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Research Article

Food Security as A Geopolitical Challenge: India's Role in Building Resilient and Sustainable Global Food Systems

Surjit Singh

Trained Graduate Teacher at Govt. Co-ed. Secondary School, West Azad Nagar, Delhi, under Directorate of Education, Government of NCT of Delhi, New Delhi, India

Corresponding Author: * Surjit Singh

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Abstract

As armed conflicts, climate change, trade restrictions, supply chain disruptions, resource scarcity, and volatile food prices threaten food systems worldwide, the issue of food security has gained renewed geopolitical significance. This review paper attempts to conceptualize the issue of food security within the framework of International Relations by focussing on India's emerging role as a provider of resilient and sustainable global food systems. The paper tries to analyse the shift of food as an issue from development and agricultural sector-centric to its current status as a strategic good linked to statecraft, geopolitics, economic interdependence, and national security. The Paper analyse the Russia-Ukraine war, climate disasters, export bans, and disruptions in energy, fertilizers, and maritime logistics, as factors that have reshaped global food security. In its first part, the paper looks at India's food security situation, including agricultural production, public distribution, food availability, climate change, groundwater depletion, and malnutrition. However, the second part focusses on India's use of its emerging status as a global food provider in its geopolitical strategies and examines India's food diplomacy in G20 and South-South partnerships. The study contends that India can play a pivotal role in building strategic food security through a combination of diversified production, climate-smart agriculture, sustainable groundwater management, digitalization of agriculture, reduction of food loss and waste, and trade for food security to build resilient food systems both within and outside the country. The paper recommends that India's future role in global food security discourse moves beyond being a food bowl for others to engage in food diplomacy to shape global food governance to make international food systems more inclusive, resilient, and sustainable.

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KEYWORDS: Food Security; Geopolitics; India; Global Food Governance; Climate Resilience; Food Diplomacy.

1. INTRODUCTION

Food security has evolved from an issue relating to one's nation or humanity to an important component of international security, statecraft and governance. The food system is open to geopolitical competition, violence, division in trade, climatic disasters, fluctuations in prices of energy and problems in transport and input supplies, thus access depends more on international relations than food production, with food insecurity persisting in the face of surplus in global agriculture demonstrating how the source of food insecurity has changed from that of lack to that of unequal access, affordability and supply and political disruptions. The Russia–Ukraine war, for example, affected wheat, maize, vegetable oil, fertilizer and energy supplies, while restrictions further added to uncertainty in stressed commodity markets. Research finds that Russia and Ukraine supplied roughly 12% and 17% of global wheat exports respectively before the conflict, indicating the systemic vulnerabilities for food-importing states due to the concentration of agricultural trade. As restrictions peaked in 2022, they covered roughly 17% of globally traded food and feed calories, illustrating the effect national measures to address domestic food-security concerns can have on food-importing countries. Conflict makes food security a geopolitical issue since access to production, transport corridors, fertilizers, export markets and humanitarian access determines states' resilience and negotiating power.

The impacts of climate change intensify geopolitics of food security through posing risks to food production through its impact on the agricultural productivity and availability of water and ecology involved in the process of food production. Agrifood production is responsible for one-third of anthropogenic greenhouse-gas emissions in the world, while agriculture consumes about 70% of total freshwater withdrawals in the world, creating conflicts between food production, sustainability and climate change. The cost of invisible economic, environmental and health problems associated with agrifood systems equals around US\$11.6 trillion at purchasing power parity in 156 countries, revealing the unsustainability of systems that focus on production and economic value instead of well-being.

In this international context, Indian position is increasingly important as the size of its agriculture sector entails both domestic and international responsibilities. India produced about 357.73 million tonnes of foodgrains in 2024–25, nearly 8% more than the previous year, with rice output amounting to roughly 150.18 million tonnes, while wheat production came

to about 117.94 million tonnes, with India leading the world in pulses and millets, with production of approximately 25.68 million tonnes of pulses and 18.59 million tonnes of millets in 2024–25, and its rice exports valued at about US\$12.95 billion in 2024–25, with India's rice exports of around 20.1 million metric tonnes reaching over 172 countries, roughly 28% of global rice output, meaning that Indian agricultural policy has considerable implications for international food availability and prices.

The policy dilemma, however, associated with India's position is in terms of protecting the domestic food security and preserving the global markets. The export restrictions, state stockpiling and prices control create resilience of domestic food system under uncertain conditions but have market consequences and may result in increasing vulnerability of food importers among the developing nations. This policy dilemma has been mentioned in the G20 New Delhi Leaders' Declaration which emphasized on the need for climate-resilient and nutritious food, reducing losses and waste, enhancing productivity along with open and fair agricultural trade in line with WTO principles. India's significance is not only due to high levels of production but also because of the ability to link the resilience of domestic agriculture sector to the multilateral food diplomacy, South-South cooperation and sustainable innovation and governance.

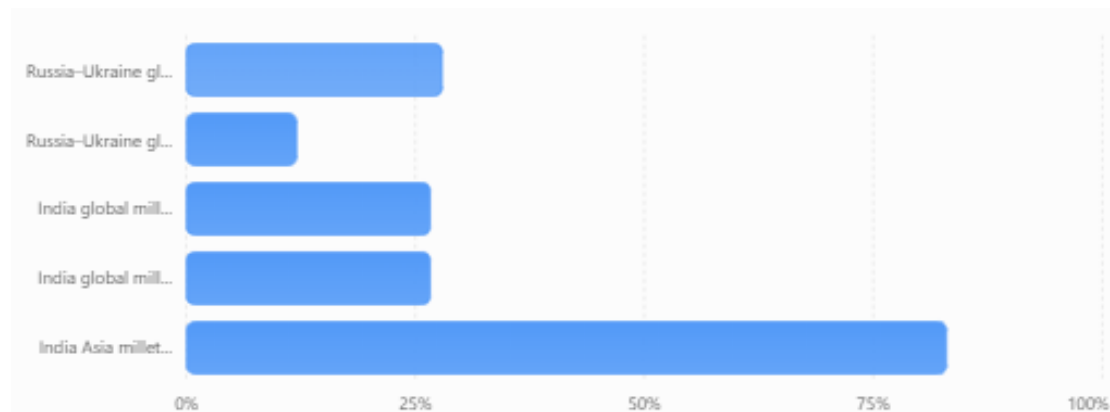
1.1 From Food Availability to Geopolitical Food Security: Evolving Global Risks

