



FAN
2020

Food, Agriculture, and Nutrition in India

.....
LEVERAGING AGRICULTURE TO ACHIEVE ZERO HUNGER

Tata-Cornell Institute for Agriculture and Nutrition
CORNELL UNIVERSITY | COLLEGE OF AGRICULTURE AND LIFE SCIENCES

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Required citation: TCI (Tata–Cornell Institute). 2020. *Food, Agriculture, and Nutrition in India 2020: Leveraging Agriculture to Achieve Zero Hunger*. Ithaca, NY: TCI.

ISBN: 978-0-578-70881-2
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Copy editing: Patricia Mason
Design and layout: Terry Marcus Design

Cover photo: Woman in rice field in Kandhamal district, Odisha. *Photo by Maureen Valentine.*

Goal 2: Zero Hunger | End hunger, achieve food security and improved nutrition and promote sustainable agriculture

Hamlet outside of Phulbani, Kandhamal district, Odisha.
Photo by Anthony Wenndt.

FOREWORD

The Tata–Cornell Institute is delighted to release the inaugural issue of the Food, Agriculture, and Nutrition (FAN) Report for India. FAN 2020 focuses on the state of hunger and malnutrition in India in the context of the Sustainable Development Goals, specifically SDG2, the Zero Hunger goal. This report provides detailed data and analysis on progress toward specific targets of SDG2. Stark spatial differences in the extent of the problem and potential paths forward are highlighted using district-level data and maps.

Over the past four decades, India has made significant progress in reducing hunger, at least in terms of meeting the minimum calorie requirements. However, micronutrient malnutrition is endemic and manifests itself most clearly in the high prevalence of child stunting. The needle on progress in the reduction of child stunting has hardly budged over the decades. Even as the country struggles to tackle these problems, it is facing an emerging threat in the rapidly rising number of adults who are overweight or obese, and consequently, on the prevalence of noncommunicable diseases. This report argues that addressing both ends of the malnutrition spectrum requires enhanced availability and access to diverse and nutritious foods that are affordable for the poor.

FAN 2020 provides a detailed assessment of the prospects for enhancing productivity and farm incomes across the numerous and highly varied agroecologies and cropping systems of India. The report emphasizes the need for continued high-level investments in agricultural infrastructure and research to sustain past gains in productivity growth and to exploit new opportunities for growth, such as the renewed interest in millets and pulses. FAN 2020 calls for reorienting agricultural policy away from its traditional focus on staples, such as rice and wheat, and toward enhancing the productivity and supply of coarse cereals, pulses, fruits, vegetables, and livestock products. It is no longer only about the quantity of grain, but about better quality, diversity, and safety of the food system.

FAN 2020 recognizes that rural income growth through agricultural productivity is one among multiple pathways to achieving zero hunger. Reducing gender discrimination in access to food within the household as well as better sanitation and food handling practices are also important in ensuring positive nutrition outcomes. The focus on food diversity should be accompanied by investments in rural drinking water systems, public health infrastructure, and behavior change communication.

Finally, the multisectoral nature of the zero-hunger challenge requires explicit strategies for convergence of policies and programs across ministries at the central, state, and local levels. Breaking out of our disciplinary and organizational silos is crucial for ensuring success in achieving the zero hunger goal.

I hope you find the FAN 2020 report useful in the pursuit of hunger reduction and nutrition improvement for India.

Prabhu Pingali
Founding Director
Tata–Cornell Institute for Agriculture & Nutrition

EXECUTIVE SUMMARY

This report is the inaugural issue in a series that the Tata–Cornell Institute (TCI) plans to release to provide periodic assessments of the food, agriculture, and nutrition situation in India. In this issue, we focus on India’s prospects for achieving Sustainable Development Goal 2 (SDG2)—achieving zero hunger by 2030 (Box ES.1). Reducing hunger and improving nutrition remain top developmental priorities in India, where 194 million individuals remain undernourished, and 43.3 million children under the age of five are too short for their age (stunted). At the same time, India is also increasingly struggling with the problem of obesity: 21 percent of adult females and 19 percent of adult males can be classified as obese, adding to the double burden of malnutrition. If one includes the very high prevalence of micronutrient deficiencies, India now faces an enormous challenge, which scholars refer to as the “triple burden of malnutrition.”

Getting to zero hunger is not just about calorie adequacy. A person whose intake of calories is adequate can still be stunted or overweight due to micronutrient deficiency. In order to address micronutrient deficiency, India’s policy must turn away from production of staple grains and toward production of micronutrient-rich foods, like coarse cereals, pulses, fruits, vegetables, and animal products. Demand for these more diverse foods is on the rise, and there is a burgeoning opportunity for small farmers to take advantage of this demand. By diversifying and commercializing their production, small farmers can increase their income, which will also increase their access to micronutrient-rich foods in the market. Household access to micronutrient-rich foods, however, does not necessarily equate to individual access, as inadequate allocation of food to women is a common problem in rural India. To address this issue, development programming must focus on empowering women, as empowered women are more likely to eat diverse diets and less likely to suffer from iron deficiencies. Healthier women, in turn, have healthier children. Individual nutrition also depends on good sanitation and hygiene, which ensure nutrient absorption by the body. Good sanitation and hygiene require food safety, toilets, behavior change interventions to reduce open defecation, and improved infrastructure for water treatment and piped water.

The explicit focus of SDG2 on the importance of ending all forms of malnutrition—and the recognition of agriculture as a key player in achieving this goal—are especially relevant in India, where the majority of the population is rural and malnutrition is a persistent problem. Sixty-seven percent of the Indian population lives in rural areas, and 64 percent of rural households rely on farming as their main source of income. Twenty-six percent of the rural population is living under the poverty line, but the poverty rate is far from being equal across regions. Poverty is particularly concentrated in eastern India, which is also the region where undernutrition and micronutrient deficiency are most prevalent. To understand how to improve nutrition outcomes, it is important to learn from these regional differences. We find that regions that have invested in agriculture have experienced improvements in income and nutrition, and we use this finding to argue that the regions with persistent undernutrition need to invest in agriculture. At the same time, we argue that investments in agriculture in more developed regions can also address the overnutrition problem by increasing the availability and accessibility of more nutritious foods, like coarse cereals, pulses, fruits and vegetables, and animal products. The key findings of our report are elaborated here:

1. India’s progress on undernutrition has been slow compared to economic progress.

Despite India’s significant progress on reducing poverty, the prevalence of undernourishment remains a glaring problem. By 2016–18, 14.5 percent of the population was still classified as undernourished, falling short of the Millennium Development Goal (MDG) target, which called to halve the prevalence of undernourishment from 23.7 in 1990–92 to 11.9 percent in 2015. Lack of sufficient progress on hunger reduction appears even starker in terms of the absolute numbers. In 2016–18, about 194 million people remained undernourished in the country, a marginal 8 percent decrease from the 210 million undernourished individuals in 1990–92.

2. Getting the nutrition metric right is essential to getting the policy right.

Anthropometric measures give a more accurate picture of malnourishment. Undernourishment, which is based on calorie adequacy, does not account for the quality of diets. Many consuming sufficient amounts of calories may still suffer from symptoms of malnutrition due to diets deficient in micronutrients. In 1992–93, 52 percent of Indian children were classified as stunted. In 2015–16, the prevalence of stunting was still high, at 38 percent. In addition, another form of malnutrition, obesity, has significantly increased, posing a new public health challenge. Obesity prevalence doubled among Indian men and increased by 62 percent among Indian women, between 2005–06 and 2015–16.

3. Access to nutritious foods is lagging, despite increasing demand.

While access to cereals in India has increased due to the persistent focus of Green Revolution-era food security policies on staple grains, access to more nutritious and diverse foods is limited. The demand for more nutritious foods is certainly present, as evidenced by higher expenditures on fruits and vegetables, milk products, meat, eggs, and fish. However, this demand is not translating into increased caloric intake from these food groups. Instead, caloric intake from cereals, which decreased from 71 percent in 1993–94 to 61 percent in 2011–12, is being replaced by processed foods, beverages, oils, and fats. Part of the reason for limited consumption of more nutritious foods, like protein-rich pulses and micronutrient-rich fruits and vegetables, is the high and fluctuating prices for these foods. Changes in dietary patterns, together with a stasis in production policies, have therefore led to the consumption–production disconnect, adding to the nutritional challenge. Policies, as a result, must prioritize making these nutritious foods affordable by encouraging increased production of such foods.

4. Regional disparities in nutritional outcomes can be attributed to varying trajectories of subnational structural transformation.

Symptoms of malnutrition, including child stunting and wasting, anemia in women of childbearing age, and obesity in adults, vary significantly between and within states in India. Such variation in nutrition outcomes at the country level has been related to a country’s progress along the path of structural transformation—the process by which a region’s economy, stimulated by growth

in the agriculture sector, experiences subsequent growth in the industrial and service sectors, thus prompting a shift of labor to those sectors and a reduction in agriculture’s share of total gross domestic product (GDP). Just as structural transformation influences nutrition outcomes at the country level, differing stages and trajectories of structural transformation within Indian states are leading to varied nutrition outcomes between states. In agriculture-led growth states and urbanizing states, the rate of stunted, wasted, and underweight children is lower, compared to lagging states, but the rate of obesity and noncommunicable disease is higher.

5. Investing in agriculture in the lagging states is fundamental to reducing malnutrition.

The process of structural transformation begins with agricultural growth. While some states in India have certainly experienced this growth, others, particularly in eastern India, are lagging behind. For these states, investment in agriculture is necessary to kick-start the process of structural transformation, and ultimately, to achieve higher incomes and better nutrition outcomes. Theoretically, as regions progress through the process of structural transformation, the share of agriculture in GDP decreases, as does the share of the population employed in agriculture when they move to employment in other sectors. This should allow for agricultural incomes to increase, as there are fewer people to share the profits. However, if the share of the population employed in agriculture does not decrease as quickly as the share of agriculture in GDP, then agricultural incomes do not increase, and the people in the agriculture sector do not benefit. In states where this is the case, investment in agriculture is necessary. Only by investing in agriculture can these states bring about the agricultural growth needed to raise the agricultural GDP to the level necessary to support the share of labor in agriculture.

6. Investment in agriculture leads to better nutrition at the household level via higher incomes, access to diverse foods, more equitable intrahousehold food allocation, and improved health environments.

Increased agricultural productivity leads to increased income, which in turn is well known to lead to improved nutrition. In India, increase in agricultural income over time has been associated with an increase in women’s body mass index (BMI)—an indicator for overall nutrition that is also associated with child nutrition. Agricultural productivity can also lead to improved nutrition by increasing access to diverse foods—both via increased incomes and via increased supply of diverse foods

Box ES.1 | SUSTAINABLE DEVELOPMENT GOAL 2: ZERO HUNGER
End hunger, achieve food security and improved nutrition, and promote sustainable agriculture

TARGETS

- 2.1 | By 2030, end hunger and ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round.
- 2.2 | By 2030, end all forms of malnutrition, including achieving, by 2025, the internationally agreed targets on stunting and wasting in children under 5 years of age, and address the nutritional needs of adolescent girls, pregnant and lactating women, and older persons.
- 2.3 | By 2030, double the agricultural productivity and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists, and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition, and non-farm employment.
- 2.4 | By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding, and other disasters and that progressively improve land and soil quality.
- 2.5 | By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed.
- 2A | Increase investment, including through enhanced international cooperation, in rural infrastructure, agricultural research and extension services, technology development and plant and livestock gene banks in order to enhance agricultural productive capacity in developing countries, in particular least developed countries.
- 2B | Correct and prevent trade restrictions and distortions in world agricultural markets, including through the parallel elimination of all forms of agricultural export subsidies and all export measures with equivalent effect, in accordance with the mandate of the Doha Development Round.
- 2C | Adopt measures to ensure the proper functioning of food commodity markets and their derivatives and facilitate timely access to market information, including on food reserves, in order to help limit extreme food price volatility.

Source: UN (2020)

in the market. Diet diversity, in turn, reduces the risk of both stunting and obesity. Nutrition outcomes also depend on equitable intrahousehold allocation of food and the individual’s ability to absorb nutrients, which can be affected by the health and hygiene environment. Directing agricultural investments toward self-help groups to increase women’s empowerment in agriculture, or toward labor-saving technology to reduce women’s time spent in agriculture, can help improve intrahousehold food allocation. The health and hygiene environment can be improved by directing investments toward food safety, sanitation facilities, behavior change programming to encourage better hygiene practices, and improved drinking water.

