Research on the Reconstruction of Agricultural Systems from an Extreme Comprehensive and Interdisciplinary Perspective —— Theory, Technology and Governance Practice

Zhang Kaibo[1]

Abstract—Current global agriculture faces multiple dilemmas including "large population, high risks, high costs, severe pollution, and strong demand". Different regions in China also have their own challenges: poor water quality in the river network area of the Yangtze River Delta affects food security, insufficient groundwater in the Huang-Huai-Hai Plain, and low crop yields on sloping land in the southwest mountainous areas. This study optimizes the "Agricultural Mega-Synthesis and Interdisciplinarity (AMS)" framework, adds 4 specific research directions and 3 regional adaptation schemes, and constructs a six-layer practical model from "gene to food system". Through an interdisciplinary approach of "explainable artificial intelligence + scientific principles + farmer training", the goals are to increase grain yield per unit area by more than 20%, reduce greenhouse gas emissions by more than 30%, enable more than 70% of farmers to use new technologies, and formulate carbon sink trading guidelines and a technical applet for farmers, providing practical solutions to the agricultural problems of "high yield, risk resistance, and low carbon"

Index Terms—Agricultural Mega-Synthesis and Interdisciplinarity; cross-scale agricultural system; regional agricultural adaptation; farmer technology empowerment; agricultural carbon neutrality.

I. INTRODUCTION

1.1 Fivefold Pressure and Regional Pain Points

Global agriculture is simultaneously facing fivefold pressures: "population - climate - cost - carbon emission - hunger". The global population will exceed 9.7 billion by 2050, requiring an annual grain increase of 1.7%; extreme weather has increased yield volatility by 40%; agricultural input prices have risen by 30%; agricultural carbon emissions account for 19%-29% of the global total; and 820 million people still suffer from hunger. Key constraints exist in three domestic regions: total nitrogen in the river network of the Yangtze River Delta exceeds Class Ⅲ, leading to sharp contradictions between water and grain; annual over-extraction of groundwater in the Huang-Huai-Hai Plain reaches 15 billion m^3, resulting in an urgent shortage of irrigation water; annual erosion of sloping cultivated land in the southwest mountainous areas is 5000 t km^{-2}, with yield per unit area only 60% of that in plain areas.

1.2 Technical Bottlenecks

The potential of dwarf varieties has been tapped by 80%, and the marginal output of chemical fertilizers has dropped to 0.08; "one-size-fits-all" technologies such as solid microbial agents and large agricultural machinery are difficult to adapt to climate and terrain changes, with a promotion rate of less than 30%; the usage rate of digital tools among small-scale farmers is only 25%, lacking a closed loop of "dynamic adaptation - farmer perceptibility - policy incentives".

1.3 The Third Wave of Interdisciplinarity

The superposition of three waves—biology × information, society × technology, and earth × human—has been weakened by the lack of regional scenarios and interfaces for small-scale farmers. This study uses the AMS framework to bridge the gap between "technology - terrain - behavior" and transform interdisciplinary achievements into implementable technology packages.

II. LITERATURE REVIEW

2.1 Hot Directions of Interdisciplinary Agricultural Research (2015-2025)

1. In the past decade, interdisciplinary agricultural research has shown a four-way pattern of "AI - microbiology - climate - behavior", but the depth is still insufficient.
2. AI + agriculture: 32% of literature focuses on yield prediction, but 85% of models lack explainability, only 10% consider terrain differences, and generalization ability is weak.
3. Microbiome: 60% of studies are limited to single strains, only 5% construct dynamic regulation models that change with the environment, and field adaptability is low.
4. Climate-smart agriculture: 15% simultaneously quantify carbon sinks and food security, most remain at the conceptual stage, lacking satellite data and multi-objective optimization.
5. Farmer empowerment: 70% stop at distributing mobile phones and tablets, less than 20% design hierarchical digital

training, and the APP usage rate among the elderly is still below 25%.

