Can sustainable intensification boost agricultural productivity and fertilizer use efficiency? Insights from wheat systems in the eastern Indo-Gangetic Plains

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1. Introduction

- Sustainable intensification (SI): process of producing more food from the same land without damaging environment [1].
- Early sowing of wheat is promoted as a SI strategy to increase productivity and minimize terminal heat stress in the Indo-Gangetic Plains (IGP) of South Asia [2,3].
- However, little is known about the fertilizer use efficiency impacts of early wheat sowing in the IGP.
- Excessive fertilizer application results lower fertilizer use efficiency and contribute to environment pollution, and climate change [4].
- SI technologies that increases fertilizer use efficiency are urgently required to minimize negative environmental impacts.
- This study assesses the impacts of early wheat sowing on nitrogen (NUE), phosphorous (PUE), and potash use efficiency (KUE), as well as productivity in the eastern IGP.

2. Study area & data

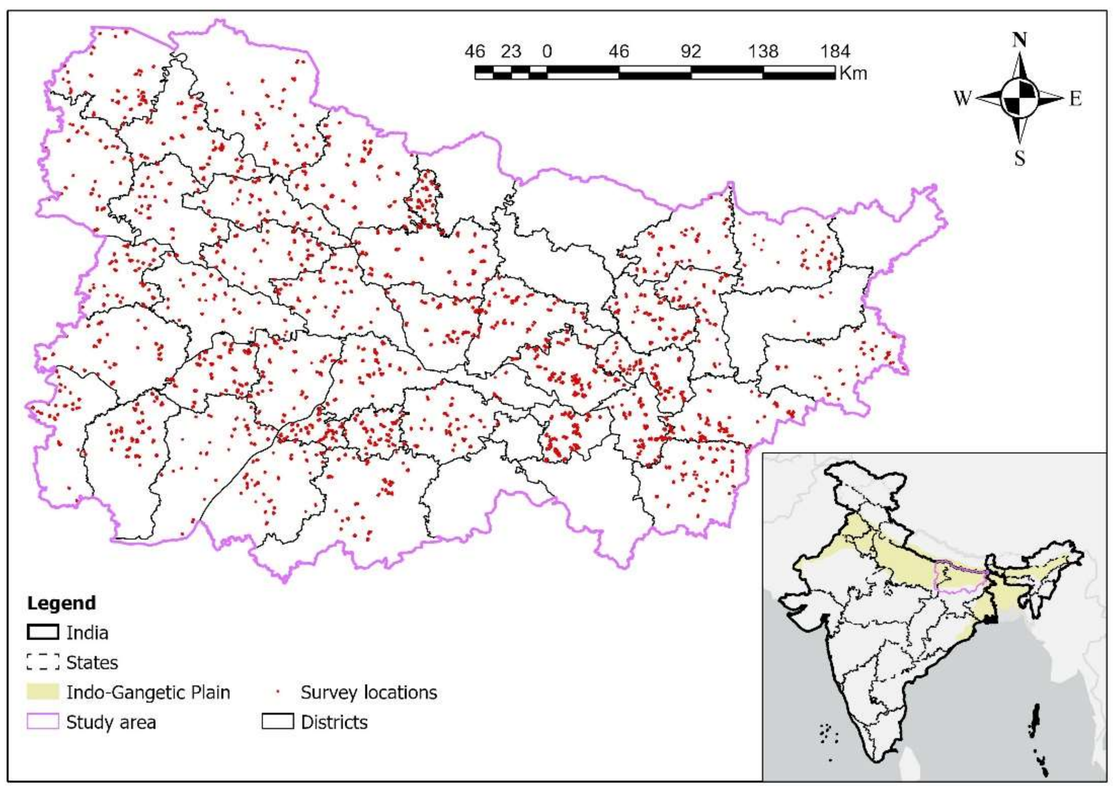

Fig. 1: The distribution of samples in the eastern IGP.

