China's sustainable food system requires concerted efforts

Using an integrated assessment modelling framework, this study finds that under current trends, most social and environmental targets related to the Chinese food system are not aligned with the UN 2030 Agenda. Bundling policies addressing public health, environmental sustainability and livelihood improvement can minimize trade-offs, revealing the importance of coordinated strategies for achieving a sustainable food system.

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The question

China's economic growth over the past decades has lifted millions of people out of poverty and hunger while reshaping its food system. However, this reorganization poses pressing challenges to public health, the environment and livelihoods[1] – for example, malnutrition leads to 2–3% gross domestic product loss, and food system inefficiencies cause 20% of greenhouse gas emissions[1] in the country.

Both the global development agenda and Chinese policymakers recognize the imperative of comprehensively transforming the food system for sustainable development[2,3]. Achieving a sustainable food system, framed as 'green' agriculture with high-quality development in the Chinese context, requires high standards not only for sustainable agricultural production but also in terms of food consumption and public health[1]. However, the feasibility of achieving future targets for the Chinese food system, as well as trade-offs and co-benefits, is still poorly understood.

The solution

We examined potential pathways for the sustainable development of the Chinese food system by assessing the combined health, environmental and socio-economic dynamics under multiple future scenarios. We used an integrated modelling framework, the core of which is MAgPIE-China (a China-specific version of the Model of Agricultural Production and its Impact on the Environment)[3–5], linked with several sectoral models to cover health and livelihood aspects. We also incorporated livelihood aspects to broaden our understanding of the impacts related to social progress.

Our study quantifies the social and environmental impacts of the Chinese food system transformation in 5 scenarios, in which we estimate the outcomes in terms of 18 indicators related to social and environmental impacts and highlight domains requiring urgent changes, such as reducing malnutrition, mitigating climate change and securing livelihoods. The food system is projected to remain a major driver of environmental and social damage under current trends, rendering the UN 2030 Agenda for the Sustainable Development Goals (SDGs) and the Paris Agreement unachievable even by 2050.

We further revealed potential trade-offs when pursuing strategies aimed at public health, environmental sustainability and livelihood improvement in isolation (Fig. 1). For example, efforts on climate change mitigation and ecological conservation lead to trade-offs such as an increase in low-income population. By contrast, a shift towards healthy diets exhibits the lowest level of trade-offs between public health, environment and livelihoods. Bundling measures across all three dimensions can generate co-benefits between public health, environmental sustainability and livelihood improvement, highlighting the importance of coordinated strategies for achieving a sustainable food system (Fig. 1).

The implications

Substantial social and environmental progress in the Chinese food system is contingent on the joint implementation of multiple measures spanning public health, the environment and livelihoods. Our model results highlight the need for a comprehensive and coordinated approach to address these interlinked challenges.

This study provides a detailed analysis of potential measures for transforming the Chinese food system and model-based insights on domains where urgent changes are needed. A sustainable food system can only be reached through coordinated governance because of the wide range of social and environmental problems connected to the food system. The food system needs diverse and varied policy instruments owing to its greater complexity compared with the energy system. Our findings support the establishment of a monitoring framework to inform future actions and policies for the Chinese food system transformation towards achieving the UN 2030 Agenda.

Our study addresses a subset of the potential social and environmental impacts of China's food system transformation. Future research should aim to include a more comprehensive representation of SDG indicators. We used a globally consistent poverty model to analyse poverty and inequality impacts, but future research incorporating more detailed national datasets may provide a deeper understanding. This study extends the assessment scope by including livelihoods, in addition to health and environmental impacts, which increases the complexity of conducting a systematic sensitivity analysis. We recognize that the uncertainty in model results needs to be considered in more detail. A comprehensive uncertainty analysis can be considered for future research.