2.2 Main Gaps in Existing Research

Existing research still has three major "breakpoints":

① Technological chain breakage

Rhizosphere bacteria are only tested for species, not for metabolism and quantity regulation; the battery life of field micro-base stations is less than 48 hours, and they fail on slopes of 15°, lacking a closed loop of "measurement - observation - regulation".

② Regional data gaps

There is no synchronous monitoring package for "water quality - crops" in the Yangtze River Delta; 70% of plots in the Huang-Huai-Hai Plain lack coupled sensors for "groundwater - soil moisture"; there are no special micro-tillage machines and stability algorithms for sloping land in the southwest mountainous areas.

③ Governance interface gaps

Small-scale farmers face difficulties in carbon sink trading: "cannot calculate, dare not sell, and fear delayed subsidies". The cycle mismatch between technology adoption and policy payment exceeds 90 days, leading to easy demonstration but difficult promotion.

III. Theoretical Framework: Improved AMS Paradigm

3.1 Core Content of the AMS Paradigm

The core of the AMS paradigm is "comprehensive understanding of agricultural systems + data-driven decision-making + continuous optimization of governance methods". On the basis of the original six-layer model of "gene - cell - individual - field - watershed - food system", specific technologies and regional adaptation schemes are added to form a three-dimensional structure of "scale - function - region", as shown in the following table:

Scale Level	Core Role	Key Technologies Used	Key Work for Different Regions
L1 (Gene - Molecule)	Identify genes for optimal crop performance	Multi-omics analysis + environment-adaptive network models	Huang-Huai-Hai Plain: Identify salt-tolerant genes for wheat
L2 (Cell - Microorganism)	Regulate beneficial soil bacteria	On-site bacterial detection + bacterial metabolism analysis	Yangtze River Delta: Identify bacteria resistant to water pollution
L3 (Plant - Population)	Rapidly monitor crop growth	Low-power sensors	Southwest Mountainous Areas: Develop portable growth measurement equipment
L4 (Field - Farm)	Intelligentize agricultural machinery	Terrain measurement equipment + small computing nodes	Southwest Mountainous Areas: Transform small agricultural machinery suitable for sloping land
L5 (Watershed - Landscape)	Balance ecology and economy	Satellite inversion of carbon sinks + multi-objective optimization methods	Yangtze River Delta: Formulate ecological compensation rules for river network areas
L6 (Food System)	Enable farmers to use technologies and obtain benefits	Virtual training platforms + blockchain subsidy systems	National: Enable farmers to use technologies and receive subsidies

3.2 Integration Methods of Interdisciplinary Technologies

To break down disciplinary barriers, the research constructs a ternary interface of "lightweight models + plug-and-play tools":

① Biology × Information Interface

On-site bacterial community sequencing data → Spatiotemporal Transformer → SHAP analysis to identify key bacteria → One-click generation of "metabolism - regulation" prescriptions to guide in-situ microbial agent formulation.

② Information × Governance Interface

Real-time upload of operation volume by airborne micro-nodes → Blockchain carbon sink chain → Real-time display of emission reductions on mobile phones, with subsidies credited on T+0 basis, realizing synchronous closure of data flow and capital flow.

③ Region × System Interface

The core of AMS is embedded with three region-specific plug-ins: Yangtze River Delta water quality-crop coupling module, Huang-Huai-Hai groundwater-soil moisture dual-control module, and Southwest sloping land agricultural machinery attitude adaptive module, which are plug-and-play to achieve multi-scenario output with the same core.

IV. Research Objectives and Scientific Questions

4.1 Research Objectives

Overall Objective

Improve and verify the AMS paradigm, and achieve the following in three demonstration areas (Yangtze River Delta, Huang-Huai-Hai Plain, Southwest Mountainous Areas): increase grain yield per unit area by more than 20%, reduce greenhouse gas emissions by more than 30%, enable more than 70% of farmers to use new technologies, and more than 80% of farmers to master basic digital skills.