Food security traditionally focused on food availability as a fundamental pillar of community health but has evolved to include the dimensions of access, affordability, resilience and strategic autonomy. Recent research indicates that the interlinked nature of food markets means that the food security of a state is increasingly contingent upon its policy and exposure to geopolitical and commercial risks occurring elsewhere (Hellegers, 2022, pp. 1503–1510). The Russia–Ukraine war is a pertinent example, as the two countries provided roughly 28% of internationally traded wheat in 2020, and their agricultural exports represented around 12% of internationally traded calories, posing a significant risk to states reliant on importing food (Hellegers, 2022, pp. 1505–1507). Food security should be considered in a geopolitical context, where strategic dependence, market concentration and state capacity play crucial roles in determining exposure to risk, rather than just focusing on domestic production as the sole determinant of risk (Glauben et al., 2022, pp. 157–163).

Table 1. Selected Statistical Indicators Demonstrating the Geopolitical Vulnerability of Global Food Systems

Indicator	Statistical evidence	Geopolitical significance	Supporting research
Russia–Ukraine share of global wheat trade	27.9% in 2020	High exporter concentration creates systemic vulnerability for import-dependent states	Hellegers (2022), pp. 1505–1507. https://doi.org/10.1007/s12571-022-01306-8
Russia–Ukraine share of globally traded calories	≈12% in 2020	Disruption can propagate beyond bilateral markets into global food availability	Hellegers (2022), pp. 1506–1507. https://doi.org/10.1007/s12571-022-01306-8
Potential additional population facing undernourishment after Russia–Ukraine shock	67.3 million	Demonstrates the international transmission of geopolitical conflict into nutrition insecurity	Guan et al. (2022). https://doi.org/10.1007/s43621-022-00112-8

Potential population exposed to extreme national food insecurity	316.7 million	Illustrates the disproportionate burden of geopolitical shocks on vulnerable economies	Guan et al. (2022). https://doi.org/10.1007/s43621-022-00112-8
Developing-country share of populations affected by the estimated war-related food shock	≈95%	Highlights the Global South as the principal geopolitical risk-bearer	Guan et al. (2022). https://doi.org/10.1007/s43621-022-00112-8
India's share of global millet production	26.6%	Gives India strategic capacity to promote diversified and climate-resilient food systems	Sanjay Kumar et al. (2024), Vol. 4, Article 73. https://doi.org/10.1007/s44187-024-00149-w



1.2 OBJECTIVES OF THE STUDY

1. To study food security as a rising geopolitical and international security issue
2. To study the impact of conflict, climate change, and disruption of global food trade on global food systems
3. To study the strategic standing of India in global food governance
4. To study India's contribution to making robust, sustainable, and inclusive food systems
5. To develop policy directions to improve India's leadership role in global food security.

1.3. RESEARCH METHODOLOGY

This study uses secondary data, which involves using qualitative, analytical and multidisciplinary research methods appropriate to a survey of International Relations. The study focuses on such secondary sources as articles, reviews, book chapters, books, reports by international organizations and reports on international relations, food security, geopolitical factors affecting food security, food trade, climate change and international law. Particular attention is paid to reviewing articles and reports published between 2021 and 2026 in order to understand the latest trends in international relations. Particular attention is paid to analysing the challenges of food security in the context of geopolitical tensions, disruptions in food supplies and prices, climate change, stocks of strategic food reserves, food diplomacy and sustainable agriculture. In addition, a comparison is made between developing countries in terms of food security and the role of India in the G20, WTO, FAO in addressing food security challenges. Statistical data on agricultural production, foreign trade, food security, climate change and food security assessments were also used. Thus,

this study focuses on a literary analysis and critical assessment of the published information rather than on collecting new data through surveys or experiments.

