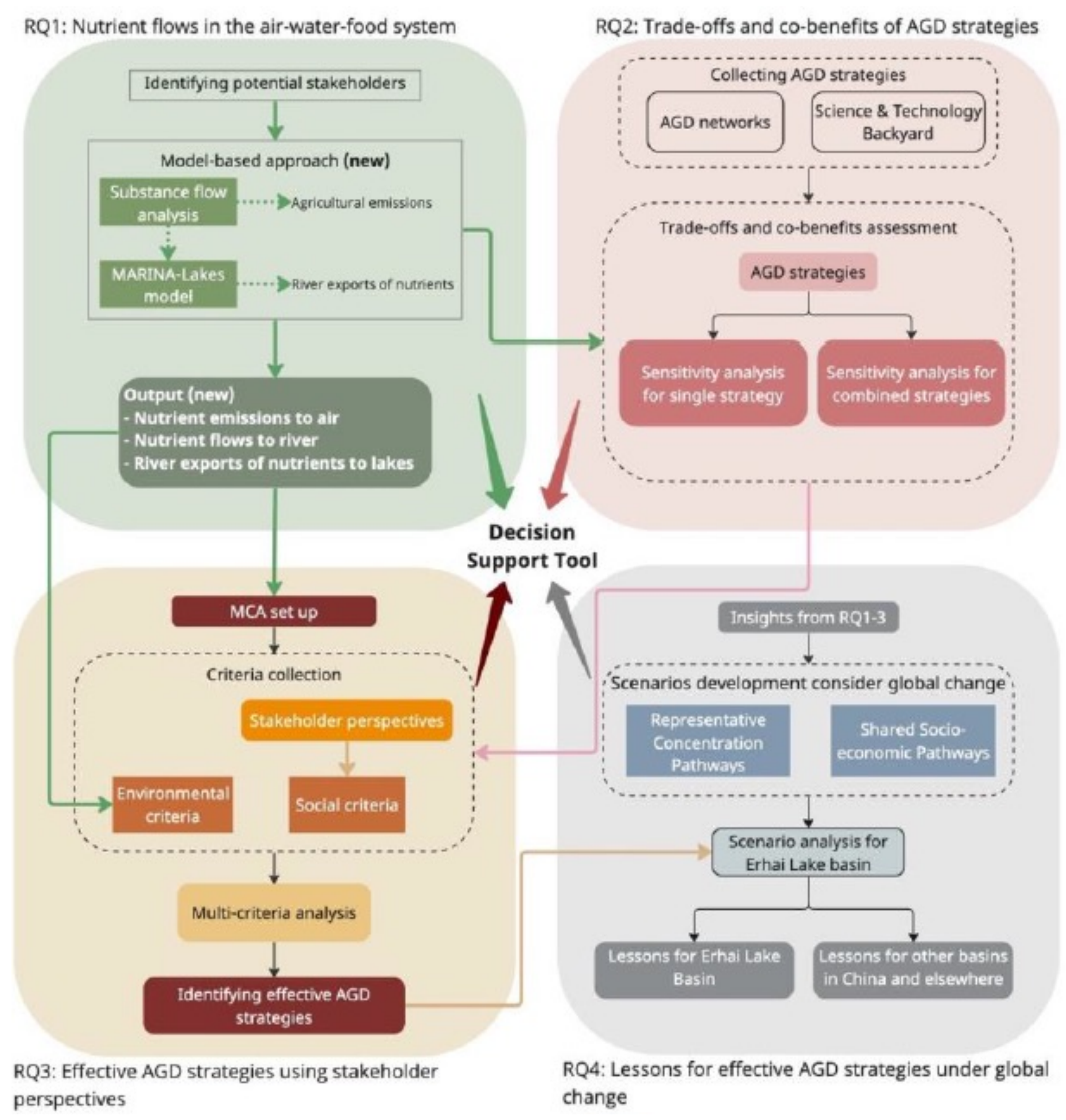

Figure 2. Research framework of the PhD project

Preliminary Results

- Hotspots of air and water pollution in the year 2022 (Fig.3);
- Pollution hotpots are defined as the top 20% highest emissions of nitrogen to air and nutrients to waters;
- Integrated modeling approach: MARINA-Lakes for river exports of nutrients and the substance flow analysis for nutrient fluxes in the crop and livestock production systems

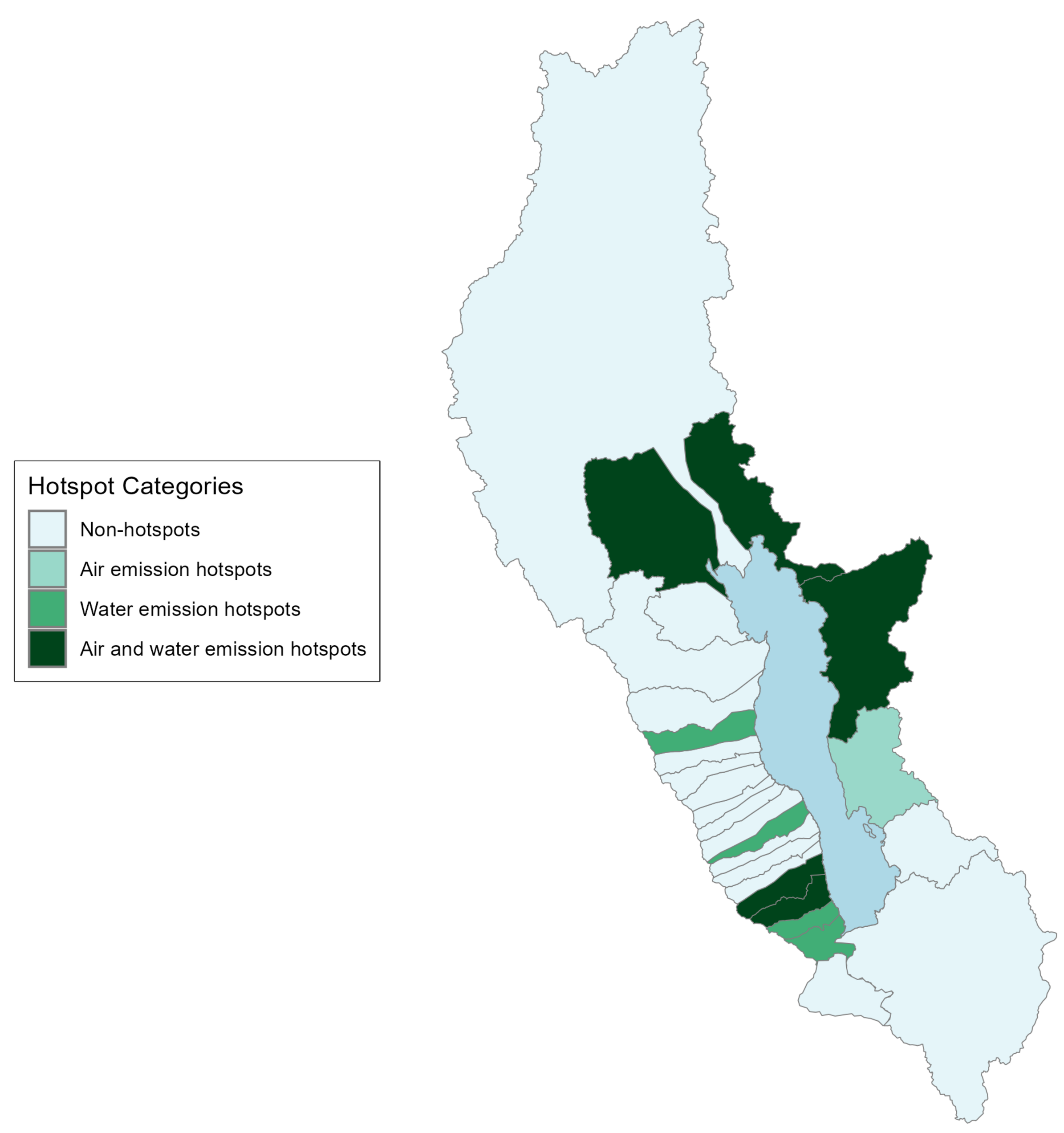

Figure 3. Preliminary results for air and water losses as defined by hotspots in Erhai Lake basin.

Acknowledgements

We gratefully acknowlege the sponsors of this research:China Scholarship Council (NO.20222260)

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Analysis of the Current Situation and Potential of Non-point Source Pollution Control Technologies in Typical Areas of the Erhai Lake Basin

Xin Wang, Yong Hou

Background

Rapid economic development and global climate change have led to a serious deterioration of lake ecosystems, and eutrophication is a major problem in lake waters. Non-point source pollution control work has been carried out in the Erhai Lake. Existing non-point source pollution control technologies in typical agricultural production areas of the Erhai Lake were technically evaluated, and integrated technologies for the whole process of non-point source pollution control were constructed and disseminated to other areas of the Erhai Lake.

Objectives

- Nitrogen and phosphorus flow characteristics and non-point source pollution contribution of food system in typical area of Erhai Lake.
- Removal efficiency and influencing factors of non-point source pollutants in ecological ditches /wetlands.
- Integration and potential analysis of non-point source pollution process prevention and control and terminal treatment technologies in typical areas of Erhai Lake.

Methods

Chapter 1. Characterisation of nitrogen and phosphorus flows in food systems

Obtaining data through field surveys and using the NUFER model to quantify the flow characteristics, use efficiency and loss of nitrogen and phosphorus in the food systems of the ancient typical sub-watershed of Erhai and the typical sub-watershed of the Xihu Wetland in Eryuan.

Constructing the system boundary of nitrogen and phosphorus nonpoint source pollution in food system of typical sub-watersheds: According to the local actual situation, the system boundary map of NUFER model was established.

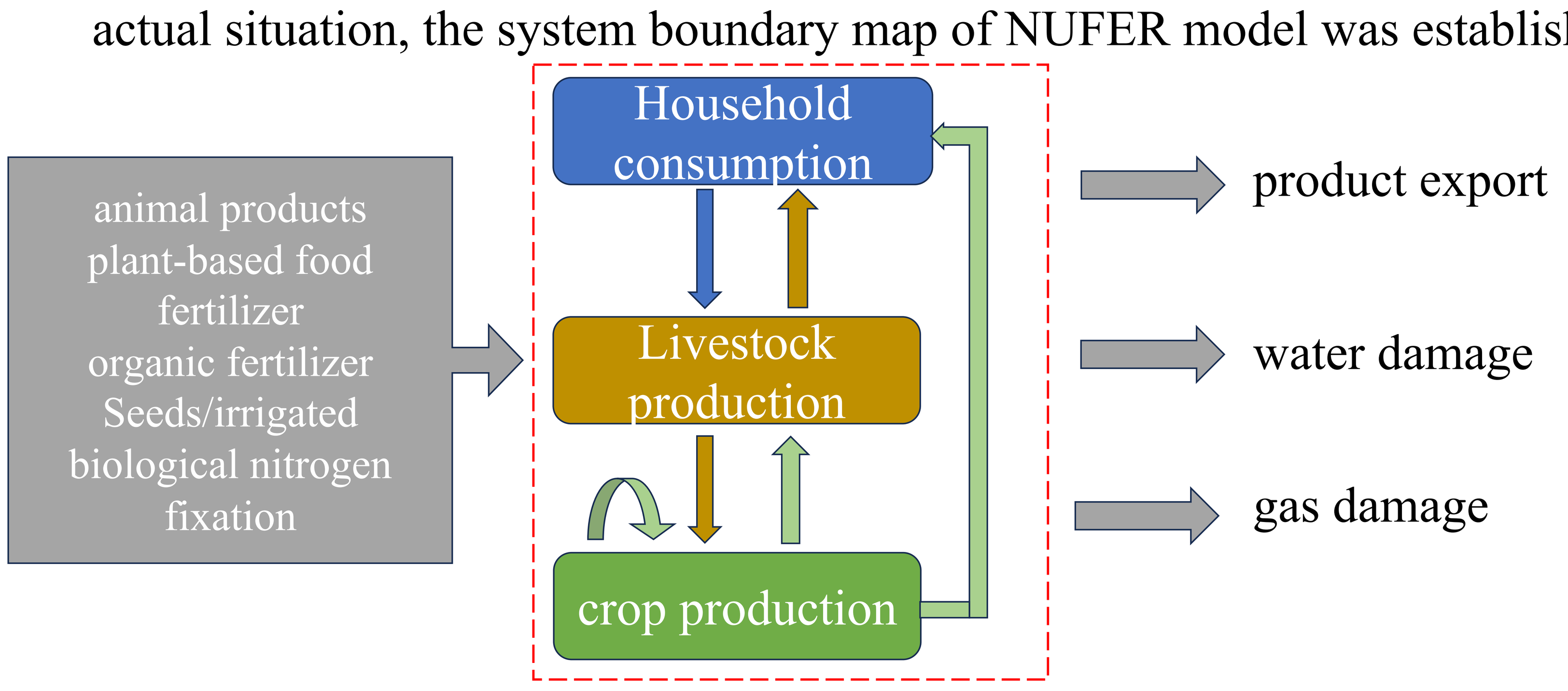


Figure 1. Boundary diagram of the NUFER modelling system for a typical sub-watershed

Chapter 2. Removal efficiency and influencing factors of non-point source pollutants in ecological ditches/ wetlands.

Using keywords to form a search formula in the Web of science, China Knowledge Network and other search libraries, etc. to carry out a search for relevant literature, and according to the following figure to filter the summary.

Key words：nitrogen、phosphorus、non-point source pollution
purification、removal、interception
ecological ditch/wetland、ecological drainage ditch/wetlands、
ecological channel/wetland

Chapter 3. Integration and potential analysis of non-point source pollution prevention and control technologies.

Multiple Scenario Simulation Based on Random Forest Algorithm

S1: Source abatement - Simulate the potential of farmland surface pollution abatement under different irrigation volume scenarios through water-saving irrigation measures.

S2: Process prevention and control - Simulate the pollution reduction potential under different removal efficiencies by optimising the removal efficiency of ecological ditches.

S3: End-of-pipe control - Simulate the reduction potential under different removal efficiencies by optimising the removal efficiency of the reservoir pond wetland.

Milestone outcomes

the removal rates of ammonia nitrogen (NH4+-N), total nitrogen(TN) ,total phosphorus (TP),chemicaloxygen demand (COD) and total organic carbon (TOC)