7. In regions where agriculture is underdeveloped and poverty is high, diets are mainly staple-based, and nutrition outcomes are poor.

In eastern India, agricultural development has lagged behind the other states for many reasons, including unfavorable climatic conditions, lack of economic incentives, low adoption of high-yielding varieties, and lack of irrigation infrastructure and electrical connectivity. As a result, the GDP per capita is still low, and diets are still comprised mainly of staple grains. The effect of low incomes and lack of diet diversity is evident in nutrition outcomes: the prevalence of stunting is higher in these areas.

8. In more developed regions, diets and nutrition outcomes have improved, but overnutrition is emerging as an important concern.

In both agriculture-led growth states and urbanizing states, cereals have become less prominent in diets. While some of the foods replacing cereals are healthy, and stunting has certainly decreased in some parts of these regions, greater consumption of processed foods is contributing to a rise in obesity and noncommunicable diseases, such as diabetes and heart disease. Consumption of fruits and vegetables, despite economic progress, continues to be chronically low, leading to continued micronutrient deficiency.

9. Achieving SDG2 requires policy focus to move toward more nutritious and micronutrient-rich foods, such as pulses, coarse cereals, vegetables, fruits, and animal products.

Greater demand for more nutritious foods in India is not being met, yet the persistence of Green Revolution-era policies retains the focus only on staple grains. As a result, prices for nonstaples have increased, further contributing to the persistence of malnutrition. Meeting the rising demand for nonstaples is not only essential for future nutrition security, it also provides an enormous economic opportunity for smallholder farmers. Institutional arrangements—access to inputs, technology, markets, credit, loans, and extension services—must be made to give smallholders the support that they will need to diversify. The government must also strive to promote market infrastructure and value chain development. Encouraging farmer producer organizations (FPOs) and other aggregation models, which can lower contracting and operating costs, reduce fixed costs of quality determination, reduce transportation costs, and enable better linkages to financial services, needs to be prioritized.

10. Effort to double incomes and productivity needs to be tailored to various different cropping systems in the country.

India has a vast array of cropping systems, each of which require a different set of interventions to improve farmers’ incomes and productivity. For example, in the highly productive rice–wheat systems of northern India and rice–rice systems of southern India, efficiency of input use must be prioritized to address pollution and low water tables. Diversification to high-value crops that require less water should also be considered as alternatives to rice in these regions. In the low-productivity regions of eastern India, continued investment in irrigation infrastructure and electrical connectivity is necessary for increasing rice and wheat productivity, but diversification should also be pursued. In regions with large areas that lie fallow for half of the year, adding a second crop that can be grown with minimal irrigation, such as pulses or coarse cereals, has the potential to greatly increase production. Future research on improving agricultural productivity and incomes should focus on further tailoring strategies to cropping systems.

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ABBREVIATIONS

APMC	Agricultural Produce Market Committees	IIMR	Indian Institute of Millets Research
BMI	Body mass index	IIPS	International Institute for Population Sciences
CGRPT	Regional Co-ordination Centre for Research and Development of Coarse Grains, Pulses, Roots and Tuber Crops in the Humid Tropics of Asia and the Pacific	IPM	Integrated pest management
		ISAAA	International Service for the Acquisition of Agri-Biotech Applications
		MDGs	Millennium Development Goals
CLTS	Community-led total sanitation	MDMS	Mid-Day Meal Scheme
CNNS	Comprehensive National Nutrition Survey	NCA	Net cropped area
DLD	District Level Data	NCD	Noncommunicable disease
DSR	Direct seeded rice	NCDEX	National Commodity and Derivatives Exchange
e-NAM	National Agriculture Market (electronic trading platform)	NFHS	National Family Health Survey
		NSS	National Sample Survey
EPWRF	EPW Research Foundation	NSSO	National Sample Survey Office
FAO	Food and Agriculture Organization of the United Nations	OD	Open defecation
		OECD	Organisation for Economic Co-operation and Development
FICCI	Federation of Indian Chambers and Commerce of Industry)	OFSP	Orange-fleshed sweet potato
FPO	Farmer producer organization	OPHI	Oxford Poverty and Human Development Initiative
GCA	Gross cropped area	PDS	Public Distribution System
GDD	Global Dietary Database	R&D	Research and development
GDP	Gross domestic product	ReMS	Rashtriya e-Market Services
GDS	Grameen Developent Services	SD	Standard deviation
GST	Goods and services tax	SDGs	Sustainable Development Goals
HYV	High-yielding variety	TARINA	Technical Assistance and Research for Indian Nutrition and Agriculture
ICAR	Indian Council of Agricultural Research		
ICDS	Integrated Child Development Scheme	TCI	Tata–Cornell Institute
ICRIER	Indian Council for Research on International Economic Relations	TFP	Total factor productivity
		UMP	Unified Market Platform
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics	UN	United Nations
		USAID	United States Agency for International Development
IFPRI	International Food Policy Research Institute	VC	Vertical coordination
IGP	Indo-Gangetic Plain	WASH	Water, sanitation, and hygiene
IHDS	Indian Human Development Survey	WEAI	Women’s Empowerment in Agriculture Index
IIMA	Indian Institute of Management Ahmedabad	WHO	World Health Organization

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Women harvesting rice in Kandhamal district, Odisha.
Photo by Maureen Valentine.

1

The State of Nutrition in India

This report provides an assessment of food, agriculture, and nutrition in India in 2020, focusing on prospects for achieving Sustainable Development Goal 2 (SDG2), which calls for zero hunger by 2030. Addressing the issues of hunger and malnutrition have been major developmental policy challenges in India. While a persistent policy focus on staple grains has increased calorie availability, eradication of malnutrition requires more than adequate calories. In this first chapter, we provide an assessment of nutrition and diets in India today.

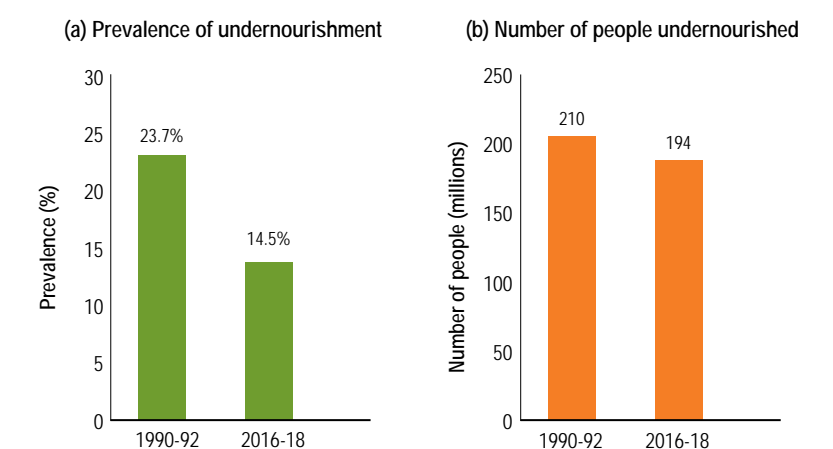
Indian diets are changing, moving away from staple food products toward calorie-dense, convenience-based food items, which tend to be lacking in micronutrients. Overnutrition now coexists with micronutrient deficiency and undernutrition, together posing the “triple burden” of malnutrition. The distribution of this burden shows a spatial pattern, too: while richer regions are increasingly overweight, poorer regions are persistently undernourished. Highlighting this subnational variation paves the way for our inquiry, in subsequent chapters, into the role of agriculture in nutrition outcomes. SDG2 clearly recognizes the significance of agriculture for nutrition in its call to double agricultural incomes and productivity. In the final chapters, we address prospects for doubling income and productivity, and present an approach tailored to individual cropping systems.

1.1 National Nutrition Trends

Despite India’s spectacular economic growth—from a gross domestic product (GDP) of US\$320 billion in 1990 to US\$2.7 trillion in 2018—it has not made comparable progress in reducing hunger. The Millennium Development Goals (MDGs)—predecessors to the Sustainable Development Goals (SDGs)—called for halving, between 1990 and 2015, the proportion of people living under the poverty line and the proportion of people whose calorie intake was below

a minimum dietary requirement, referred to as the “prevalence of undernourishment.” India has made significant progress in reducing poverty: the percentage of people under the poverty line more than halved between 1993 and 2011, from 46 percent to 21 percent.¹ However, the prevalence of undernourishment, which decreased from 23.7 percent in 1990–92 to 14.5 percent in 2016–18 (Figure 1.1a), has still not reached the MDG target of 11.9 percent.

Figure 1.1 | (a) Prevalence of undernourishment and (b) Number of people undernourished, 1990–92 and 2016–18



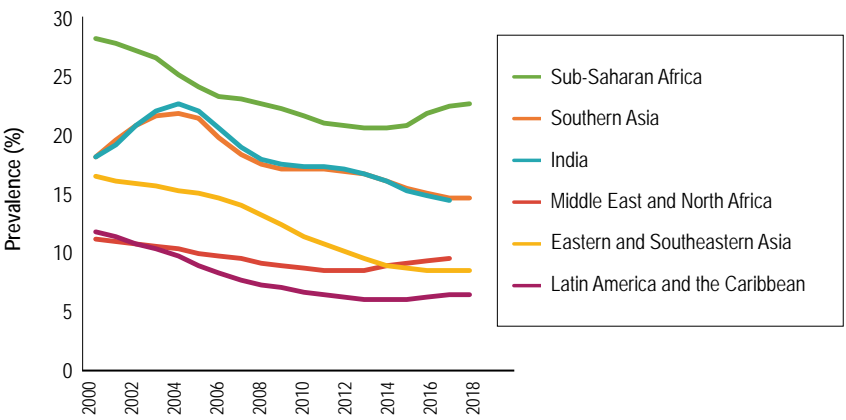
Data sources: 1990–92 data – State of Food Insecurity 2015;² 2016–18 data – FAOSTAT

¹ Poverty is measured in India in terms of the consumption expenditure required to ensure a minimum calorie intake. The latest data on the prevalence of poverty in India is from the 2011–12 National Sample Survey (NSS). There have been no recent poverty estimates released by the Government of India.

² FAO (2015)

Given India’s huge population, lack of sufficient progress on hunger reduction appears even starker in terms of the absolute numbers. In 2016–18, about 194 million people remained undernourished in the country, a marginal 8 percent decrease from the 210 million undernourished individuals in 1990–92 (Figure 1.1b). To put this in perspective, it is useful to compare India and some of the other low- and middle-income countries. The prevalence of undernourishment in India is much higher when compared to countries in Eastern and Southeastern Asia, the Middle East and North Africa, and Latin America and the Caribbean (Figure 1.2). It is sobering to find that

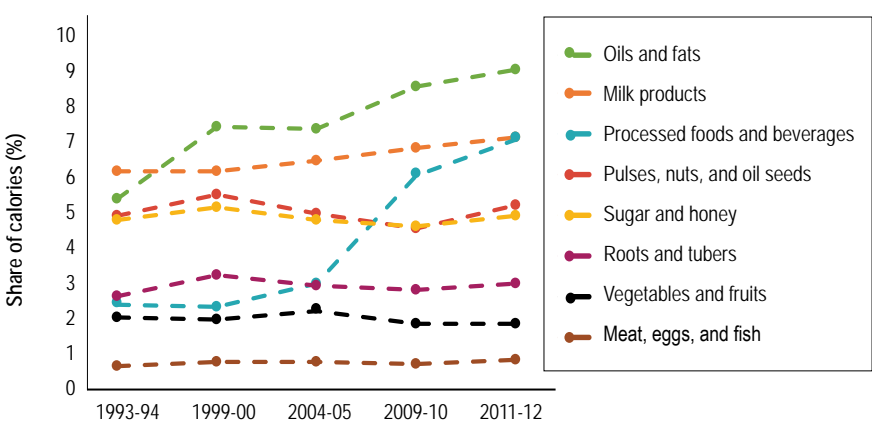
Figure 1.2 | Prevalence of undernourishment by global region, 2000–2017



Note: Middle East and North Africa data is calculated from FAO data using the countries that the World Development Indicators include in that group.

Data source: FAOSTAT

Figure 1.3 | Share of calorie intake from non-cereals, 1993–94 to 2011–12



Note: This is the latest available data on the share of calories consumed by different food groups.

Data source: NSS, various rounds, as reported in Table T18, p. 40, Government of India (2014)

India, the largest democracy in the world, fares only marginally better than sub-Saharan Africa, which performs significantly worse on all economic indicators. In order to meet SDG2 by 2030, India would need to reduce the number of hungry people by at least 194 million.

