Indian Journal of Agricultural Economics
Volume 79, Number 1, January-March 2024

Reassessing Agri-Food Systems for Sustaining Nutritional Food Security: Evidence, Imperative and Way Forward*

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ABSTRACT

Despite significant progress in food security, India faces several challenges in achieving nutritional security for its population. Sustaining nutritional food security requires a holistic approach focusing on all the components of food security and revamping the food systems. The strategies must be flexible and address the regional variations and challenges of different population strata. They also need to ensure synergies between food production and environmental sustainability. The focus on crop diversification, wild fruit domestication, aquaculture, and animal foods may bring significant direct and indirect benefits, especially to the poor and vulnerable sections such as children, women, and tribals. It will improve access to food, diet diversity, and nutritional security and raise farm incomes. Strengthening food value chains will enhance farmers' remuneration, reduce wastage, and improve food availability, affordability, and acceptability. Integrating crop breeding programs, increasing investments for research and extension, expanding markets, and focusing mainly on vulnerable sections will be essential ingredients for a nutritional security strategy.

Keywords: Agriculture, Agri-food Systems, Nutritional Security, Food Policy

JEL codes: O13, Q13, Q18

I

INTRODUCTION

The World Food Summit of 1996 defines food security as physical and economic access to sufficient, safe, and nutritious food for all people at all times. Food security has four major dimensions: access, availability, utilization, and stability. The access to food reflects physical and economic access. It depends on production and the economic ability to buy food in the desired quantity. The availability depends mainly on the production and trade of food. The utilization of food not only includes the quantity but also the nutritional status of the food. The last dimension of the system, stability, considers the risk and uncertainty in the first three dimensions of food security.

Suffering from chronic food deficits, Indian agriculture focused on substantial increases in food production to achieve national food security. The success of the Green Revolution in the 1960s and 1970s helped to bring a significant rise in food production and per capita food availability in India. The food production in India jumped from 50.82 million tonnes in 1951 to 316 million tonnes in 2021-22, and daily per capita food availability increased from 395 gm to 512 gm per month during this period

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* Keynote Address delivered at the 83rd Annual Conference of the Indian Society of Agricultural Economics (Mumbai) organised by the Odisha University of Agriculture and Technology, Bhubaneswar (Odisha) from December 18-20, 2023.

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(Government of India, 2022). Despite significant improvements in food production, India ranks poorly at 111th (out of 136 countries) in the Global Hunger Index (GHI). Such ranking also points towards the lack of access to food by the poor. The GHI also reflects the highest child-wasting rate of 18.7 per cent, undernourishment at 16.6 per cent, and under-five mortality at 3.1 per cent in India.

The prevalence of anaemia amongst women between 15-24 years of age is high at 58.1 per cent. India ranks comparatively poorly with neighbouring countries such as Pakistan, Bangladesh, Nepal, and Sri Lanka. Despite some arguments over the authenticity of these figures, there seems to be a massive gap between improving food security and achieving widespread nutritional security in India. Improvements in agricultural production alone will not be able to address the problem of malnutrition and provide food and nutritional security unless holistic interventions are made to address all four components of food security. It is vital to eliminate hunger and achieve food and nutritional security as articulated in the Sustainable Development Goals (Rasul *et al*., 2018). India's poor performance on critical indicators of food and nutritional security does not match well with substantial economic progress. Widespread hunger and malnutrition severely limit human resources and a country's socio-economic outcome. A successful march towards nutritional security may need a diversified food system characterised by multiple crops, a shift toward high-value crops, fruits and vegetables, aromatic and medicinal plants, nutri-cereals, mushrooms, tuber, and aquatic foods. Milk and milk products, meat, and fish also are essential components of nutritional food.

