XVIII World Water Congress
International Water Resources Association (IWRA)

Understanding the paradox of irrigation efficiency from the perspective of water pricing impacts on irrigation behavior

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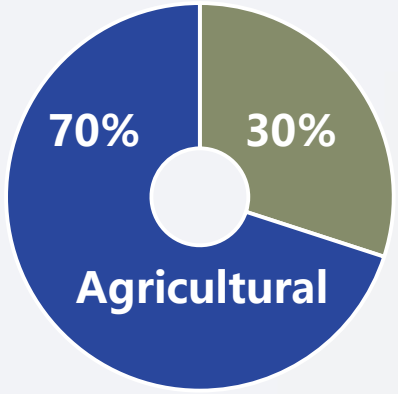
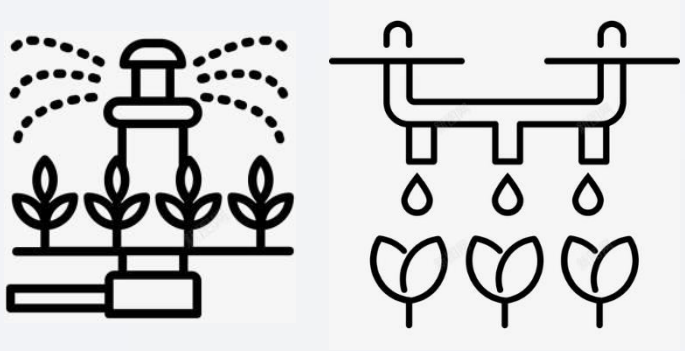
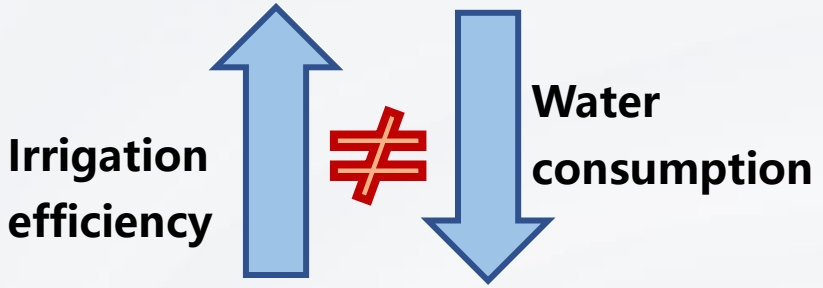
The paradox of irrigation efficiency



70% of freshwater withdrawals



Technologies that promote irrigation efficiency



Paradox of irrigation efficiency

The paradox of the irrigation efficiency has been confirmed by many cases

- ✓ Hamidov, A., Kasymov, U., Djumaboev, K., & Paul, C. (2022). Rebound Effects in Irrigated Agriculture in Uzbekistan: A Stakeholder-Based Assessment. Sustainability, 14(14).
- ✓ Wang, Y., Long, A., Xiang, L., Deng, X., Pei, Z., Yang, H., . . . Yang, L. (2020). The verification of Jevons' paradox of agricultural Water conservation in Tianshan District of China based on Water footprint. Agricultural Water Management, 239.

The paradox of irrigation efficiency

***Science*, 2018**

Grafton, R.Q., Williams, J., Perry, C.J., Molle, F., Ringler, C., Steduto, P., Udall, B., Wheeler, S.A., Wang, Y., Garrick, D., Allen, R.G., 2018. The paradox of irrigation efficiency. *Science* 361, 748-750.

Two significant factors causing the paradox

- **The omission of the reduction in return flow.**

  Redefine the irrigation efficiency (Xiong et al., 2021)

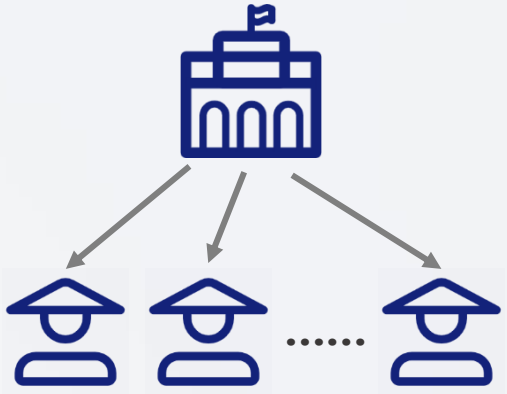
- **The expansion of irrigated land or a strong marginal yield response from additional water.**

  Studies that consider farmers' behavioral factors and economic mechanisms are few.

