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Assessing key drivers in shaping farmers' decision towards crop species diversity across Indian districts and agroecological zones

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Abstract

India, an agrarian country, is highly vulnerable to climate variability, particularly fluctuations in temperature and precipitation. Agrobiodiversity, especially higher crop species diversity (CSD), is considered a potential adaptation strategy that enhances the resilience of the agricultural system against climatic stress. Although several studies have examined climatic variables separately, very limited empirical studies have quantified CSD in relation to climate variability, at both national and sub-national scales in India. This study addresses this gap by analysing the spatiotemporal pattern of CSD across 625 districts grouped into 20 agroecological zones over 23 years (1997–2019), evaluating the impacts of heatwaves, rainfall deficit and irrigation intensity on farmers' crop diversification decisions. CSD was quantified using the Shannon index; heatwaves and rainfall deficit were measured as total heat spell days and standardised rainfall anomaly, respectively. Irrigation was measured as irrigation intensity, a key management variable representing farmers' adaptation capacity. Trend analysis was performed using the MMK test and Sen's slope, while Pearson correlation and the dynamic panel system GMM identified the dominant drivers. Results revealed that CSD exhibits a slow yet significant increase, alongside a strong increase in irrigation intensity ($+1.081\,\text{year}^{-1}$), heatwave days ($+0.220\,\text{days year}^{-1}$), and rainfall deficit ($+0.020\,\text{year}^{-1}$). About 24 % of districts showed a significant increase in CSD, mainly in Southern Peninsular India (agroecological zones - AEZs 3, 6, 7, 8), whereas 23 % showed a significant decline, mostly in the western and south-eastern regions (AEZs 11, 12, 18). Heatwave exhibited the strongest negative relationship with CSD, whereas irrigation showed a positive association. Nearly 42 % districts were identified as vulnerable to heatwaves, particularly the western region (AEZ 2 and 4). System GMM further revealed that lagged CSD ($\text{CSD}\,\text{t}^{-1}$) positively influenced current CSD. Lagged heatwave reduced CSD, whereas lagged irrigation positively supported CSD, highlighting that current crop choices are strongly shaped by past climatic exposure and management conditions. The findings establish heatwaves as the strongest climatic constraint, rainfall deficit as a region-specific stress factor, and irrigation as the most effective adaptation mechanism, highlighting the need for region-specific adaptation policies to build climate-resilient agricultural systems.

Keywords: Generalised method of moments (GMM), heatwaves, irrigation intensity, modified Mann-Kendall (MMK) test, rainfall deficit, shannon index

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