It is important to note that, while the prevalence of undernourishment in India is declining (albeit slowly), many of those who are no longer classified as undernourished still continue to suffer from other forms of malnutrition. The prevalence of undernourishment is calculated solely on the basis of daily calorie intake and does not consider the quality of food consumed. Without nutritious food—foods rich in protein and micronutrients—people who otherwise consume sufficient calories can still suffer from micronutrient deficiencies, causing symptoms of malnutrition, such as stunting, wasting, and anemia. Lack of nutritious food also contributes to symptoms of overnutrition, such as obesity. This is not only a technical point, but highlights how changing dietary habits of people, especially in the developing world, is not accounted for in the metrics of undernourishment. Thus, in line with the evolution of global thinking around food security (Box 1.1), SDG2.1 calls specifically to “ensure access by all people, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round.”³

1.1.1 Transitioning diets

The focus on nutritious food is particularly important in the case of India. Traditionally, food access policies in India have focused solely on staple grains—rice and wheat. Although access to calorie-dense staples increased due to Green Revolution-era policies that promoted production of staples via subsidies, support prices, and irrigation infrastructure, access to more nutritious and diverse foods remains a concern and lags behind in policy agendas. Even as the share of calories from cereals in Indian diets has decreased, from 71 percent in 1993–94 to 61 percent in 2011–12, these calories are being replaced mainly by oils, fats, processed foods, and beverages, rather than by healthy foods like fruits, vegetables, pulses, or animal products (Figure 1.3). Milk is the only micronutrient-rich food that has shown a noticeable rising trend; yet, milk consumption in India is still far below world averages: the latest comparative data available show Indians consume 85.4 g/day of milk, while the world average intake is 162.7 g/day.⁴ Even as of 2015–16, diverse diets are far from the norm: only 6 percent of women consume eggs, fish, or meat daily; only 7 percent consume fruit daily;

³ UN (2020)
⁴ GDD (2019)

and less than half consume any quantity of green leafy vegetables daily (Figure 1.4).

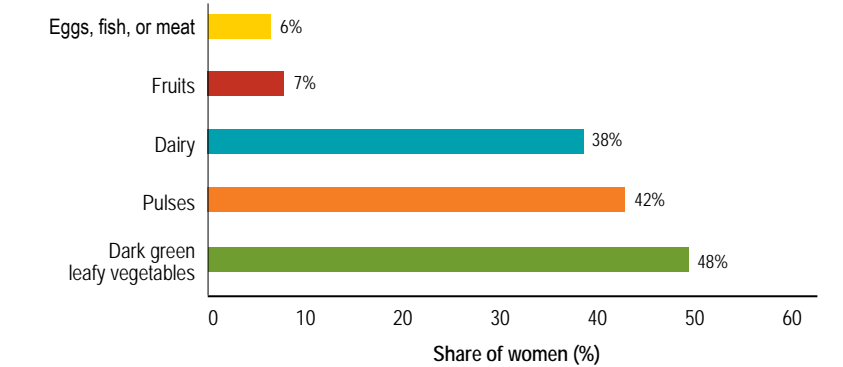
These trends stand in contrast to what one would expect from the “nutrition transition” observed in other countries as they have advanced economically. Traditionally, the nutrition transition consists of two stages. The first stage is marked by increased consumption of vegetables, fruits, and animal products, while the second stage is marked by increased consumption of energy-dense foods. India seems to have skipped directly to the second stage. Part of the reason for the consistently low consumption of these more diverse food groups is low availability (Figure 1.5). Low availability also contributes to another factor limiting access: affordability. Over the past 50 years, we have seen a sharp increase and high volatility in the prices of fruits, vegetables, pulses, and animal products (Figure 1.6). Rising relative prices of nonstaples hinders the affordability of a nutritious diet, especially for the poor. The cost of the recommended diet in 2011 was 53 percent of male wages, and 68 percent of female wages.⁵ However, the fact that the share of food expenditures (Figure 1.7) spent on some of these more nutritious items (especially fruits and vegetables) is increasing in tandem with prices indicates that there is an unmet demand for these products. Increase in the supply is critical to bring down the relative prices of nutritious food items, so that the poor are also able to include them in their diets as an affordable option.

The high relative prices of protein- and micronutrient-rich foods not only limit the consumption of such food items, but also incentivize the consumption of cheap processed foods. Low consumption of micronutrient-rich foods leads to what has been termed “hidden hunger,” which is manifested through poor nutrition outcomes, such as child stunting (low height-for-age), underweight (low weight-for-age), and wasting (low height-for-weight). Rising consumption of cheap processed food, on the other hand, is contributing to the emerging problem of overweight and obesity. Together, undernutrition (lack of calorie adequacy), micronutrient deficiency, and overnutrition form what has been termed the “triple burden of malnutrition.” As SDG2 calls to end all three forms of malnutrition, it is therefore imperative to monitor them continuously and identify the various factors which contribute to them. Box 1.2 provides definitions for the indicators of malnutrition.

⁵ Raghunathan, Headey, and Herforth (2020)

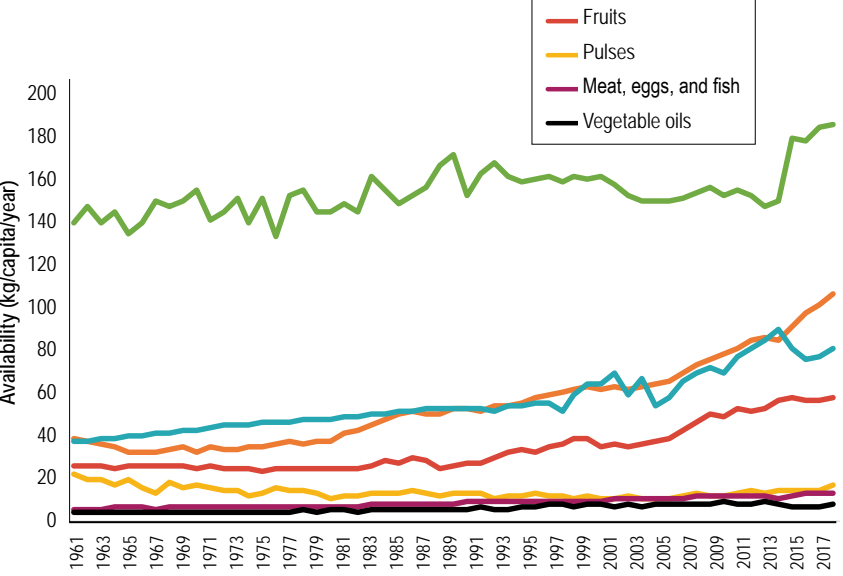
Low consumption of micronutrient-rich foods leads to what has been termed “hidden hunger,” which is manifested through poor nutrition outcomes, such as child stunting (low height-for-age), underweight (low weight-for-age), and wasting (low height-for-weight).

Figure 1.4 | Share of women consuming micronutrient-rich foods daily, by food group, 2015–2016



Data source: Authors’ calculations from National Family Health Survey (NFHS) 2015–16 district-level data.

Figure 1.5 | Historical availability of foods, 1961–2016



Data source: FAOSTAT

Box 1.1 | THE EVOLVING DEFINITION OF FOOD SECURITY

Food security originally referred to self-sufficiency at the national level: if a country had enough food to meet the dietary energy requirements of its population, then it was food secure.^a This supply-focused definition disregarded the question of who had access to the food, and whether the food was safe and nutritious. In the mid-1970s, scholars and practitioners, seeking to address this oversight, redefined food security as access by all people to enough food to live a healthy and nutritious life.^b The definition used today was coined at the 1996 World Food Summit and asserts that food security “exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for a healthy and active life.”^c Although this definition was definitely an improvement from the earlier definition, which was solely focused on calorie adequacy, it is important to note that this definition still does not equate to nutritional security, which depends on

other factors, such as sanitation, water quality, infectious diseases, and access to health care.^d In addition, food security at the household level, which is often the level used for design, implementation, and evaluation of programs, projects, and policies, does not necessarily ensure food security at the individual level because of unequal intra-household food allocation. Due to many of these confounding factors, anthropometric measures, which account for age-specific, individual biophysical characteristics (height and weight), especially for children, can be more accurate measures of food security. Anthropometric indicators are not only able to evaluate quality of diets, but also the health and hygiene environment, and therefore, are an improvement over other measures of food security, hunger, or nutrition.

^a Pinstrup-Andersen (2009)

^b Pinstrup-Andersen (2009)

^c FAO (2006, 1)

^d Pinstrup-Andersen (2009)

Box 1.2 | DEFINITIONS OF MALNUTRITION INDICATORS

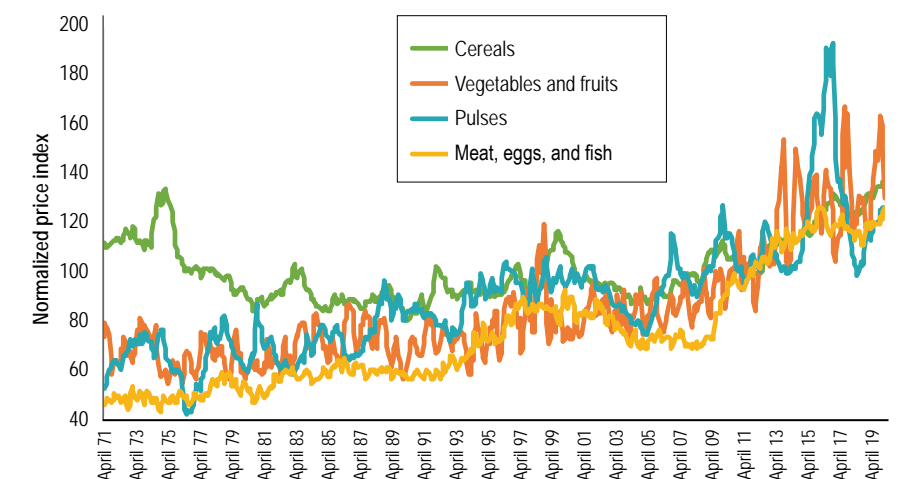
Stunting: Height-for-age < -2 standard deviations (SD) of the World Health Organization (WHO) Child Growth Standards median

Wasting: Weight-for-height < -2 SD of the WHO Child Growth Standards median

Underweight: Weight-for-age < -2 SD of the WHO Child Growth Standards median

Overweight: Weight-for-height > +2 SD of the WHO Child Growth Standards median

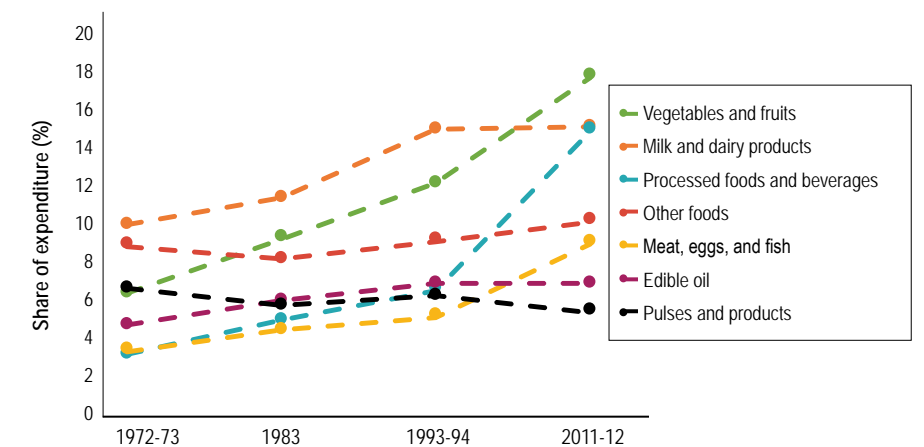
Figure 1.6 | Price trends and volatility by food group, 1971–2020



Note: Prices shown are monthly price indices, normalized by index for all commodities based on 2012 prices.

Data source: EPWRF India Time Series

Figure 1.7 | Share of food expenditure on non-cereals, 1972–73 to 2011–12



Note: This is the latest data available on expenditure by food group.

Data source: NSS, various rounds

Women pick green gram (mung beans) in Sarobag, Munger district, Bihar.
Photo by Kiera Crowley.