- **Clarifying farmers' irrigation behavior under different policies** would be a breakthrough in **revealing the economic mechanism of the irrigation efficiency paradox**.

Agent-based model

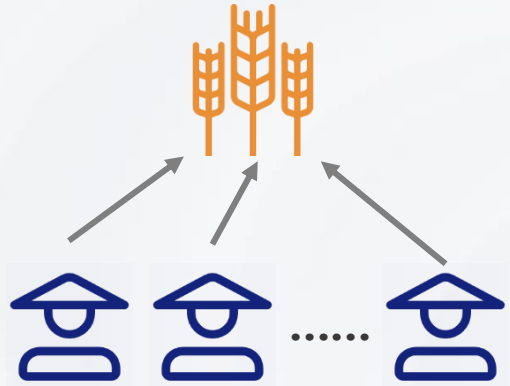
Agent-based model: An effective tool for modeling human responses to changing environments in complex systems. Individual actors are described as unique entities.



Top-down approach

Socio-hydrological models: managers' pursuits coincide with those of stakeholders.

An agricultural irrigation system is a complex adaptive system.
Individual decisions are inconsistent with centralized water managers.



Bottom-up approach

Agent-based model synthesizes the impacts of agent- and system-level behaviors and their interactions.

Agent-based socio-agro-hydrological (ABSAH) model

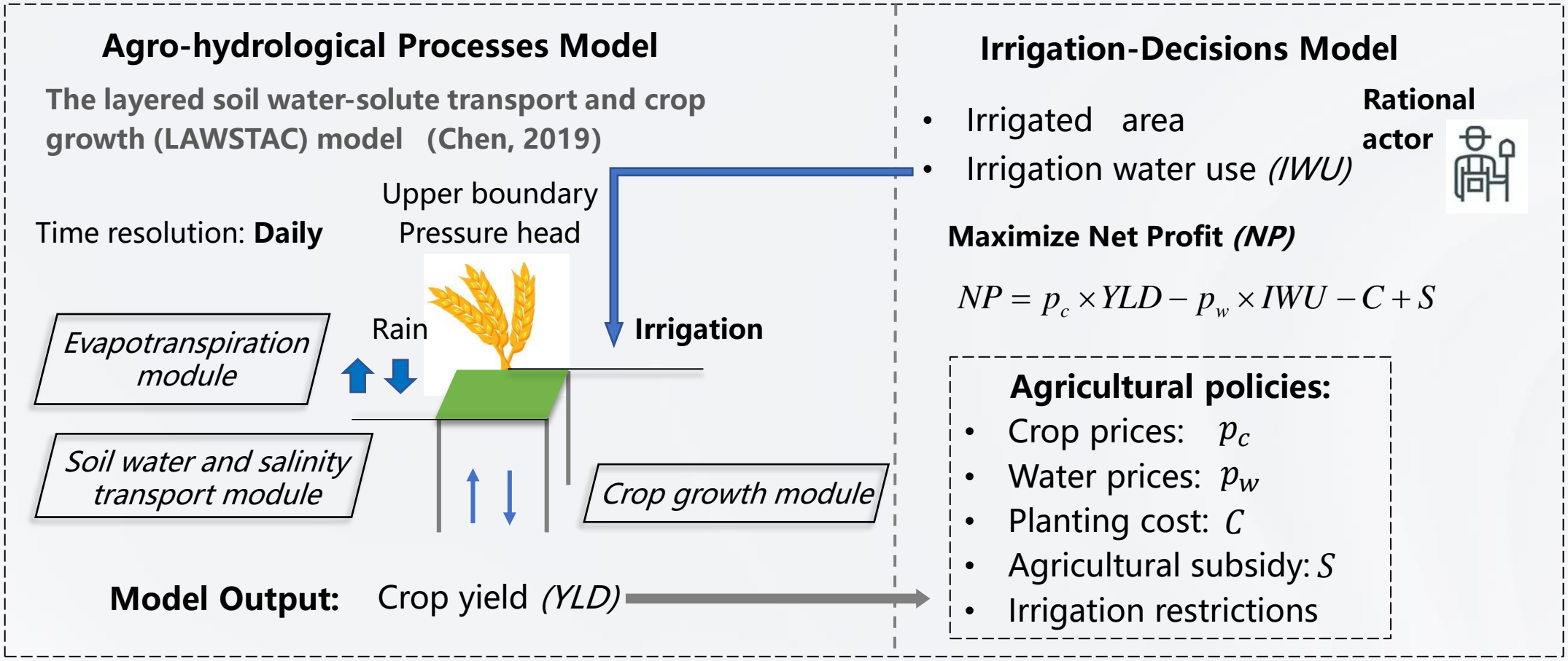


Figure 1. The overall structure of the proposed ABSAH model