2. RESULT AND DISCUSSION

THE GEOPOLITICS OF GLOBAL FOOD SECURITY

2.1 Food as a Strategic Resource: Power, Dependence and Global Interdependence

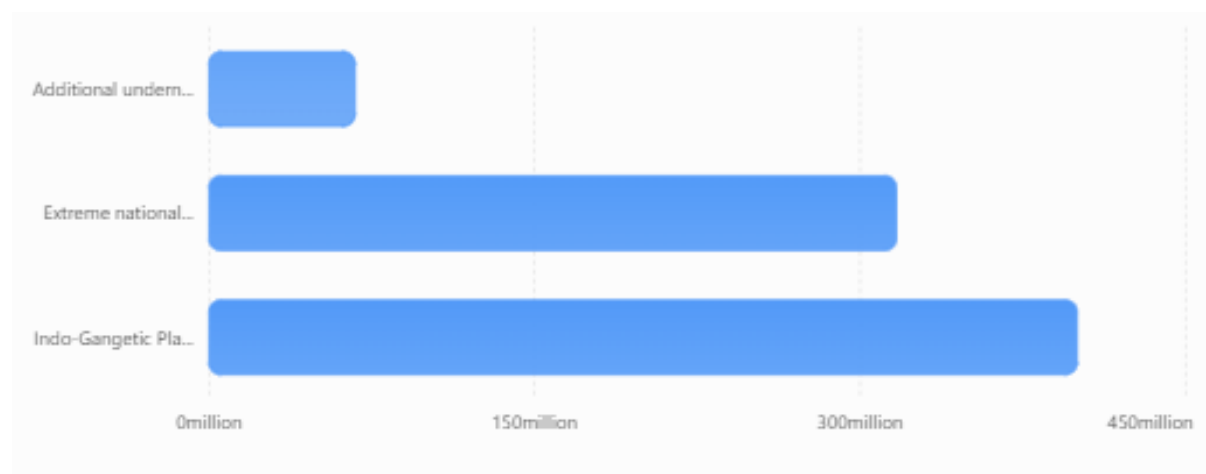
Today's global food system operates as a strategic infrastructure in that agricultural goods, fertilizer, energy, logistics, finance and information serve to determine the state's power and exposure. Studies of food-system resilience reveal that stable supply of food is dependent not only on domestic production but also on redundancy, diversity, logistics, institutional capacity and actors' ability to adjust to shocks (Zurek et al., 2022, pp. 511–534). Empirical work underlines the interdependences: 127 countries with roughly 87% of the world's population possess high self-sufficiency potential for key nutrients, yet, only 41 countries, about 33% of the global population, are fully self-sufficient, which exposes large populations to disruptions in the trade (Wassénius et al., 2023). Self-sufficiency and food security are not synonymous terms, as the diversification of sources and reliable international connections can reduce systematic risk even when domestic production is inadequate (Wassénius et al., 2023). Food has become a tool of geopolitical leverage as states with significant export capacities can dictate prices, availability and the bargaining position of importers. Concentration of production and distribution among a few firms, technologies or locations reduces the resilience of the agricultural value chains, whereas diversity, redundancy and cooperation improve the capacity to absorb shocks (Vicol et al., 2021, pp.

1–12). The global food economy is competitive and cooperative as trade increases efficiency and access, yet, concentration of dependence can make import-dependent states vulnerable (Wassénus et al., 2023). These consequences of food-security are compounded when agricultural production

is tied to energy and fertilizer systems as disruption in one sector increases costs throughout the food chain (Bakker et al., 2025).

Table 2. Selected Indicators of Global Food-System Interdependence and Vulnerability

Indicator	Statistical evidence	Analytical significance	Academic source and URL
Countries/population with high potential self-sufficiency	127 countries; 87% of global population	High potential production capacity does not eliminate trade vulnerability	Wassénus et al. (2023), <i>Global Food Security</i> , 37, 100673. https://doi.org/10.1016/j.gfs.2023.100673
Fully self-sufficient population	41 countries; 33% of global population	Only about one-third of humanity lives in countries fully self-sufficient across assessed nutrient categories	Wassénus et al. (2023). https://doi.org/10.1016/j.gfs.2023.100673
Low self-sufficiency	66 countries; about 6% of global population	Identifies states with particularly high exposure to external trade disruption	Wassénus et al. (2023). https://doi.org/10.1016/j.gfs.2023.100673
Global food-system GHG emissions	18 Gt CO ₂ -equivalent in 2015; 34% of global GHG emissions	Food security and environmental security are structurally interconnected	Crippa et al. (2021), <i>Nature Food</i> , 2, 198–209. https://doi.org/10.1038/s43016-021-00225-9
Agriculture and land-use share of food-system emissions	71%	Production-side transformation is central to sustainable food security	Crippa et al. (2021). https://doi.org/10.1038/s43016-021-00225-9



Food's strategic nature is also evident in the relationships between commodity dependence and geopolitical risks. The Russia–Ukraine crisis revealed how complex interrelations may exist within a system of production chains, beyond direct trade links between the warring states. For instance, the disruption of Ukraine's production processes has triggered indirect losses of up to 89%, 85%, and 25% for sunflower oil, maize, and poultry meat, respectively, in specific links of the supply chain (Laber et al., 2023, pp. 508-517). In turn, this has implications for geopolitical food security, which should consider not only direct but also indirect effects through animal feed, processed food, and other inputs (Laber et al., 2023).

Strategic assessments have to account for a broader perspective, going beyond the traditional understanding of food availability (Zurek et al., 2022, pp. 511-534).

2.2 War, Sanctions, Export Restrictions and the Weaponisation of Food Supply Chains

Wars are one of the key factors shaping modern food security as they disrupt not only agricultural production but also transportation, labour markets, credit financing, and confidence in the functioning of markets. In the context of post-pandemic challenges and the Russia-Ukraine war, there is growing recognition of how food systems can be resilient to shocks while causing significant welfare costs to producers, consumers, and vulnerable groups (Fan et al., 2021; Balistreri et al., 2022). At the same time, the Russia-Ukraine crisis illustrates how a particular challenge to food production in one country can trigger indirect effects in other countries through trade and processing linkages, which are often underestimated in traditional trade relations (Laber et al., 2023, pp. 508-517). In turn, export restrictions highlight how domestic political considerations can intersect with international food security challenges. A significant study on export restrictions and their consequences concluded that they could have short-run benefits for domestic prices while creating long-run welfare losses for producers and undermining incentives for future