1.1.2 Child malnutrition

Stunting, low weight-for-age, and wasting in children can be indicative of either undernutrition, micronutrient deficiency, or both. Child malnutrition is particularly concerning. Poorly nourished children are at a greater risk of mortality, and adults who were poorly nourished as children are at greater risk for chronic health problems.⁶ In the long run, poor nutrition in early childhood can negatively impact cognitive skills and educational outcomes, and eventually, lead to reduced labor and wages.⁷ This situation triggers a perpetual cycle of poverty that is transmitted across generations. Addressing child nutrition, therefore, goes a long way toward ensuring sustainable and equitable development, which the SDGs aspire to promote.

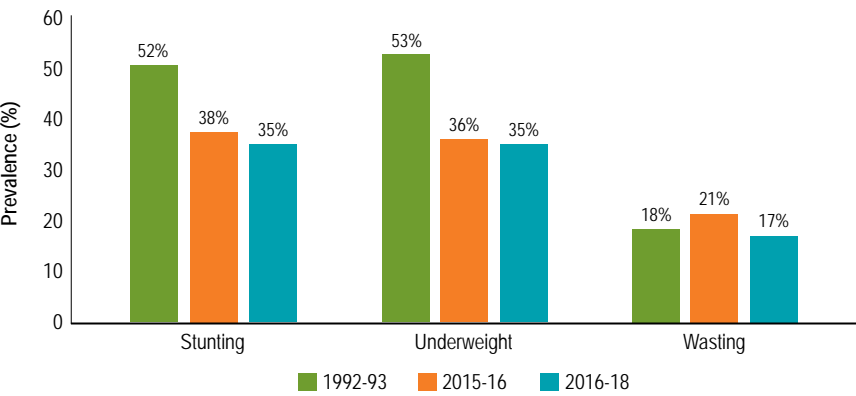
In India, child malnutrition remains one of the most important development challenges. Judging by measures of child malnutrition, India’s lack of progress on nutrition is quite revealing. Compared to the prevalence of undernourishment, which was 24 percent in 1990–92 and 15 percent in 2016–18, the prevalence of stunted children has been consistently and significantly higher: 52 percent in 1992–93 and 35 percent in 2016–18 (Figure 1.8). The prevalence of underweight children has followed a similar trajectory (Figure 1.8). As of 2015–16, India accounted for almost a third of stunted children worldwide.⁸ Furthermore, the proportion of children classified as wasted increased between 1992–93 and 2015–16, from 18 to 21 percent, though it was back to 17 percent according to the most recent 2016–18 survey. The 2016–18 percentages translate to 39.5

million stunted children, 39.5 million underweight children, and 19.2 million wasted children.⁹ It is also important to highlight that much of the improvements in stunting and underweight numbers came from recategorizing severely malnourished cases as moderately malnourished cases. A comparison with other developing regions of the incidence of stunting and underweight among children further highlights India’s poor progress on this front (Figure 1.9).

1.1.3 Overnutrition

While India continues to grapple with the problems of undernutrition and micronutrient deficiency, experts are now calling for greater attention to the unprecedented increase in obesity rates, both in rural and urban areas.¹⁰ Obesity is a well-known risk factor for noncommunicable diseases (NCDs). The onset of hypertension, high blood glucose, diabetes, heart disease, cancer, and other chronic illnesses among individuals has a high correlation with being obese or overweight. In addition, children born to women who are obese during pregnancy are at greater risk for early development of obesity and diabetes.¹¹ In the last 10 years, the obesity rate in India has doubled for men and increased by 62 percent for women (Figure 1.10). In 2015–16, 21 percent of adult females and 19 percent of adult males were classified as obese by the NFHS.¹² Hypertension, which is often caused by obesity, is already affecting 27 percent of men and 23 percent of women aged 40–49, and is becoming a major public health concern, with roots in changing diets, occupations, and lifestyles.¹³

Figure 1.8 | Prevalence of child stunting, underweight, and wasting in 1992–93, 2015–16, and 2016–18

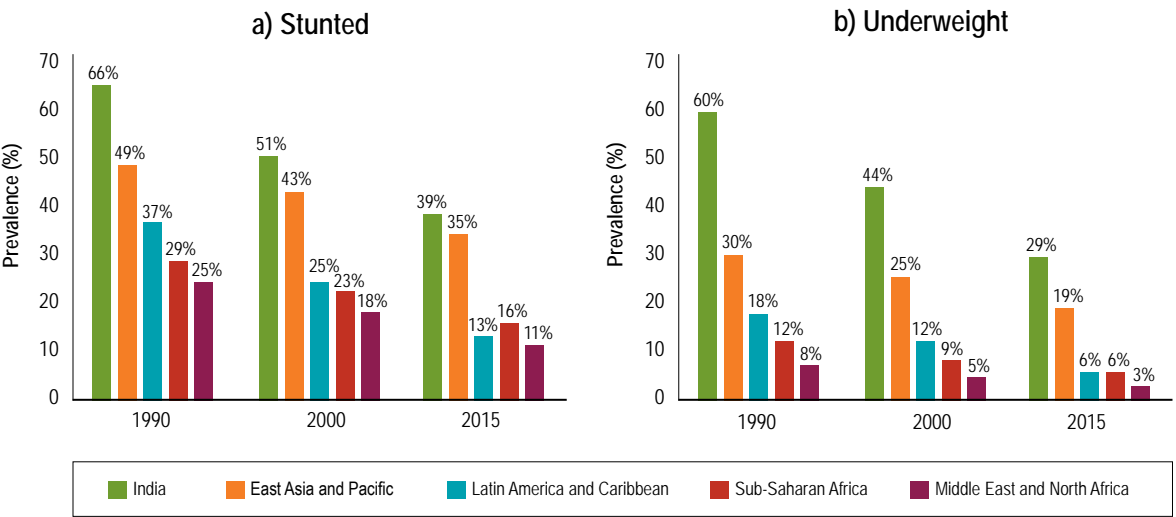


Note: Prevalence in 1992–92 is in children under 4 years of age, while prevalence in 2015–16 is in children under 5 years of age.

Data source: NFHS 1992–93 and 2015–16; Comprehensive National Nutrition Survey (CNNS) 2016–18

The 2016–18 percentages translate to 39.5 million stunted children, 39.5 million underweight children, and 19.2 million wasted children.

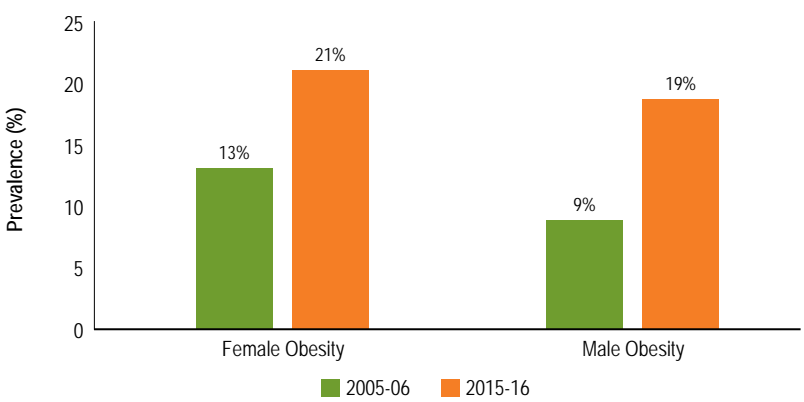
Figure 1.9 | Prevalence of (a) stunted and (b) underweight children by global region, 1990–2016



Note: Due to data availability, the India data for this figure are taken from 1989, 1999, and 2014. Numbers from the World Development Indicators are used for India for the sake of comparison with other countries, although the numbers differ from the NFHS data.

Data source: World Development Indicators

Figure 1.10 | Prevalence of overweight and obese adult females and males, 2005–06 and 2015–16



Note: Overweight in adults is defined as BMI ≥25 kg/m².

Data source: NFHS 2005–06 and NFHS 2015–16

⁶ Victora et al. (2008)
⁷ Black et al. (2017)
⁸ Development Initiatives (2018)

⁹ Calculated with the number of children under 5 from the 2011 census, multiplied by the percentages in National Family Health Survey 4 (NFHS-4).

¹⁰ Pingali et al. (2019)
¹¹ Popkin, Adair, and Ng (2012)
¹² IIPS (2017)
¹³ Meenakshi (2016)

1.2 Regional Variation in Nutrition Outcomes

These national-level figures, however, do not portray the degree of the malnutrition burden in different parts of the country. Being a large and diverse nation with differential subnational growth trends, some regions in India perform much worse than others in terms of human development, especially in the nature of the malnutrition burden. It is therefore important to observe regional variation. Urban–rural regional disparity is the most obvious. All measures of child malnutrition are much higher in rural areas, as compared to urban areas: the prevalence of underweight, stunting, and wasting, as of 2016–18, was 36, 37, and 18 percent in rural areas, respectively, compared to 26, 27, and 16 percent in urban areas, respectively (Figure 1.11). Given that two-thirds of India’s population lives in rural areas, we therefore focus our discussion of spatial variation in malnutrition within rural areas.¹⁴

1.2.1 State-level variation in nutrition outcomes

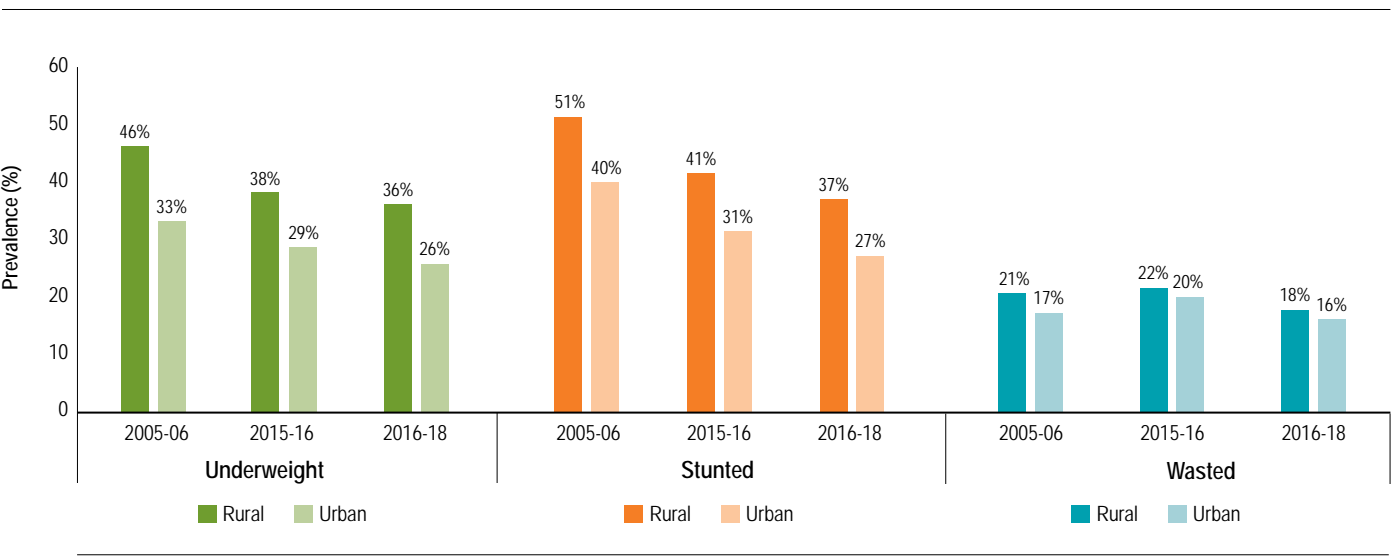
Clear regional patterns emerge when examining the state-level data on child malnutrition. Bihar, Jharkhand, Uttar Pradesh, Madhya Pradesh, and Gujarat have the highest prevalence of both underweight and stunted children in rural areas (Figure 1.12). The three states with the highest prevalence of stunting are Bihar, Uttar Pradesh, and Jharkhand, where 49, 49, and 48 percent of rural children, respectively, are stunted—compared to the national average of 41 percent. The three states

with the highest prevalence of underweight children are Jharkhand, Madhya Pradesh, and Bihar, where 50, 45, and 45 percent of rural children, respectively, are underweight—compared to the national average prevalence in rural populations of 38 percent.

Regional variation in wasting shows a slightly different trend, which could be explained by the fact that wasting is an acute condition rather than a chronic one, like underweight and stunting. While Jharkhand, Gujarat, and Madhya Pradesh are still at the top of the list for the highest prevalence of wasting among children, at 30, 29, and 27 percent, respectively, Uttar Pradesh and Bihar perform slightly better on this indicator (18 and 21 percent, respectively). Maharashtra and Karnataka, which are two of the more developed states of India, however, exhibit higher levels of wasting among children—almost one in every four children.