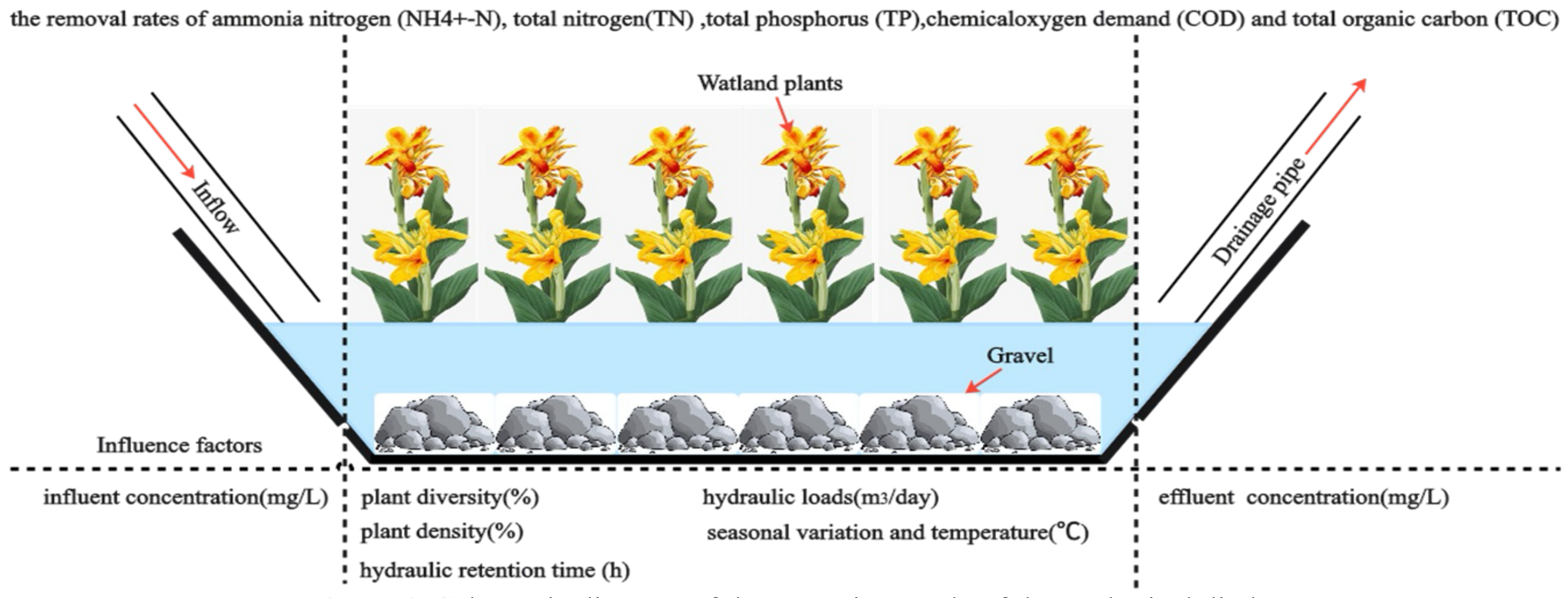
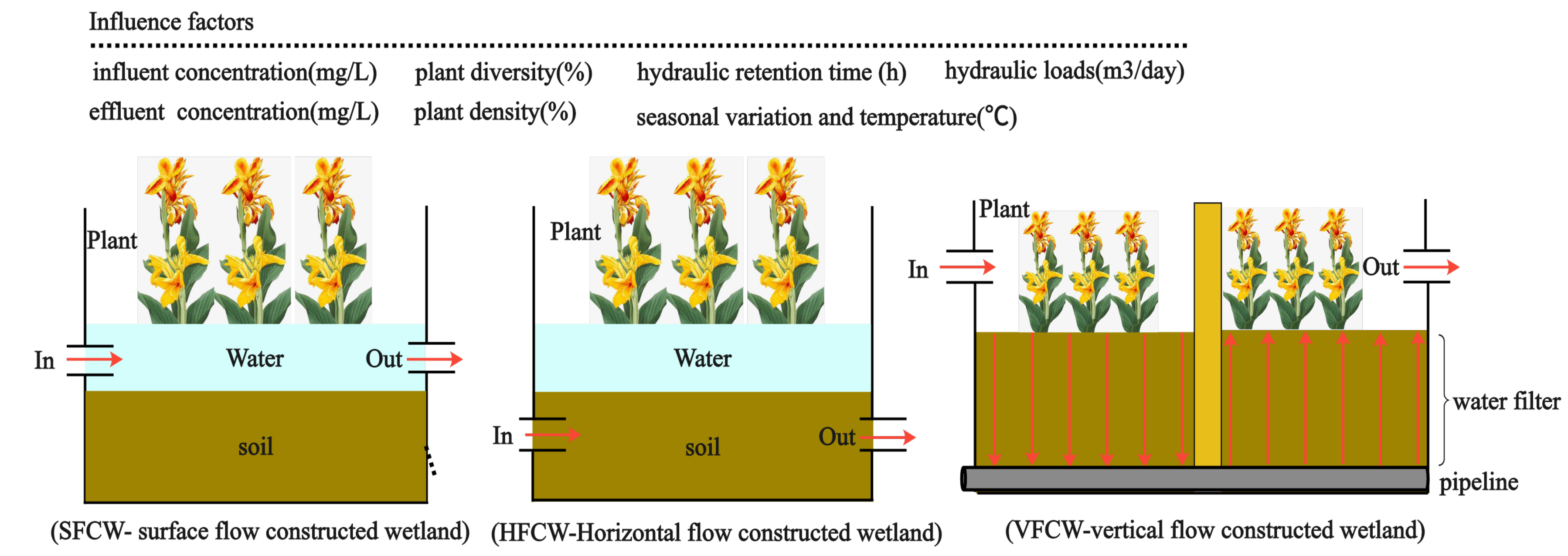


Figure 2. Schematic diagram of the operation mode of the ecological ditch



the removal rates of ammonia nitrogen (NH4+-N), total nitrogen(TN) ,total phosphorus (TP),nitrate nitrogen(NO_3-N),chemicaloxygen demand (COD) and total organic carbon (TOC)

Figure 3. Schematic diagram of wetland operation mode

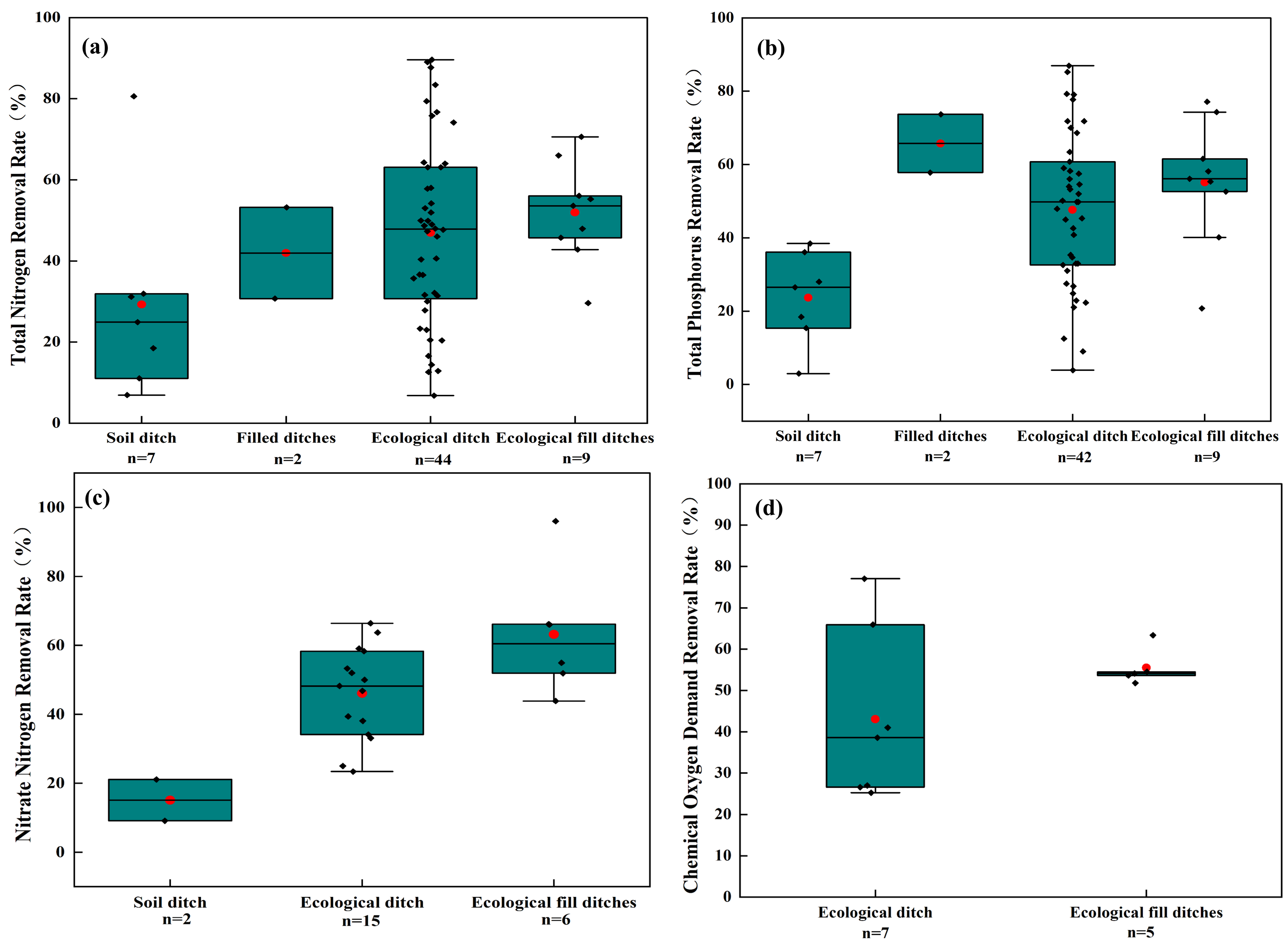


Figure 4. Removal rates of pollutants from different sources of pollution

Expected outcomes

- Define the characteristics of nitrogen and phosphorus flow in the food system at the scale of typical sub-basin of Gusheng in Haixi and typical sub-basin of Xihu in Eryuan in Haibei, and define the contribution of nitrogen and phosphorus surface pollution in the food system in typical areas.
- Summarise the pollutant removal efficiency of ditch and reservoir pond wetlands, and clarify the influencing factors and their mechanisms. Produce two Meta-articles.
- To form the integration of surface source pollution control technologies in typical Erhai sub-watersheds, and further clarify their reduction potentials.

Acknowledgements

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Nitrogen Losses and Reduction Control Potential during Manure Fertilization Process in China

Peiyu Tian
Fusuo Zhang, Nico Heerink, Weifeng Zhang, Yangyang Li

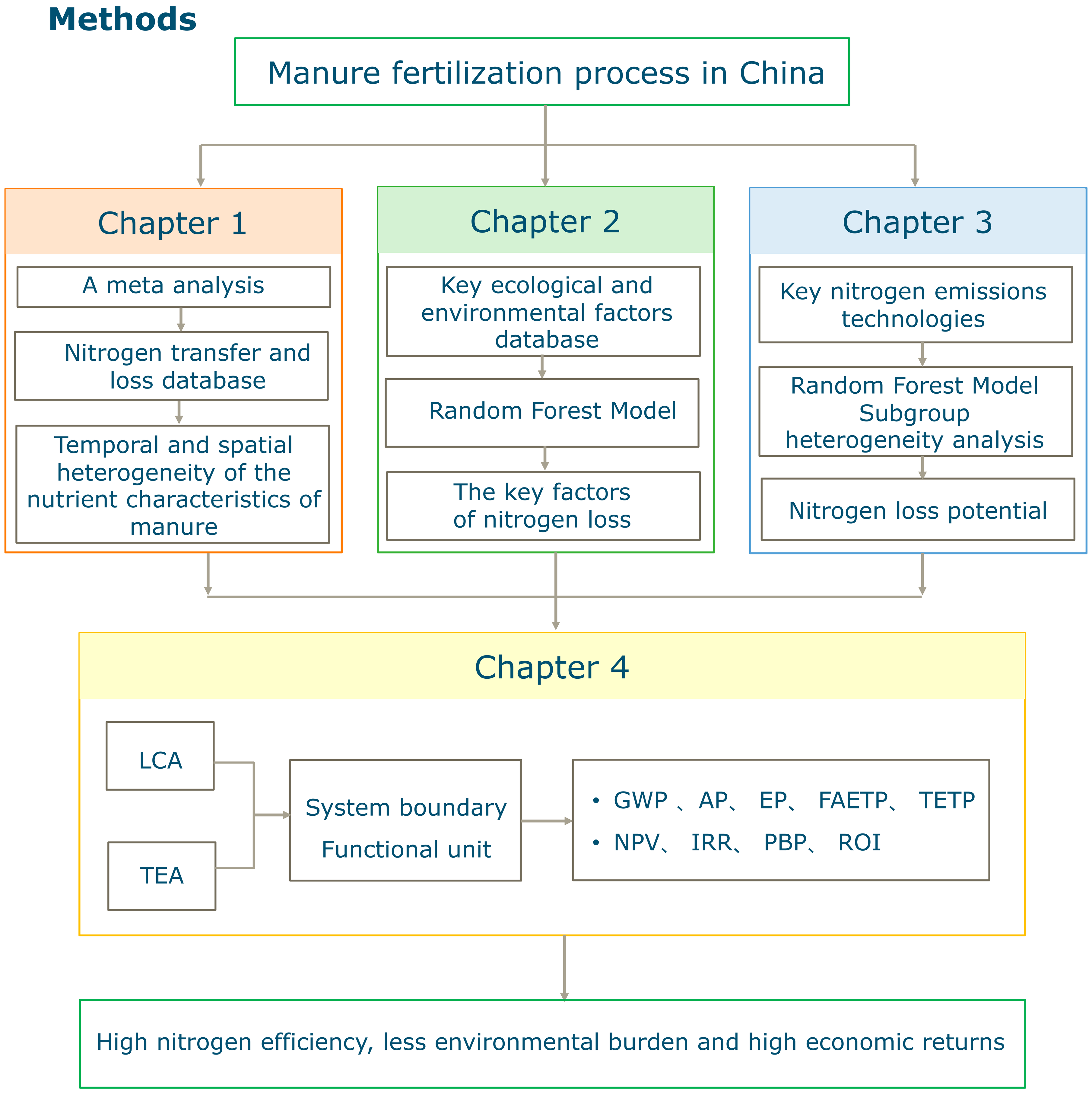
Background

The annual yield of livestock and poultry manure in China is as high as 4 billion tons. However, the recycling rate of livestock and poultry manure is less than 40%, resulting in the waste of nutrient resources and environmental pollution. Fertilization utilization is the main way for the recycling of manure. Nevertheless, the mechanism of nitrogen migration and transformation during the manure fertilization process is still unclear. The technology for controlling nitrogen during the manure fertilization process is a research hotspot. However, there are many types of nitrogen emission reduction technologies, and they are highly affected by time and space, leading to large fluctuations in the nitrogen emission reduction effect. The emission reduction potential of the manure fertilization process in China remains unclear.

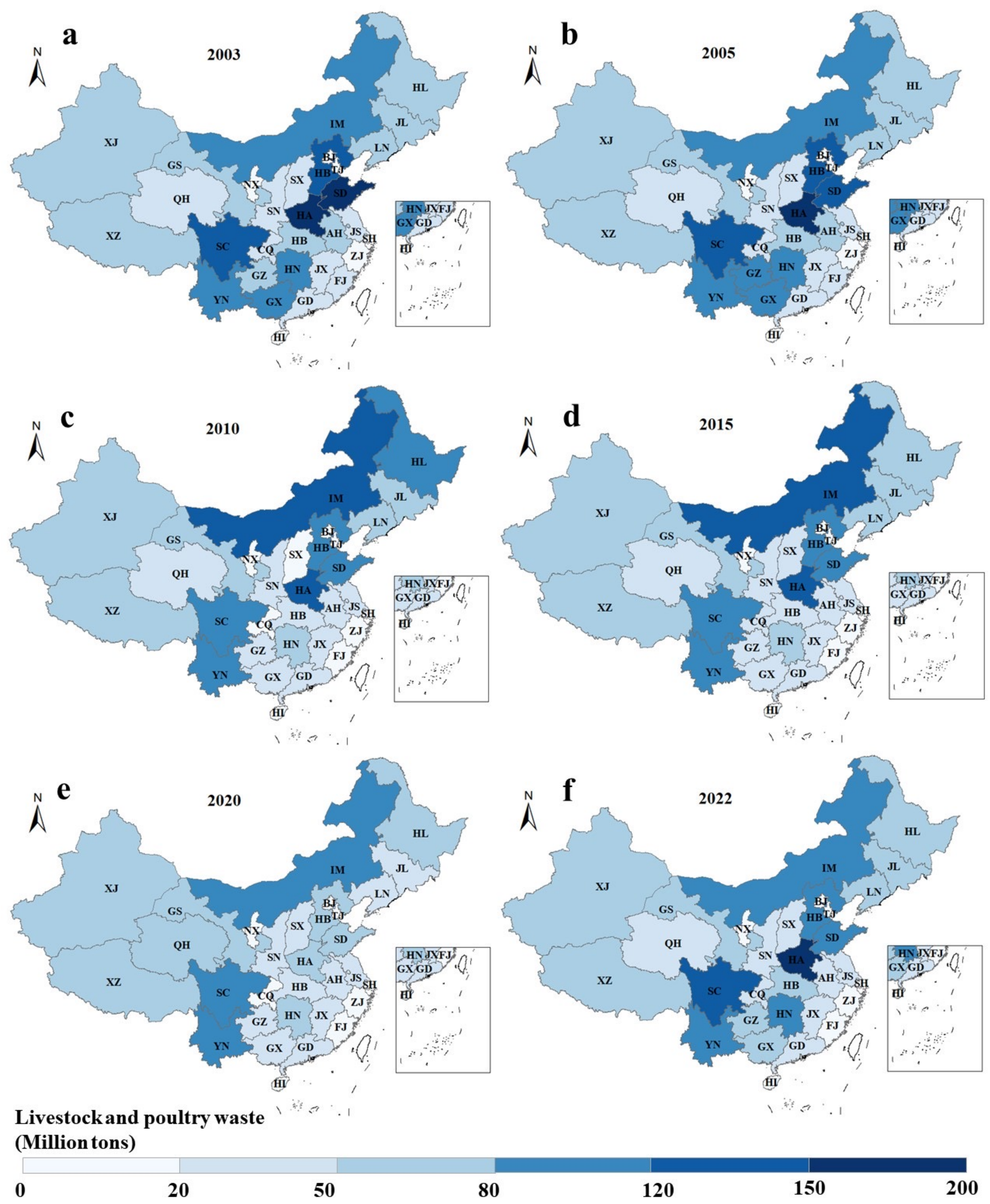
Objectives

We hope that through literature review, meta-analysis and model assessment, 1) to clarify the spatial and temporal variations of the nutrient characteristics of livestock and poultry manure; 2) to identify the key ecological and environmental factors in manure fertilization process; 3) to quantify the spatial and temporal differences in the impacts of various individual technologies on nitrogen loss during the manure fertilization process, and predict the potential for nitrogen emission reduction; 4) to comprehensively evaluate the manure fertilization process from the perspectives of environment, technology and economy, and quantify the environmental and economic benefits of key links

Methods



Results



Over the past 25 years, livestock and poultry waste production ranged from 1259.1 Mt to 1932.6 Mt. The temporal trend of livestock and poultry production can be divided into three periods: a period of steady increase (2003-2006), a period of fluctuating decrease (2007-2010) with an unexpected sudden increase in 2009, a period of steady increase (2011-2016) and a period of fluctuating increase (2017-2022). A series of policies promulgated by the Chinese government, such as the "Relocation of Pig Farming from the South to the North", have shifted the hotspots of livestock and poultry manure emissions from the southern regions to the northern part of China.