II

NUTRITIONAL SECURITY THROUGH IMPROVING FOOD SYSTEMS

A food system is a complex set of activities involving production, processing, transport, and consumption. Various issues concerning the food system include governance and economics of food production, its sustainability, food wastage, and the effect of food production on the natural environment and its impact on health. Caiazza and Volpe (2015) define the agri-food system as a network of institutions, activities, and businesses that develop and deliver material inputs to the farming sector, produce primary commodities, and then handle, process, transport, market, and distribute food. Agriculture-based and agriculture-related enterprises are yet another set of agri-food system building blocks (Jaffee *et al*., 2003). While the former produces agricultural goods, the latter includes food processors, manufacturers, retailers, traders, and agricultural input suppliers. Agri-food businesses can be found in rural and urban areas and may be large or small, domestic or foreign, public or private, or a combination. The rising population across the globe is pressing for increasing agricultural production, but it may lead to over-exploitation of natural resources. There are, however, arguments that improved food distribution can also ease pressure on agricultural production to feed a rising population (Sunderland *et al*., 2013). While the transition to nutritional security globally depends on a fixed set of factors, the strategies

to achieve it may differ significantly, causing huge variations in impacts and outcomes (Smith, 2013).

A food system approach is an effective strategy for sustainable nutritional security. Five significant changes are occurring in the food systems in developing countries: i) urbanisation, ii) changes in diets, iii) agri-food system transformation, iv) rural factor market transformation, and v) intensification of farm technology. As these transformations are interlinked, overall changes in the agri-food systems will be complex and have significant effects.

In the past, food systems in developing countries mainly evolved around achieving national food security in terms of attaining larger and larger food production. However, nutritional security has not received as much attention as required. Lack of a balanced diet and malnutrition adversely affect human health and cause almost 11 per cent loss of annual gross domestic product (GDP) in Asia and Africa. About two billion people in the world suffer from malnutrition, and 815 million are undernourished.

The scientific literature mainly addresses food systems and sustainability in isolation. Such disconnection adversely affects the transition of conventional food systems into sustainable ones. Food system sustainability must address long-term food and nutritional security by improving availability, accessibility, utilization, and stability. The strategy for a sustainable transition of food systems must focus on sustainable intensification, diet, and alternative food systems. A food system makes optimum use of resources, is socially acceptable, environmentally sound, and economically fair and viable (Capone *et al*., 2014). Strengthening food systems should be complemented by the engagement of public health, water, sanitary, and hygiene systems to ensure adequate food and nutritional security, health, and well-being for all (Fanzo *et al*., 2017a, b). Also, cultural, religious, and traditional knowledge deserves a more critical role in food and nutritional security (Alonso, 2015). In India, the National Food Act 2013 aims to cover the most vulnerable households and address food security. Food distribution through the Public Distribution System (PDS) has the potential to improve nutritional security in India significantly (Rai *et al*., 2015). There is a need for an integrated approach towards a sustainable food system for nutritional security. Such an approach may focus on multiple indicators such as i) Food nutrient adequacy, ii) Ecosystem stability, iii) Food affordability and availability, iv) Socio-cultural well-being, v) Food safety, vi) Resilience, and vii) Waste and reduction (Gustafson *et al*., 2016). In India, sufficient nutritious food can be produced by reducing cropland, water use, and input use. Even the greenhouse gas emission could be reduced by 26-34 per cent. Such a transition, however, will require a shift from traditional cereal production to more traditional and nutritious food (Damerau *et al*., 2020).

III

NUTRITIONAL SECURITY THROUGH DIVERSIFICATION OF FOOD SYSTEMS

The diversification of food systems may include growing multiple crops, domestication of wild crops, aquatic foods, and foods from animals, and taking up other

allied activities by the households. Such strategies have numerous benefits that directly or indirectly affect nutritional security.

*Crop Diversification***:** With increased per capita income, the demand for high-value, nutritious, and diverse food is rising. Including coarse cereals (such as millets), pulses and oilseeds may increase the demand for food crops (Konapur *et al*., 2014). It may also increase the area under fruits and vegetables and shift towards agri-forestry. It is well-documented that crop diversification causes improved food access, increased dietary diversity, and improved nutritional security (Wani *et al*., 2012). Crop diversification enhances affordability and availability and improves access to more nutritious food. It may also improve various ecosystem services necessary for food production (Pellegrini and Tasciotti, 2014). With future food demand growing significantly, it will be difficult to achieve food security for a growing population with a limited number of crops such as paddy and wheat. Crop diversification is a promising alternative in such a situation (Wani *et al.,* 2012; Pellegrini and Tasciotti, 2014). It also improves the resilience of the food production system to biotic and abiotic stress arising from climate change (Furman *et al*., 2021). Despite the positive impacts of crop diversification on nutritional security, there are some incidences of mixed results where an increase in farm diversity improves food consumption and nutritional diversity to a certain extent. The extent of positive impact may vary considerably across various farm size categories, regions and countries (Rajendran *et al*., 2017; Nicholson *et al*., 2021). It is also observed that crop diversification efforts affect children and women differently (Chinnadurai *et al*., 2016). The government of India has undertaken various interventions to promote crop diversification in India. These interventions include the Technology Mission for Integrated Development of Horticulture in North East India, the National Agricultural Insurance Scheme, the Technology Mission on Cotton, the Watershed Development Fund, the Strengthening of Agricultural Marketing, etc. Keeping in mind the benefits of crop diversification on nutritional security, there is a need to intensify crop diversification efforts across the country. Particular focus is needed in economically backward regions and those more adversely affected by climate change. Other interventions may include strengthening agricultural value chains through 1) promoting agricultural entrepreneurship, 2) encouraging public-private partnership, 3) linking farmers to more remunerative and large markets, 4) expanding agricultural extension, and 5) re-orienting agricultural research and extension towards crop diversification.