The states with the highest proportions of rural women and men who are overweight and obese are in the far north and the far south—the more developed parts of India (Figure 1.13). In Kerala, Punjab, and Delhi, the proportions of rural women who are obese are 32, 31, and 30 percent, respectively. The states with the lowest prevalence of overweight and obese rural women are Jharkhand, Chhattisgarh, and Madhya Pradesh, all among the poorer states, where the proportions are 6, 8, and 9 percent of those populations, respectively.

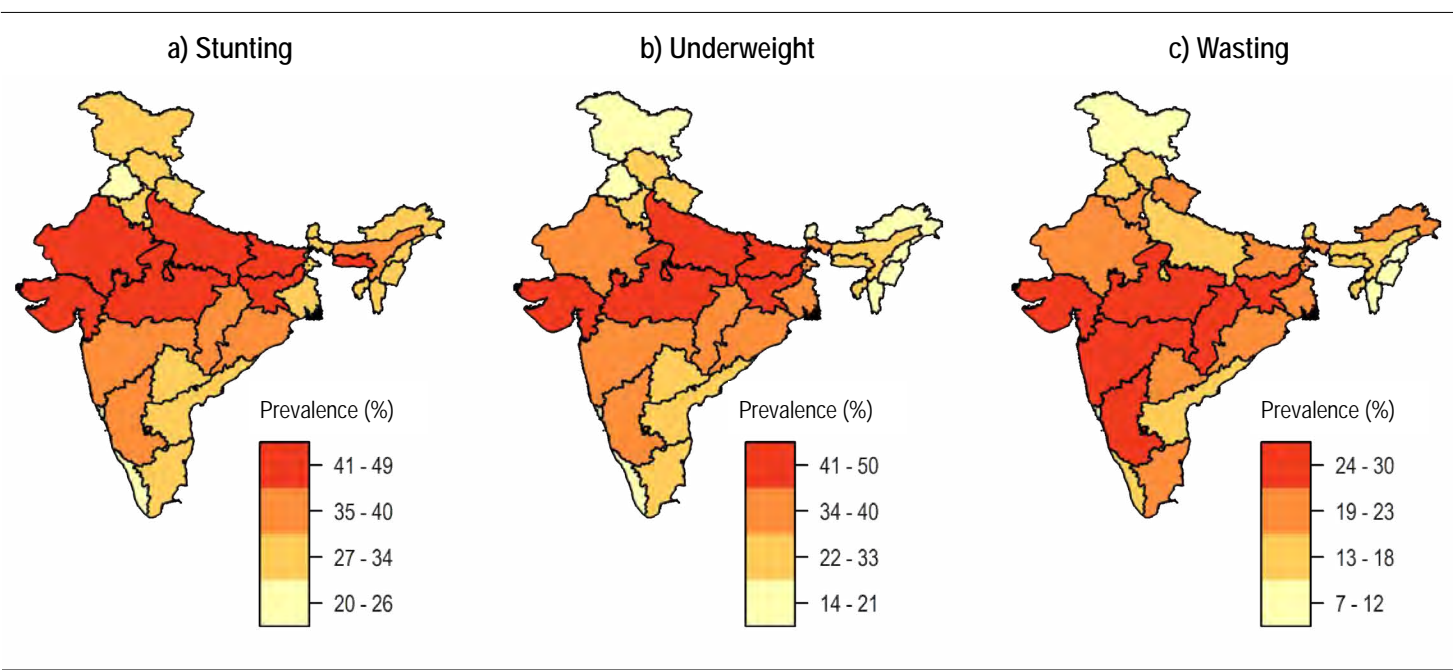
Figure 1.11 | Prevalence of underweight, stunting, and wasting among children in rural and urban areas, 2005-06 and 2015-16



Data source: NFHS 2005–06; NFHS 2015–16, and; CENS 2011–12

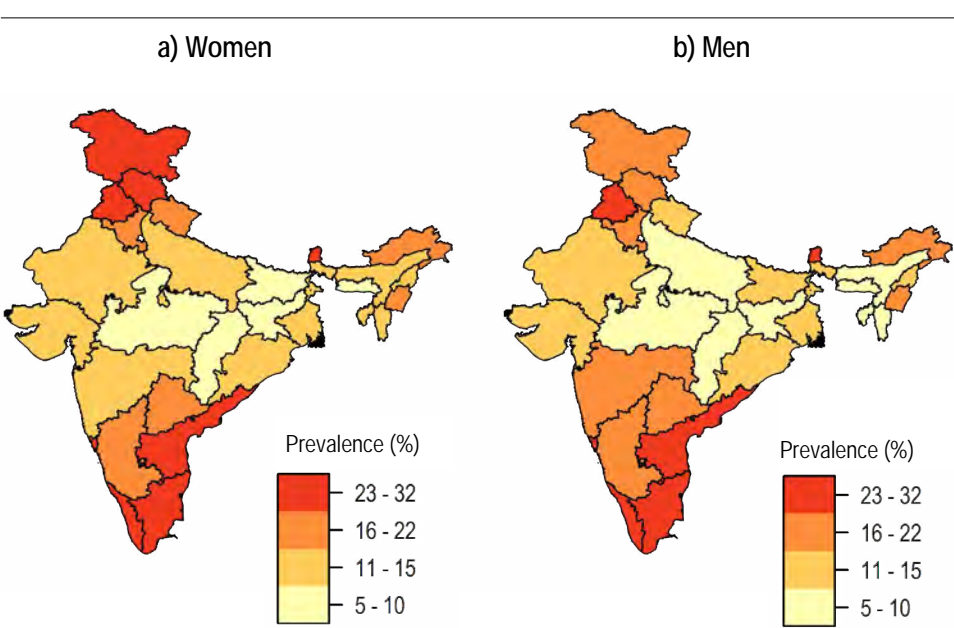
¹⁴ All of our district-level discussions refer to the numbers for rural population, henceforth, except when otherwise noted.

Figure 1.12 | Prevalence, by state, of (a) underweight, (b) stunting, and (c) wasting among rural children, 2015–16



Data source: NFHS 2015–16

Figure 1.13 | Prevalence, by state, of overweight and obesity among rural (a) women and (b) men, 2015–16

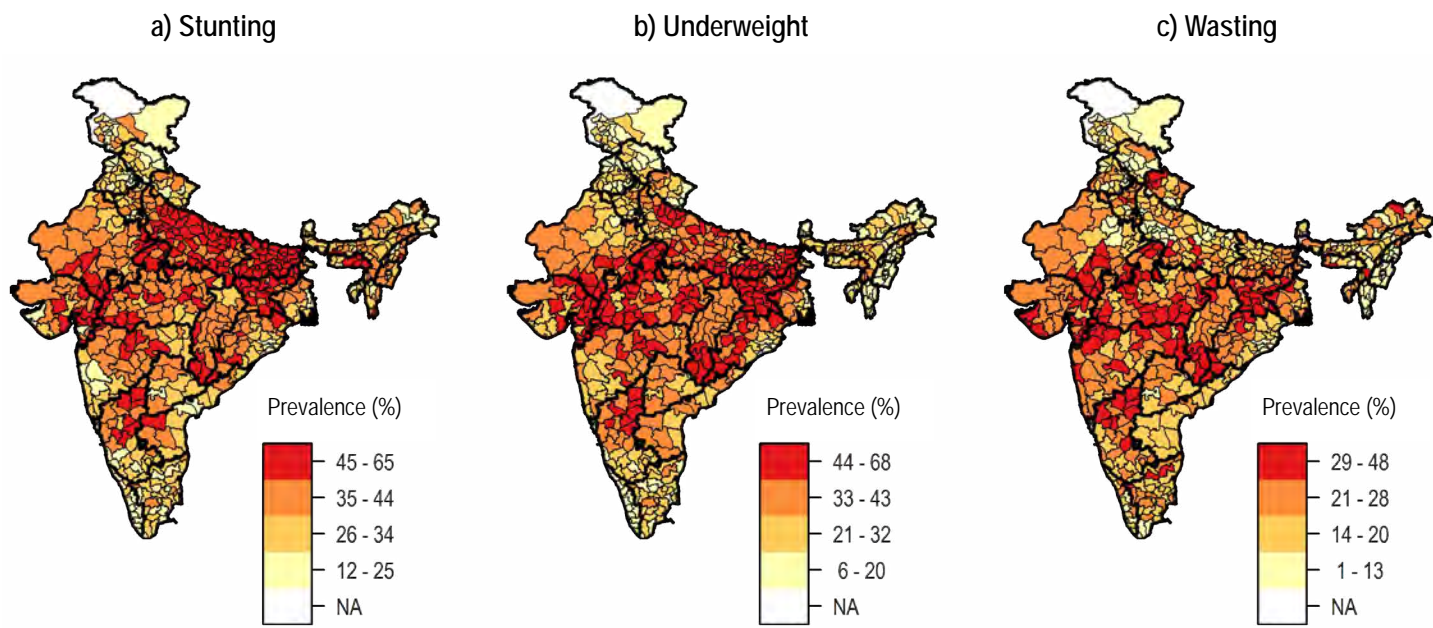


Note: Overweight in adults is defined as BMI ≥ 25 kg/m².

Data source: NFHS 2015–16

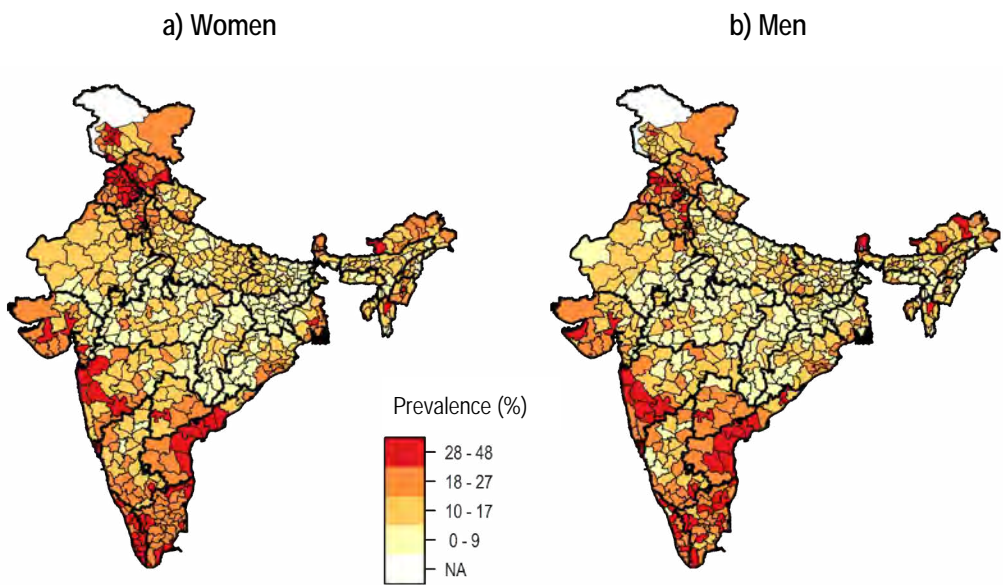
The three states with the highest prevalence of stunting are Bihar, Uttar Pradesh, and Jharkhand, where 49, 49, and 48 percent of rural children, respectively, are stunted—compared to the national average of 41 percent.

Figure 1.14 | Prevalence, by district, of (a) stunting, (b) underweight, and (c) wasting among rural children under 5, 2015–16



Data source: NFHS 2015–16, 2011 district boundaries

Figure 1.15 | Prevalence, by district, of overweight and obesity among rural (a) women and (b) men, 2015–16



Note: Overweight in adults is defined as BMI ≥ 25 kg/m².

Data source: NFHS 2015–16, 2011 district boundaries

1.2.2 District-level variation in nutrition outcomes

Even within states, there is substantial variation in the burden of child malnutrition (Figure 1.14). For example, in Karnataka, only 17 percent of rural children are stunted in Mandya district, but in the same state, 60 percent of children are stunted in Koppal district. Similarly, in the state of Odisha, child stunting rates in Malkangiri are as high as 47 percent, but as low as 12 percent in Cuttack, the lowest rate of any district in the country. In Gujarat, one of the more developed states of India driven largely by industrialization, 53 percent of rural children are stunted in Sabarkantha district, but only 19 percent are stunted in Jamnagar. Many of the districts with the worst rates of undernourishment are concentrated in the states of Uttar Pradesh and Jharkhand. The districts with the highest rates of stunting in the entire country are located in Uttar Pradesh: in Bahraich, Balrampur, and Shravasti districts, 65, 64, and 63 percent of children are stunted, respectively. The districts with the highest percentages of underweight children are in Jharkhand: in West Singhbhum, East Singhbhum, and Bokaro, 67, 63, and 61 percent of children are underweight, respectively. In addition to Cuttack, Odisha, the other districts with the lowest levels of stunting are all in Kerala. Interdistrict variation can be explained by agriculture productivity potential, market infrastructure, public health infrastructure, and size of landholdings. We will discuss these factors further in the following chapters of this report.