- 40 districts (8 - eastern UP & 32 - Bihar) selected for survey.
- Around 190 interviews in each district conducted based on probability proportionate sampling to village size.
- Overall, 7,214 wheat cultivating farms data used for analysis.
- Farmers largest plots GPS were recorded.
- Rainfall data (CHIRPS: 0.05°), temperature data (ERA5: 0.10°) and soil data (ISRIC: 0.25°) were integrated with survey data.

3. Empirical model

- Early sowing (i.e., before 21st November) is endogenous due to farmers risk aversion, managerial skills etc.
- We used heteroscedasticity based instrumental variable (IV) approach to control for endogeneity following Lewbel (2012) [5].

$$Y_i = \lambda + \phi ES_i + \theta X_i + \varepsilon_i \qquad (1)$$

$$ES_i = \varphi + Y_i + \pi Z_i + \xi_i \qquad (2)$$

- Y_i = outcome variables for the i^{th} household
- ES = early sowing dummy; λ=constant; ε_i = random error
- X_i = farm, crop management, soil, and climate variables
- $Z_i \leq X_i$ (internal instruments); ξ_i= residuals
- External instrument: amount of rainfall in the lag season

4. Results

- After controlling for all the control variables, we find a strong positive and significant effect of early sowing on wheat productivity, NUE, PUE, and KUE.

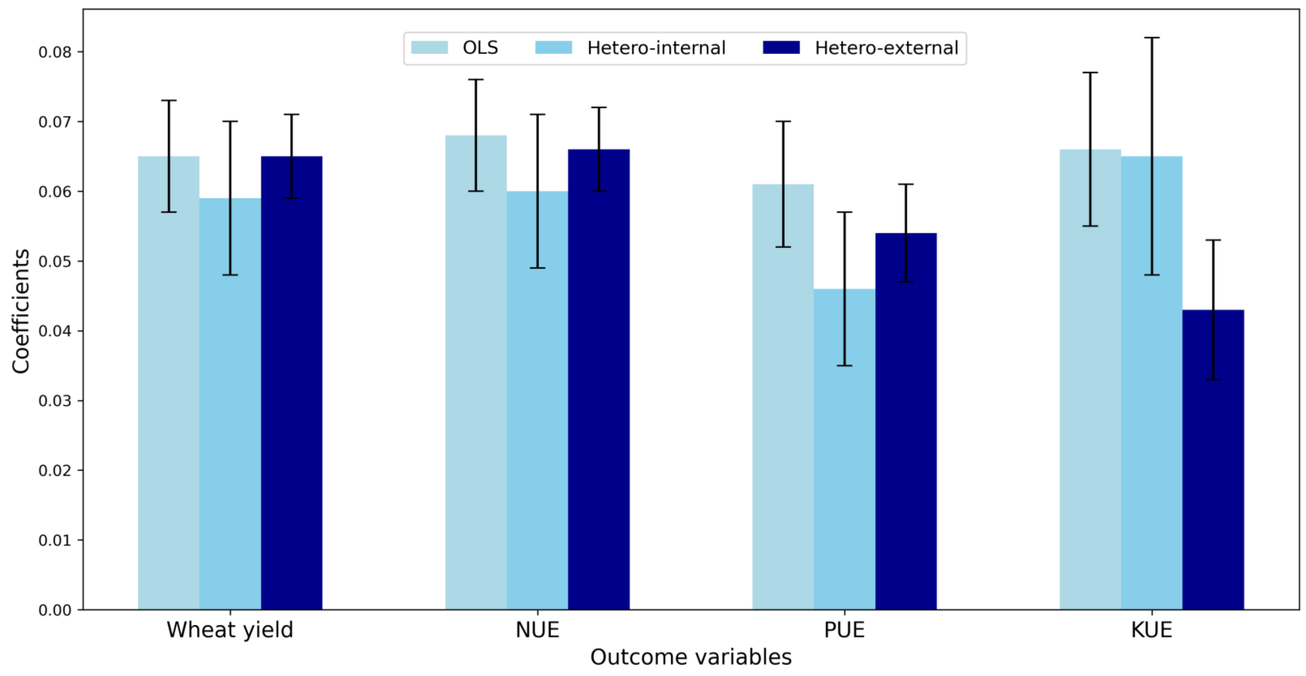

Fig. 2: The impact of early wheat sowing on productivity, NUE, PUE, & KUE.