*Wild Fruit Domestication***:** The cultivation of climate-resilient and under-utilised wild crops is being considered an important future agricultural strategy (Singh *et al*., 2019). Such wild crops are being recognised as future smart crops by FAO. Globally, many wild fruits have been recognised for potential domestication (Mahapatra *et al*., 2012; Bisht *et al*., 2017; Barua *et al*., 2019; Omotayo and Aremu, 2020; Hazarika *et al*., 2022). The annual value of such wild crops, globally, is estimated at US$ 115-120 billion. Several wild fruits are being domesticated and consumed by India's rural and tribal people as they cannot afford commercial fruits. Some of these fruits have better

nutritional value than the cultivated fruits. More than 150 wild edible fruit species occurring in different parts of eastern India are consumed by rural communities (Mahapatra *et al*., 2012). Some fruits, such as Chironji, Mahua, and Cashew, are collected from forests for sale. The wild fruits are important sources of nutrition. They often compared well with traditional fruits (Mahapatra *et al*., 2012; Borelli *et al*., 2020). Wild fruit domestication has been observed to have a significant impact on household income and food security, especially for vulnerable sections, including the tribals (Akinnifesi *et al*., 2007; Bisht *et al.*, 2017; Kumar and Bhalothia, 2020). It improves the income of rural households by increasing market opportunities and consumption, diet diversity, and employment generation (Barua *et al*., 2019; Borelli et al., 2020)**.** In recent times, however, the natural habitat of wild fruits has been degrading fast, leading to a significant decline in their availability (Bisht *et al*., 2017)**.** To encourage wild fruit domestication, there is a need to improve the quality of production through improved breeding for domestication and standardization of agronomic practices (Akinnifesi *et al*., 2007; Singh *et al*., 2019)**.** Also, we should encourage sustainable harvesting of wild fruits (Bisht *et al*., 2017) and develop an effective extension strategy for large-scale dissemination of wild fruit cultivation (Akinnifesi *et al*., 2007)**.** To encourage marketing, a particular focus on generating consumer awareness and evidence of nutritional value will be helpful (Borelli *et al*., 2020; Singh *et al*., 2022)**.** There is also a need for large-scale commercialization of wild fruit production in the country by strengthening the value chains and increasing consumer access to the market (Akinnifesi *et al*., 2007; Omotayo and Aremu, 2020). Finally, the policy should incentivize wild fruit domestication by linking producers to the market and encouraging proper research evidence (Borelli *et al*., 2020; Kumar and Bhalothia, 2020; Singh *et al*., 2022).

*Aquatic Foods and Food from Animals***:** Aquatic food can play a significant role in global nutrition and food security. This sector is often ignored, and significant fluctuations in the supply and consumption across regions and countries further complicate the situation (Norman *et al*., 2019)**.** Aquaculture technology based on low-value and moderate to low input use has supplied large quantities of fish for domestic market and home consumption. It can directly affect nutritional security through consumption and indirectly through income enhancement (Prein and Ahmed, 2000)**.** As a protein-rich food, fishery offers solutions to protein deficiency, considerably affecting the poor population, especially children and women (Pradeepkiran, 2019)**.** While there are apparent positive effects on income and consumption, the impact on employment is insignificant (Ahmed and Lorica, 2002). Also, multiple health benefits are associated with consuming aquatic food (Toppe *et al*., 2012)**.** Aquatic animal food production accounts for a significant proportion of almost one-fifth of the animal product intake of the global population (Tacon and Metian, 2013)**.** It may also be an essential source of high-quality and affordable products for the poor. This sector may grow substantially as technological changes dramatically increase the fish supply, lower relative fish prices, and check price volatility (Belton and Thilsted, 2014)**.** The