Scenario settings

	Subject	Variable control		Purpose
		Water price (RMB/m^3)	Agricultural subsidy	
Scenario 1	 100×100m grid An individual farmer	0.01–0.05	None	The effects of water pricing on an individual farmer’ s irrigation behaviors and outcomes
Scenario 2	**2a**  **2b**  A farmland with multiple farmers	0.01–0.05	None	2a: With cultivated land area restriction 2b: Without cultivated land area restriction The effects of water pricing on farmland with multiple farmers
Scenario 3	 A farmland with multiple farmers	0.035	**3a** On water saving **3b** On the crop yield **3c** On the planting area	Examine the performance of three agricultural subsidy policies on a farmland

Effects of water pricing on an individual farmer's behavior

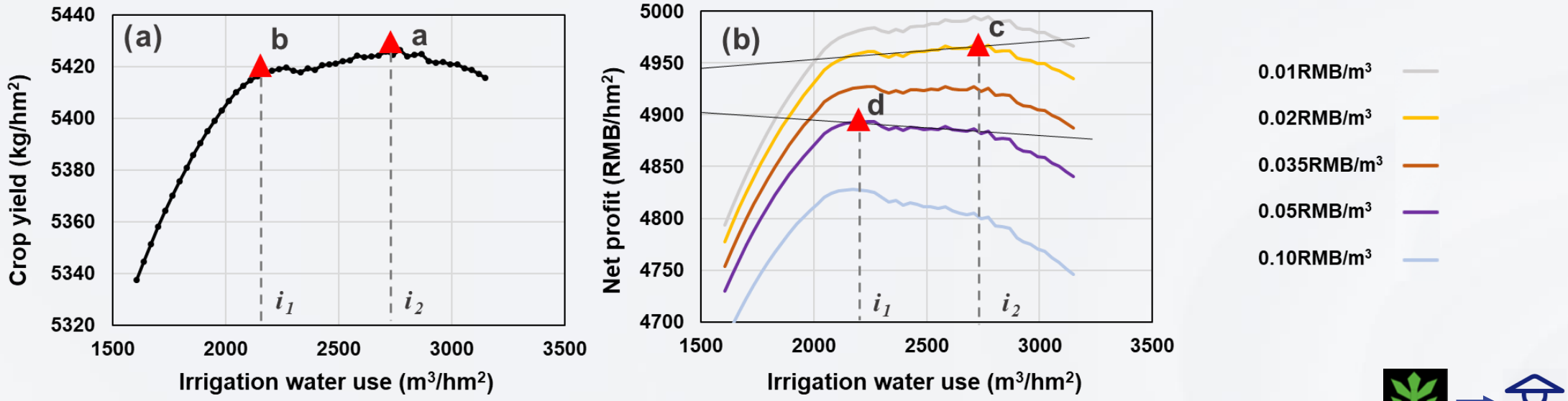


Figure 2. Effects of irrigation water use on farmer's behavior (a) the crop yield and (b) the net profit.