Conclusions

We have completed the Chapter 1, clarifying the temporal and spatial changes in the production volume of livestock and poultry manure and the nitrogen content in China. Policies had been determined the main driving force behind the spatial and temporal changes. Next, we will identify the ecological and environmental factors in the seven major regions of China and complete the work of Chapter 2.

Acknowledgements

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Developing site specific sustainable phosphorus management in China based on phosphorus legacy and soil properties

Lidong Qi, Jianbo Shen, Yang Lyu, Wim de Vries, Gerard Ros

Background

In China, the amount of phosphorus (P) fertilizer used annually has increased from <0.1 Tg in 1961 to 6.5 Tg in 2019. This accumulated amount, also referred to as legacy P in soil, is a huge P resource and leads to eutrophication of water systems when not appropriately managed. Developing site specific sustainable P management, depending on the soil available P content across different cropping systems and regions is crucial for Chinese agriculture green development, combing high crop yields with low P losses.

Objectives

- To define the spatio-temporal evolution of legacy P in Chinese cropland;
- Interpreting the key factors controlling the turnover of legacy P across different P pools;
- Assessing the effects of management practices on PUE and P loss
- Exploring multi-objective optimization pathways to enhance PUE and realize the ainable utilization potential of P resources.

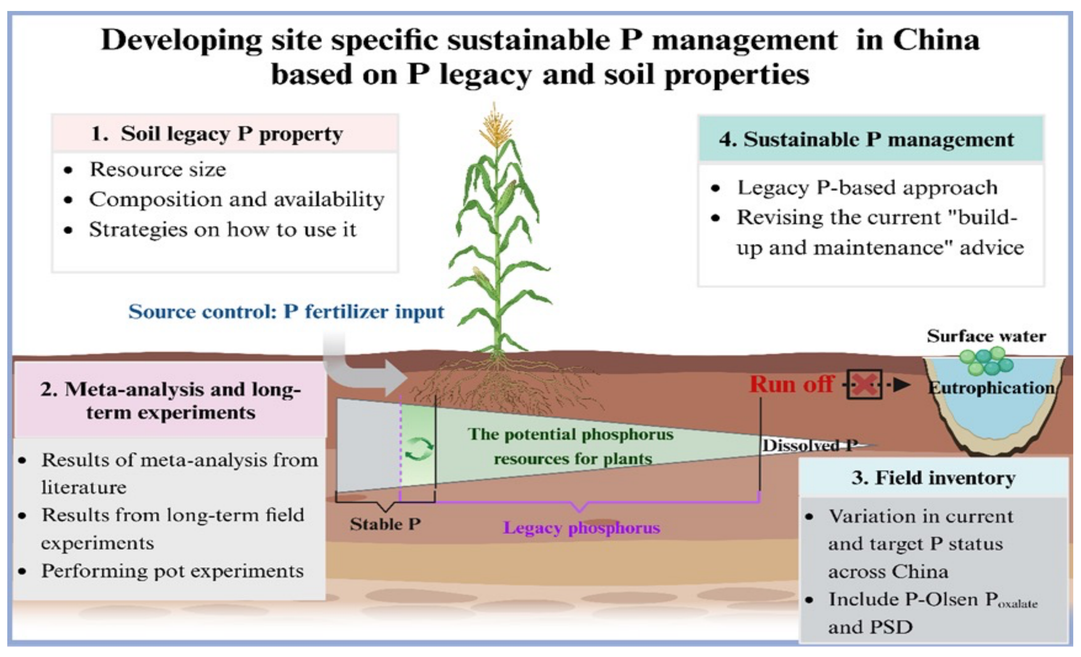

Fig. 1 Concept model of the P project.

Research framework

The framework is designed based on the following scientific questions:

- What are the composition, availability, and key soil properties controlling the turnover of legacy P in China?
- The P sustainability boundaries at the national and regional scales based on legacy P?
- How do management practices (MPs) influence the turnover of legacy P, and what's their potential to enhance PUE?
- How can MPs be adapted to regional legacy P characteristics and soil properties to achieve agricultural sustainability?

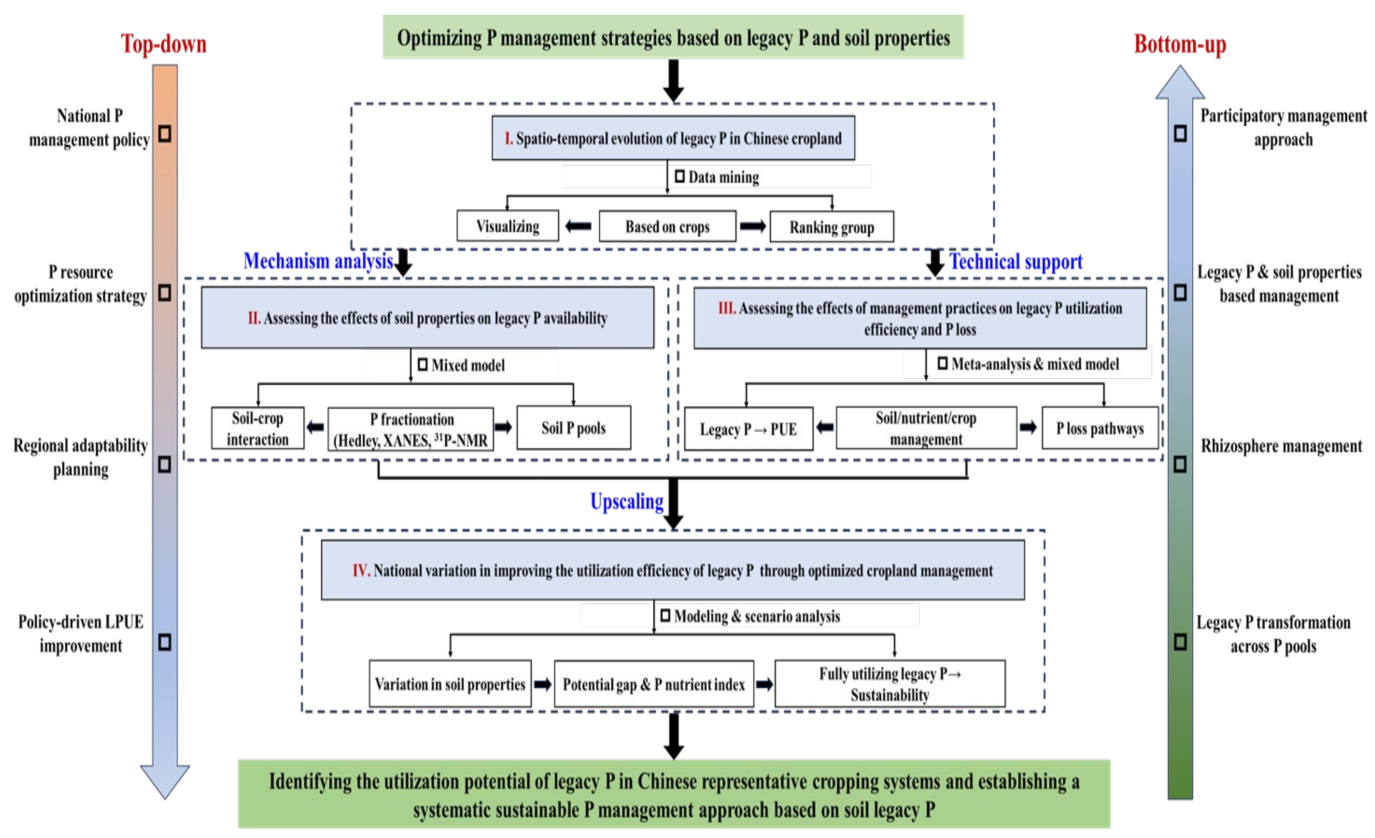

Fig. 2 Framework of the whole research.

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Research contents

1. Spatio-temporal evolution of legacy P in Chinese cropland

To identify and visualize the spatio-temporal dynamics of legacy P in cropland, ranking it into groups (Fig. 3).

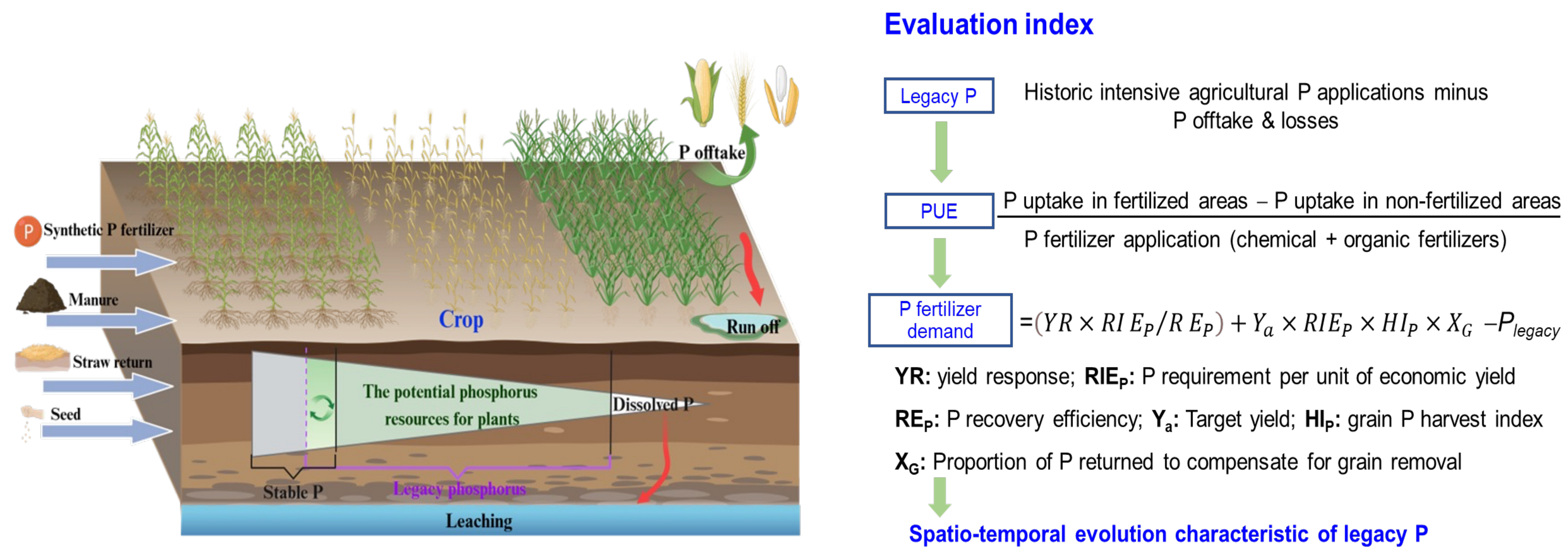
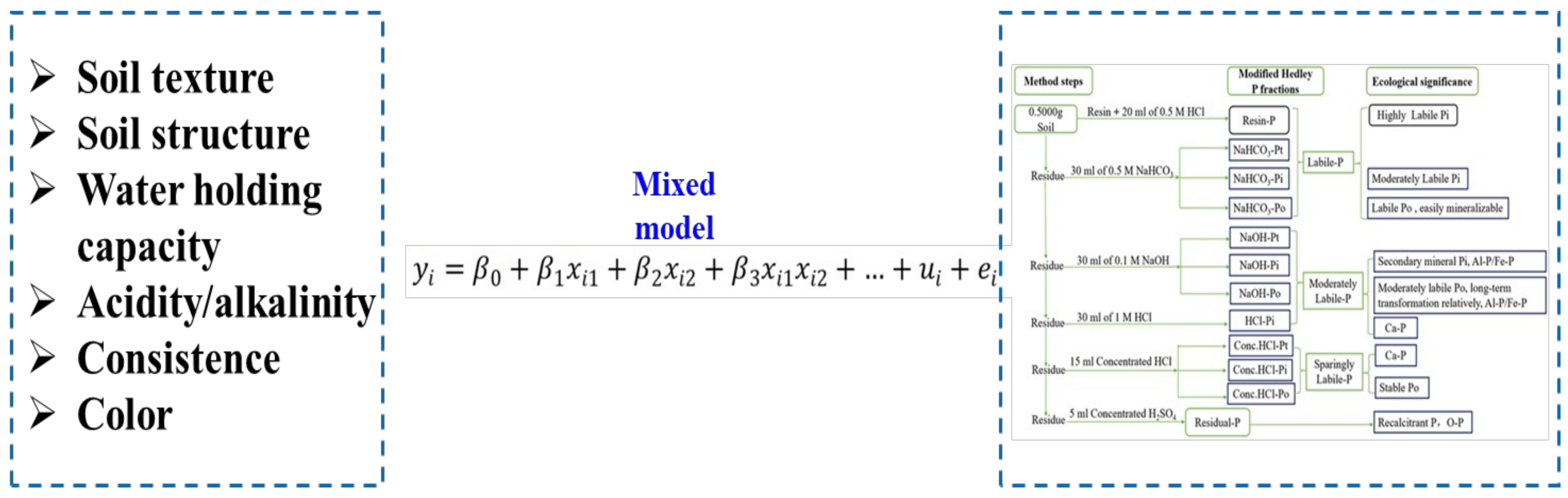


Fig. 3 Research boundary and evaluation index system.

2. Modelling the link between soil properties and the bioabailability of legacy P



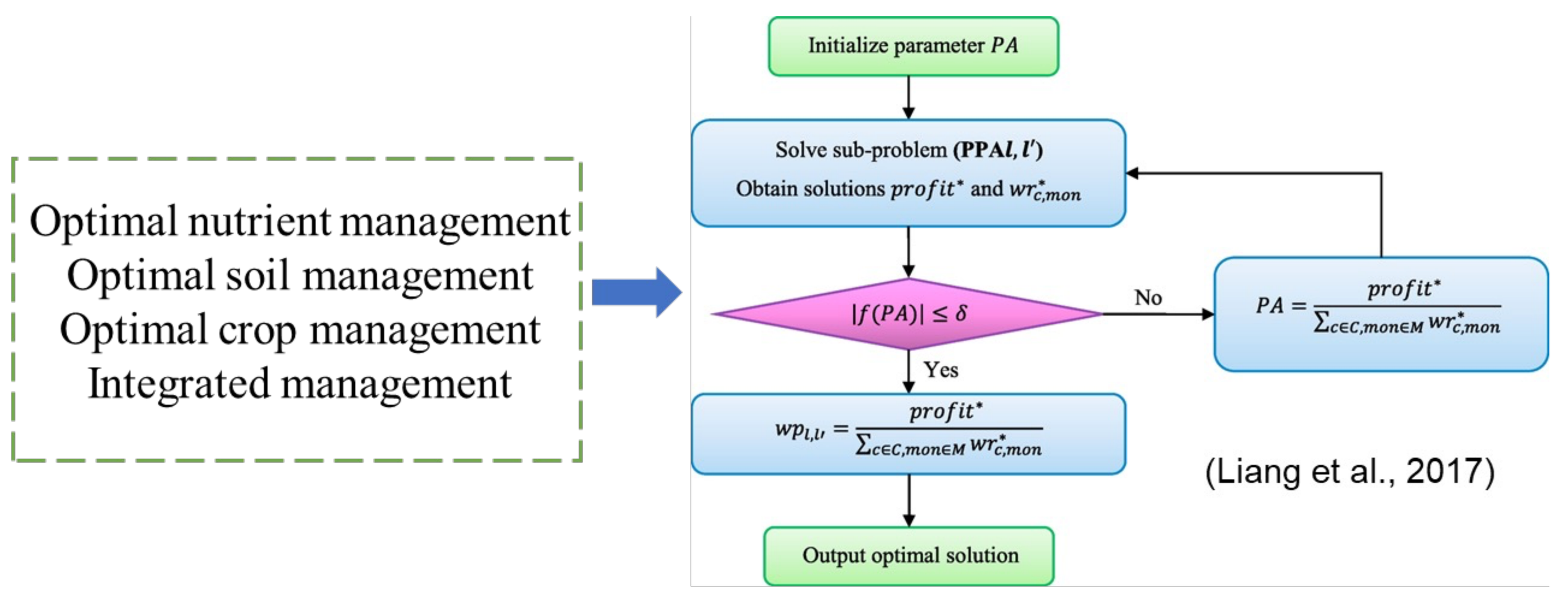
3. Assessing the effects of management practices on legacy P utilization

Meta-analysis

- The study includes **at least one management practice** and evaluates its impact on **P fractions or PUE.**
- It is limited to **cropland** management, excluding grasslands and forests.
- The focus is on **field-based results**, excluding greenhouse and pot experiments.