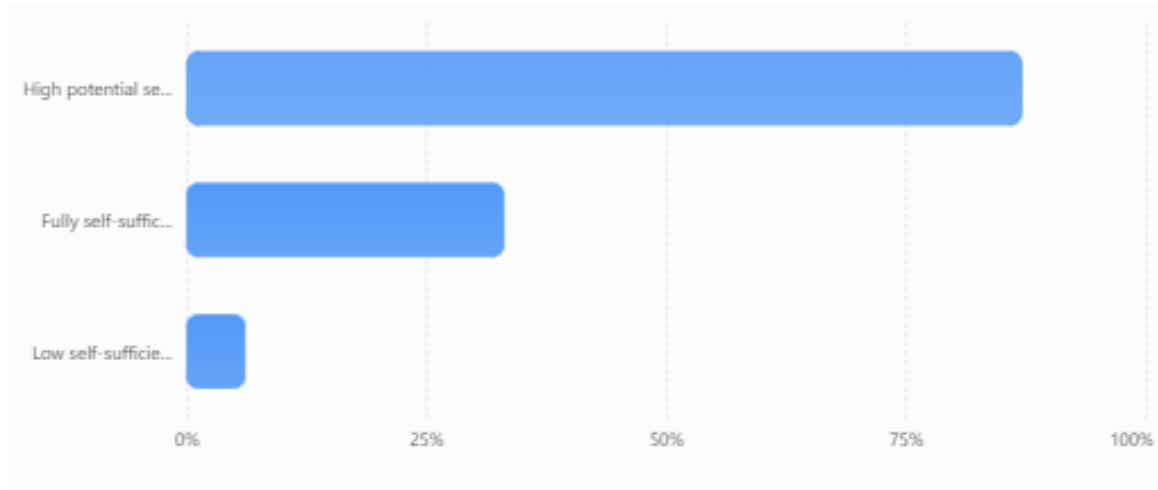
production (Akter, 2022, Article 100657). At the same time, significant exporters are estimated to face geopolitical risks, including adverse reactions from import-dependent countries to restrictions, which could trigger protectionist responses (Akter, 2022). In essence, commodities can be weaponized, with food, energy, and transport being a key leverage to influence other countries' economic and strategic decisions (Bakker et al., 2025).

India's experience with export restrictions is illustrative of these challenges, as demonstrated by research analysing retail prices of non-basmati rice. The study used daily data for eastern India to assess the relationship between export

restrictions and retail prices, finding that export bans did not dampen domestic prices while contributing to reduced volatility in specific regions (Valera et al., 2024, Article 100754). In turn, analysis suggested that, for both Asian and African economies, rice prices were vulnerable to global market forces, with differences seen in the ability to respond to supply disruptions depending on the status of a country as an exporter or an importer (Valera et al., 2024). Overall, food export restrictions do more to serve domestic political and economic interests than to contribute to food security on a regional or global scale.

Table 3. Conflict, Supply-Chain Shock and Trade-Restriction Indicators

Indicator	Statistical evidence	Geopolitical implication	Academic source and URL
Ukrainian production shock—sunflower oil	Up to 89% relative loss in affected pathways	Demonstrates transmission beyond national borders	Laber et al. (2023), <i>Nature Food</i> , 4, 508–517. https://doi.org/10.1038/s43016-023-00771-4
Ukrainian production shock—maize	Up to 85% relative loss	Intermediate trade dependencies amplify localized shocks	Laber et al. (2023). https://doi.org/10.1038/s43016-023-00771-4
Ukrainian production shock—poultry	Up to 25% relative loss	Feed-production linkages create indirect food-system vulnerability	Laber et al. (2023). https://doi.org/10.1038/s43016-023-00771-4
India rice-price research window	2017–2023; 2,500+ daily observations per series	Longitudinal evidence on export-policy transmission	Valera et al. (2024), <i>Global Food Security</i> , 41, 100754. https://doi.org/10.1016/j.gfs.2024.100754
Food-export restriction review evidence	29 countries; 44 food items affected by restrictions during a recent crisis episode	Shows rapid diffusion of protectionist food policy	Akter (2022), <i>Global Food Security</i> , 35, 100657. https://doi.org/10.1016/j.gfs.2022.100657



The strategic use of food is also linked to sanctions and geopolitical fragmentation through fertilizer systems. Given that fertilizer production demands heavy energy inputs, is concentrated in few regions and is increasingly shaped by geopolitics, pursuing food security through input security may lead to new dependencies and environmental trade-offs (Bakker et al., 2025). Modelling has suggested that, at the extreme of strategic rivalry, a major nuclear conflict could lead to catastrophic decreases in global food availability; a 5–47 Tg soot-loading range associated with an India–Pakistan nuclear-war scenario was modelled to lead to severe climatic disruption, with more than 2

billion deaths possible under the modelled India–Pakistan scenario (Xia et al., 2022, pp. 586–596). While these are rare cases, they indicate that food security can no longer be separated from the greater structures of international security, including deterrents, war avoidance and strategic stability (Ray, 2022, pp. 567–568).

2.3 Global Food Governance and the Roles of the FAO, WFP, WTO and G20

Due to the fragmented nature of food systems, multilateral governance is crucial. However, existing institutions operate under conflicting mandate structures and motivations. Studies

on the governance of food system highlight that resilience will be achieved through co-ordination between humanitarian relief, trade, agricultural production, environmental management and social protection, rather than individual institution actions (Teeuwen et al., 2022). While the FAO and WFP play an important role in knowledge development, crisis management and humanitarian aid, the WTO regulates trade policies that influence public stockholding, export restrictions and market access (Shajahan, 2023, pp. 150–166). The G20 occupies a unique political place since it includes the leading agricultural producers, importers, developing countries, and industrialized nations. This makes it the most significant organization for food, fertilizers and sustainable agricultural policies (Singh, 2026, pp. 44–48).

The central institutional problem is not governance, but its fragmentation. International food security increasingly relies on cooperation across trade, climate, water and development institutions, yet institutional rules can lead to conflicting incentives (Teeuwen et al., 2022). The public-stockholding debate is particularly illustrative; climate shocks reinforce the need for strategic reserves, whilst existing trade rules may limit the modalities by which developing countries can use administered prices to procure food (Shajahan, 2023, pp. 150–166). Research on global trade rules also suggests that public food reserves have long been vital for managing production shocks, yet current rules leave insufficient policy room for governments facing an increasing frequency of climate-induced disruptions (Bellora et al., 2023, 100198).