- The deficit irrigation strategy provides significant opportunities for water conservation without compromising food production.
- An appropriate increase in the water price reduces the optimal *IWU* to a more efficient level.

Effects of water pricing on an individual farmer's behavior

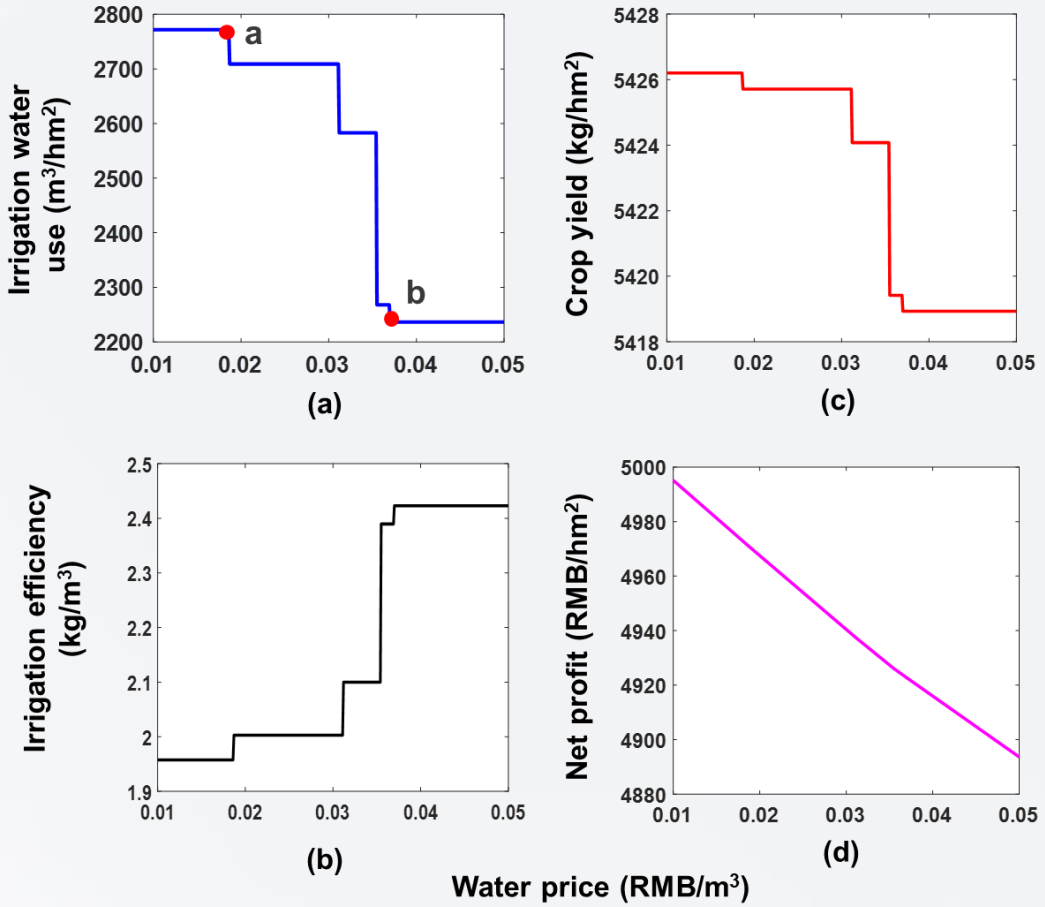
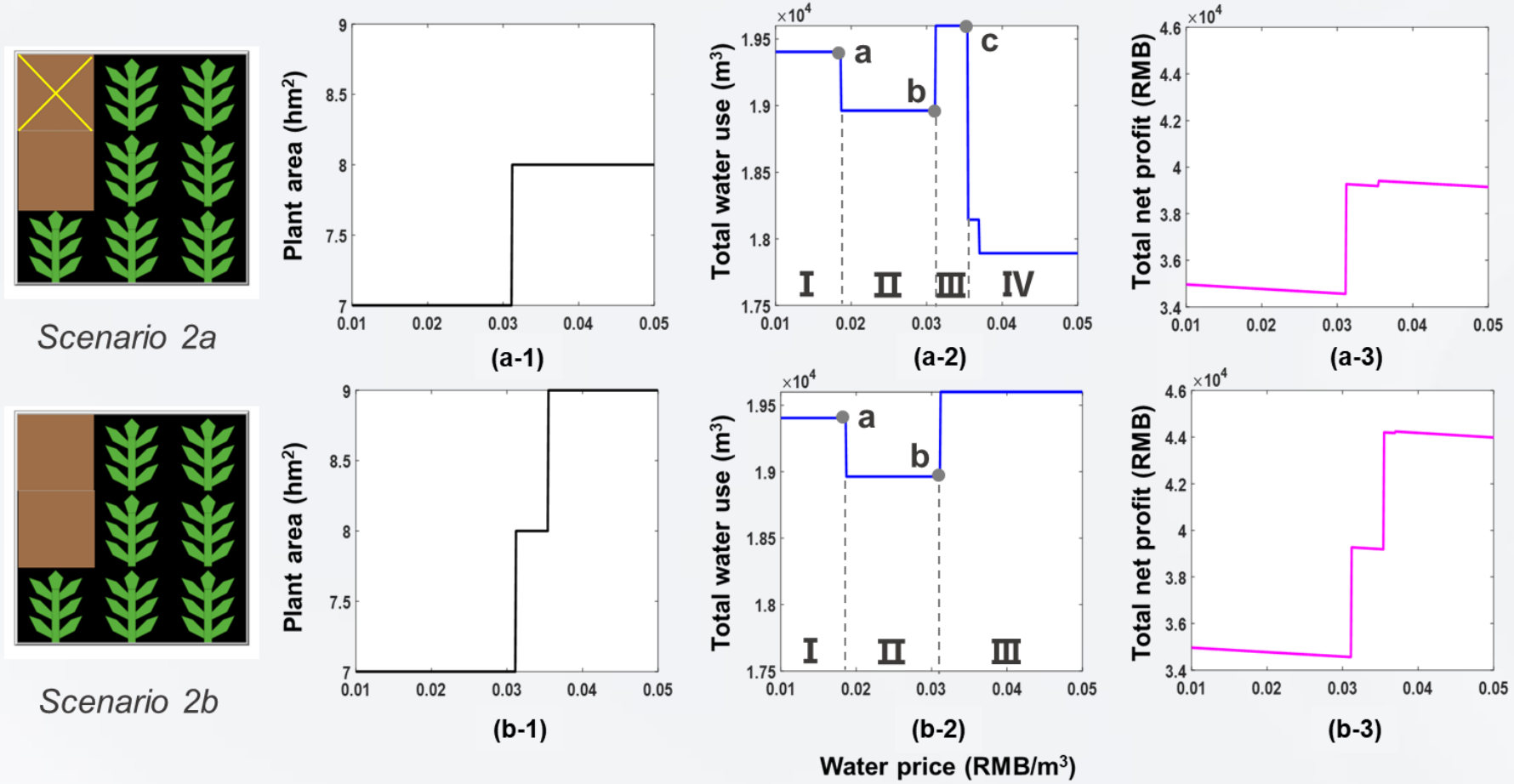