aquaculture growth helps mitigate a sharp reduction in fish consumption from capture fishery, though the reduction is not fully compensated (Belton and Thilsted, 2014). The impact of aquatic food on nutritional security is well-recognized in policy practices (Farmery *et al*., 2020). Most national fishery policies in the world identify nutrition as a critical objective (Koehn *et al*., 2022). Recent studies have compared a high growth scenario in aquatic animal source food production with the moderate growth scenario and found that high growth will increase the consumption of aquatic foods, reduce aquatic food prices by 26 per cent, and reduce the consumption of red and processed meat (Golden *et al*., 2021)**.** Challenges to the growth of aquaculture include the supply of raw materials, losses due to disease outbreaks, high food safety, and standard and environmental limits to expansion (Norman *et al*., 2019)**.** There is a significant connection between aquatic foods and food security and nutrition (FNS), but many gaps and weak points need to be strengthened. The policy framework is narrow, and many policies lack political commitments. Only aiming to increase aquatic food availability and access may not provide nutritional security. Affordability is an essential component that may need evaluation in the policy framework. Some examples are the second county investment plan 2016-2020 from Bangladesh, the Samoan Agriculture Sector Plan 2016-2020 (Volume 1 and 2), and the National Fisheries Sector Policy 2016-2031 for Vanuatu. They established a connection between aquatic foods and FNS across various contexts. They showed a high level of political commitment through identified actions and targets linked to the policy's overarching aims and objectives. These instruments provide potential examples of food system policy framing that can be revised to suit different country contexts in future policy development reviews. Some other policy interventions to encourage aquaculture may be lowering the fish price by concentrating on low-value, small, and indigenous fish species (Prein and Ahmed, 2000)**.** Changes in consumption behavior and demand for more diverse food will also encourage aquaculture (Toppe et al.2012)**.** Raising income and lowering fish prices will also help increase demand (Prein and Ahmed, 2000)**.** There is a need to develop synergies between aquaculture and capture fishery through policy intervention (Belton and Thilsted, 2014**).**

The demand for livestock products is also increasing fast in India. Despite significant reservations about meat consumption, livestock production has the potential to contribute significantly to nutritional security (Ali, 2007)**.** Livestock contributes to one-third of the protein people consume: poor people depend on animal-sourced food (especially dairy products) to ensure their diets deliver the nutrients necessary for cognitive and physical development (Randolph *et al*., 2007). Increased intakes of animal-sourced foods are known to provide critical benefits to nutritionally vulnerable groups, such as children, women of reproductive age, or the elderly, in developing countries like India (Murphy and Allen, 2003; Randolph *et al.*, 2007; Grace *et al*., 2018). To better identify intervention options for the livestock sector that meet food security, livelihoods, and nutrition objectives, there is a need to better understand the nature and impacts of these dietary transitions. The livestock sector is fundamental for

food security not only at the household level, for small producers who depend directly on livestock to obtain food, income, and services but also at the national level. By enhancing food and nutritional security and raising the income of the poor, livestock production can pay for the household's education and other consumption needs. The significant challenge is to minimize the trade-off between the positive and negative impact of livestock production (Smith *et al*., 2013)**.** Improper management would increase pressure on natural resources, enhance greenhouse gas emissions, and separate zoonotic diseases (Nabarro and Wannous, 2014)**.** Backyard poultry is another option that is common in low-income food-deficient regions. Women are the key players in backyard poultry, and a gender-sensitive approach to promoting this sector will be beneficial (Bruyn *et al*., 2015; Kumar *et al*., 2021)**.** Significant constraints in backyard poultry are high chick mortality rate, lack of infrastructure, low production, lack of scientific knowledge, malnutrition, and feed price fluctuations (Ali, 2007)**.** To promote the livestock and poultry sector, there is a need to aim for managed intensification of livestock production. Applying one health approach will mitigate health risks at the interface between animals and humans. One health approach may be incorporated within the animal, environmental, and public health policies (Nabarro and Wannous, 2014).