The emerging governance agenda therefore calls for a shift from crisis management to anticipatory resilience. A review of food-security governance simulations across 110 peer-reviewed modelling studies revealed substantial variation across how policy instruments were represented and their effectiveness, demonstrating the need for integrated rather than single-sector interventions (Teeuwen et al., 2022). Research on global food-system resilience also highlights robustness, recovery, and long-term reorientation, rather than just the return to pre-crisis conditions (Zurek et al., 2022, pp. 511–534). Here, the G20 can bridge formal multilateral rules and political co-ordination, whilst India, as a major developing-country economy, can link food sovereignty concerns to global market stability.

3. INDIA'S FOOD-SECURITY LANDSCAPE AND STRATEGIC VULNERABILITIES

3.1 Agricultural Production, Public Stockholding and Domestic Food-Security Institutions

India's food-security policy framework was initially developed to prevent famine, stabilize cereal markets and protect low-income consumers. Revisions of the National Food Security

Act and the Public Distribution System reflect a shift from discretionary welfare to a rights-based institutional design, which continues to debate the most efficient combination of in-kind, cash, producer subsidy and diversified nutritional approaches (Lindgren & Lang, 2022, 1159–1173). India's approach thus embodies a critical strategic concept: national food security requires incentives for domestic production and institutions for transforming agricultural production into reliable access for vulnerable groups (Rahman & Pingali, 2024, 133–166).

The value of these institutional mechanisms is highlighted by the COVID-19 experience, revealing their ability to cushion food-insecure populations against shock. A rural-household survey demonstrated that public transfers had alleviated food insecurity during the pandemic, suggesting that state protection can be a critical resilience factor if labour and market systems fail (Kumar et al., 2022, 636–659). Survey findings from 1,767 wheat and tomato growers in Haryana illustrate the capacity of state procurement to shield wheat producers from significant income losses, while tomato growers experienced a 50% decrease in income compared to a normal year (Ceballos et al., 2021). Such evidence supports the capacity of public procurement and social protection to reduce vulnerability, but raises the question of whether a cereal-centric approach is optimal for long-term sustainability.

3.2 Climate Stress, Water Scarcity, Land Degradation and Agricultural Vulnerability

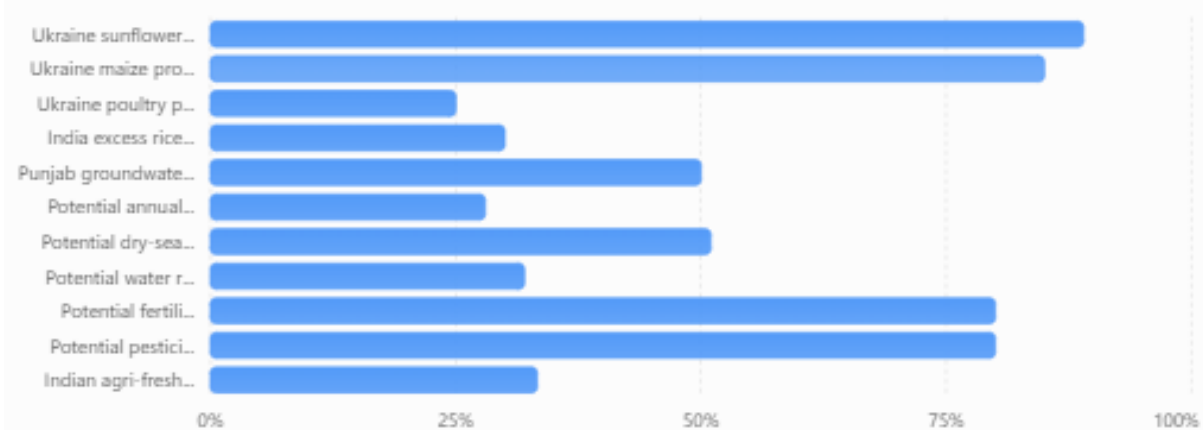
India's food-security challenge is increasingly characterized by the dilemma of agricultural intensification and resource sustainability. A systematic review of 231 studies concluded that climate change would negatively impact all dimensions of Indian food security—availability, access, utilization and stability—as temperature fluctuations, inconsistent rainfall and extreme weather patterns affect crops, livestock, fisheries and livelihoods (Das et al., 2025, 1–18). Groundwater is a critical resource as its expansion in agricultural irrigation has raised productivity but increased long-term ecological risk (Devineni et al., 2022).

Research on Indian agricultural subsidies provides exceptionally strong quantitative evidence of this paradox. Output subsidies have been associated with approximately 30% over-production of water-intensive rice and wheat, and rice procurement may account for at least 50% of groundwater-table decline in Punjab over 34 years (Chatterjee et al., 2024). The same analysis estimated that losing access to groundwater would reduce annual crop production by 28%, dry-season production by 51% and cropping intensity by 68%, illustrating how short-sighted food-security policies can erode long-term food availability if resource constraints are not considered (Chatterjee et al., 2024).

Table 4. India's Water, Production and Climate-Resilience Pressures

Indicator	Statistical evidence	Strategic significance	Academic source and URL
Excess rice and wheat production associated with subsidy structure	≈30%	Signals mismatch between cereal incentives and ecological sustainability	Chatterjee et al. (2024), <i>Nature Communications</i> , 15, 8654. https://doi.org/10.1038/s41467-024-52858-6

Punjab groundwater decline attributable to procurement mechanism	At least 50% over 34 years	Links agricultural policy directly to water-security risk	Chatterjee et al. (2024). https://doi.org/10.1038/s41467-024-52858-6
Potential annual crop-production decline after groundwater loss	28%	Shows long-run threat to food availability	Chatterjee et al. (2024). https://doi.org/10.1038/s41467-024-52858-6
Potential dry-season production decline	51%	Indicates disproportionate vulnerability during seasonal water stress	Chatterjee et al. (2024). https://doi.org/10.1038/s41467-024-52858-6
IGP population	≈400 million	Food-bowl sustainability has regional and international significance	Chakraborti et al. (2023), <i>Nature Water</i> , 1, 864–878. https://doi.org/10.1038/s44221-023-00135-z
Potential water reduction through crop switching	32%	Diversification can support food, water and farmer-income objectives simultaneously	Chakraborti et al. (2023). https://doi.org/10.1038/s44221-023-00135-z