Figure 3. Effects of water pricing on (a) irrigation water use, (b) irrigation efficiency, (c) crop yield and (d) net profit.

Raise the water price from 0.01RMB/m³ to 0.05RMB/m³ in steps of 0.0001. Find the optimal irrigation water use.

- Raising water price helps to reduce water use and **improve irrigation efficiency.**
- **The adjustment range of water price is limited** (*0.019RMB/m³~0.037RMB/m³*).
- **Crop yield and net profit sustain losses when raising water price.**

Economic mechanism of irrigation efficiency paradox at farmland scale

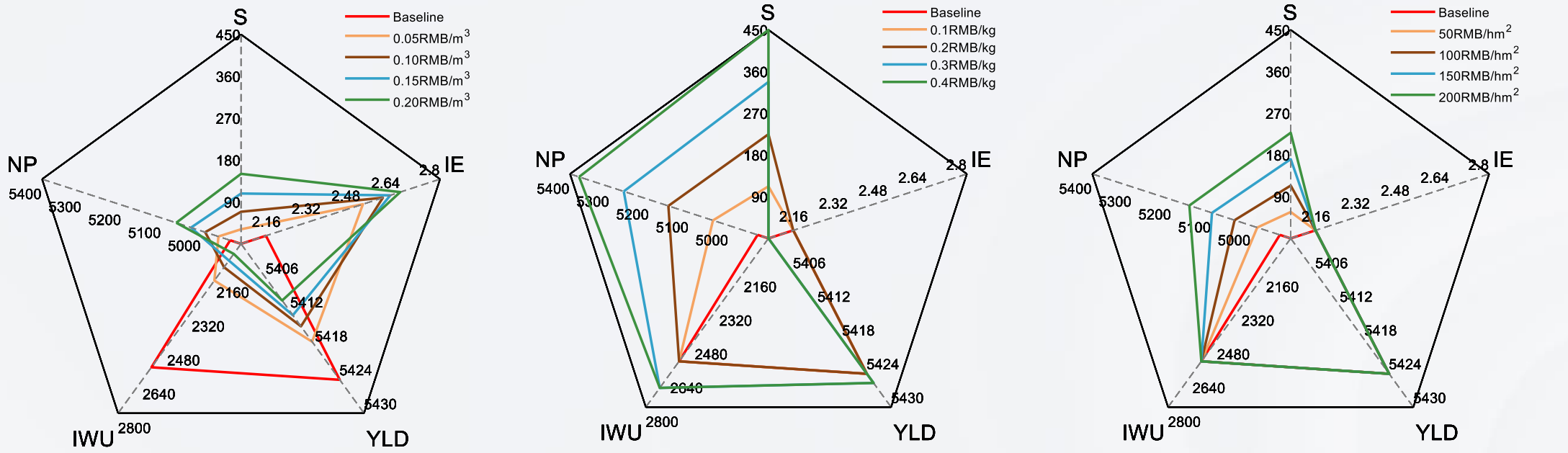


Inadequate increase in water price (efficiency) leads to increased water use.

Unrestricted expansion of cultivated land leads to increased water use.

Figure 4. (a) Effects of water pricing on the planting area, total water use, and total net profit with cultivated land area restriction. (b) Effects of water pricing on the planting area, total water use, and total net profit without cultivated land area restriction.

Performance of subsidy policies in resolving irrigation efficiency paradox



(a) the subsidy on water saving **(b) the subsidy on the crop yield** **(c) the subsidy on the planting area**

Figure 5. Effects of (a) water-saving subsidy, (b) crop yield subsidy, (c) planting area subsidy on NP, IWU, YLD, and IE. The vertexes of each subgraph represent the total subsidies (S), NP, IWU, YLD, and IE, respectively. The colored lines represent different subsidy scenarios.

- A subsidy for the planting area is more appropriate for achieving the dual goals of water saving and ensuring food security and farmers' income

Conclusion

Develop a model

- An **agent-based socio-agro-hydrological (ABSAH) model** that integrates (1) an agent-based model for farmers' irrigation decisions and (2) a physics-based one-dimensional agro-hydrological model was proposed.

Analyze the economic mechanism of the paradox

- The irrigation efficiency paradox can be attributed to (1) ***the insufficient efficiency growth*** and (2) ***unobstructed expansion of cultivated land***.

Propose policy portfolios for resolving the paradox

- ***Increasing water prices***, ***setting cultivated-land restrictions***, and ***providing subsidies for planting areas*** are recommended to achieve water-saving goals without compromising the crop yield or farmers' income.

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Thanks for listening!

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