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Determinants of Food Insecurity in Africa and Asia: A Comparative Analysis

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HIGHLIGHTS

- Higher cereal productivity consistently reduced food insecurity, precision agriculture adoption enhanced efficiency and food security, and climate adaptation reduced vulnerability; GHG emissions increased insecurity.
- Agricultural R&D investment showed strong food-security gains.
- Africa–Asia cooperation is critical for resilient food systems.

ARTICLE INFO

Keywords: Food insecurity, Precision agriculture adoption, Climate adaptation, Environmental sustainability, Africa–Asia cooperation.

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ABSTRACT

Food insecurity remained a persistent challenge in Africa and Asia due to interacting agricultural, technological, climatic, and environmental factors. The study conducted during 2025 examined the determinants of food insecurity across selected African and Asian countries using cross-country data from 2020 to 2024. It assessed the effects of agricultural productivity, technological adoption, research investment, climate adaptation spending, and environmental pressure on food insecurity. A quantitative cross-sectional design was employed, and data were analysed using Pearson's correlation and multiple linear regression. The results indicated that cereal yield, precision agriculture adoption, research and development expenditure, and climate adaptation spending showed significant negative associations with food insecurity. In contrast, greenhouse gas emissions and higher agricultural value added exhibited positive associations. The regression model explained 82 per cent of the variation in food insecurity, indicating strong explanatory power. The findings demonstrated that productivity enhancement, technological diffusion, research investment, and climate-responsive measures were critical determinants of reduced food insecurity across the selected countries.

INTRODUCTION

Food insecurity continues to be a persistent structural challenge, particularly in Africa and Asia, where a substantial proportion of the world's smallholder farmers and malnourished populations reside (FAO, 2023; World Bank, 2024). While earlier discourse primarily emphasized aggregate food production shortfalls, contemporary scholarship recognizes food security as a multidimensional outcome shaped by agricultural productivity, technological capacity, environmental sustainability, and climate resilience (Jin et al., 2024; van Dijk et al., 2025). Variations in these structural determinants have contributed to uneven progress toward sustainable food and nutrition security across both regions. Agricultural productivity, especially cereal yield, remains a fundamental determinant of food availability and access. Empirical evidence consistently shows that yield-enhancing interventions and sustained productivity growth reduce vulnerability to food insecurity, particularly in smallholder-dominated systems (Hazell et al., 2010; Ravi et al., 2023; Bharat et al., 2022; Kumbhare et al., 2023). Beyond production gains, technological innovation has emerged as a key driver of efficiency, risk mitigation, and resilience. Studies on precision agriculture adoption report improvements in input-use efficiency, yield stability, and resource optimization

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(Lowenberg-DeBoer & Erickson, 2019; Kendall et al., 2021; Nowak, 2021; Pandeya, 2025). These findings align with diffusion theory, which emphasises the role of innovation characteristics and institutional support in shaping adoption outcomes (Rogers, 2003; Baliwada et al., 2017; Kademani et al., 2026). Complementing technological diffusion, sustained investment in agricultural research and development (R&D) generates significant social returns through productivity enhancement, knowledge spillovers, and long-term system resilience (Copenhagen Consensus, 2023; Jin et al., 2024).

Climate variability and environmental degradation further complicate food security dynamics. Evidence from diverse agro-ecological contexts demonstrates that erratic rainfall, rising temperatures, and land degradation increase production risks and household vulnerability (Meena et al., 2022; Sarkar et al., 2022). Investments in climate adaptation measures, including climate-smart agricultural practices, have been associated with improved resilience and dietary outcomes (Madaki et al., 2024; Shin et al., 2024). In contrast, environmentally unsustainable agricultural intensification, particularly greenhouse gas (GHG) emissions, poses long-term threats to food system stability (Pretty et al., 2011; Baraj et al., 2024). These interrelated factors underscore the need to examine productivity growth, technological advancement, adaptation investment, and environmental pressure within an integrated analytical framework.

Despite extensive scholarship, important gaps persist. Much of the literature remains region-specific, focusing separately on African or Asian contexts, or concentrates on micro-level analyses of household food security and localized adoption behaviour (Gautam & Jha, 2022; Jairu et al., 2023; Imrankhan Jiragal et al., 2025). Comparatively fewer macro-level studies integrate agricultural productivity, technological diffusion, research investment, climate adaptation, and environmental sustainability within a unified cross-country empirical model. Consequently, consolidated comparative evidence explaining how these structural determinants jointly influence food insecurity across Africa and Asia remains limited.

Addressing this gap, the present study conducted a cross-country comparative analysis using data from 2020–2024 to examine the combined effects of agricultural value added, cereal yield, R&D expenditure, precision agriculture adoption, climate adaptation spending, and GHG emissions on food insecurity across selected African and Asian nations.