Agricultural management practices	
Nutrient management	Organic Fertilizer
	Organic-Inorganic Mixed Fertilizer
	Optimized Fertilization Rate
	Optimized Fertilization Timing
	Optimized Fertilization Placement
	Enhanced and Reduced Fertilizer
Crop management	Crop Rotation
	Cover Crops
	Stubble Retention
Soil management	No-Tillage
	Reduced Tillage

4. National variation in improving PUE in China through optimized management



(Liang et al., 2017)

Optimization model

Productive performance and ecological benefits of intercropping adopted by smallholder farmers in China - A case study in Gansu

PhD candidate: Chengran Zhao
CAU supervisor: dr. Chunjie Li
WUR supervisor: dr. ir. Wopke van der Werf

Background

Intercropping, as one of the new Green Revolution, is vital for sustainable agricultural intensification. Global meta-analyses indicate it can increase yield and protein production per unit area of land, **especially in maize-based intercropping systems**. Long-term researches, field experiments, and meta-analysis have shown both benefits and potential trade-offs. Yet, the benefits of intercropping and the trade-offs between productive performance and ecological benefits used by farmers at large spatial scales remains unclear. **Understanding the performance of intercropping in smallholder fields is crucial to optimize the yield response and inputs required.**

Objectives

This study will **investigate the adoption of maize-based intercropping by smallholder farmers in Northwest China and elucidate the production performance and ecological benefits of maize-based intercropping in different ecological zones of Gansu** under different field management conditions, such as low N input levels and high N input levels. Main activities are:

- **Visiting farms in Gansu** to record the main maize-based intercropping systems used by smallholder farmers, along with yield and nitrogen input information.
- **Conducting farmer-led on-farm trials on 40 farms in Zhangye, Wuwei, Huining and Jingyuan.** Soil and plant samples will be collected to determine soil fertility - related properties, yield and protein concentrations.
- **Calculating the yield differences** between intercropped and monocultured maize and comparing them with those in global meta - analyses.

Methods

Farm Survey

The study will survey smallholder farmers in four Gansu Province counties (Minle in Zhangye, Liangzhou in Wuwei, Jingyuan, and Huining in Baiyin) from June to August 2025. To ensure accurate data on cultivation, we'll count the cultivated area of all smallholder farmers in these four counties. Then, based on the proportion of the actual cultivated area in the four counties, we'll randomly select participating smallholder farmers in equal proportions. The system boundary from planting to harvesting will be adopted, and data will be collected through face-to-face household interviews with questionnaires.

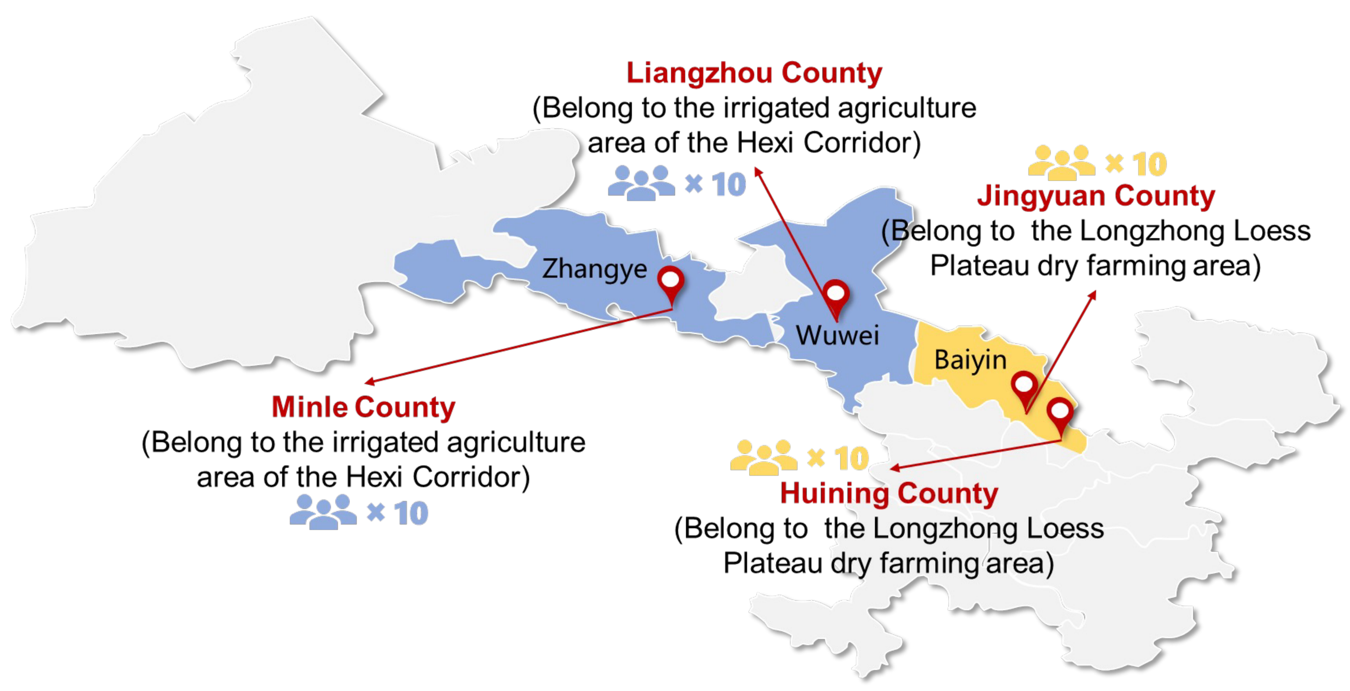


Figure 1 Map of the research area

Table 1 Farmers' research content

Objects	Content of the survey
Farmers	Basic information, level of education, years of cultivation
Cultivation	Intercropping systems present, yields, fertilizer application, machinery use, irrigation, etc.
Farmers' Willingness	Willingness to plant, reasons affecting intercropping, willingness to participate in farmer trials

On-farm Experiment

Gansu has diverse ecological zones due to its complex terrain and climate. **To study intercropping's yield and ecological benefits in different environments, we have chosen 4 counties: 2 from the Hexi Corridor's irrigated agriculture zone (Minle and Liangzhou), and 2 from the Longzhong Loess Plateau's dry farming zone (Jingyuan and Huining)** (Fig. 1). In each county, we will stratify farm households by operation scale (small ≤ 1 mu, medium 1-5 mu, large > 5 mu) and will select 10 households based on the proportion in each category. Priority will be given to those with over 3-year intercropping experience and willingness to cooperate. **As a result, 20 households will be selected from each ecological zone, making 40 in total.**

Four cropping treatments will be established, namely farmer's traditional maize monoculture, farmer's traditional monoculture of corresponding paired crops (e.g. soybean, fresh pea, wheat, potato, etc.), farmer's traditional intercropping and optimized intercropping (Fig. 2). **All tested intercrops are based on local farmers' existing combinations.**

Maize/wheat intercropping in Hexi irrigation area

Maize/coriander intercropping in Hexi irrigation area

Maize/potato intercropping in Yellow River irrigation area

Maize/fresh pea intercropping in Yellow River irrigation area

Season 1 (2025-26)	Maize Monoculture Famer traditional	Another Crop Monoculture Famer traditional	Maize-Based Intercropping Famer traditional	Maize-Based Intercropping 75%N+ Intraspecific fertilization
Season 2 (2026-27)	Maize Monoculture Famer traditional	Another Crop Monoculture Famer traditional	Maize-Based Intercropping Famer traditional	Maize-Based Intercropping 75%N+ Intraspecific fertilization

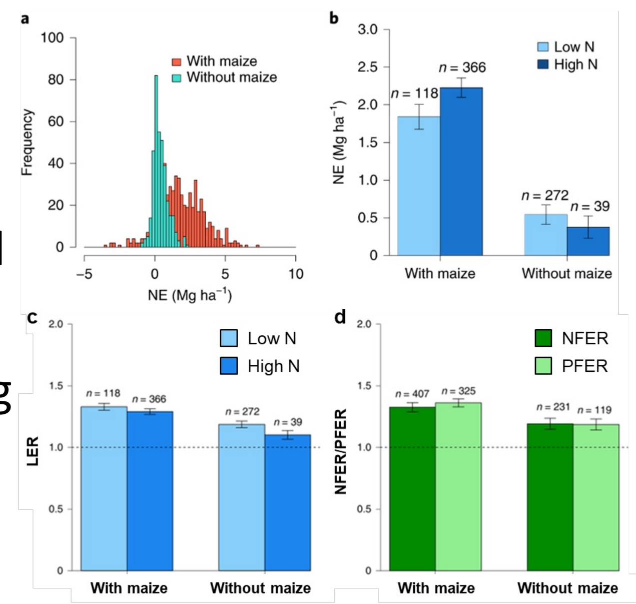
Figure 2 Intercropping adopted by smallholders in Gansu and on-farm experimental treatments

Assessment of intercropping productivity and ecological benefits

(1) Yield gap

In intercropping, the yield gap is the difference between potential yield (1.5 ± 0.1 Mg ha^{-1}) in the global meta-analysis and experimental yield for each component species.

We will compare the actual LER of intercropping among farmers with the LER in the global meta-analysis (1.29 ± 0.02) (Li *et al*., 2023).



(2) Greenhouse gas (GHG) emissions

Apply LCA with a 1,000 kg maize functional unit to establish life cycle resource profiles for cropping systems under different patterns (Table 2) using primary data. Assess environmental impacts of monoculture and intercropping via standardized LCA.

Input-output inventory		Monoculture maize	Intercropped maize	N optimized intercropped maize	Remarks
Input	**N** (kg mu^{-1})				The boundaries covered **agricultural material production (fertilizers, diesel, electricity)** and energy use and GHG emissions during **cultivation (tilling, fertilizing, irrigation, harvesting)**
	P_2O_5 (kg mu^{-1})				
	K_2O (kg mu^{-1})				
	Irrigation water (m^3 mu^{-1})				
	Electricity (kW h mu^{-1})				
	Diesel oil (kg mu^{-1})				
Output	**Grain yield** (kg mu^{-1})				

Table 2 Input-output inventory of intercropped and monoculture maize

Acknowledgements

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The distinction of hyphosphere microbiome diversity and phosphorus activation ability of different Arbuscular Mycorrhizal (AM) Fungi

Reporter: Jiayin Feng
Supervisors: Lin Zhang from CAU and Erik Limpens from WUR

Background

- AM fungi do not function in isolation and the plant-mycorrhiza symbiont can recruit beneficial bacteria that support the symbiosis.
- The hyphosphere bacteria derived from soil and roots, and the hyphae formed a different microbial community from the soil
- The rhizosphere was in a P-limited condition compared with bulk soil. There was a strong competition of inorganic P not only between AM fungi and root, but also between different AM fungal species.
- The traits of AM fungal associated bacterial consortia cause niche differentiation and recruit different bacterial communities.
- Two isolates of the same AM fungi had different strategies to improve plant P uptake at the same soil available P level

Objectives

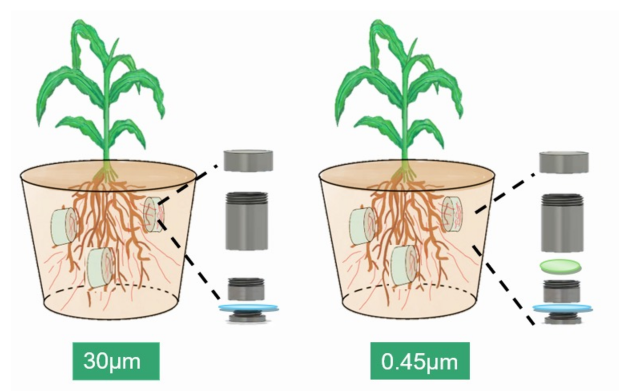
Differences of hyphosphere microbial diversity and phosphorus solubilization in different AM fungi:

- What are the differences of phosphorus solution-promoting ability of different AM fungi? What are the differences in microbial diversity and composition of hyphosphere recruitment?
- What are the differences in the function of the hyphosphere microbiome of different AM fungi?

Methods

(1)Different AM fungal treatments:
No fungi were inoculated, 41833, 43194, 46238 and 49410, respectively

(2)Hyphae chamber isolation/non-isolation of hyphae growth:
Non-isolated (30μm) and isolated (0.45μm)

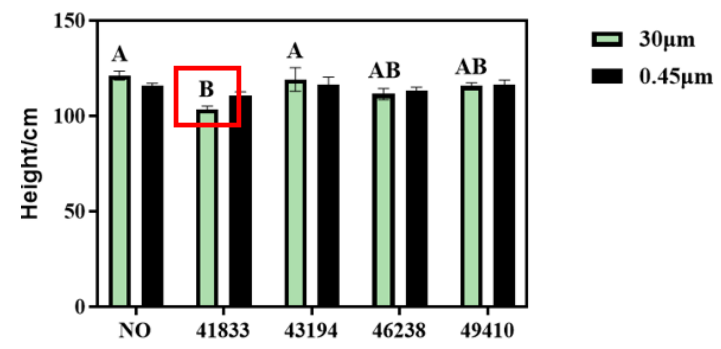


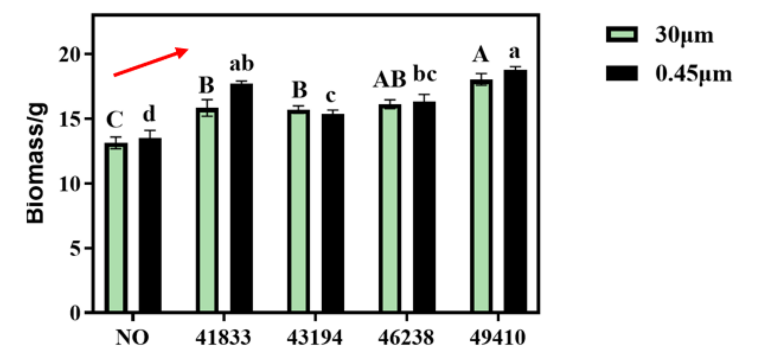
A total of 10 treatments, 4 replicates per treatment

- Test plant: Corn (Zhengdan 958)
- Test soil: Shandong Tai 'an brown loam soil(pH 7.37, available phosphorus 8.1mg/kg, organic matter 15.7g/kg), available phosphorus adjusted to 20mg/kg
- AM Fungi: *R. irregularis* MUCL 41833, *R. irregularis* MUCL 43194, *R. clarus* MUCL 46238, *R. intraradices* MUCL 49410
- The soil in the root chamber was sterilized and inoculated with bacterial filtrate. The hyphosphere chamber was filled with fresh soil and sodium phytate was added.
- 1 month after seeding, the hyphae collection tube was buried: buffer zone 4g, hyphae chamber 20g, 3 in each pot.
- Buried in the hyphae collection tube for 40 days and harvested.

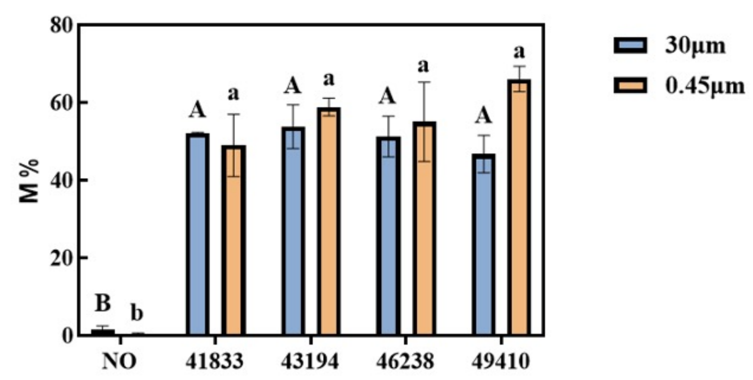
Results

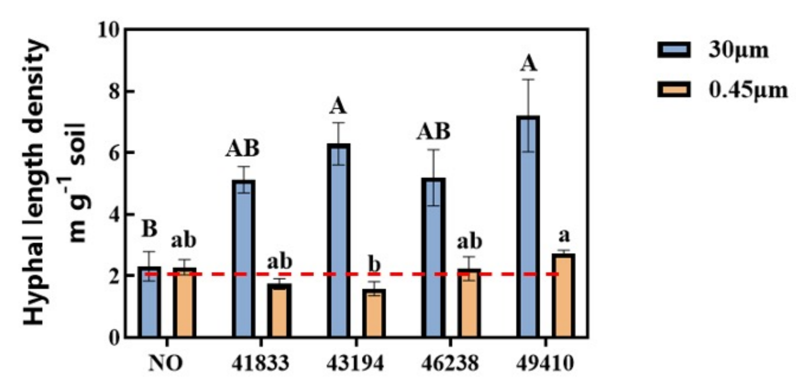
- Inoculation with AM fungi significantly increased plant above-ground dry weight. The effects of different AM fungi were significantly different.