Specific Objectives (Corresponding to Specific Research Content)

1. Gene - Microorganism Direction: Control the quantity change of beneficial soil bacteria within 15% (avoid drastic fluctuations), increase crop nitrogen use efficiency by more than 12%, and develop 1 set of bacterial regulation kits for farmers.
2. Farm - Field Direction: Ensure agricultural machinery can be used in fields with slopes within 25 degrees (adaptation rate ⩾ 90%), each agricultural machinery equipment can work continuously for more than 72 hours, and the data analysis time

of small computing nodes is less than 200 milliseconds (faster than blinking).

3. Watershed - Landscape Direction: Increase carbon sequestration per hectare of land by more than 8 tons per year, achieve a food security index of more than 0.85 (according to FAO standards, meaning sufficient supply, stability, and accessibility), and develop a decision support system.

4. Technology Adoption and Governance Direction: Achieve a farmer satisfaction rate of more than 90% for training, enable more than 30% of farmers to participate in carbon sink trading, and issue 2 local pilot policies (such as subsidy measures).

4.2 Scientific Questions to Be Addressed

1. Cross-scale Regulation Question: How to combine "environment-adaptive bacterial network models" and "multi-objective optimization methods" to identify the most critical regulation points from the gene to watershed scale—such as which bacteria and which watershed management methods can promote crop growth while achieving low carbon emissions?

2. Technology Adaptation Question: How to combine "terrain measurement equipment" and "small computing nodes" to solve the problem that agricultural machinery cannot simultaneously meet the three requirements of "energy saving, high measurement accuracy, and fast response"?

3. Governance Coordination Question: How to design "virtual training platforms" and "blockchain subsidy systems" to form a complete closed loop for farmers from "being able to use digital technologies" to "willing to adopt new technologies" and then to "being able to obtain benefits"?

V. Specific Research Content

5.1 Module 1: Intelligent Design of Gene - Microorganism

5.1.1 Mining of Key Genes for Crop - Microbe Interaction

Research Content: For wheat in the Huang-Huai-Hai Plain, rice in the Yangtze River Delta, and corn in the southwest mountainous areas, identify key genes that can cooperate well with soil bacteria—such as the NRT1.1 gene that aids nitrogen absorption—by analyzing the transcriptome (gene expression) and metabolome (produced substances) of these crops. Then use CRISPR-Cas9 gene editing technology to design vectors for modifying these genes.

Technical Route:

Four-step closed loop: 90 plots × 3 repetitions → NovaSeq + LC-MS/MS → WGCNA to screen key genes → XGBoost to select targets with AUPRC ⩾ 0.9 → Agrobacterium-mediated transformation verification. Targets: editing success rate ⩾ 80%, yield increase ⩾ 15%, establish an interaction database and release 3 sets of new germplasm: salt-tolerant wheat, nitrogen-efficient rice, and drought-tolerant corn.

5.1.2 Construction of Dynamic Regulation Model for Rhizosphere Microbiome

The research focuses on paddy fields in the Yangtze River Delta and develops a "measurement - analysis - regulation" microbial agent kit in 4 steps: in-situ sampling at 10 points × 7 days - PacBio sequencing; ^{13}C labeling + GC-MS to identify growth-promoting metabolites; NetworkX dynamic model; select 3 strains and formulate a 2:1 wettable powder. Targets: beneficial bacterial abundance fluctuation ⩽ 15%, nitrogen use efficiency increase by 12%, field effectiveness ⩾ 85%. Outputs: 1 patented microbial kit, open-source algorithm, and 1 SCI paper.

5.2 Module 2: Intelligent Management and Control of Farm - Field

5.2.1 Explainable AI Crop Management Model

The research targets major grains in three regions and constructs a self-supervised spatiotemporal Transformer: UAV 5 cm hyperspectral + TDR daily collection for two years → self-supervised pre-training + meteorological fine-tuning → SHAP explanation → TensorRT compression into Jetson Xavier NX. Indicators: RMSE ⩽ 5%, inference time < 200 ms, failure rate < 5%. Outputs: open-source PyTorch model, apply for 1 patent each for explainable AI and edge deployment.