We find similarly large differences between districts in the prevalence of overweight and obesity (Figure 1.15). For example, in Maharashtra, 35 percent of adult females are obese in Raigarh district, but only 5 percent are obese in Gondia district. This disparity is reflective of the regional disparity in Maharashtra’s economic development, which has affected the planning process of the state as well. Similarly, districts with a significant tribal population have markedly different nutritional behavior. Within Gujarat, a prosperous state, 40 percent of rural women are obese in Surat, but only 2 percent of women are obese in Dang, where the population is mostly tribal.¹⁵ This is an astonishing difference for districts that are adjacent to one another.

¹⁵ In Dang, about 94 percent of the population is tribal, and more than three-quarters of the population are officially classified as poor.

¹⁶ Pingali and Sunder (2017)

1.3 Explaining Spatial Disparities

We understand from the preceding discussion and maps that undernutrition is largely concentrated in the central and eastern regions of India, which are also the poorest regions in the country. While undernutrition is lower among districts that are more urbanized, the same districts are now beginning to see an increase in the incidence of obesity. How do we explain these large subnational variations? Are they only caused by poverty, or are there some confounding factors that explain different regional growth patterns?

Why do some regions have better development outcomes compared to others within the territorial boundaries of a nation? Reducing spatial disparities in development outcomes—both across and within countries—has historically remained one of the most pressing challenges of development. There is a very well-developed scholarship around spatial inequalities in nutritional outcomes across countries. Challenges of malnutrition vary depending upon the nature of economic growth, agricultural production, and the stage of structural transformation of respective countries.¹⁶

Structural transformation can be understood in the following way: in the initial stages of economic development, the largest share of the population is employed in farming, and agriculture represents the largest share of total output. Government investment in the agricultural sector kick-starts the growth process. Agricultural growth drives overall economic growth, which subsequently spills over to the nonagricultural sectors—industry and services. Consequently, there is greater migration from rural to urban areas, thereby increasing rural productivity. The share of agriculture in total output declines while rural wages increase, reducing overall poverty.

.....

Challenges of malnutrition vary depending upon the nature of economic growth, agricultural production, and the stage of structural transformation of respective countries.

However, in many developing countries, the structural transformation process has not been smooth. The rural share of the population has not fallen as quickly as the share of agriculture in GDP. Hence, the benefits of growth have not been able to reach the rural population, especially smallholder farmers. Therefore, it becomes important for governments to invest in agricultural productivity, even as the share of agriculture in the overall economy is declining. This investment has the potential to both reduce the amount of agricultural labor required and raise agricultural incomes, thereby bringing the share of employment in agriculture closer to the share of agricultural GDP.

Investing in agriculture is also essential to bringing down the rate of malnutrition. As malnutrition is generally worse among the rural populations, who rely on agriculture for their incomes, structural transformation abets the process of improving nutrition among those populations via increased incomes. Indeed, a multicountry, historical analysis by Webb and Block suggested that nation-states that facilitated the growth of agriculture in the initial stages of the development process saw a faster reduction in poverty and malnutrition.¹⁷ The analysis showed that although nations’ investments in agriculture have led to reductions in malnutrition via increases in incomes and reductions in the share of population employed in agriculture, these same trends have led to increased obesity and chronic diseases. For example, in China, income growth between 1989 and 1997 brought changes in diet, from high-carbohydrate foods to high-fat foods with high energy density, and these changes led to increases in obesity, especially among poor households. It is clear from Webb and Block’s analysis that countries with the lowest GDP per capita have the highest rates of stunting and wasting but the

lowest rates of obesity, while countries with the highest GDP per capita have the lowest rates of stunting and wasting but the highest rates of obesity.

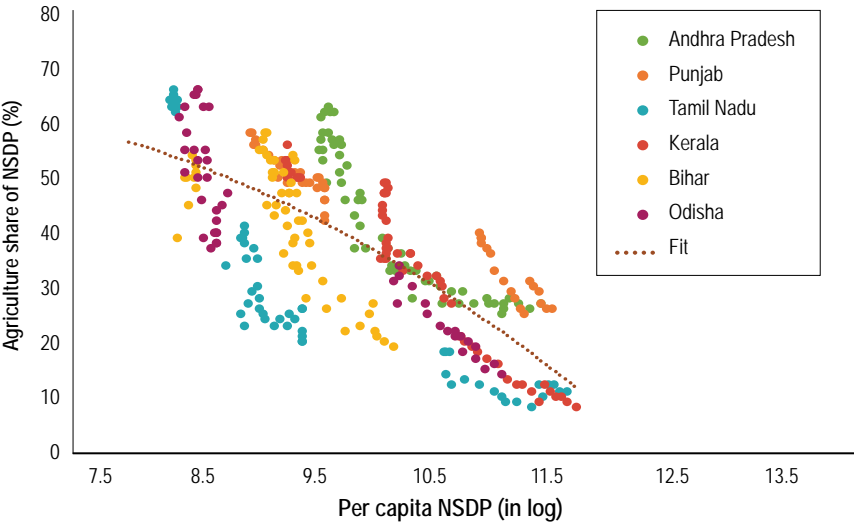
We argue here that the importance of agriculture to kick-start the growth process is not only relevant to understanding disparity in nutrition across nation-states, but also within the national boundaries. Therefore, to understand the regional distribution of the nutrition burden in India, it is essential to look at differential trajectories of agricultural development and subnational structural transformation. Different states in India have followed radically different trajectories of structural transformation (Figure 1.16).¹⁸

In the states of Punjab, Haryana, and Andhra Pradesh, greater agricultural investments during the Green Revolution led to high yields of staple grains and spurred economic development. TCI categorizes these states as “agriculture-led growth states,” which highlights that these states have experienced economic growth largely driven by agriculture, yet agriculture still represents a large share of GDP, and the degree of urbanization is

low (see Table 1.1).¹⁹ States like Kerala, Karnataka, and Maharashtra also benefitted from early investment in agriculture, though this investment was in cash crops rather than in staple grains and occurred between the 1980s and 2000s. These states were able to transfer growth from agriculture to manufacturing and service industries, resulting in a drop in the share of agriculture in GDP, high GDP per capita, and increased urbanization. TCI classifies these as “urbanizing” states. In states in the eastern part of India, particularly Bihar, Jharkhand, and eastern Uttar Pradesh, productivity-enhancing technologies of the Green Revolution did not catch on at the same rate. As a result, the agricultural growth has been slow, leading to persistently low GDP per capita and low urbanization. These states are therefore categorized as “lagging.”²⁰ The effect of these differing trajectories of agricultural development and structural transformation on nutrition outcomes are evident: the “agriculture-led growth states” and “urbanizing” states have lower rates of undernutrition but higher rates of overnutrition, and the “lagging” states continue to experience high rates of undernutrition (see Figures 1.12 and 1.13).

We argue here that the importance of agriculture to kick-start the growth process is not only relevant to understanding disparity in nutrition across nation-states, but also within the national boundaries.

Figure 1.16 | Subnational structural transformation in India, 1970–2017



Note: NSDP = Net State Domestic Product
Source: EPWRF India Time Series. Adapted from Figure 2.3 in Pingali et al. (2019)

Table 1 | CLASSIFICATION OF STATES BASED ON DEVELOPMENT TRAJECTORY

	Agriculture-led growth states	Urbanizing states	Lagging states
Criteria	<ul style="list-style-type: none">• Low urbanization rates• High GDP per capita• High share of agriculture in GDP	<ul style="list-style-type: none">• High urbanization rates• High GDP per capita• Low share of agriculture in GDP	<ul style="list-style-type: none">• Low urbanization rates• Low GDP per capita• Low agricultural productivity
States	Punjab, Haryana, Andhra Pradesh, Himachal Pradesh	Kerala, Goa, Maharashtra, Tamil Nadu, Gujarat, Karnataka, Telangana, Uttarakhand	Bihar, Madhya Pradesh, Uttar Pradesh, Odisha, Jharkhand, Chhattisgarh, West Bengal, Rajasthan, Jammu and Kashmir, northeastern states

Source: Adapted from Table 2.2 in Pingali et al. (2019)

¹⁷ Webb and Block (2012)

¹⁸ Pingali et al. (2019)

¹⁹ Pingali et al. (2019)

²⁰ Pingali et al. (2019)



Farmer harvests orange-fleshed sweet potato in Uttar Pradesh. Photo by Kathryn Merckel.

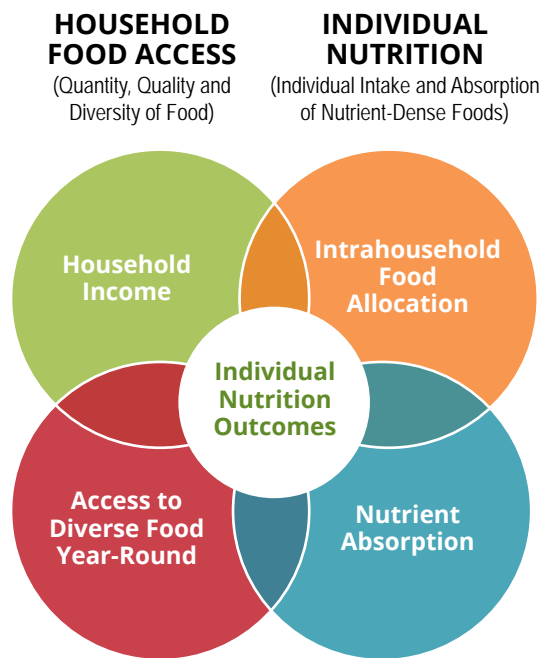
2

Role of Agriculture for Nutrition

Why is agriculture important for nutrition? The role of agriculture in better nutritional outcomes traverses multiple scales. At the macro-level, increases in agricultural productivity improve nutrition by improving livelihoods via structural transformation (as discussed previously), and by increasing the overall supply of food. The increase in food supply also leads to reduced food prices and ensures greater affordability. These changes lead to wide-scale reductions in hunger and improvements in nutrition. In a largely agrarian economy like India's, agriculture also plays an important role in nutrition at the household and individual levels, which are the focus of this chapter.

The TCI framework defines four overlapping pathways from agriculture to improved individual nutrition (Figure 2.1), which are grouped into two categories: household food access and individual nutrition. Household food access depends on income and access to diverse foods throughout the year (Pathways 1 and 2), while individual nutrition depends on equitable intrahousehold food allocation and the individual's ability to absorb nutrients (Pathways 3 and 4).²¹ In the Indian case, where smallholder farming is the dominant form of production, household income is determined by smallholder productivity, market linkages, and nonfarm opportunities. Income also determines access to diverse foods, as does proximity to food retailers year-round, diversification of production to support diversity in food markets, and social protection policies, such as cash transfers or other safety net programs. Equitable intrahousehold food allocation depends largely on women's empowerment, and nutrient absorption depends on food safety, as well as access to clean water and sanitation. While the role of agriculture in the last two pathways is less obvious,

Figure 2.1 | Four pathways from agriculture to nutrition



²¹ Pingali and Ricketts (2014)

it is certainly present. For example, directing agricultural investments toward self-help groups to increase women’s empowerment in agriculture, or toward labor-saving technology to reduce women’s time spent in agriculture, can help improve intrahousehold food allocation (Pathway 3). Nutrient absorption (Pathway 4) can be enhanced by changing agricultural and grain storage practices to decrease the accumulation of mycotoxins, thereby improving food safety. There is a pressing need to understand the multidimensional pathways toward improving nutrition as India works toward attaining the SDGs: a feat that the country now has exactly one decade to achieve.