METHODOLOGY

The study employed a quantitative cross-sectional design based on secondary data to examine the determinants of food insecurity across selected African and Asian countries for the period 2020–2024. Cross-country analysis was adopted to capture regional variation and enable comparative assessment of structural determinants. Data were compiled from internationally recognized databases, including the Food and Agriculture Organization (FAO), World Bank World Development Indicators, Consultative Group on International Agricultural Research (CGIAR), United Nations Environment Programme (UNEP), and the International Food Policy Research Institute (IFPRI). These sources provide standardized and internationally comparable indicators widely used in food security and agricultural policy research.

A total of 15 countries (10 Asian and 5 African) were included based on data availability for all study variables during the reference period. Food insecurity, measured as the percentage of the population experiencing moderate to severe food insecurity, was treated as the dependent variable. Independent variables included agricultural value added (% of GDP), cereal yield (kg/ha), research and development (R&D) expenditure (% of GDP), precision agriculture adoption (%), climate adaptation spending (% of agricultural GDP), and greenhouse gas (GHG) emissions (tonnes per hectare). These indicators were selected to represent productivity, technological advancement, research investment, climate resilience, and environmental pressure dimensions.

Descriptive statistics were computed to examine regional patterns. Pearson's correlation analysis was used to assess bivariate associations among variables. To estimate the combined influence of explanatory variables on food insecurity, multiple linear regression using the ordinary least squares (OLS) method was applied. The model specification was:

$$\text{Food Insecurity} = \beta_o + \beta_1 \bullet (\text{Agri Value Added}) + \beta_2 (\text{Cereal Yield}) + \beta_3 (\text{R\&D Expenditure}) + \beta_4 (\text{Precision Agriculture Adoption}) + \beta_5 (\text{Climate Adaptation Spending}) + \beta_6 (\text{GHG Emissions}) + \varepsilon$$

where β_o represented the intercept, β_1 to β_6 denoted regression coefficients of the respective predictors, and ε represented the error term.

RESULTS

The results of the cross-country analysis highlighted significant regional differences in food insecurity, agricultural performance, technological adoption, and environmental indicators across the selected African and Asian countries during the period 2020–2024.

The determinants of food insecurity were first examined through multiple regression analysis to assess the combined influence of productivity, technological, research, climate, and environmental variables. The regression results (Table 1) demonstrated strong explanatory power, with the model accounting for a substantial proportion of cross-country variation in food insecurity during 2020–2024. Cereal yield, research and development (R&D) expenditure, precision agriculture adoption, and climate adaptation spending exerted statistically significant negative effects, confirming that productivity enhancement, technological diffusion, and adaptive investment function as protective structural factors.

Table 1. Regression estimates for determinants of food insecurity

Predictor	Coefficient (β)
Intercept	32.10
Agricultural value added (% GDP)	+0.12[b]
Cereal yield (kg ha^{-1})	-0.0042[a]
R&D expenditure (% GDP)	-3.80[a]
Precision agriculture adoption (%)	-0.25[a]
Climate adaptation spending (% agri GDP)	-0.90[b]
GHG emissions (t ha^{-1})	+4.10[a]

Model statistics: $R^2 = 0.82$; F-statistic = significant at $p < 0.01$; Durbin–Watson = 2.1, [a]Significant at $p < 0.01$; [b]Significant at $p < 0.05$

Among these, R&D expenditure and precision agriculture adoption showed comparatively stronger effects, underscoring the importance of innovation systems and modernization in reducing food insecurity. Conversely, greenhouse gas (GHG) emissions exhibited a statistically significant positive effect, indicating that higher emission intensity was associated with increased food insecurity after controlling for other factors. Agricultural value added (as a percentage of GDP) also showed a positive association, suggesting that structural dependence on agriculture, without sufficient technological upgrading or diversification, may heighten vulnerability. The Durbin–Watson statistic indicated no evidence of autocorrelation, supporting model reliability (Table 2).

Table 2. Correlation between food insecurity and key variables

Variables	Correlation (r)
Food insecurity – Cereal yield	-0.78[a]
Food insecurity – Precision agriculture adoption	-0.72[a]
Food insecurity – R&D expenditure	-0.60[b]
Food insecurity – Climate adaptation spending	-0.55[b]
Food insecurity – GHG emissions	+0.70[a]
Food insecurity – Agricultural value added (% GDP)	+0.50[b]

[a]Correlation significant at $p < 0.01$; [b]Correlation significant at $p < 0.05$.