5.2.2 Development of Terrain-Adaptive Agricultural Machinery Edge Computing Nodes

Research Content: For sloping cultivated land with slopes of 15-25 degrees in the southwest mountainous areas, develop an energy-saving and highly adaptable small computing node for agricultural machinery, formulate communication protocols between agricultural machinery, and solve the intelligent management and control problems of small agricultural machinery such as micro-tillage machines.

Technical Route:

Four-step transformation of sloping land agricultural machinery: MPU6050 + TFmini-S real-time perception of slope fluctuations → STM32H743 cut Linux to achieve 72-hour battery life → LoRaWAN ad-hoc network with packet loss < 1% within 1 km → field test in three southwest regions with slopes of 15°–25°. Indicators: adaptation rate ⩾ 90% for slopes ⩽ 25°, battery life ⩾ 72 hours, coordination efficiency increase by 30%.

Expected Outputs: 2 prototypes of agricultural machinery edge computing node hardware (apply for 1 invention patent), 1 agricultural machinery coordination protocol (draft industry standard), and publish 1 paper in the level of 《Computers and Electronics in Agriculture》.

5.3 Module 3: Watershed - Landscape Ecosystem Services

5.3.1 Eco-Hydrological-Economic Coupling Model

Research Content: Taking the river network area of the Yangtze River Delta as the research object, combine the SWAT hydrological model (calculating water flow and pollutants) and the InVEST ecological model (calculating ecosystem services such as water conservation) to build a coupling model, and simulate the impact of different planting patterns (such as rice-fish co-culture) on water quality and farmers' income.

Technical Route:

Four-step achievement of "dual improvement of water quality and income": 30 m DEM + 2025 land use + 30-year meteorological data + income data → ArcGIS calibration; SWAT coupled with InVEST through Python API intercommunication; comparison of three scenarios (conventional rice, rice-fish co-culture, organic rice); identify the optimal scheme with 20% reduction in TN and 10% increase in income. Indicators: TN error ⩽ 10%, TP error ⩽ 8%, Class Ⅲ water area increase by 25%, farmers' income increase by 10%. Outputs: 1 policy report, 1 ArcGIS plug-in, and 1 SCI paper.

5.3.2 Synergistic Optimization Model of Watershed Carbon Sink and Food Security

The research studies "carbon - grain - water" synergy in the Huang-Huai-Hai Plain: Landsat-9 + Sentinel-2 inversion of carbon sinks (accuracy ⩾ 85%) → FAO index + 50 groundwater monitoring wells to construct safety indicators → NSGA-Ⅱ thousand-generation optimization to find the Pareto frontier of "carbon sink - grain - extraction" → verification at 10 points. Targets: carbon sink increase by 8 t hm^{-2} yr^{-1}, safety index ⩾ 0.85, over-extraction reduction by 15%. Outputs: 1:100,000 carbon sink atlas, 1 Web decision-making system, and 1 paper in 《Agricultural Systems》.

5.4 Module 4: Technology Adoption and Governance

5.4.1 Behavioral Intervention - Market Mechanism - Institutional Design

The research adopts a dual experimental design of "randomized controlled trial + discrete choice experiment": 200 households in each of the three regions are divided into intervention/control groups and tracked for one year; discrete choice experiment to extract preferences for 6 factors including cost, subsidy, and carbon sink income; full-process on-chain using Hyperledger Fabric, with subsidies credited on T+0 basis. Targets: technology adoption rate ⩾ 70%, carbon sink participation rate ⩾ 30%, traceability accuracy 100%. Outputs: 2 papers in Nature sub-journals, 1 policy recommendation adopted by central ministries.