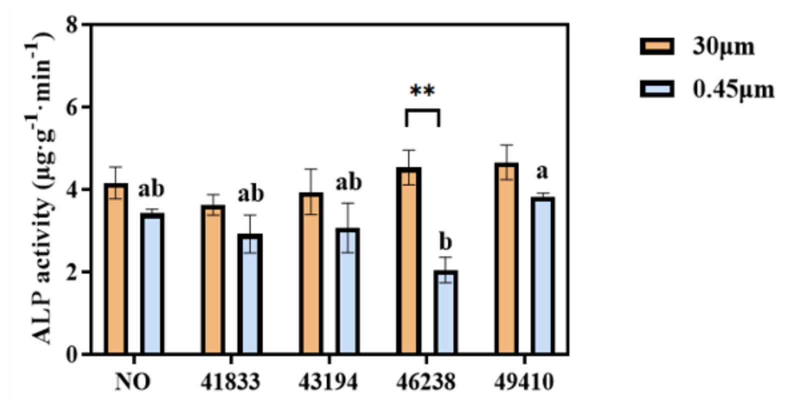


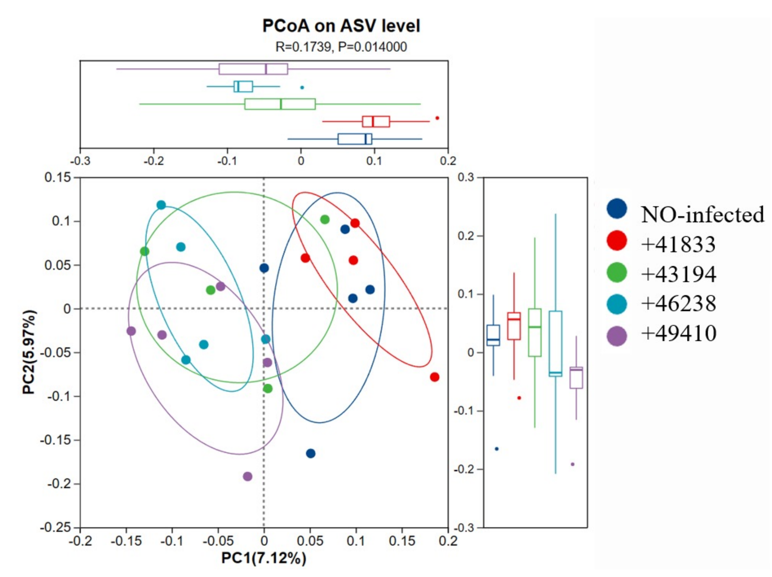
- There was no significant difference between the infection rates of different AM fungi, which were all above 46%. There was a small amounts of hyphae in the hyphae chamber (fresh soil), and HLD increased significantly after inoculation with AM fungi.
- The infection rate of AM fungi was higher, and the mycelium collection tube achieved the expected effect.





- Compared with hyphae chamber phosphatase activity, the ALP of the treatment with hyphae passage was significantly higher than that without hyphae when RC 46238 was inoculated.
- The hyphosphere bacterial community structure was obviously separated in different treatments.





Conclusions

- The hyphosphere alkaline phosphatase activity of different AM fungi was significantly different, and the increase of ALP secretion was most significant after inoculation with RC 46238
- There were significant differences in community Beta diversity and species composition at the genus level between different species of AM fungi, even between different ecotypes of the same AM fungi.
- Further results are still to be found.

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Modelling and optimization of agri-food system towards coupled food supply and environment conservation in China

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Supervisors: Qichao Zhu, Yong Hou, Hannah van Zanten

Background

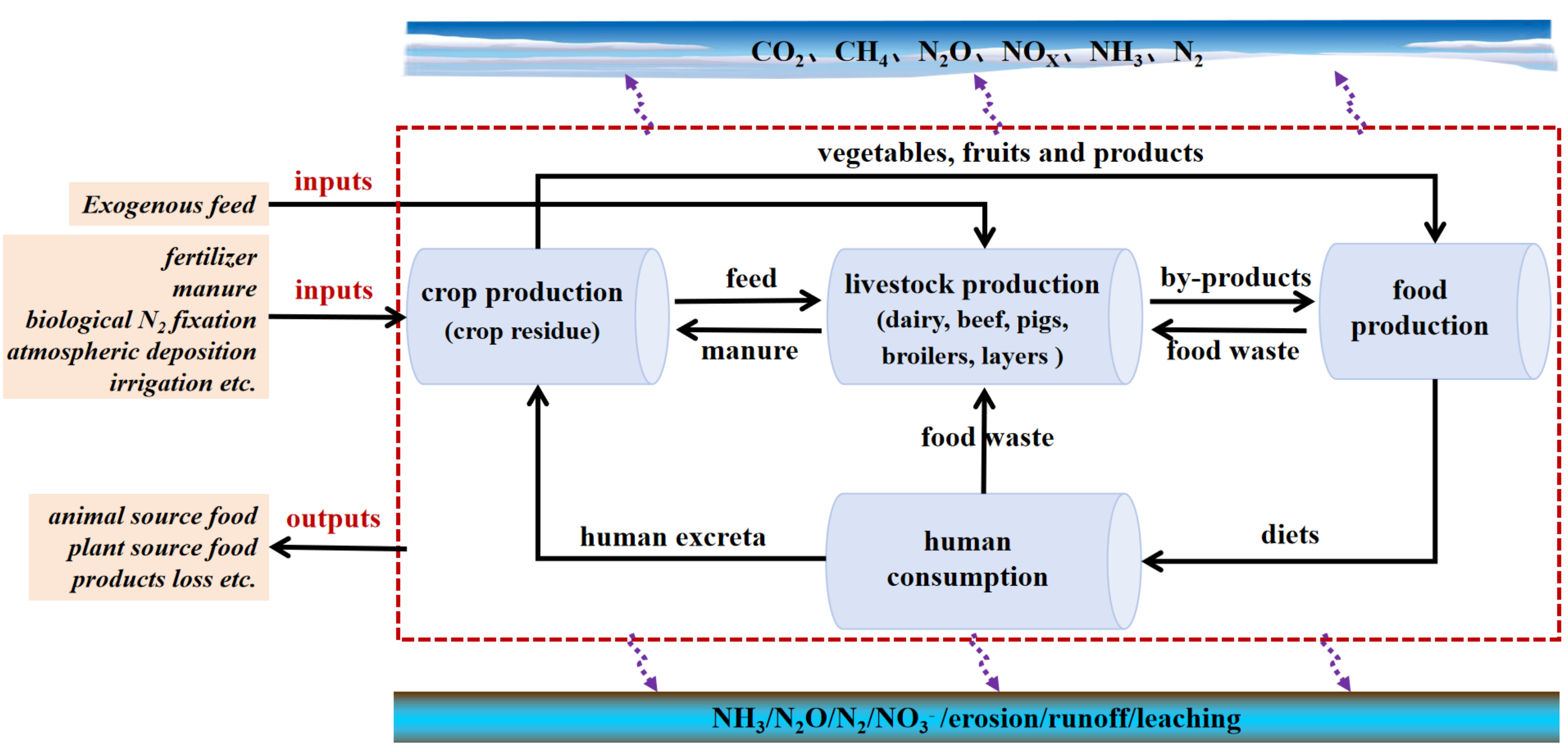
Food systems are critical for achieving healthy human nutrition and protecting environmental sustainability, however, current food systems has posed challenges to both of these goals (Willett et al. 2019). China has seen an alarming rise in food loss and waste, which contradicts its efforts to sustain 19% of the world's population using only 7% of global arable land, while also impacting the security of its food supply (Ren et al. 2023; Xue et al. 2024). In addition, the shift towards more animal-intensive diets is putting pressures on the resource environment and human health (Ren et al. 2023). Seeking a sustainable pathway to coordinate food supply and environmental conservation has thus become urgent for China.

Redesigning and optimizing the current food system to a more circular one can reduce the impact of multiple environments in food systems (Billen et al. 2021). Circularity as a key strategy by reducing unavoidable waste streams such as food waste, human excrement and excessive consumption of nutrients, reusing of waste streams in the most sustainable way (Van Zanten et al. 2023; Simon et al. 2024). However, modelling and optimizing the agri-food system combined with consideration of food supply and multiple environmental conservation has not yet been implemented in China.

Consequently, reducing nutrient losses from agricultural production is essential for the future development of green agriculture in China. This study aims to focus on systematically assessing and optimizing the agri-food system through modelling tools to identify the potential and pathways toward a sustainable and environmentally friendly agricultural system.

Objectives

- Quantify the nitrogen (N) and phosphorus (P) flows in the agri-food systems of China and how these flows influence the nutrient use efficiency
- Modelling the contributions of diet optimization towards a more sustainable agri-food system
- Contributions of residue and waste recycling in the agri-food system transformation towards a more sustainable system
- Exploring solutions for the optimized agri-food system in China to reduce the negative impacts on human health and environment

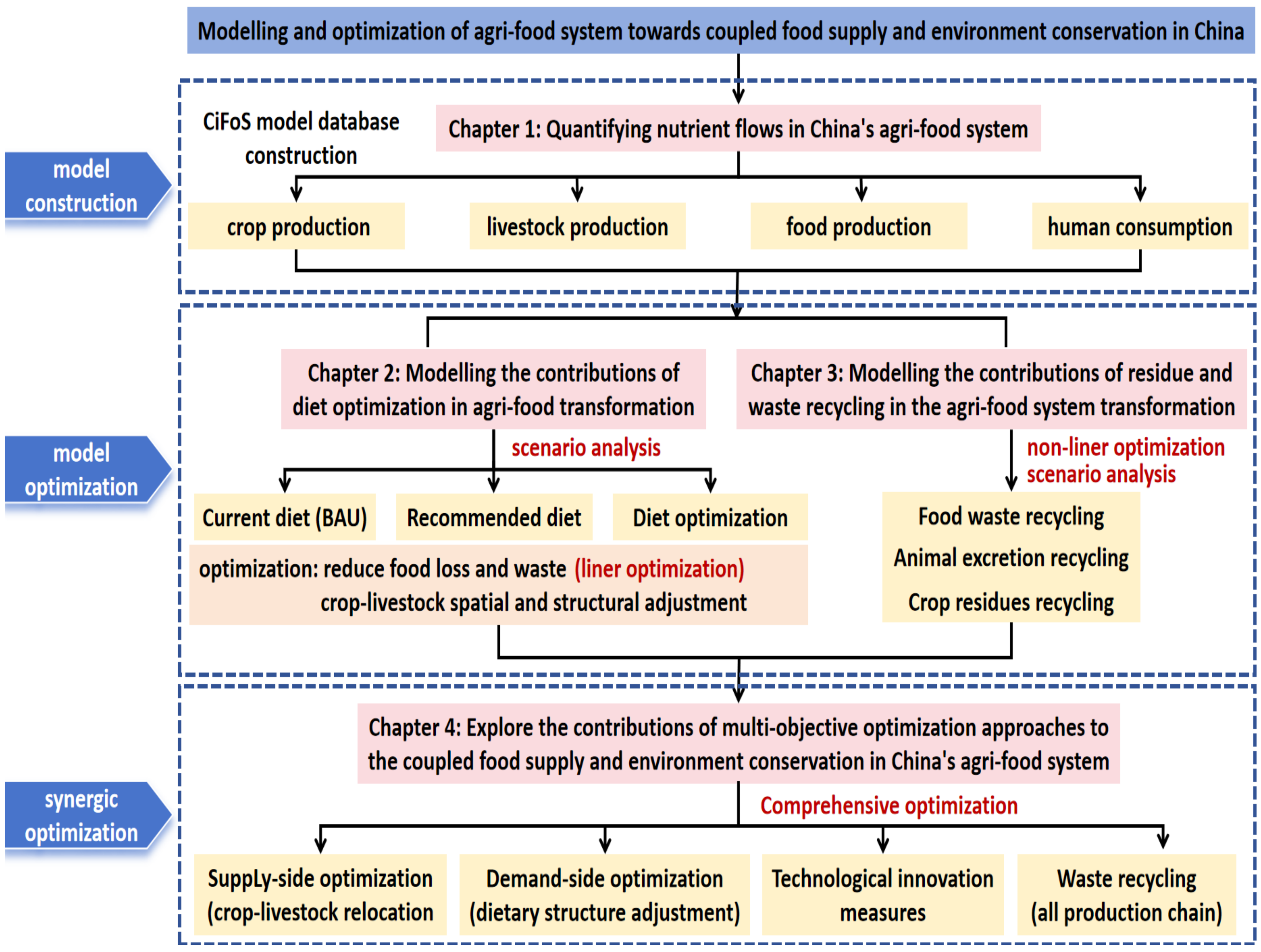


System boundary

Methods

- Data collection: literature review and statistical reports
- Model methods: CiFoS model (Circular Food System), liner optimization and non-liner optimization

Framework



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Organic-inorganic nutrient management in farmland in China: regional differences and optimization strategies

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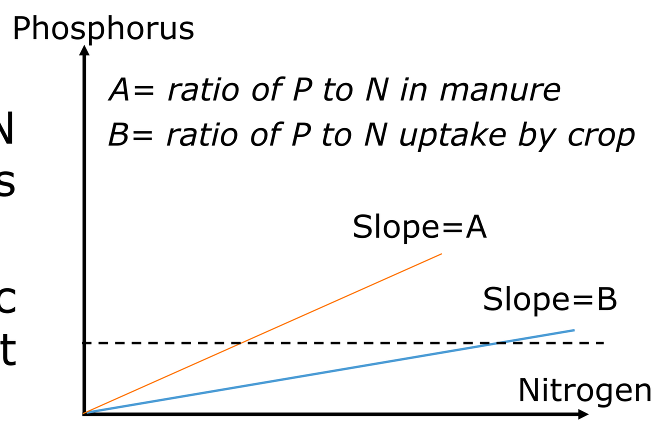
CAU Supervisors: Yong Hou; Xinping Chen; Fusuo Zhang

WUR Supervisors: Oene Oenema; Xueqin Zhu

Background

In China, large nutrient inputs from synthetic fertilizers and manure, with the associated large losses of N (nitrogen) and P (phosphorus). Although many measures have been introduced in practice to improve nutrient management, nutrient management systems in China are complex due to large differences in agricultural systems and environments. Therefore, observations, experimentation, theory, and modeling at different temporal and spatial scales are warranted to evaluate, predict, and provide possible solutions for integrated organic-inorganic nutrient resource management.

- **Challenges:**
  - The mismatch between the availability of N and P in manure and crop nutrient demands contributes to soil nutrient imbalance.
  - Lack of cost-effective organic-inorganic nutrient management strategies at different soil types and agro-ecological zones.



Objectives

This study will focus on improving the quantitative understanding of variations in organic nutrient use and losses among sub-regions in China at a high spatial resolution, and explore regional organic-inorganic nutrient management strategies based on spatially specific agronomic targets, to provide targeted management recommendations.

- To establish a database for organic fertilizers (nutrient effectiveness, nutrient loss parameters, etc.).
- To precisely quantify the fate of N and P nutrients after the application of organic fertilizers to farmlands, estimate the N and P loss amounts in different regions, and identify the driving factors.
- To develop the N and P balance pattern for China's organic-inorganic nutrient resource management, assess N and P utilization of organic fertilizers in farmlands at a regionally refined scale, and to propose optimal organic-inorganic fertilization strategies.

Methods

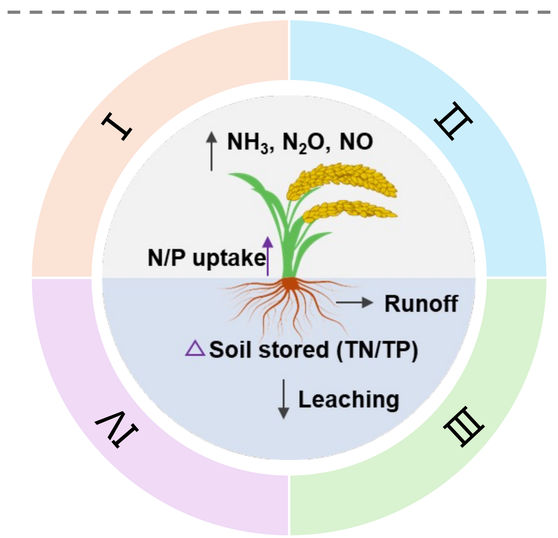
- **Data extraction**
  - Data collection from literature or database. Peer-reviewed papers were searched for using Web of Science, and CNKI. Search terms included 'organic fertilizer', 'manure', 'compost', 'crop uptake', 'runoff losses', 'leaching losses', 'N_2O', 'NH_3' in the article title, abstract or keywords.
- **Meta-analysis**
  - Integrating data at appropriate temporal and spatial scales, combining large amounts of field trial data with spatially characterized climate and soil data to create databases.
  - Quantify the effect of organic management practices on the fate of N and P added to the soils, and assess key moderator importance.
- **Scaling-up estimation**
  - Utilize machine learning models to develop an inventory of N and P fate associated with the use of organic fertilizers.
  - Combine survey data to analyze the N and P use efficiency and fate in organic fertilizer-applied farmlands in China. Identify the limiting factors.
- **Scenario analysis**
  - Develop various scenarios to investigate the optimal organic-inorganic fertilization strategies and pathways.
- **Cost–benefit analysis**
  - Calculate the implementation costs of organic management practices and their social and environmental benefits.