To examine the direction and strength of association between food insecurity and selected agricultural, technological, and environmental variables, Pearson's correlation analysis was conducted (Table 2). The results revealed strong negative associations between food insecurity and cereal yield as well as precision agriculture adoption, reinforcing the central role of productivity and technology in food system stability. R&D expenditure and climate adaptation spending were moderately and negatively associated with food insecurity, while GHG emissions showed a strong positive association. These bivariate patterns were consistent with the regression findings, indicating structural coherence across analytical levels.

Descriptive statistics (Table 3) highlighted notable regional disparities between African and Asian countries. On average, food insecurity levels were higher in the selected African countries, accompanied by lower technological adoption and research investment. Asian countries generally demonstrated higher cereal productivity and greater diffusion of precision agriculture technologies, alongside moderately stronger climate adaptation spending. These structural contrasts provide contextual grounding for the regression and correlation results.

Overall, the integrated findings indicate that food insecurity across Africa and Asia is systematically shaped by differences in agricultural productivity, technological advancement, research investment, climate responsiveness, and environmental sustainability.

Table 3. Regional comparison of food insecurity and key indicators

Region	Food insecurity (%)	Precision agriculture adoption (%)	R&D expenditure (% GDP)
Asia	13.2	27	0.7
Africa	24.8	11	0.5

Africa and Asia; mean values, 2020–2024

DISCUSSION

The findings demonstrate that structural determinants, particularly agricultural productivity, technological diffusion, research investment, climate adaptation, and environmental sustainability, systematically shaped food insecurity across the selected African and Asian countries. Rather than reflecting isolated production shortfalls, food insecurity appeared strongly associated with broader innovation and resilience capacities. The negative association between cereal yield and food insecurity confirms that staple crop productivity remains a foundational driver of food availability and access, particularly in systems dominated by smallholder agriculture. This aligns with earlier evidence showing that sustained productivity growth reduces structural vulnerability (Hazell et al., 2010; Ravi et al., 2023). However, the regression results indicate that productivity alone was not sufficient; its protective effect operated alongside technological and institutional factors.

Precision agriculture adoption and R&D expenditure showed comparatively strong negative effects, underscoring the role of innovation systems in stabilizing food outcomes. This supports literature emphasizing the efficiency gains and risk-reduction benefits of technological modernization (Lowenberg-DeBoer & Erickson, 2019; Kendall et al., 2021; Shitu and Nain, 2024) and the long-term social returns of agricultural research investment (Jin et al., 2024). The results suggest that countries with stronger research ecosystems and higher technological diffusion were better positioned to mitigate food insecurity, reinforcing the argument that structural transformation, rather than input intensification alone, underpins resilience. Climate adaptation spending also exhibited a protective association, consistent with findings that climate-responsive agricultural measures reduce vulnerability to production shocks (Madaki et al., 2024; Shin et al., 2024). However, the magnitude of this effect was moderate, indicating that adaptation complements but does not substitute for productivity and innovation investments.

In contrast, greenhouse gas emissions were positively associated with food insecurity, suggesting that environmentally unsustainable intensification may undermine long-term food system stability. This finding is consistent with sustainability literature highlighting the risks of emission-intensive growth pathways (Shitu et al., 2018; Pretty et al., 2011; Baraj et al., 2024). Similarly, the positive association between agricultural value added and food insecurity implies that economic dependence on agriculture, without adequate modernization or diversification, may increase exposure to systemic shocks. The results support an integrated policy orientation that combines productivity enhancement, technological upgrading, research investment, and sustainability measures within a coherent food system framework.

CONCLUSION

The study establishes that food insecurity across Africa and Asia is systematically shaped by differences in agricultural productivity, technological adoption, research investment, climate adaptation efforts, and environmental sustainability. The findings confirm that higher cereal yields, greater diffusion of advanced agricultural technologies, increased investment in agricultural research, and stronger climate adaptation measures consistently correspond to lower food insecurity, while environmentally unsustainable practices and excessive reliance on agriculture without diversification intensify vulnerability. These results validate the central hypothesis that innovation-driven and climate-resilient agricultural systems form the foundation of sustainable food and nutrition security. The study further demonstrates that regional disparities in food insecurity reflect unequal access to technology and research capacity, underscoring the practical importance of cross-regional cooperation. Strengthening collaborative knowledge exchange, innovation partnerships, and climate-responsive agricultural strategies emerges as an essential pathway for building resilient food systems and advancing long-term food, nutrition, environmental, and health security.

DECLARATIONS

Ethics approval and informed consent: Informed consent was sought from the respondents regarding the study during the course of the data collection.

Conflict of interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest. The authors declare that during the preparation of this work, they thoroughly reviewed, revised, and edited the content as needed. The authors take full responsibility for the final content of this publication.

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