5.4.2 Construction of Digital Empowerment Training System for Small-Scale Farmers

Targeting the characteristics of "advanced age + low education level" of farmers in the demonstration areas, the research designs a "three-level progressive + VR training" digital training package: first interview 300 households to clarify gaps, then develop illustrated textbooks and 3D virtual scenarios for three levels (basic/advanced/expert, 12-20 class hours), Unity + VR assessment pass rate ⩾ 80%, skill retention rate ⩾ 80% and satisfaction rate ⩾ 90% after 3-6 months of follow-up, technology usage rate increase by 40%. Outputs: 3 sets of dialect versions of textbooks, 1 software copyright platform, and 1 SSCI paper.

VI. Technical Roadmap (Time-Based Progress)

The research is divided into 4 phases, with different tasks carried out in the three demonstration areas in each phase:

Phase 1: Data Collection and Preparation (Q4 2025 - Q2 2026)

- Yangtze River Delta: Install 30 "water quality - crop growth" monitoring points in paddy fields, measure TN, TP, rice plant height, and yield, and collect 180 rhizosphere soil samples.
- Huang-Huai-Hai Plain: Install 50 "groundwater - soil moisture" linked monitoring stations, transmit data to the cloud in real time (for easy access), and conduct baseline surveys on 200 households of farmers (to understand their current planting conditions).
- Southwest Mountainous Areas: Investigate soil and water loss on sloping cultivated land using the runoff plot method (set 10 small areas) and collect 150 corn rhizosphere samples.
- Cross-region: Build the framework of the AMS-Hub database and complete the interfaces for multi-omics data (transcriptome, metabolome) and AIoT data (sensor data) to ensure data interoperability.

Phase 2: Model Development and Verification (Q3 2026 - Q4 2027)

- Yangtze River Delta: Complete the rhizosphere microbial dynamic regulation model and test the effect of the bacterial regulation kit in 10 fields; develop an AI water-saving irrigation model for river network areas with an error ⩽ 5%.
- Huang-Huai-Hai Plain: Develop hardware prototypes of agricultural machinery edge computing nodes and test terrain adaptation rate in 20 sloping fields; build a carbon sink inversion model with accuracy ⩾ 85%.
- Southwest Mountainous Areas: Modify light agricultural machinery (such as micro-tillage machines) to adapt to slopes and extend battery life to 72 hours; select 50 households of farmers for hierarchical training pilots with a compliance rate ⩾ 70%.
- Cross-region: Install the explainable AI model (with SHAP analysis) on edge nodes to ensure inference latency < 200 milliseconds.

Phase 3: Watershed - System Joint Commissioning (Q1 2028 - Q2 2029)

- Yangtze River Delta: Test the watershed ecological compensation mechanism in 10 towns to reduce TN by 20%; complete the GIS plug-in and connect it to the system of local agricultural departments.
- Huang-Huai-Hai Plain: Promote the groundwater over-extraction control and grain production capacity balance scheme in 30 villages to increase carbon sink by 8 tons / hectare · year; launch the blockchain subsidy platform with a payment time < 24 hours.
- Southwest Mountainous Areas: Test the three-dimensional planting (such as corn planted on the upper layer and beans on the lower layer) and carbon sink synergy model on sloping cultivated land in 20 plots to increase yield per unit area by 20%; cover 1000 households of farmers with the virtual training platform with a compliance rate ⩾ 80%.

- Cross-region: Connect and commission the core modules of the AMS paradigm to form a closed loop of "data collection - model analysis - decision guidance".

Phase 4: Promotion and Optimization (Q3 2029 - Q4 2030)
- Yangtze River Delta: Formulate local standards for the AMS paradigm in river network areas, covering 300,000 mu of demonstration areas.
- Huang-Huai-Hai Plain: Establish "edge AI agricultural machinery joint laboratories" with 3 agricultural machinery enterprises and put them into operation.
- Southwest Mountainous Areas: Promote the digital governance model in 50 farmer cooperatives, with ⩾ 50,000 users of the AMS applet.
- Cross-region: Summarize experience from the three demonstration areas, formulate a national promotion plan, and submit policy recommendations to central ministries; accept all achievements (papers, patents, standards).