Research framework

Organic-inorganic nutrient management in farmland in China

Establish a database for organic fertilizers

- Ⅰ - Fertilizer trait
- Ⅱ - Environment factors
- Ⅲ - Agricultural management
- Ⅳ - Soil characteristics



Develop inventory of organic fertilizer N and P fate

- Meta-analysis: Effect + Emission factor
- Survey data: Fertilization status
- Meta forest and Random forest model:
  - Identify the driving factors affecting the fate of nutrients in organic fertilizers
  - Generation of global maps of crop-specific soil F-Nr and NUE for Organic fertilization

Cost-effective organic-inorganic nutrient management strategies

- Scenario analysis
- Cost-benefit analysis
- • Business as usual (BAU) • Optimal scenarios
- Implementation cost | Yield benefit | Ecosystem benefit | Climate benefit

Timeline

- Year 1 (2024-2025): Learn the methodologies. Establish a database.
- Year 2 (2025-2026): Master the models. Complete data analysis.
- Year 3 (2026-2027): Draft 1-2 manuscripts for submission.
- Year 4 (2027-2028): Refine the thesis framework. Finalize thesis.

Acknowledgements

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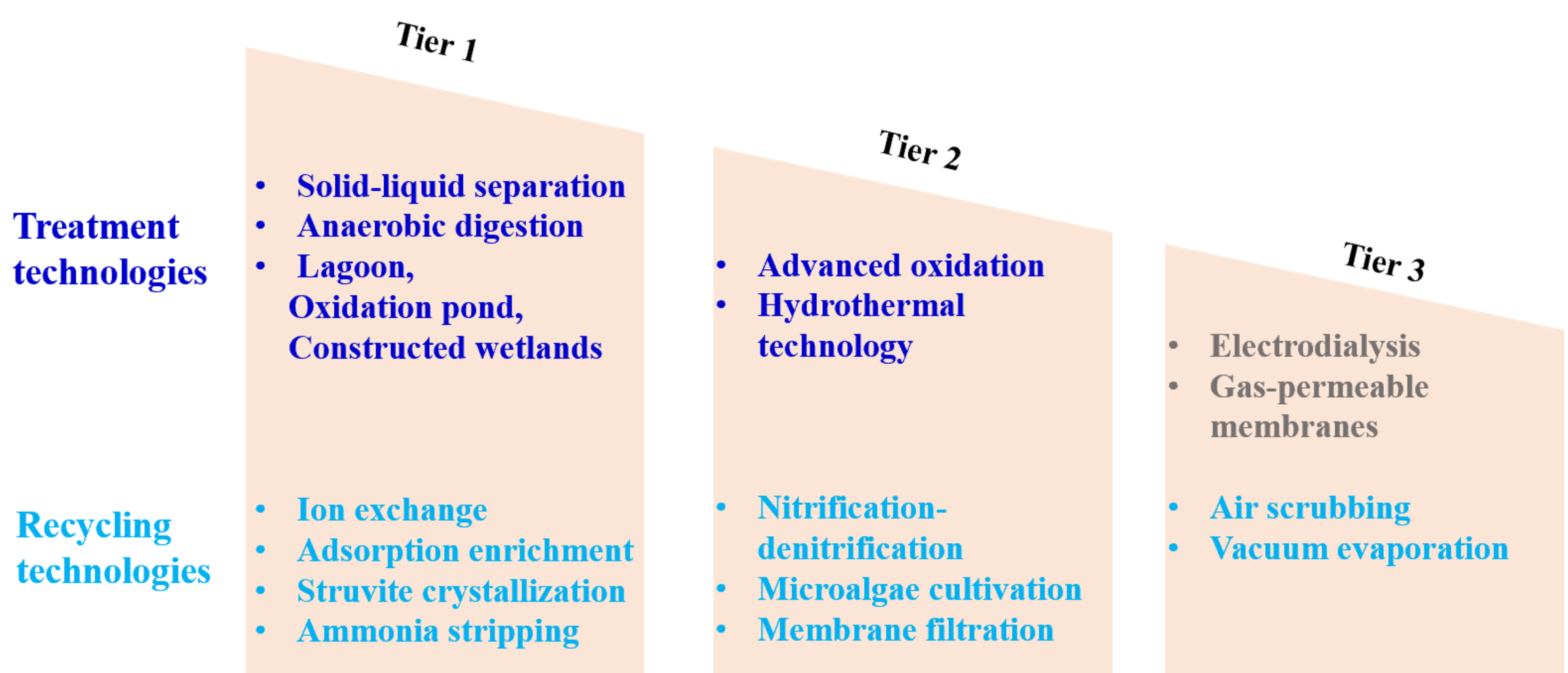
Innovating Precision Management Frameworks for Carbon, Nitrogen, and Phosphorus in Livestock Slurry: From STB Upscaling to Regional Application

PhD Student: Xuhao Chen   Supervisors: Yong Hou, Oene Oenema

Background

The breeding industry has undergone rapid intensification, driven by the need for enhanced production efficiency, which has consequently increased reliance on external inputs. Simultaneously, the decoupling of crop-livestock system has resulted in more nutrient losses. Managing slurry during storage, transport, and treatment remains a significant challenge.
Achieving efficient utilization of carbon, nitrogen, and phosphorus synergistically during slurry management is crucial for advancing multiple Sustainable Development Goals (SDGs), However, existing research has largely focused on individual elements, overlooking the critical interdependencies among multiple elements.
Material flow analysis (e.g., NUFER, CHANS models) has identified the key nutrient loss stages, but quantitative research on downstream treatment and recycling technologies is lacking. Meta-analysis integrates data for comprehensive technology comparisons, while machine learning predicts nutrient recycle efficiency, identifies importance and upscales feasibility. Yet, the integration of multiple methods to achieve multi-objective nutrient management frameworks of slurry remains unexplored.
Meanwhile, our macro-level research aims to promote better practical implementation. Combining top-down and bottom-up approaches, we propose a novel slurry management model. This methodological innovation not only guides the evolution of management practices but also aligns with the policy imperatives of AGD, ensuring that scientific advancements translate into tangible environmental and economic benefits.

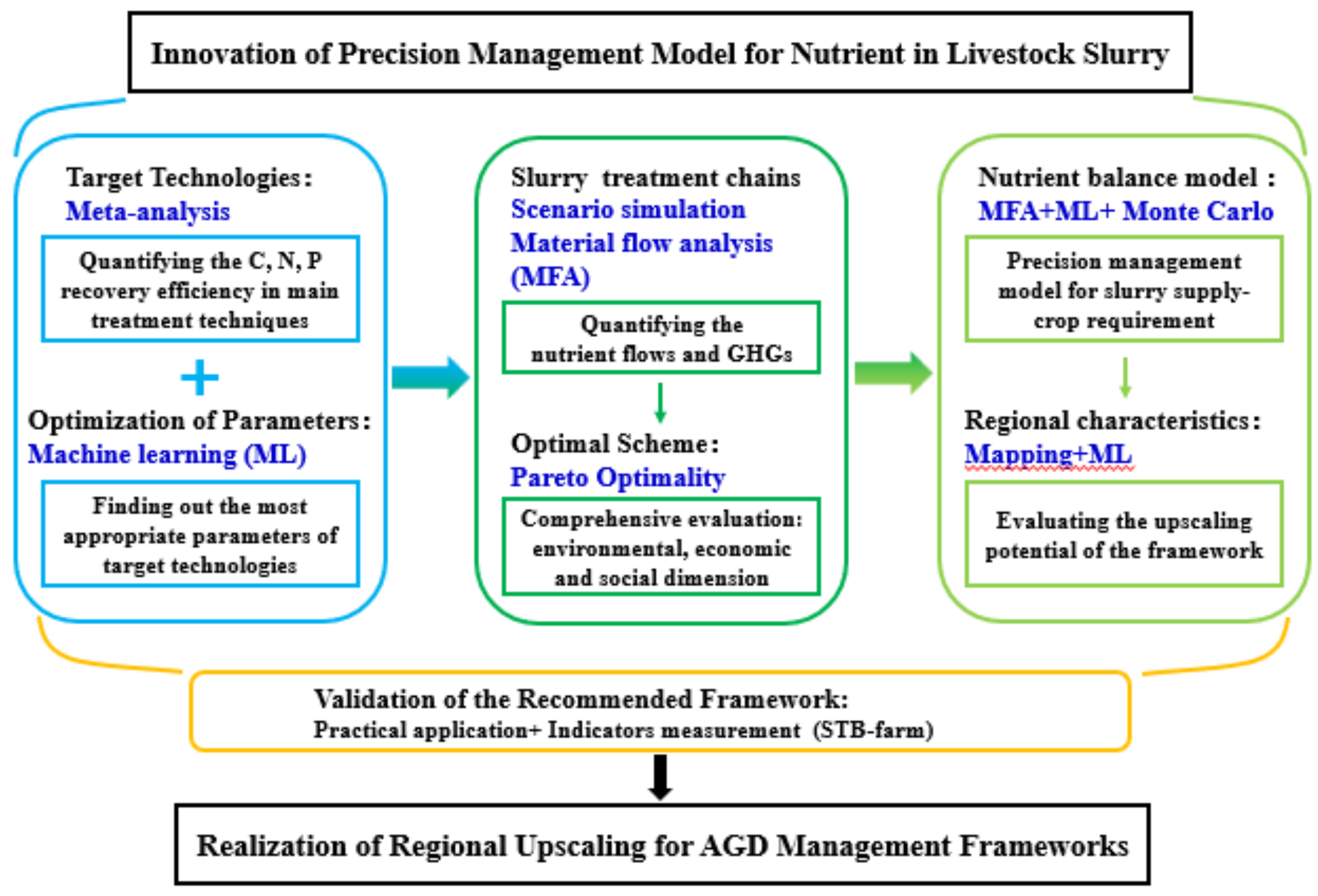
The technologies concerned:



Objectives

1. Perform quantitative analysis and identify key factors of nutrient recovery technologies from slurry by developing an innovative methodology that progressively links and couples multiple macro-level approaches.
2. Establish a widely applicable precision management framework for slurry nutrient recovery. By validation at Science and technology backyard (STB) -farm experimental sites, assess its potential for large-scale application.

Work Packages (Methods)



Research Contents

Chapter Ⅰ:
1. Meta → Quantifying the C, N, P recovery efficiency of slurry treatment techniques
2. ML → Identify the key influencing factors → Find out the best treatment of each technologies

Chapter Ⅱ:
1. MFA → Quantifying the nutrient flows and GHGs in recommended slurry treatment chains (based on Chapter Ⅰ)
2. Scenario simulation → Technique combination
3. Comprehensive evaluation → environmental, economic and social dimension → Optimal Scheme

Chapter Ⅲ:
1. MFA+ML → Nutrient balance model for coupled crop-livestock systems → Precision management framework for slurry in crop-livestock driven by farm Scenario (based on Chapter Ⅱ)
2. Mapping → Regional characteristics

Chapter Ⅳ:
1. Practical application+ Measurement → STB-farm → Evaluate the feasibility and upscaling potential of the framework (based on the preceding Chapters)

Research Plan

The research will be carried out in four phases:
1. Feb 2025 - Sept 2026: The first phase will focus on data collection and analysis for Chapter Ⅰ and Ⅱ, under the guidance of CAU (mainly) and WUR.
2. Sept 2026 - Sept 2027: The student is meant to go to WUR for models and frameworks developing and to produce the preliminary results for Chapter Ⅲ.
3. Oct 2027 - May 2028: The research in Chapter IV will be carried out in China.
4. June 2028 - Dec 2028: The final phase, I will complete my doctoral thesis and defense in CAU.

Acknowledgements

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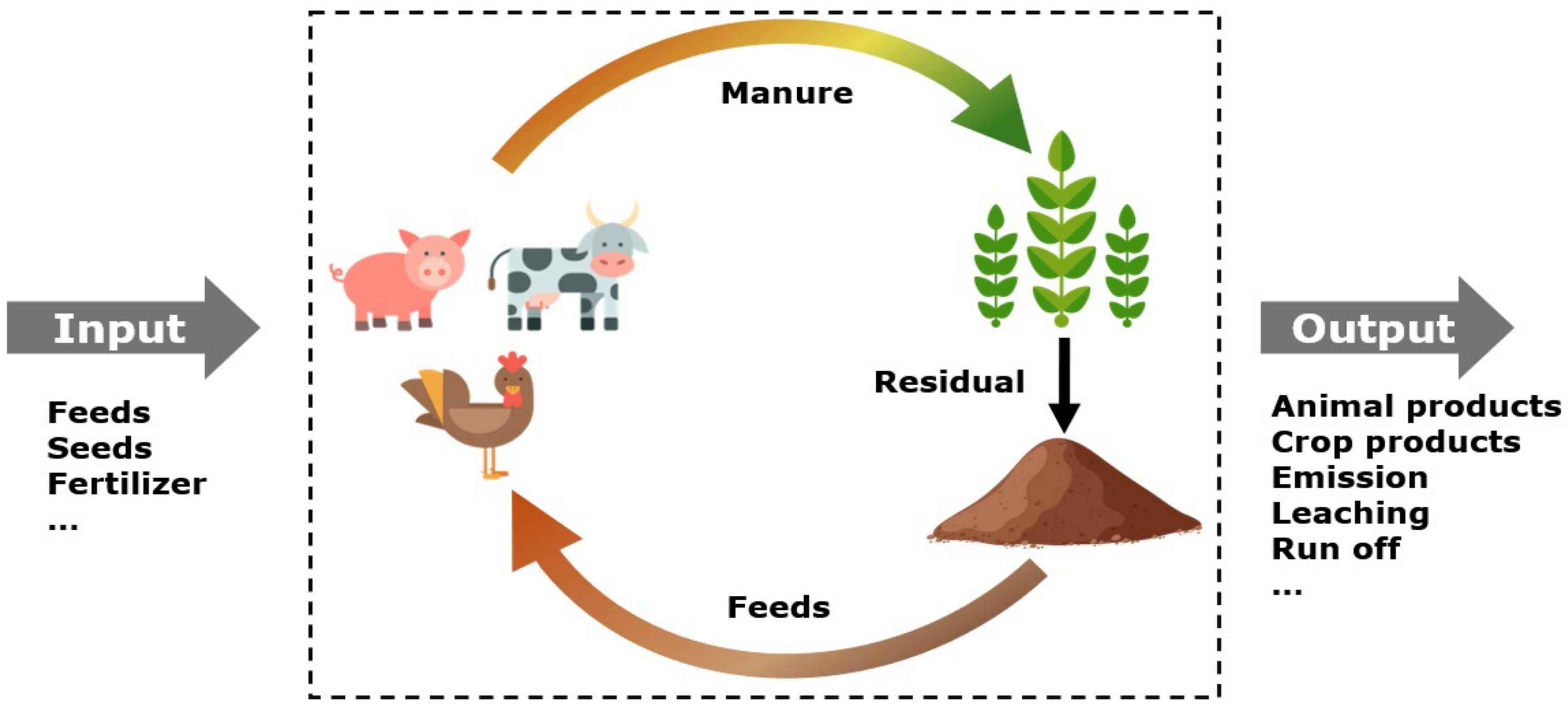
Optimizing nutrient management in integrated livestock-crop systems to enhance soil health.

Jiayu Lu, Gerard Velthof, Yong Hou

Background

Soil health as the continued capacity of soil to function, is critical for sustainable agricultural production, yet it faces significant challenges due to soil degradation and inefficient nutrient management practices in China. Smallholder-dominated farming systems, especially in regions like Quzhou County and the Erhai Basin, suffer from fragmented farmland, low mechanization, and excessive reliance on synthetic fertilizers, leading to inefficient manure use, unbalanced soil organic matter (SOM) and increased environmental pollution. In this context, integrated crop-livestock (ICL) systems offer a promising approach to optimize nutrient cycling, reduce synthetic fertilizer dependency and improve soil health. This research focuses on understanding the relationship between soil health and nutrient management in ICL systems. By examining various farm types and agricultural practices, this study aims to optimize nutrient management strategies to support soil-based green agriculture.