IV

NUTRITIONAL SECURITY THROUGH CROP BIOFORTIFICATION

Crop biofortification is considered a promising technology to tackle micronutrient deficiency. An unbalanced diet or prolonged dependence on a specific diet may cause malnutrition and lead to adverse health conditions and work efficiency (Babu *et al.*, 2013)**.** Biofortification aims to put micronutrient traits in varieties with preferred agronomic and consumption traits, such as yield and disease resistance (Bouis *et al*., 2013)**.** Both conventional and transgenic methods are used for biofortification. Evidence shows that biofortification is a promising strategy for containing hidden hunger (Saltzman *et al*., 2013)**.** The poor cannot have a diversified diet for balanced nutrition and may benefit more from crop biofortification (Ansari and Thapa, 2019). It is the most sustainable and cost-effective approach compared to dietary diversification and medical supplementation (Ansari and Thapa, 2019; Singh, 2017)**.** Despite being cost-effective, crop biofortification suffers from poor access to biofortified cultivars, stakeholder acceptance, and availability of biofortified germplasm in the public domain (Sheoran *et al*., 2022)**.** Realising the importance of nutritional quality, the National Agricultural Research System (NARS) research efforts have now led to the development and release of a series of biofortified varieties. The first biofortified high-iron variety of pearl millet, *Dhanashakti*, was released in 2012. Other biofortified crops that are ready or in progress include orange flesh sweet potato (β- carotene), wheat (Fe & Zn), lentil (Fe), Rice (Zn), maize (β-carotene), and cauliflower (β-carotene). Although several varieties have been released, their adoption

remains challenging without incentive. A better understanding of the constraints and their potential solutions and providing a favourable policy environment and incentives are necessary to adopt these varieties. There is evidence that biofortification increases staple crop yield and nutritional quality. However, no significant proof exists of its positive impact on human health. To encourage crop biofortification in India, there is a need to strengthen the plant breeding programs and mainstream biofortification traits into it (Bouis and Saltzman, 2017; Saltzman *et al*., 2013)**.** There is a need to increase the number of efficiency trait and effectiveness studies. The biofortification is to be integrated strongly with NARS. The government also should invest more in research and extension for biofortified crops. There is a need to widen the genetic-based biofortified crops and explore their tolerance to major biotic and abiotic stresses (Hossain *et al*., 2022)**.** The markets for biofortified crops need extension (Ramadas *et al*., 2020). Increased awareness and strengthening of supply chains for biofortified crops can build consumption demand (Bouis and Saltzman, 2017). Market research is also essential for expanding markets (Saltzman *et al*., 2013). More investment is needed in biofortified foods. The promotion of public-private partnerships can play an important role**.** Promoting biofortified food must be integral to government programmes focusing on health, rural development, and agricultural production (Laurie *et al*., 2015; Bouis and Saltzman, 2017)**.** An institutional mechanism is also necessary to encourage a biofortified ecosystem in India (Bouis and Saltzman, 2017). Exploring the positive economic incentives through assured and remunerative prices may also be helpful (Singh, 2017). Finally, strengthening agricultural extension activities is essential for generating awareness, increasing adoption, and expanding demand (Singh, 2017; De Valenca *et al*., 2017)**.** The extension activities should focus on promotional campaigns and field demonstrations for better results.

V

STRENGTHENING FOOD VALUE CHAINS FOR NUTRITIONAL SECURITY

Developing and strengthening food value chains can play a significant role in achieving sustainable nutritional security. To contribute to national security, the food value chain must identify innovative ways to improve the availability, affordability, and acceptability of nutritious food (Fanzo *et al*., 2017a,b). The transformation of the food value chain may pose challenges and opportunities. While they may alleviate micro-nutrient deficiency and increase over-nutrition among high-income classes, they may have a limited impact on the rural population and urban poor (Gomez and Ricketts, 2013). Linking farmers to the remunerative value chains has direct benefits as they gain significantly in terms of productivity increases, improvements in quality, rise in income, and improved nutrition (Swinnen and Maertens, 2007; Birthal *et al*., 2009; Dries *et al*., 2009; Ramaswami *et al*., 2009). They also benefit indirectly through risk reduction and better access to inputs and markets (Bellemare, 2012; Swinnen and Maertens, 2007). In India, many value chains affect nutrition, especially among the