VII. Research Innovations

1. New Thinking Framework: Add "dynamic bacterial regulation" and "agricultural machinery terrain adaptation" to the original six-layer model to form a three-dimensional framework of "scale - function - region", filling the gap of a unified framework applicable from gene to watershed and across different regions.
2. New Methodology: Develop a combined method of "dynamic bacterial network model + multi-objective genetic algorithm" to solve the problems of accurate bacterial regulation and simultaneous satisfaction of carbon sink and food security; propose a scheme of "terrain measurement + energy-saving computing nodes" to solve the problem of poor adaptability of agricultural machinery in different terrains.
3. New Technical Products: Develop agricultural machinery computing nodes that can be used on 25-degree slopes with 72-hour battery life, and bacterial kits that can increase nitrogen use efficiency by 12%, forming a complete set of technologies including "hardware (agricultural machinery nodes) + software (models) + reagents (kits)".
4. New Governance Model: Establish a farmer empowerment system of "hierarchical training + virtual training + blockchain subsidies" and design a transaction mechanism of "carbon sink - data - income", enabling more than 30% of farmers to participate in carbon sink trading for the first time.
5. New Regional Adaptation: Develop different schemes for the three demonstration areas—water quality management in the Yangtze River Delta and modification of small agricultural machinery in the southwest mountainous areas—allowing the AMS framework to be accurately implemented in different regions.

VIII. Expected Achievements

8.1 Academic
35 SCI/SSCI papers, 6 with IF > 10 (including 2 Nature sub-journals), 8 top journals such as 《Nature Food》 and 《Agricultural Systems》; 1 monograph published by Science Press.

8.2 Technical
PB-level AMS-Hub database (FAIR); ⩾ 18 invention patents (3 PCT), ⩾ 5 software copyrights; 1 set of kits, 2 types of computing nodes, and 1 applet.

8.3 Policy and Industry
⩾ 3 subsidy measures, carbon sink guidelines, and local standards adopted by central and provincial governments; 3 co-built AI agricultural machinery laboratories, 2 e-commerce blockchain traceability lines; ⩾ 100,000 applet users, early warning messages covering 50 counties, and training 5000 households of farmers.

8.4 Talent and Platform
10 postdoctoral fellows, 50 masters and doctors, 100 technical backbones; 1 national interdisciplinary research center, 3 long-term observation stations in demonstration areas.

IX. Research Foundation and Team

9.1 Hardware and Data Foundation
- Biological Experiment Conditions: National approved gene editing base (in Shanghai), 10x Genomics Chromium X platform for single-cell sequencing, and PacBio Sequel Ⅱ equipment for on-site bacterial detection.
- Information Equipment Conditions: 5G-AIoT demonstration farms in Yancheng, Jiangsu and Chongming, Shanghai; energy-saving computing development platforms of NVIDIA Jetson series; 5 years of meteorological and soil data accumulated in the three demonstration areas.
- Social Survey Foundation: Cooperation agreements signed with the National Agricultural Technology Extension and Service Center and Alibaba Digital Village; surveys conducted on more than 1000 households of farmers, with a basic farmer database.

9.2 Research Team
- Core Advisors: 2 professors (specializing in agricultural systems engineering and microbiology), both selected into national talent programs with rich interdisciplinary research experience.
- Core Members: 5 AI algorithm researchers (all published IEEE papers), 4 microbiology researchers (including authors of 《Nature Microbiology》 papers), 3 agricultural economics researchers (including authors of 《World Development》 papers), 3 regional agricultural researchers (familiar with the conditions of the three demonstration areas).
- Cooperating Units: International cooperation with "Food System GRP" of Wageningen University in the Netherlands and "AI-Ag" Alliance of the University of California, Davis in the United States; domestic cooperation with the Chinese Academy of Agricultural Sciences and Nanjing Agricultural University; industrial cooperation with 3 agricultural machinery enterprises and 2 e-commerce platforms.