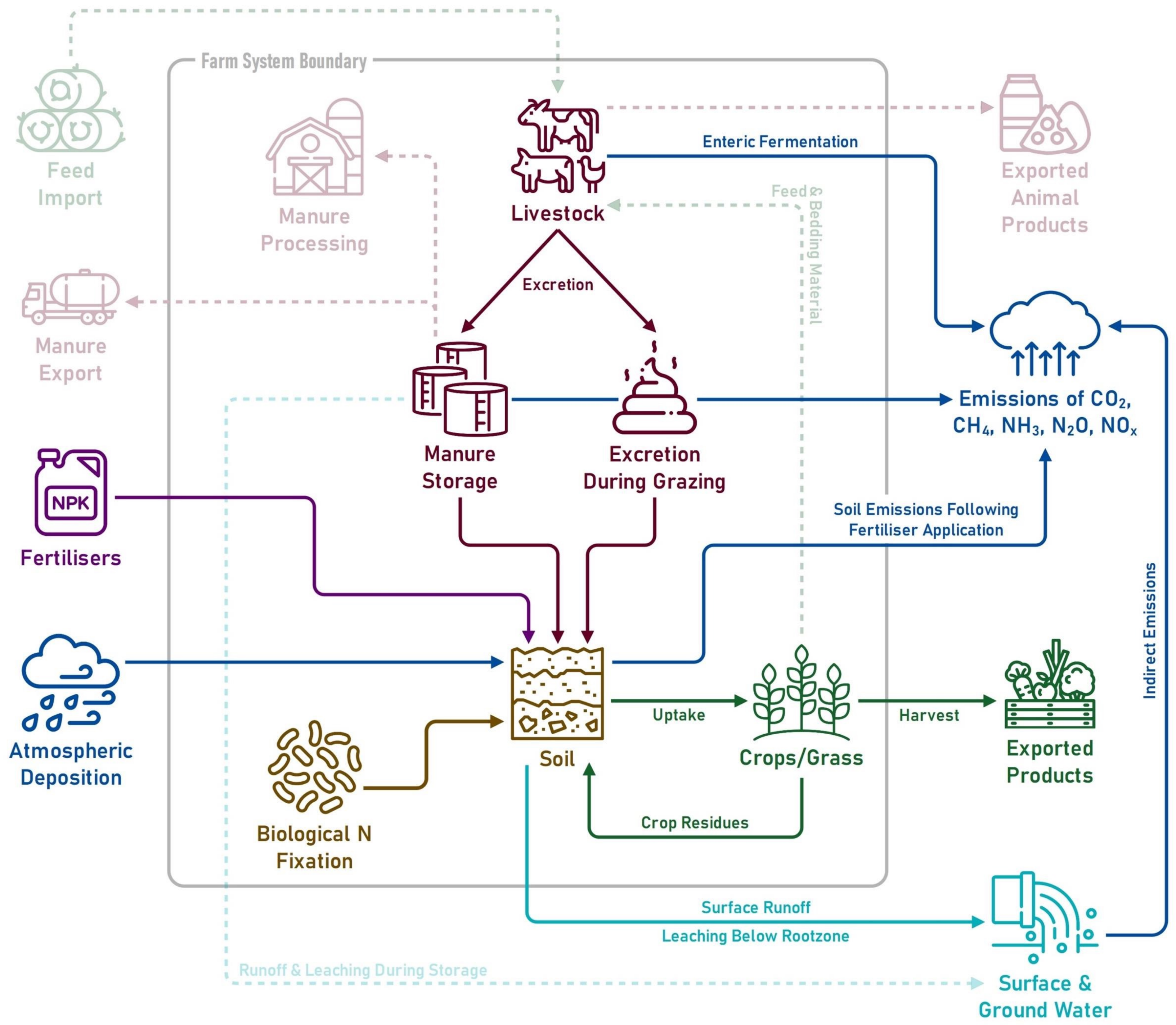
Objectives

1. Investigate the characteristics of nutrient management in ICL systems at the farm level.
2. Analyse the status of soil health in the ICL system and its main constraints.
3. Identify the relationship between soil health and nutrient management in ICL systems at the farm level.
4. Examine pathways for developing soil health assessment guidelines through analysis of the relationship between nutrient management and soil health in ICL systems.

Methodology

Select 3 - 4 farms with both livestock and crop production in each Erhai Basin and Quzhou County. Data collection will be done through questionnaires and soil sampling. Nutrient flow analyses will be conducted using the Miterra-Farm model. Soil health evaluation will use the soil health assement method.

Model Structure



Schematic illustration of the system boundary and nutrient flows modelled in Miterra-Farm. Dashed lines indicate processes not yet implemented

Future Research

- Initial data has been collected. Further discussion based on the model and the ICL systems at the two study locations will provide guidance for the collection of additional data.
- Parameter localisation or further extension of the Miterra-Farm model for China.

Acknowledgements

We gratefully acknowlege the sponsors of this research:China Scholarship Council (NO.20222260)

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The impact and scale-up strategy of the “Science and Technology Backyard + Market” Model in empowering smallholders for Green and High-Value Cultivation

PhD candidate: Dongmei Wang
Supervisors: Kemo Jin，Cees Leeuwis，Nico Heerink

Background

Food security is crucial for a nation's stability and long-term development. However, the overuse of fertilizers and pesticides in traditional farming poses significant sustainability challenges for China's agriculture. Green agricultural technologies offer a solution by boosting productivity while protecting the environment. Yet, promoting their widespread adoption is complex and requires the joint efforts of all stakeholders.

In recent years, China's agricultural technology extension has shifted from a government-led model to a multi-stakeholder approach involving the government, enterprises, universities, cooperatives, and markets. The "Science and Technology Backyard" (STB) model is a prime example of this collaborative approach. Studies show that by uniting multiple stakeholders, STBs can significantly increase the adoption and effectiveness of green agricultural technologies. As consumer demands for quality agricultural products rise, the role of the market in technology extension has become increasingly important. This market-oriented approach has also drawn more attention from scholars.

The Southwest Region, covering Chongqing, Sichuan, Yunnan, Guizhou, and Tibet, is a key area for economic crop production and is home to the Erhai STB cluster.Based on this background, we have developed and implemented a "STB + Market" model in the Yunnan Erhai STB cluster to promote green agricultural technologies. While many studies have demonstrated the effectiveness of the STB multi-stakeholder model, research on the market-led mechanism for large-scale technology adoption is still limited. Moreover, strategies for replicating and promoting this model nationwide remain unclear.

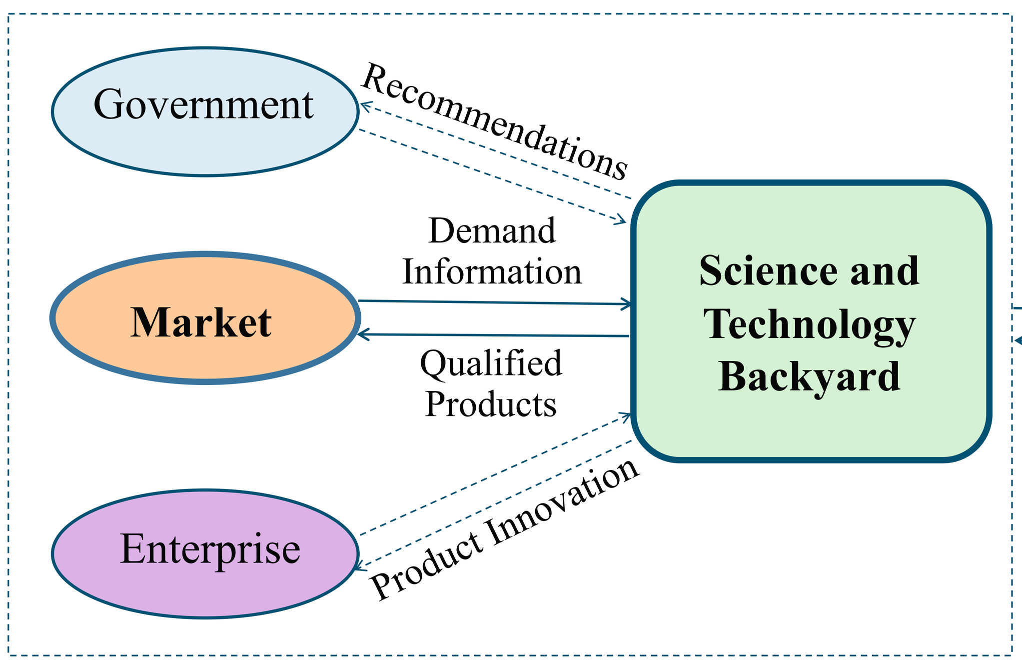
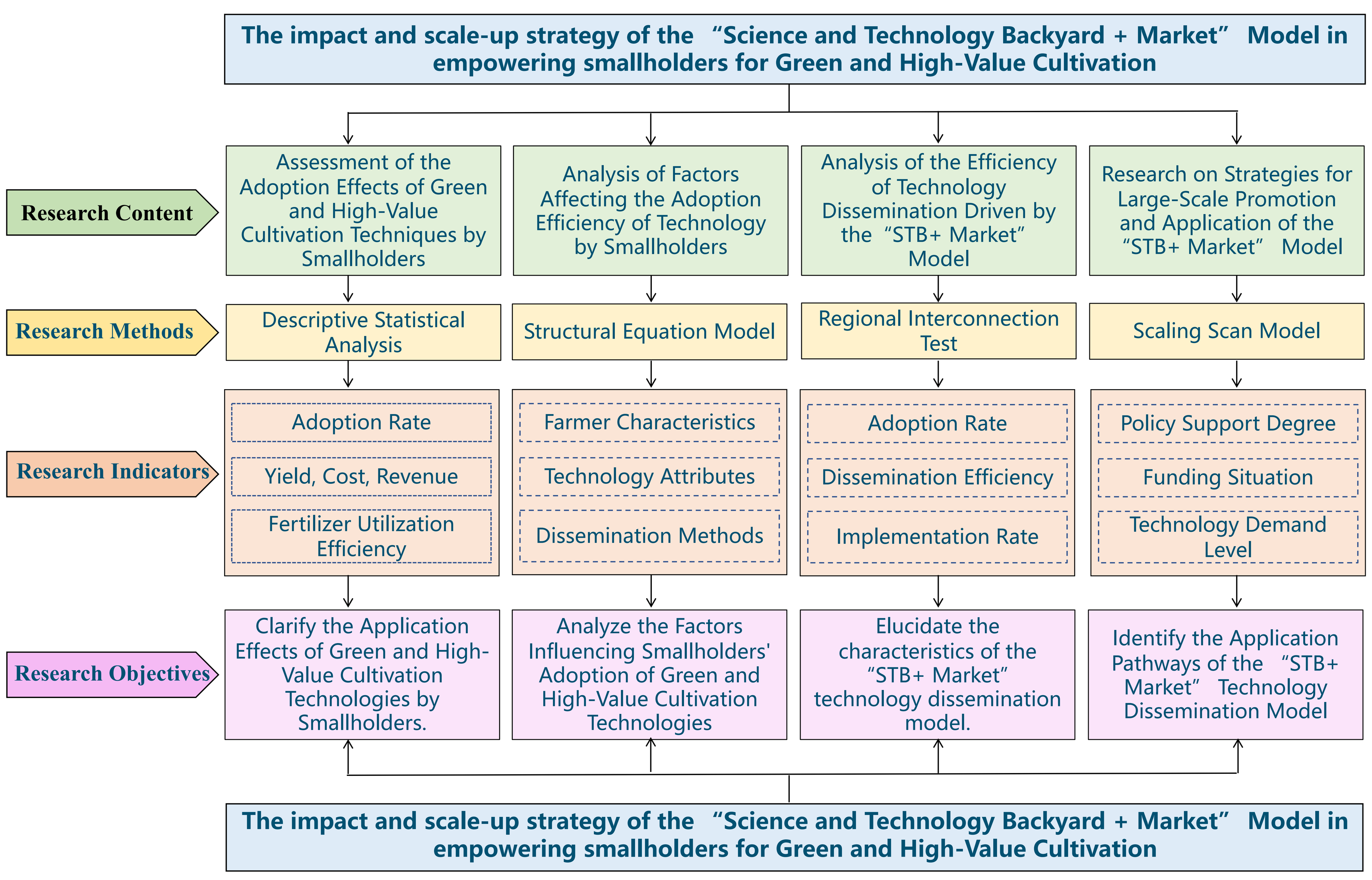