poor. For nutritional security, the food must be safe to eat on a sustainable basis, nutrient-dense at the point of consumption, and must be consumed in adequate amounts. For these, the value chain for micronutrient-rich food must be improved, making such food more available and affordable for consumption. It requires public action and policy to save the functioning of the food value chain **(**Maestre *et al*., 2017; Allen and Brauw, 2018). Strengthening the food value chain will also increase the consumption of nutritional food. Increased investment by the state to expand storage facilities, cold chains, and improved connectivity is also vital to reduce wastage and increase marketing options for smallholders. Institutional interventions such as producer organisations and cooperatives have helped provide inputs, reduce transaction costs, and form market linkages (Barrett *et al*., 2012; Bellemare, 2012; Boselie *et al*., 2003; Reardon *et al*., 2009; Schipmann and Qaim, 2010).

VI

CONCLUSIONS

There has been significant progress in food production and food security in India since Independence, and the Indian economy has also witnessed tremendous annual growth in GDP during the last two decades. Despite this, the progress in nutritional security of the Indian population is not encouraging as India ranks poorly on the global hunger index and multiple other indicators of nutritional security. It points toward the need for reorienting the agri-food systems from a major focus on food security to nutritional security. There are multiple dimensions of food security, such as access, availability, utilisation, and stability, and focusing merely on enhancing production will not yield the desired results. This will require holistic interventions aiming not only at enhancing production but also at improving access and utilization along with eliminating risk and variability across various components of food security. A food system comprises complex activities to supply food from producers to consumers. With nutritional security as the central focus rather than food production, the food systems will need a major revamping across its various components. It will also include changes in the role of multiple stakeholders in the food systems. Strengthening the synergies between nutritional security and sustainability of natural resources is essential. The transformation of the food systems will require designing strategies based on regional characteristics and the peculiarities of major players such as producers, consumers, and other stakeholders. The National Food Security Act 2013 aims to provide free food to the most vulnerable Indian households through a public distribution system and improve food access. Such an intervention can also help address the challenge of nutritional security in India in the medium to long run.

Diversification of food systems through crop diversity, wild fruit domestication, aquaculture, and animal foods can influence nutritional security directly through increased production and consumption and indirectly through enhanced income, enabling nutritious consumption. With growing income levels in India, the demand for

food is shifting to high-value crops, fish, and livestock products. The poor and more vulnerable sections of the society also need more diversified food for better nutrition, but the affordability of such food is a challenge. Hence, the diversification efforts must focus on disadvantaged regions and vulnerable sections of society. The potential benefits for the poor are very high through wild fruit domestication as the prices may be reasonable, making them more accessible, and the potential nutritional gains will be more significant. Aquaculture may also help adapt to the reduction in fish production through capture fisheries. Low-cost and low-input aquaculture technologies will improve access and nutritional status for relatively poor consumers. Aquaculture can also help reduce land use, input use, and greenhouse gas emissions by reducing the dependence on meat consumption in the long run. Livestock production for nutritional security must also minimise the trade-offs between production and environmental concerns. Backyard poultry can enhance nutrition directly and indirectly and empower women, especially in rural areas. The policy on backyard poultry promotion, however, should be more gender sensitive.

Crop biofortification may be another promising intervention for improving nutritional security. The public plant breeding programmes should effectively integrate biofortification and must be an integral part of the national agricultural research system. Increasing efficacy trials and effectiveness studies will also help. Investing more into research and extension and focusing on expanding the markets for biofortified foods is also necessary. The promotion of biofortified food must be an integral part of government programs. There must also be special incentives for the adoption of such crops. Finally, strengthening food value chains is necessary for considerable progress in nutritional security in India. The value chains must ensure better availability, affordability, and acceptability. Reducing food wastage across value chains will reduce costs, improve quality, and make the food more affordable at lower prices. Increased investment by the state to expand storage facilities, cold chains, and improved connectivity is also vital to reduce wastage and increase marketing options for smallholders. Linking farmers to the more remunerative value chains will help increase farm income and reduce risks across value chains. Institutional interventions such as producer organizations and cooperatives will also help strengthen the food value chains and improve nutritional security in India.

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