A key policy opening lies in changing what is produced, rather simply producing more. An optimization model for the Indo-Gangetic Plain found that replacing rice with pearl millet and sorghum during kharif, and wheat with sorghum during rabi, would reduce water use by 32%, increase calorie production by 39%, and raise farmer profits by 140% compared to current practices (Chakraborti et al., 2023, pp. 864-878). This has strategic importance, in that it demonstrates how food security, farmer welfare and environmental resilience can stop being at odds with each other once the agricultural incentives are rethought (Chakraborti et al., 2023). Groundwater studies also reveal that procurement geography and cropping patterns are amenable to change while national procurement goals are maintained, and that average net farm income can rise by approximately 30% within irrigated scenarios (Devineni et al., 2022).

3.3 Food Inflation, Nutritional Security and the Tensions between Domestic Needs and Global Markets

Food security is not achieved merely by high levels of grain output, in the face of unaffordable, nutritionally inadequate diets for the household. Indian evidence demonstrates substantial heterogeneity of food insecurity across income, geography, household assets, market access and livelihood structure (McKay et al., 2023, pp. 358-367). Local research illustrates this divergence, with a study on 474 farm households identifying calorie-based food insecurity among

about 26% of farmers, demonstrating that farming does not guarantee household food security (Ravi et al., 2023). Household diets also have an impact, in that cereal dependence may exist alongside inadequate intake of fruits, vegetables, protein, and micronutrient-rich foods (Ogotu et al., 2023). The tension between domestic affordability and international markets is therefore structural. While increasing domestic food inflation may make export restrictions appear politically attractive, they carry adjustment costs for producing nations and their trading partners (Aker, 2022). India's rice restrictions are particularly significant, in that policy shifts within a major exporter influence international expectations and price formation, even when domestic goals are legitimate (Valera et al., 2024). Food diplomacy must therefore move away from the binary of "exports" versus "domestic food security" in favour of pairing predictable exports, targeted domestic protections and transparent crisis rules.

4. INDIA AS A GEOPOLITICAL ACTOR IN GLOBAL FOOD SYSTEMS

4.1 India's Position in Global Trade in Rice, Wheat, Pulses, Millets and Agricultural Commodities

India's geopolitical food role is built on vast cereal production, significant rice exports, agricultural diversification, and an extraordinarily large domestic market. Rice's strategic significance is particularly evident, in so much as trade

restrictions originating in India can shape price formation across Asian and African markets (Valera et al., 2024). As the nation's global role in millets rises, it offers an alternative

paradigm of food diplomacy which is based in climate resilience, nutritional variety and sustainable farming, rather than volume alone (Mehta et al., 2024, Article 104527).

Table 5. India's Potential Leverage through Millets, Crop Diversification and Digital Agriculture

Indicator	Statistical evidence	Strategic relevance	Academic source and URL
Indian millet share of global production	≈26.6%	Gives India a strong platform for millet diplomacy and diversified food systems	Kumar et al. (2024), <i>Discover Food</i> , 4, 73. https://doi.org/10.1007/s44187-024-00149-w
Indian millet share of Asia's millet-cropping area	≈83%	Supports India's regional influence in climate-resilient crop systems	Kumar et al. (2024). https://doi.org/10.1007/s44187-024-00149-w
IGP cereal production	≈135 million tonnes	Shows the global relevance of South Asian cereal-water systems	Chakraborti et al. (2023), <i>Nature Water</i> , 1, 864–878. https://doi.org/10.1038/s44221-023-00135-z
Agricultural digitalisation review corpus	136 peer-reviewed papers + 28 project documents	Indicates rapid growth of evidence on digital agriculture	Huck et al. (2024), <i>Smart Agricultural Technology</i> , 8, 100441. https://doi.org/10.1016/j.atech.2024.100441
Potential fertilizer-use reduction through selected digital technologies	Up to 80% in some applications	Illustrates resource-efficiency potential of precision agriculture	Huck et al. (2024). https://doi.org/10.1016/j.atech.2024.100441
Potential pesticide reduction with variable-rate technologies	Up to 80%	Links digital agriculture to sustainable production and ecological resilience	Huck et al. (2024). https://doi.org/10.1016/j.atech.2024.100441

Millets are acquiring increasing importance since their geopolitical importance surpasses that of their export value. Recent reviews note drought and other abiotic stress tolerances and high nutritional value as reasons to adopt them into future food-security strategies (Kumar et al., 2024; Mehta et al., 2024). India could present agricultural trade as an opportunity to promote alternative crops and diets rather than simply expanding traditional cereal exports.

4.2 Export Restrictions, Public Stockholding and India's Negotiating Position in the WTO

India's WTO position reflects a concern across the Global South that trade rules should allow governments enough freedom to fulfill major food-security obligations. The debate on public stockholding is not only a technical disagreement on subsidy calculations but a conflict of domestic food-security goals and a trade regime guided by market-distortion concerns (Shajahan, 2023, pp. 150-66). Recent scholarship notes that India's stance reflects the political economy of procuring food for its large population and the institutional underpinnings of the PDS (Singh, 2026, pp. 44-8).

However, India needs to acknowledge the impact of its trade measures on other vulnerable states. 2024 evidence on non-basmati rice shows that export restrictions do not always lead to uniform domestic price stabilization and may have international spillovers (Valera et al., 2024). India's best negotiating position would be to distinguish between emergency, short-term trade interventions and long-term protectionism, favouring transparency and preset conditions for crisis measures.