2.1 Household Income (Pathway 1)

Analogous to the macro phenomenon in which overall agricultural productivity spurs structural transformation and leads to higher incomes and improved nutrition, increase in household-level agricultural productivity directly leads to an increase in the incomes of rural households. In turn, the increase in agricultural income leads to better nutrition. The positive nutrition effect results from many factors. Higher incomes improve households’ access to diverse food, health care, and better sanitation, which are key to improved nutritional outcomes. Income security

Higher incomes improve households’ access to diverse food, health care, and better sanitation, which are key to improved nutritional outcomes.

also protects households against adverse productivity shocks, such as poor harvest or illness, reducing their vulnerability to poverty traps and undernutrition. There is plenty of evidence available from across the globe on the pathway from agricultural income to improved nutritional outcomes. An analysis of multiyear data from 29 developing countries concluded that stunting responds positively to rising agricultural income, and not as well to rising nonagricultural income.²²

The effect of rising agricultural incomes on better nutrition needs no less emphasis in the case of India, where 67 percent of the population lives in rural areas, a large share of whom rely—directly or indirectly—upon agriculture for their livelihoods.²³ We know that agricultural productivity is a key driver of household income: income from cultivation represents 52 percent of total income for rural households.²⁴ There is plenty of evidence that agricultural income in India is key to improved nutrition: a five-year panel data set of rural households, from 18 villages across

five Indian states, showed that for households that regularly farm, a 10 percentage point increase in agricultural income was associated with a 0.10 percentage point growth in women’s body mass index (BMI) over a period of four years.²⁵ Maternal BMI, in turn, is strongly associated with children’s nutrition status.²⁶ The authors of the five-year panel study noted that the effect of agricultural income on women’s BMI “is economically modest, but important considering that we do not find a corresponding effect for growth in non-agricultural income.”²⁷

2.2 Household Access to Diverse Foods (Pathway 2)

One of the most important pathways through which growth in agricultural income can lead to improved nutrition is by unlocking access to a more diverse set of food items. According to BenNET’s Law, increase in household income leads to a decline in the share of money spent on staple food products and an increase in demand for nonstaple foods. Greater diet diversity, in turn, is directly correlated to better nutrition.²⁸ Specifically, diet diversity has been shown to be a good indicator for micronutrient adequacy,²⁹ and low diet diversity is linked to both stunting³⁰ and higher risk of obesity.³¹

In addition to income, several other avenues exist for increasing access to diverse and nutritious foods. These include safety net programs and market accessibility—both for producers and consumers—and supply. Increasing supply of diverse foods is an essential tool, not only for the obvious reason of enhanced availability, but also for the economic reason of increasing affordability. Fortunately, many of these foods, such as fruits and vegetables, are high-value crops that also have the potential to increase farmers’ income. Traditionally, productivity-enhancing public investments have largely been focused on staple grains or the major cash crops, but not on the production of other nutritious crops, such as fruits, vegetables, and pulses, which promote dietary diversity through facilitating greater micronutrient consumption. Research on how to encourage production of diverse foods, such as the research presented in Box 2.1, is a necessary step to increasing overall supply.

It is important to note the difference between encouraging the supply of diverse foods and on-farm diversification. Increasing supply of diverse foods does not necessarily require diversification at the farm level, but rather diversification between farms. While production diversity at the farm level has been found to increase diet diversity of smallholders in certain instances, mainly in regions where markets are not well developed,³² evidence suggests that the production–consumption link is not strong in most instances. A review of 45

Box 2.1 | ENCOURAGING DIVERSITY OF SUPPLY: ORANGE-FLESHED SWEET POTATO IN UTTAR PRADESH

In an attempt to increase demand for and production of nutritious crops, and simultaneously to understand what factors encourage such changes, TCI, in collaboration with Grameen Development Services (GDS), and as part of the Technical Assistance and Research for Indian Nutrition and Agriculture (TARINA) project, has introduced orange-fleshed sweet potato (OFSP) in a vitamin A-deficient district of Eastern Uttar Pradesh.

OFSP is rich in micronutrients, particularly vitamin A, which is essential during late pregnancy and lactation for a child’s immunity, eyesight, and lung function. Due to its nutritious properties, OFSP is considered a strategic crop for addressing vitamin A deficiency, particularly among women of reproductive age. For this reason, TCI–TARINA introduced OFSP in Maharajganj district of Eastern Uttar Pradesh, where diets tend to be deficient in vitamin A. Concurrently, Tata–Cornell Scholar Kathryn Merckel, a PhD candidate in International Nutrition at Cornell University, is leading a study to understand the role that nutrition knowledge has in decision-making around the cultivation and consumption of OFSP. The study promoted OFSP as a crop in 10 villages, five of which were randomly selected to receive additional programs on nutrition behavior change and information on the importance of vitamin A in the diet. By assessing the differences in OFSP cultivation and consumption between the villages that received only the agricultural promotion and those that received additional nutrition education, Merckel could examine how knowledge of nutrition motivates households to adopt more diverse crop systems and healthier diets.

Findings from this study indicate promise for OFSP promotion to increase not only production and consumption diversity, but also improved knowledge of healthy diets for women and children. Knowledge of OFSP spread rapidly in the intervention villages, well beyond the households that were directly exposed to intervention activities. After a year of intervention programming, 94 percent of all households in intervention villages knew of OFSP and were able to list 1.94 more facts about OFSP than control households. Rather than learning about OFSP from intervention events, households were more likely to report that they learned about OFSP from their friends, neighbors, and other people in their village. By the end of the study, households in intervention villages also knew significantly more about vitamin A and proper feeding practices for infants and young children compared to households in the control villages.

Initially, around 25 percent of households in intervention villages tried growing OFSP. Unfortunately, despite previous work with the varieties of OFSP introduced, farmers

experienced poor performance due to pest and climate pressure. Despite these setbacks, half of farmers still reported that they would like to grow OFSP in the future, and 85 percent reported that, if available in their market, they would buy OFSP.

An important finding of this study is that there were not significant differences in OFSP cultivation or in nutrition knowledge improvements between the two intervention arms. Attendance at intervention events was not significant in predicting improved knowledge. Rather, having more familial relationships in the village increased the likelihood of learning over the course of the intervention. This means that the extra time and resources required to provide the intensive nutrition intervention may not be needed for meaningful impacts on health knowledge and behavior if enough individuals are reached that can in turn share what they learn with their friends and relatives.

Finally, Merckel’s study has revealed that policies or programs that make assumptions about gendered division of agricultural responsibility may miss key opportunities for small-scale production diversification. In field plots versus home gardens, findings suggest no clear distinction between gendered responsibilities for production of OFSP. Women are as likely to be responsible for a field plot of orange-fleshed sweet potatoes as a home garden, and men report responsibility for half of all home gardens being used to grow orange-fleshed sweet potatoes.

Diet diversification is a critical step in reducing micronutrient deficiencies and improving health outcomes, and projects like this one provide important data for understanding the underlying mechanisms that influence small farmer production systems and household decision-making around food selection. As a part of the TCI–TARINA project, this study contributes to the objective of increasing demand for nutritious foods and diversifying production of nutrient-rich crops. Merckel also notes the policy implications of this project:

“As we learn more about how individuals and households in rural Uttar Pradesh share information about food and agricultural innovation, and how interventions such as this one empower individuals to diversify their production and diets, we will be able to design policies and programs that are more effective and efficient at improving nutrition and health in rural India.”



Woman in Maharajganj district, Uttar Pradesh, displays her harvest of large orange-fleshed sweet potatoes. Photo by Kathryn Merckel.

²² Webb and Block (2012)
²³ Sixty-four percent of the workforce in rural areas is primarily engaged with agriculture (Chand 2017).
²⁴ Desai and Vanneman (2019)

²⁵ Rao and Pingali (2018)
²⁶ Fenske et al. (2013)
²⁷ Rao and Pingali (2018, 1)
²⁸ Arimond and Ruel (2004); Busert et al. (2016)

²⁹ Steyn et al. (2006)
³⁰ Rah et al. (2010)
³¹ Azadbakht and Esmailzadeh (2011)
³² Jones, Shrinivas, and Bezner-Kerr (2014)

original studies from 26 countries found that the relationship between production and diet diversity and/or nutrition was positive and significant in less than 20 percent of studies, and the average marginal effect implied that farms would have to produce 16 additional crop or livestock species to increase dietary diversity by just one food group.³³ Especially where markets are more developed, increasing incomes and affordable prices are the more common paths to increasing access to diverse foods.

While access to diverse foods is the ultimate goal, poor populations with micronutrient deficiencies that require more immediate attention may benefit from biofortification as an interim strategy. Biofortification refers to the process of breeding crops for enhanced micronutrient content. To date, the main micronutrients in biofortification interventions are iron, vitamin A, and zinc. One advantage of biofortification is that people do not have to learn to grow, prepare, eat, and find markets for new crops (as with crop diversification), but merely substitute a more nutritious version of what they are already growing and eating. An analysis of costs and potential benefits of biofortification interventions in 12 countries in Africa, Asia, and Latin America found that such interventions could significantly reduce the burden of micronutrient deficiencies in a cost-effective manner.³⁴ In India, HarvestPlus is working to promote pearl millet biofortified with iron and wheat biofortified with zinc. Iron-fortified pearl millet provides up to 80 percent of daily iron needs, and zinc-fortified wheat provides up to 50 percent of daily zinc needs.³⁵

2.3 Intrahousehold Food Allocation (Pathway 3)

At the micro-level, individual nutrition can improve by changing behaviors and cultural norms around intrahousehold allocation of food. Inadequate allocation of food to women, especially to pregnant women, is common in rural India and is associated with poor maternal and child health outcomes.³⁶ Factors that can affect allocation of food to women include women's empowerment in agriculture (see Box 2.2) and women's time spent engaging in agricultural labor.

Recent research demonstrates that Indian women's empowerment in agriculture is linked to nutrition outcomes, specifically, iron deficiency. Based on survey data and multiple medical biomarkers collected from nearly 1,000 women in 2013–14, TCI researchers found a significant association between women's empowerment levels in agriculture and their iron status.³⁷ Their study found that across three different types of farming systems—landless, food-cropping, and cash-cropping households—at least 60 percent of the women who are iron deficient are also disempowered in agriculture. Moreover, the likelihood of a poor iron status declines significantly as women's empowerment levels in agriculture improve.

In addition to the link to iron deficiency, women's empowerment in agriculture is also linked to dietary diversity, meaning that women who are empowered are more likely to eat a diet containing a range of nutritious

non-cereals like pulses, meat, dairy, and eggs.³⁸ Even within a given level of market integration, defined as the total weight of market purchases of different food groups per capita, empowered women are better able to translate their influence into purchases that diversify their diets. Furthermore, greater household purchases of non-cereals, like pulses, meat, dairy, and eggs, are associated with higher levels of dietary diversity for women.

Given the association between women's empowerment and nutrition outcomes, it follows that women's nutrition can be improved by increasing the level of empowerment for women in India's agricultural households. To understand how to improve women's empowerment in agricultural contexts, it is helpful to understand their disenfranchisement and how this compares across different farming systems. According to a survey of 3,600 women carried out by TCI, using an index of women's empowerment in agriculture adapted to the Indian context (Box 2.2), the main drivers of disempowerment are lack of membership in agriculture-related self-help groups, lack of ownership of land, and lack of control over income.³⁹ In the survey of nearly 1,000 women mentioned earlier, women in households that were more market-oriented (cash-cropping households) were relatively more empowered than women from less market-oriented households (food-cropping and landless households).⁴⁰

Taken together, the research discussed here reinforces the notion that, to achieve improved nutritional security, Indian agricultural policy should be reconfigured in a way that promotes both women's empowerment and household market integration. Policies to increase women's empowerment should focus on supporting self-help groups, and research should be done on how to support women in gaining ownership of land and control over income. Targeting agricultural trainings toward women can also lead to women's empowerment by providing the support and knowledge needed for decision-making.⁴¹

In addition to their economic or social empowerment, women's time use in agriculture is also closely associated to their nutritional outcomes. Women's time spent in agricultural work, especially during peak seasons, often limits time spent on child care and cooking—practices that are equally important to nutrition (see Box 2.3). Thus, labor-saving technologies should be pursued as mechanisms to free up women's time for nutrition-related activities.

Box 2.3 | WOMEN'S AGRICULTURAL TIME USE AND NUTRITION

Women in rural areas of developing countries not only engage in labor-intensive activities, like agriculture and construction, but also are solely responsible for household chores, like cooking and cleaning, collecting fuel and water, and caring for children and the elderly. As time commitments in agricultural activities fluctuate, the amount of time a female household member can allocate to food preparation, child care, and the rest of her responsibilities is also affected. Time is a key resource used to carry out productive and nonproductive activities, and yet, within the scope of agriculture and nutrition linkages, the direct implications of changes in time allocation for women on nutrition outcomes are not well understood.