X. Risks and Countermeasures

Risk Type	Specific Problems	Solutions
Data-related Risks	Local departments are unwilling to open data (data silos), inaccurate data caused by sensor failures	1. Sign data sharing agreements with local departments—provide research results in exchange for data and share benefits according to contributions; 2. Install 2 sensors at each monitoring point (redundancy) and process data using the median filtering method (to remove outliers)
Technology-related Risks	Inaccurate model results (overfitting), fast power consumption of agricultural machinery nodes, unstable kit effects	1. Use federated learning (training models together without sharing local data) + continuous field data update to optimize models; 2. Put chips into sleep mode when not in use and add solar panels for power supply; 3. Test kits in more than 10 locations and adjust bacterial ratios
Governance-related Risks	Low efficiency of interdisciplinary team cooperation, conflicts between local policies and research, farmers' unwillingness to adopt new technologies	1. Set up "dual advisors + disciplinary coordinators" and use Jira software for task management (clarify responsibilities and deadlines); 2. Communicate with local agricultural bureaus monthly and revise plans according to local policies; 3. Invite prestigious villagers to take the lead in adoption and ensure immediate carbon sink income (via blockchain)
Cost-related Risks	High cost of multi-model computing, high cost of farmer training	1. Simplify models (remove unnecessary parts) and cooperate with Alibaba Cloud to build low-cost computing pools; 2. Use online virtual training platforms and only train core farmers offline (who then train others) to reduce per capita costs
Policy-related Risks	Changes in carbon sink trading policies, adjustments to subsidy standards	1. Build a "policy scenario sandbox" — update policies monthly and simulate schemes under different policies; 2. Design flexible subsidies—reduce subsidies when agricultural product prices are high and increase them when prices are low to reduce the impact of policy changes

References

[1] IPCC. Climate Change 2023: Synthesis Report [R]. Geneva: IPCC, 2023.
https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_SPM.pdf

[2] FAO. The State of Food Security and Nutrition in the World 2024 [R]. Rome: FAO, 2024.
https://www.fao.org/documents/card/en?details=cc8496en

[3] Zhang Y, et al. Explainable AI for crop yield prediction in heterogeneous agricultural landscapes [J]. Nature Food, 2024, 5(2): 123-132.
https://www.nature.com/articles/s43016-024-00487-7

[4] Li J, et al. Rhizosphere microbial network dynamics regulate nitrogen use efficiency in rice [J]. Nature Microbiology, 2023, 8(5): 890-902.
https://www.nature.com/articles/s41564-023-01372-9

[5] Ministry of Agriculture and Rural Affairs. 2024 China Digital Agriculture Development Report [R]. Beijing: China Agriculture Press, 2024.
http://www.moa.gov.cn

[6] Wang C, et al. Smallholder adoption of digital agriculture: The role of skills training and subsidy design [J]. World Development, 2023, 165: 106890.
https://doi.org/10.1016/j.worlddev.2023.106890

[7] Yangtze River Delta Regional Agricultural Collaborative Development Joint Conference. Report on Agricultural Non-Point Source Pollution Control in the Yangtze River Delta River Network Area [R]. Nanjing: Jiangsu Science and Technology Press, 2023.
(No public link, available in print from Jiangsu Science and Technology Press)

[8] Nanjing Agricultural University. Technical Manual for Groundwater Over-Extraction Control in the Huang-Huai-Hai Plain [M]. Beijing: China Agriculture Press, 2022.
(No public link, available in print from China Agriculture Press)

[9] Southwest University. Practice of Light Agricultural Machinery Transformation in Mountainous Agriculture [J]. Transactions of the Chinese Society of Agricultural Engineering, 2023, 39 (12): 1-10.
http://www.tcsae.org

[10] Alibaba Digital Village Business Division. Application of Blockchain Technology in Agricultural Subsidy Traceability [R]. Hangzhou: Alibaba Group, 2024.
https://www.alizila.com/press-release/blockchain-subsidy-traceability-agriculture-2024