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EXPERT OPINION

"This is an interesting and well-written paper that follows well-established methodologies and applies them to the context of China. The findings are important for domestic policymaking and provide broader lessons for other countries with regard to their food system transformation goals and approaches."
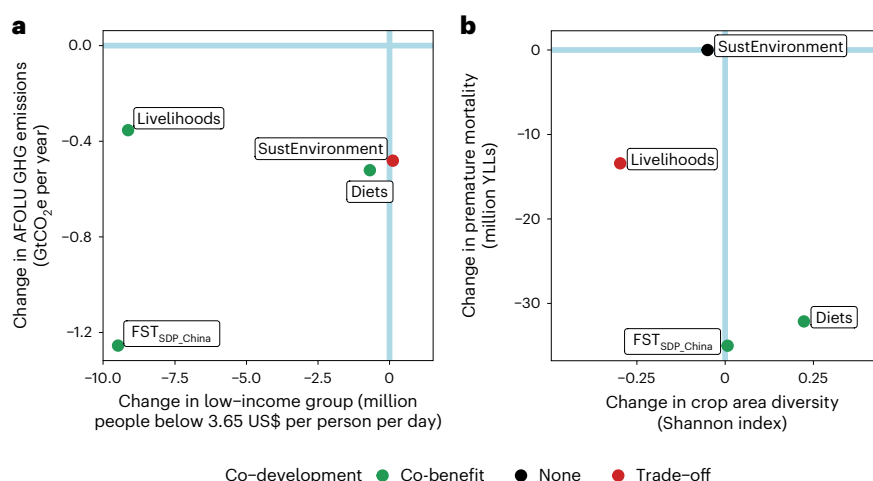**Kate Schneider, Johns Hopkins University, Washington, DC, USA.**

FIGURE

Fig. 1 | Co-development of indicators in the Chinese food system. Examples of estimated changes in two pairs of indicators compared with their baseline levels in 2050 (indicated by the light-blue lines). Coloured points represent how the changes in the indicators affect four scenarios: 'Diets', related to moving towards healthy and sustainable diets; 'Livelihoods', related to improving socio-economic conditions; 'SustEnvironment', related to promoting sustainable agriculture and climate change mitigation; and the Chinese food system transformation pathway ('FST_{SDP_China}'), which combines all previous scenarios. For example, the Livelihoods scenario results in co-benefit for reductions in both the greenhouse gas (GHG) emissions from agriculture, forestry and other land use (AFOLU) and the number of people in the low-income group (part **a**), whereas it causes a trade-off between reductions in years of life lost (YLLs) and crop area diversity (part **b**). GtCO$_2$e, gigatonnes of CO$_2$ equivalent. © 2025, Wang, X. et al.

BEHIND THE PAPER

The research was motivated by growing concerns about the sustainability of the Chinese food system amid rapid economic growth and evolving consumption patterns. Central to the project was the development of the China-specific version of the MAgPIE, led by X.W. and his MAgPIE-China team at Zhejiang University. Working closely with the MAgPIE team at the Potsdam Institute for Climate Impact Research, founded by H.L.-C., we created a holistic model, providing ground-breaking insights into potential pathways for food system transformation. By leveraging the strengths of both teams, we offered a more comprehensive understanding of sustainable development challenges. This decade-long partnership between our teams has brought together expertise from agricultural and environmental economics, public health, and agricultural sciences. Despite challenges during model validation, aligning model results with real-world data was rewarding. These insights can inform policies for transforming the Chinese food system towards sustainability. **X.W. & H.L.-C.**

REFERENCES

1. Wang, X., Bodirsky, B. L., Müller, C., Chen, K. Z. & Yuan, C. The triple benefits of slimming and greening the Chinese food system. *Nat. Food* **3**, 686–693 (2022).
   This paper presents a conceptual framework for transforming the Chinese food system towards sustainability.
2. UNFSS. Action tracks. *United Nations* https://www.un.org/en/food-systems-summit/action-tracks (2022).
   These action tracks from the 2021 Food Systems Summit indicate that the global development agenda recognizes the imperative of comprehensively transforming food systems for sustainable development.
3. Wang, X. et al. Reforming China's fertilizer policies: implications for nitrogen pollution reduction and food security. *Sustain. Sci.* **18**, 407–420 (2023).
   This paper reports that policymakers in China acknowledge the necessity of transforming the Chinese food system and presents the application of MAgPIE-China for assessing the impact of fertilizer policies reform.
4. Dietrich, J. P. et al. MAgPIE 4 – a modular open-source framework for modeling global land systems. *Geosci. Model Dev.* **12**, 1299–1317 (2019).
   This paper presents MAgPIE for studying global agricultural and land systems.
5. Lotze-Campen, H. et al. Global food demand, productivity growth, and the scarcity of land and water resources: a spatially explicit mathematical programming approach. *Agric. Econ.* **39**, 325–338 (2008).
   This paper presents a founding version of MAgPIE and its first application.

FROM THE EDITOR

"This study is comprehensive and includes health and poverty aspects, which are often overlooked. In addition, the authors looked into multiple food system pathways and associated trade-offs using a global modelling framework adapted to China."
Juliana Gil, Chief Editor, *Nature Food.*