Fig.1 The preliminary "STB + Market" model in empowering smallholders

Research Framework

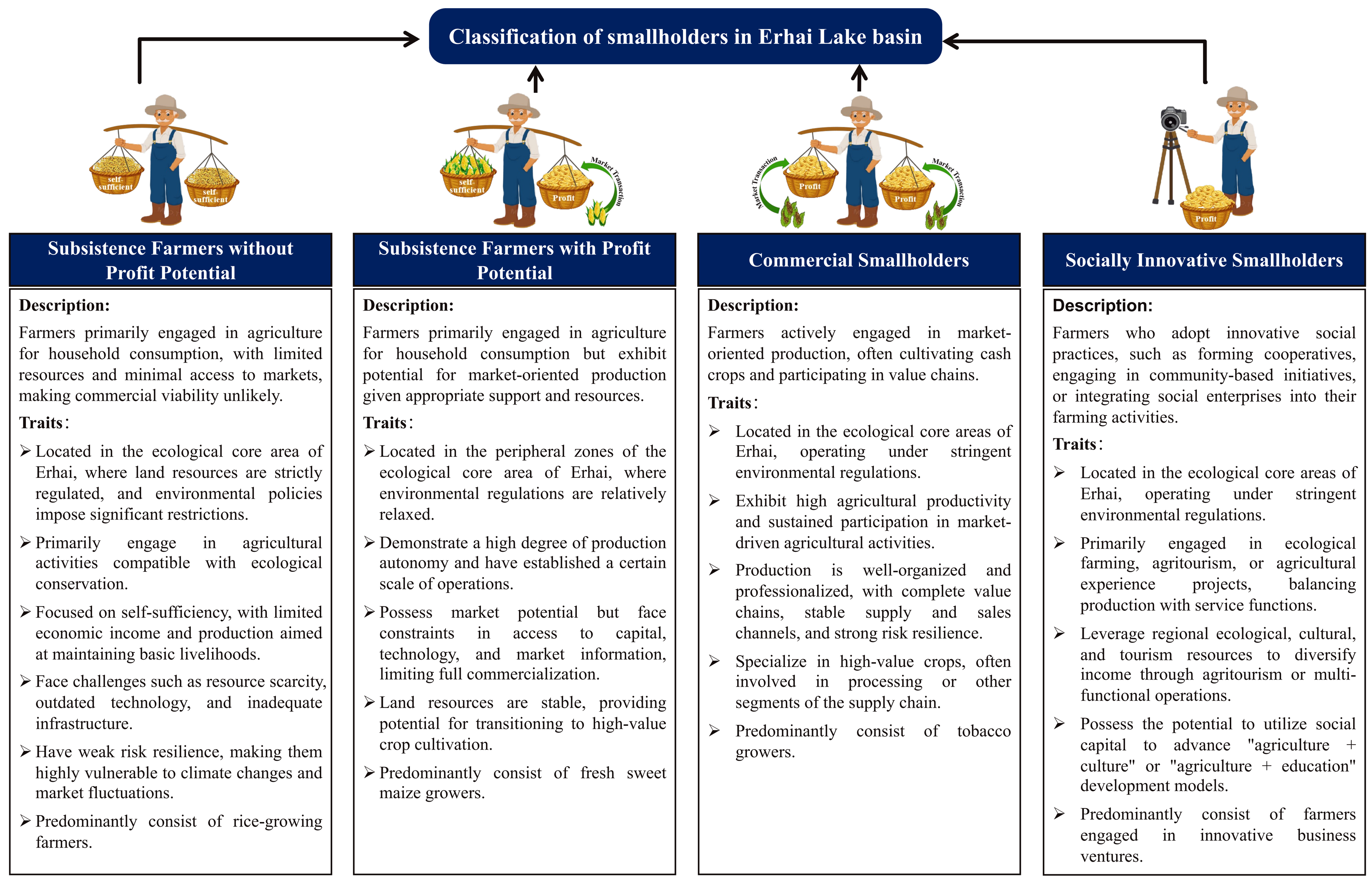


Objectives

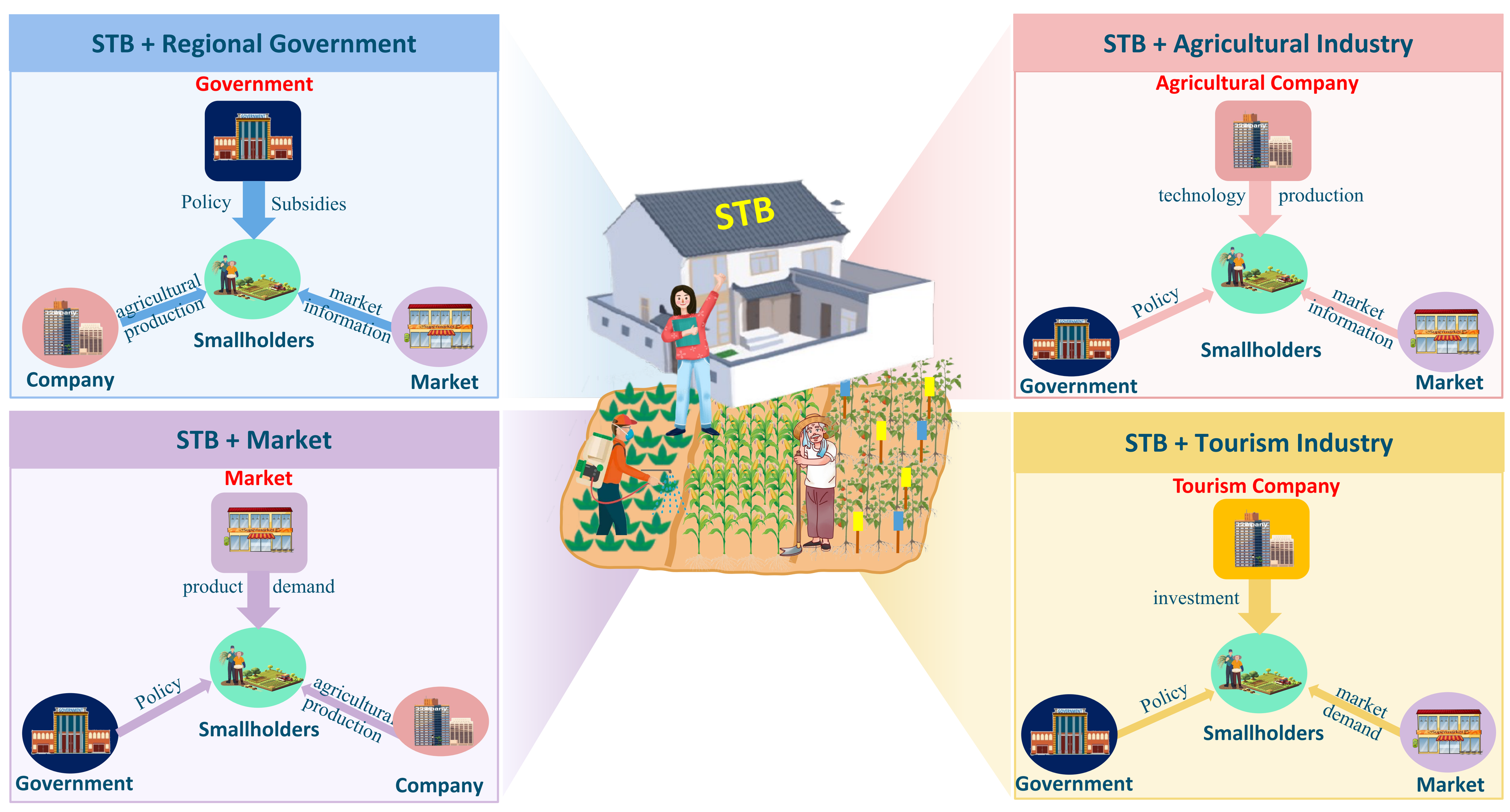
- Clarify the Application Effects of Green and High-Value Cultivation Technologies by Smallholders.
- Analyze the Factors Influencing Smallholders' Adoption of Green and High-Value Cultivation Technologies.
- Elucidate the characteristics of the “STB+ Market” technology dissemination model.
- Identify the Application Pathways of the “STB+ Market” Technology Dissemination Model.

Content Already Implemented

Firstly, the households served by the STB were categorized into four types based on their modes of production and operation, namely Subsistence Farmers without Profit Potential, Subsistence Farmers with Profit Potential, Commercial Smallholders, Socially Innovative Smallholders.



Secondly, based on the characteristics of the STB's service to the above four types of households, four multi-stakeholder collaboration models of the Science and Technology Backyard led by different main entities were summarized, namely:”STB + Regional Government” , “STB + Agricultural Industry”, “STB + Market”, “STB + Tourism Industry” Model



(Wang and Jin, in preparation)

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Modelling the effects of strategies for enhancing food production and clean water availability in China

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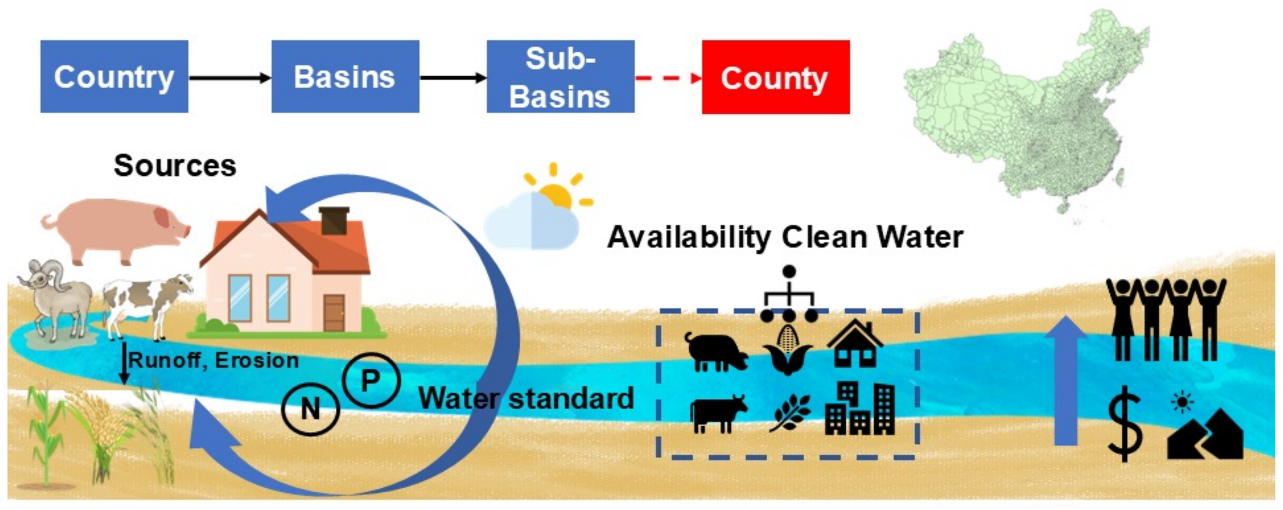
Background

China's water pollution, driven by nitrogen and phosphorus from agriculture and urban sources, lacks county-level sectoral accountability and integrated quantity-quality analysis.



Objectives

We aim to explore effective strategies that can meet the demand for clean water across various sectors, including crop production, livestock production, and human waste.

Methods

- Literature review and modeling are needed for RQ1.
- Indicators or approaches will be developed for the analysis of clean water availability in RQ2.
- Scenario analysis will be implemented in RQ3 to identify gaps for future clean water availability.
- The meta-analysis and machinery learning methods will be adapted to 4 for assessing the effects of strategies

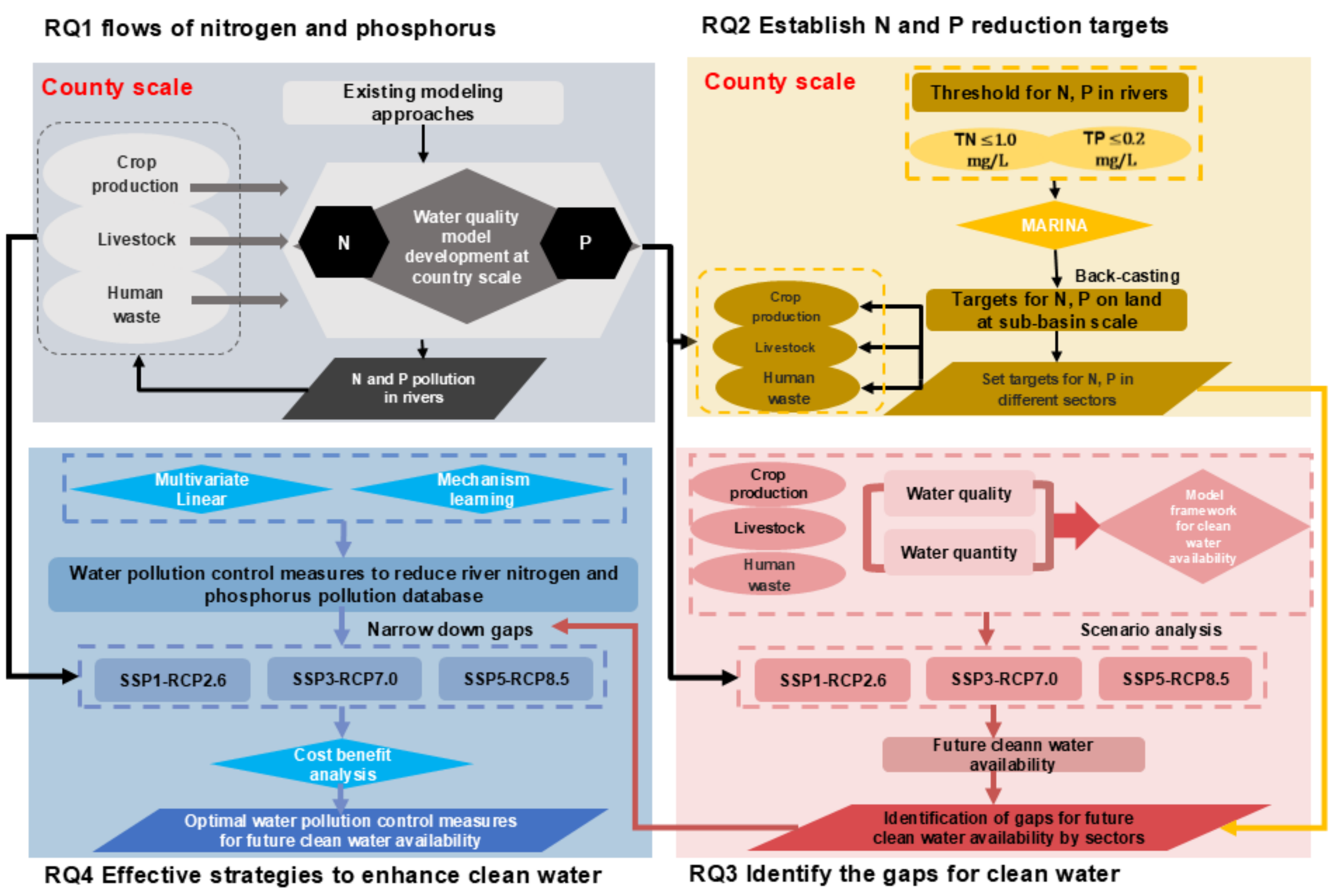


Fig.1 Model framework

Results

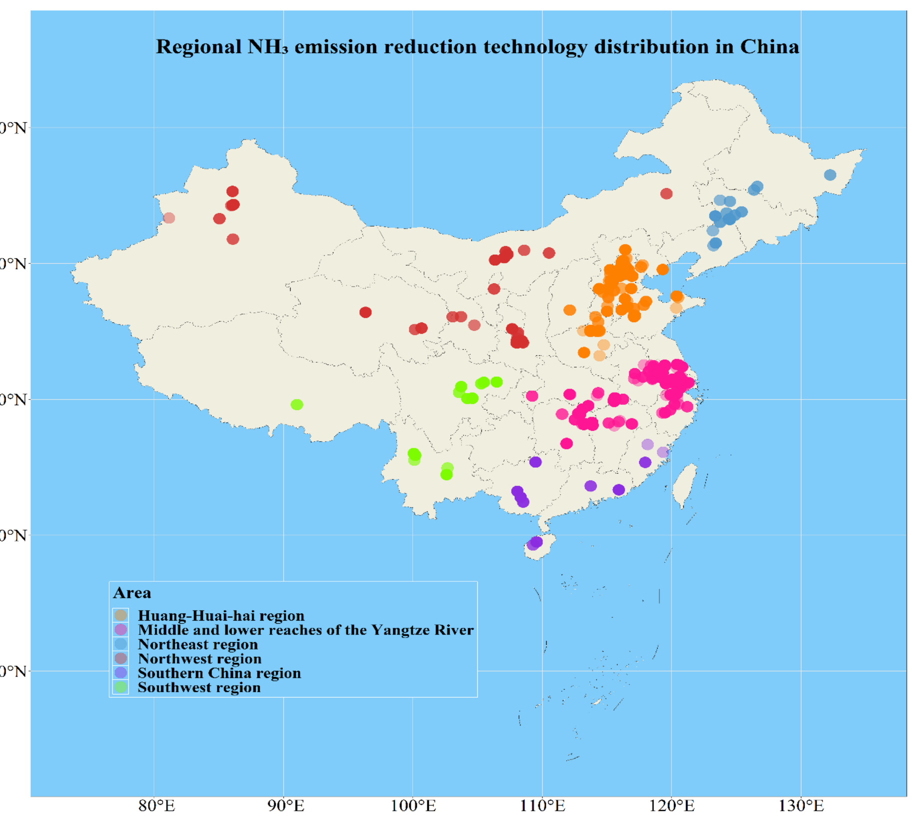


Fig.2 Global Sampling Site Distribution of NH_3 Emissions

- 360 articles
- 2065 paired observations met the literature selection criteria, the experimental locations represented diverse geographies globally (Fig. 2).

- Four individual measures, RFA (Reduced Fertilizer Application), DPM (Deep Placement Method), EEF (Enhanced Efficiency Fertilizers) and MFS (Manure Fertilizer Substitution).
- The results demonstrate that all four independent measures have achieved a significant reduction in NH_3 emissions in maize.
- For future analysis, combined with RFA+EEF, it emerges as the most effective strategy to reduce NH_3 emissions in residual crops

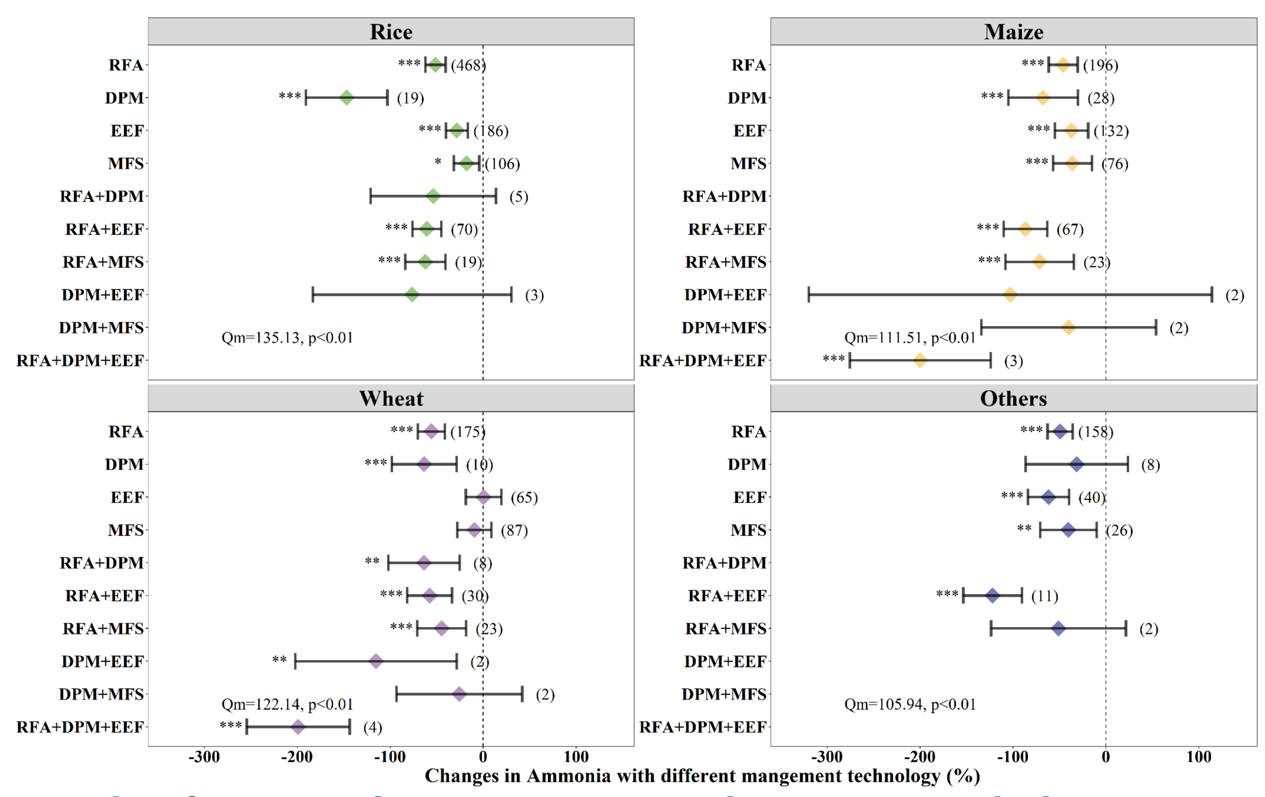


Fig.3 National Impact of Management Practices on NH_3 Emissions Across Crops

Conclusions

- Ensuring county-level clean water availability is critical for public health, ecological stability, and equitable socioeconomic progress.
- This study aims to define nutrient reduction targets for crop production, livestock, and human waste sectors, and develop effective strategies to narrow down gaps in the future.

Acknowledgements

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Poster overview of all current projects submitted for the 10th AGD symposium
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