4.3 Food Diplomacy through the G20, Global South Cooperation and Development Partnerships

India's food diplomacy could be a part of a broader leadership role within the Global South, tying development, climate

adaptation, agricultural technology and trade. Research on India's social-protection system shows that domestic experience offers transferable lessons on how public institutions can provide stability for food access amidst economic shocks (Kumar et al., 2022). India's millet leadership could also leverage a relatively non-hegemonic influence which builds on knowledge sharing, increased dietary diversification and farmer-market integration and climate adaptation rather than simply commodity dependence (Mehta et al., 2024).

This diplomacy could also rest on South-South cooperation on resilient crops, irrigation, digital extension and food distribution. Indian evidence shows that wild-food consumption increased women's dietary diversity, with consumers scoring roughly 13% higher in June and 9% higher in July than matched non-consumers (Cheek et al., 2023, pp. 476-82). This evidence is important for food diplomacy since it broadens food security beyond traditional cereals and highlights biodiversity, local knowledge and community access.

5. THE ROLE OF INDIA IN DEVELOPMENT OF RESILIENT AND SUSTAINABLE FOOD SYSTEMS

5.1 Climate Resilience Agriculture, Crop Diversification, and Sustainable Natural Resources Management

Possibly the biggest asset of India is the possibility of transition of a population-based agricultural economy from being highly resource dependent to climate resilience. It appears from the study on climate-resilient agriculture in India that the main components of adaptation in climate resilient agriculture are water, farmers' decision-making and geospatial technologies and local solutions (Adam et al., 2026; Ajatasatru et al., 2024). The evidence of crop diversification is particularly significant

since it shows that sustainability does not involve giving up food security and livelihoods of rural communities (Chakraborti et al., 2023).

Low-carbon agriculture is another field where India can set an example of a new model of leadership. Low-carbon farming practices have been recognized as measures not only for reducing greenhouse gas emissions but also for developing climate resilience through the management of nutrients, soils and water (Adam et al., 2026). This approach has significant geopolitical meaning because of the linking of Indian climate policies with international concerns about climate financing, technology transfer and sustainable agriculture.

5.2 Millets, Indigenous Crops, Sustainable Diets and Nutrition-Sensitive Food Systems

Millets present a useful bridge between geopolitically food-resilient regions and nutritionally secure countries. There have been reviews indicating that millets in general have approximately 60-70% carbohydrates, 3.5-5.2% fats, and 7.52-12.1% protein, in addition to minerals, dietary fibre, and phytochemicals (Sarkar & Naga, 2024, pp. 5580-601). These nutritional and climate resilience properties of millets are useful for diversifying food security strategies in India and other vulnerable nations of the Global South (Mehta et al., 2024).

In terms of nutritional benefits of diversified crops, their importance is evident where there is an overlap between food insecurity and micronutrient deficiency. Studies of traditional and wild crops have indicated that increased biodiversity access can improve both diet and the sustainable nature of livelihood in the community (Cheek et al., 2023). The

challenge facing policymakers is that of moving from symbolic support to the traditional crops to making substantial investments in seed systems, processing, procurement, consumer information, and market networks (Harish et al., 2024).

5.3 Agricultural Technology, Digital Innovation, Food Loss Reduction and Supply Chain Resilience

The digitalization technologies improve India's capacity to increase productivity through reduced resource consumption. A meta-analysis of 136 studies shows that digital agricultural technologies can generate significant economic and environmental benefits such as fertilizer use reduction by up to 80% under certain recording and controlled traffic systems and up to 80% pesticide usage reduction using variable rate technologies (Huck et al., 2024). The Indian literature has documented increasing use of remote sensing, IoT, AI/ML, and farm management applications along with crop-specific technology adoption inefficiencies (Kumar et al., 2023).

Transformation of supply chains is equally vital since the losses may reduce production efficiency. The systematic analysis of 152 studies on food loss and waste has highlighted improper perishable management, supply-chain disruptions, and stakeholders' practices as the major loss causes for which digitalization may provide the monitoring and redistribution solutions (Principato et al., 2021). In India, it is particularly vital to consider that the country's agri-fresh supply chain is responsible for almost one-third of annual losses of fruits and vegetables without proper supply chain management (Kumar & Agrawal, 2023, Vol. 212, Article 108161).

Table 6. Resilience, Digitalisation and Food-Loss Reduction Evidence

Indicator	Statistical evidence	Policy implication	Academic source and URL
Food-system resilience literature screened	1,547 studies; 115 selected	Resilience assessment is expanding rapidly but requires better indicators	Authors of resilience review (2024), <i>Global Food Security</i> , 40, 100744. https://doi.org/10.1016/j.gfs.2024.100744
Sustainability/resilience metrics literature	112 of 1,038 studies ≈10%	Quantitative resilience measurement remains underdeveloped	Hassan et al. (2025), <i>Frontiers in Sustainable Food Systems</i> , 9, 1479691. https://doi.org/10.3389/fsufs.2025.1479691
Geopolitical agrifood resilience review	76 articles	Geopolitical tensions are still insufficiently integrated into resilience research	Mkumbukiy et al. (2025), <i>Frontiers in Sustainable Food Systems</i> , 9, 1546851. https://doi.org/10.3389/fsufs.2025.1546851
Climate-change food-chain review	1,526 publications; 67 selected	Climate impacts extend across production, distribution, prices and access	Tchonkouang et al. (2024), <i>Science of the Total Environment</i> , 920, 171047. https://doi.org/10.1016/j.scitotenv.2024.171047
Food-loss and waste review	152 articles	Better measurement, digital monitoring and redistribution are required	2021 systematic review, https://doi.org/10.1016/j.jclepro.2021.126923
Indian agri-fresh losses	≈1/3 of fruits and vegetables	Cold-chain, logistics and market integration are central to food resilience	Kumar & Agrawal (2023), <i>Computers and Electronics in Agriculture</i> , 212, 108161. https://doi.org/10.1016/j.compag.2023.108161

The value of digitalization is more than just “smart farming,” but the creation of information systems that would facilitate the connections between farmers, markets, government, and consumers internationally. Digital traceability, blockchains and sensors might improve food safety and provenance while the environmental impact and the institutional cost of these innovations should not be overlooked (Menon et al., 2024).