- However, the impact magnitude of the coefficients are significantly smaller for large farms (>1.2 ha) compared to average or small farms.

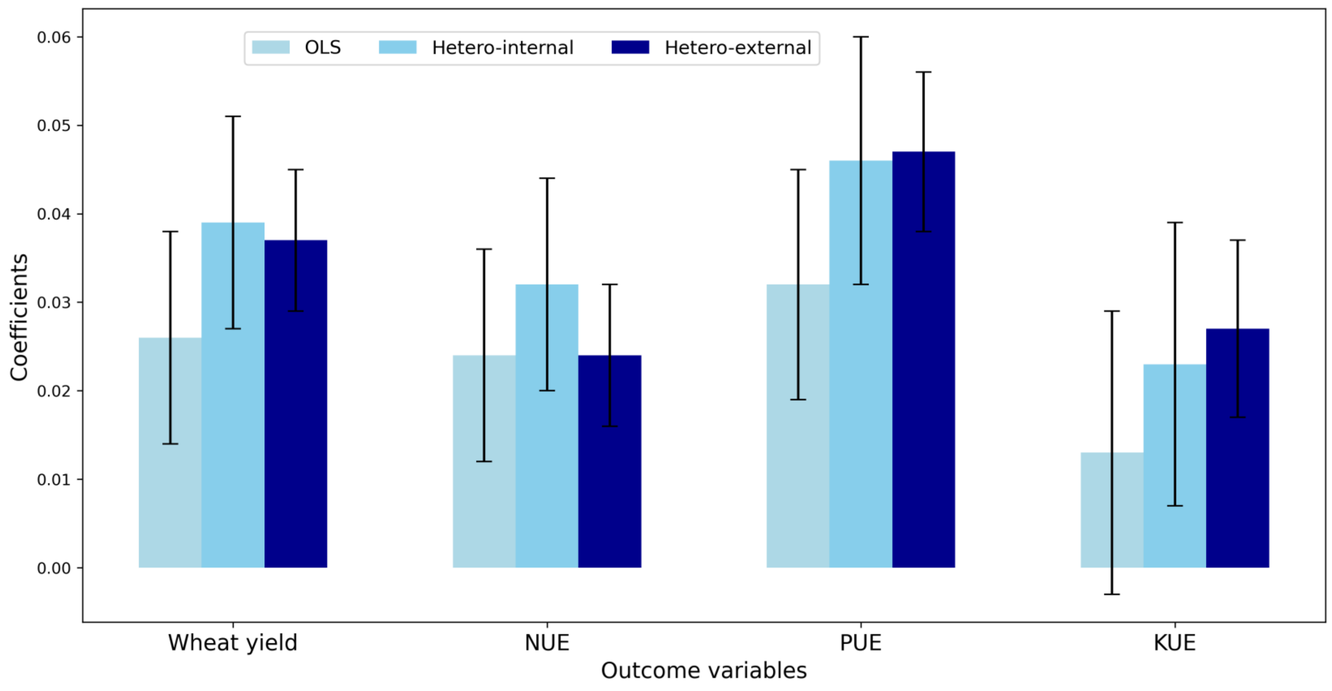

Fig. 3: Heterogeneous impact of early wheat sowing across farm size.

- We also find that farms applying higher doses (i.e., higher than states recommendation) of fertilizers also have significantly smaller coefficients compared to average or small farms.
- Our results on the test diagnostic also suggest that we adequately control the endogeneity issues.

5. Conclusion & implications

- Early wheat sowing in the eastern IGP significantly enhances wheat productivity, NUE, PUE, and KUE.
- Larger and high doses of fertilizer applying farms are less efficient and benefited less from early wheat sowing.
- Higher fertilizer doses cause nutrient losses (e.g., leaching, denitrification, and volatilization) and environmental pollution [4].
- Policy initiatives are required to promote early wheat sowing while limiting excessive fertilizer application rates in eastern India.

References

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