Thus, the Digital Agriculture model in India can turn into a policy to export in combination with farmer engagement and the protection from digital exclusion (Kumar et al., 2023).

6. CONCLUSION

Food security today is a strategic, ecological, and geopolitical issue, and it is no longer exclusively a production problem;

food production today is deeply intertwined with multinational, financial, energy, fertilizer, transport, technological, and ecological networks. The difference between potential and actual food production is massive – although 87% of people live in countries that have the potential to produce a high amount of nutrients, only 33% live in countries capable of producing everything they need (Wassénus et al., 2023). Moreover, the more diverse and the more intertwined the food production is, the more resilient it tends to be compared to autarkic approaches (Zurek et al., 2022).

Geopolitical risks have become a significant threat to interconnected food production systems; the Russia-Ukraine war already impacts alternative production and trade, with modeled transmission ranging from 89% for sunflower oil to 85% for maize and 25% for poultry (Laber et al., 2023). Export bans, fertilizer supplies, transport routes, and market access to some extents are already used as geopolitical tools (Akter, 2022; Bakker et al., 2025). Nuclear-war models also show the importance of international relations for food security (Xia et al., 2022; Ray, 2022).

Another crucial aspect of food production and security discussed later is the environmental impact of the current system. The whole food system is responsible for around 18 gigatonnes of CO₂-equivalent emissions, or 34% of all anthropogenic greenhouse-gas emissions, with agriculture and land-use change being responsible for 71% of greenhouse-gas emissions from food systems in 2015 (Crippa et al., 2021, pp. 198-209). Food systems need to be both climate-adaptive and less aggressive to address food security and climate change (Tchoukouang et al., 2024).

India's agricultural intensification, procurement, and irrigation policies have created both a food abundance and a groundwater crisis. Agricultural subsidies and procurement create a connection to around 30% of water-intensive rice and wheat production, while the same policies are responsible for at least 50% of the groundwater decline in Punjab in the last 34 years (Chatterjee et al., 2024). Groundwater depletion in India could reduce annual crop production by 28%, dry-season production by 51%, and cropping intensity by 68% (Chatterjee et al., 2024). Therefore, India's food security probably needs to be redesigned to be more sustainable rather than focused on intensive production methods.

The solution to India's agricultural problems might be in diverse crops; shifting to millet and sorghum production in the Indo Gangetic region would reduce water consumption by 32%, increase calories by 39%, and make farmers 140% more profitable (Chakraborti et al., 2023, pp. 864-878). Therefore, India's potential to produce diverse crops such as millet could be harnessed to both address its internal food-security issues and serve as a model for other countries that want to adopt similar approaches. Some scholars note that India could become a preferred destination for food imports for many countries that want to achieve nutritional and water security (Kumar et al., 2024; Mehta et al., 2024).

Nutrition needs to be considered at every level of agricultural and food-security policy; research in eastern India found that women who consumed wild food had significantly more

dietary diversity (13% higher in June and 9% in July) compared to those who did not eat them (Cheek et al., 2023, pp. 476-482). Therefore, biodiversity has the potential to be used to both improve dietary diversity and nutrition in India, and it needs to be supplemented by local traditional knowledge and ecosystems to improve the existing agricultural practices (Ogutu et al., 2023).

India's food-trade policy is another crucial aspect of ensuring not only national food security but international as well; food export bans undermine international markets but to some extent, they do the same for national food security as well (Valera et al., 2024). Therefore, international food security probably needs to be addressed through India's strategic reserves, consumer protection, enhanced productivity, and production diversification. India's WTO commitments regarding public stockholding need to be carefully considered in the context of both national food-security goals and international trade relations (Shajahan, 2023; Singh, 2026).

Technology and supply chains can also play a crucial role in enhancing food security. The use of digital technologies has the potential to reduce fertilizer use by up to 80% in some variable-rate treatments while also reducing pesticide use by up to 80% (Huck et al., 2024). Meanwhile, reducing food loss is another pivotal way to both increase food security and have a beneficial effect on the environment, and it has been found to be a substantial source of additional food. A review of 152 studies found that the interruption of supply chains, perishable goods, and organizational issues were some of the main causes of food waste and loss. India's agricultural fresh-supply chains waste around a third of all fruits and vegetables due to organizational and logistical issues (Kumar & Agrawal, 2023; 2021 systematic review).

India's role in international food security will be defined by its ability to balance its national interests and geopolitical positioning. The strategic reserves, consumer protection, diversification, and intensification of production along with digitalization and supply chains will provide opportunities for India to not only strengthen its role as a regional food-security pole but also be engaged in international relations and international trade. Using the G20, the WTO, and bilateral relations with other developing countries, India can advocate international food security through establishing regional reserves, early warning systems, food crop exchange, and also engage in technology transfer, agricultural, fertilizer, and climate security assistance (Shajahan, 2023; Singh, 2026).

Increased dietary diversity, sustainable production, strategic trade, and food security networks, policies, and mechanisms will contribute both to food sovereignty and international cooperation. The national and international levels of food production and food security can be developed as a system resilient to geopolitical and ecological threats and reduce expenses on the resources thus contributing to the sustainability of the national economy and world food system (Zurek et al., 2022; Mkumbuki et al., 2025). In such a way, India can become a proponent of such a system that will make the country influential in international trade, security, and nutrition without being fully dependent on national production.

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About the author



Surjit Singh is a Trained Graduate Teacher (TGT) at Govt. Co-ed. Secondary School, West Azad Nagar, Delhi, under the Directorate of Education, Government of NCT of Delhi. His professional interests include education, teaching, social sciences, and academic research, with a focus on contributing to meaningful educational practices and scholarly development.