To clarify how time allocation in agriculture could affect nutritional outcomes, TCI conducted a study led by former TCI Scholar and now Assistant Professor at the Indian Institute of Management Ahmedabad (IIMA), Dr. Vidya Vemireddy. The study included 960 households spread across 24 villages in the Chandrapur district of Maharashtra. Each household was visited 10 times throughout the year, and in each household, interviews were conducted with a woman within the age range of 18–49 years and a representative man. Interviews included questions about time use and diet. By creating a database of 502 local recipes and standardizing them in terms of ingredients, Vemireddy was able to calculate nutrient intakes based on a 24-hour recall of meals consumed.

Findings from this study showed that women contribute significantly to agriculture, as well as to domestic work, and that they are time-constrained. In peak agriculture seasons (for example, during July–August planting and in October–November for harvest), women can spend up to 333 minutes per day in agriculture, thereby reducing their time spent on domestic work, personal care, and sleep-related activities. The consequences of these time trade-offs are reflected in nutrient intake as well: working longer hours in agriculture during the peak season was associated with a lower intake of calories, proteins, fats, iron, zinc, and vitamin A.

Given that women already face major micronutrient deficiencies, the further reduction in micronutrient intakes during peak agricultural seasons is extremely worrisome. From the perspective of agriculture–nutrition linkages, understanding the role of time is critical to mitigating these negative consequences.

To improve nutritional outcomes, future interventions in agriculture need to keep this caveat in mind. While designing agricultural policies, close attention is needed to ensure that further work burdens are not imposed on women. Instead, novel, labor-saving technologies for agriculture are needed to reduce work burdens, especially those of women. A focus on enhancing women's empowerment, particularly in their ability to make decisions and control income, is equally important, so that the time savings translate into enhanced nutrition for better well-being.

Box 2.2 | MEASURING WOMEN'S EMPOWERMENT IN AGRICULTURE IN THE INDIAN CONTEXT

Women's empowerment in agriculture refers to women's abilities and resources to make decisions about agricultural production. In order to measure such empowerment, the International Food Policy Research Institute (IFPRI), Oxford Poverty and Human Development Initiative (OPHI), and Feed the Future (United States Agency for International Development [USAID]) launched the Women's Empowerment in Agriculture Index (WEAI) in 2012. This Index was the first comprehensive and standardized measure of women's empowerment and inclusion in agriculture. It is made up of two sub-indices: one that measures women's empowerment across five agricultural domains (production, resources, income, leadership, and time), and one that measures gender parity across these domains (comparing women's scores with men's scores).^a

Although the WEAI represented a major improvement over previous indicators of empowerment, there was a significant hurdle to its usefulness: the questionnaire used to

construct the Index was not adapted to local contexts. To address this challenge and to develop an index that could be used in India, TCI research economist Soumya Gupta, alumna Vidya Vemireddy, researcher Dhiraj Singh, and Director Prabhu Pingali developed a modified WEAI based on experience adapting and using the WEAI across 3,600 households in India.^b Modifications were made to several indicators. For example, while the original WEAI uses membership in any group as an indicator for leadership, TCI's index focuses specifically on membership in self-help groups, which play an important role in Indian women's agricultural activities.

The adapted WEAI reveals that at least 80 percent of women across the 3,600 agricultural households surveyed in four districts in Uttar Pradesh, Bihar, and Odisha are disempowered in agriculture.

^a IFPRI (2012)

^b Gupta et al. (2019)

³³ Sibhatu and Qaim (2018)

³⁴ Meenakshi et al. (2010)

³⁵ HarvestPlus (2020)

³⁶ Harris-Fry et al. (2017)

³⁷ Gupta, Pingali, and Pinstup-Andersen (2019)

³⁸ Gupta, Vemireddy, and Pingali (2019)

³⁹ Gupta et al. (2019)

⁴⁰ Gupta, Pingali, and Pinstup-Andersen (2017)

⁴¹ Grassi, Landberg, and Huyer (2015)

2.4 Nutrient Absorption (Pathway 4)

Finally, individual nutrition outcomes are affected by an individual’s ability to absorb nutrients, which in turn is affected by water, sanitation, and hygiene (WASH), including food safety. In India, the prevalence of open defecation (practiced by nearly 40 percent of the population) is a serious threat to health. In fact, evidence shows that the shorter average height of Indian children, compared to African children, can be explained largely by higher prevalence of open defecation in India.⁴² Improving the health environment will require multiple strategies, such as access to toilet facilities and behavior change interventions to discourage open defecation (see Box 2.4). Behavior change interventions should also encourage practices such as sanitizing drinking water with chlorine tablets or by boiling, and washing hands with soap before eating.⁴³ Piped water is also an important solution, both to increase hygiene and to free up women’s time (see Box 2.5).

While sanitation is perhaps the most obvious factor affecting nutrient absorption, agriculture can also affect nutrient absorption, both via food safety and via agricultural practices that affect the health environment. One food safety threat to nutrient absorption is from fungal toxins, or mycotoxins. These toxins can accumulate in crops prior to harvest or while grain is in storage, and can lead to cancers and adversely affect growth, nutrition, and immunological status. Promoting management strategies to control the spread of mycotoxins perfectly exemplifies Pathway 4 from agriculture to nutrition via the health environment (see Box 2.6). Another way in which agriculture can affect nutrition via nutrient absorption is through over-use of fertilizers and pesticides. There is some evidence from India that young children, particularly those of poor parents, when exposed to large amounts of agro-based chemicals, have experienced worse health outcomes.⁴⁴

One food safety threat to nutrient absorption is from fungal toxins, or mycotoxins. These toxins can accumulate in crops prior to harvest or while grain is in storage.

Individual nutrition outcomes are affected by an individual’s ability to absorb nutrients, which in turn is affected by water, sanitation, and hygiene (WASH), including food safety.

Box 2.4 | REDUCING OPEN DEFECATION WITH BEHAVIOR CHANGE COMMUNICATION

A critical but unexplored factor behind the rampant practice of open defecation (OD) is the preference to do so, which the mere provision of toilets does not overcome. Building on the tenets of community-led total sanitation (CLTS), a behavioral change campaign methodology that stimulates community-level behavior to stop the practice of OD is being led by TCI staff member Payal Seth. This important research is being carried out to determine the causal contribution of the behavioral change versus toilet construction approaches on outcomes, such as toilet use, child health, and safety of women. The study finds that toilet use is significantly higher in villages that have coupled toilet construction with CLTS behavior change interventions. It also finds that women’s toilet use is significantly higher than that of the men. This study highlights how critical the coupling of behavior change communication with toilet construction is to improving hygiene practices and reducing OD.

Box 2.5 | PIPED WATER IMPROVES HEALTH AND FREES UP WOMEN’S TIME

In India, only about 40 percent of the population has piped water on tap in their homes. In households without clean tap water, water must be collected from outside sources. These outside water sources are likely to be contaminated, heightening the risk of waterborne diseases. The time it takes to collect water from outside is also significant—a task typically falling upon women and girls. Water must be carried for drinking, cooking, bathing, and washing utensils and clothes. Sometimes, women make several trips a day, traveling long distances. Time spent in water collection is time not spent on other productive activities, like agricultural work, income-generating activities, attending school or trainings, caring for small children or the elderly, or simply enjoying a bit of leisure time.

In partnership with AguaClara (a Cornell-based R&D team), TCI established four water treatment systems in Jharkhand state, serving 2,000 people in total. Shiuli Vanaja, a PhD candidate in Applied Economics, is examining the time-saving effects of piped water and the determinants of waterborne diseases in villages with AguaClara interventions, as compared to those without. Her research finds that in the AguaClara villages, on average, households spent 60 minutes less on water collection, compared to the households in the villages without AguaClara infrastructure. This has led to increased time spent by women in their primary occupations, whether agricultural work or household chores (including child care). Vanaja also found that the choice of drinking water source and hygiene practices at home, like handwashing, are important determinants of drinking water quality, and that a better source of drinking water has lowered the risk of diarrhea at the household level.

Box 2.6 | REDUCING POSTHARVEST MYCOTOXIN ACCUMULATION WITH AIRTIGHT GRAIN STORAGE

Mycotoxins are potent fungal metabolites that contaminate food chains and animal feed worldwide. Exposure to mycotoxins can result in various health and nutrition deficits, both chronic and acute, in humans and in livestock. In India, as in other parts of the developing world, local regulatory capacity is insufficient to adequately detect and ameliorate mycotoxin contamination, leaving many farmers’ harvests unscreened and allowing potentially contaminated food and feed items into the diets of vulnerable people and animals.

TCI Scholar Anthony Wenndt, a PhD candidate in Plant Pathology and Plant-Microbe Biology, is conducting a household-level longitudinal survey of mycotoxin contamination, across a range of susceptible commodities in 184 houses, encompassing 6 villages in the Unnao District of Uttar Pradesh. In November 2017, stored batches of groundnut, maize, pearl millet, paddy, and milled rice from participating households’ storage facilities were selected for study. Initial findings indicated that mycotoxin contamination (primarily aflatoxin and fumonisin) was prevalent in these food systems at levels that can be detrimental to human and animal health and nutrition.

Given the prevalence of sack-based grain storage systems in the study area and their demonstrated susceptibility to spoilage, the research approach has elevated the use of hermetic (airtight) storage systems as a user-friendly intervention for introduction into enrolled households. The farmer-oriented training program has been successfully administered to 98 percent of the participating households, and preliminary findings indicate an overall positive usage experience.

⁴² Spears (2013)
⁴³ Pingali et al. (2019)
⁴⁴ Brainerd and Menon (2014)



3

Agriculture-Nutrition Linkages: Regional Patterns

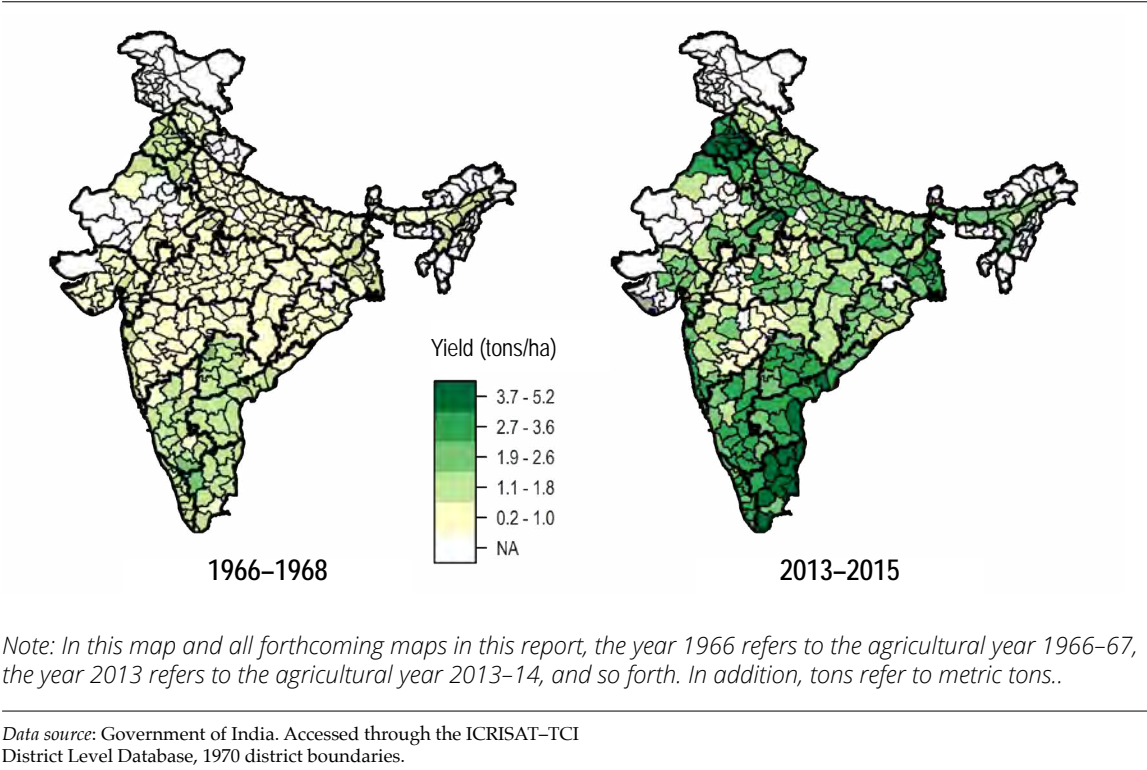
Now that we have introduced the pathways to improved nutrition, we will explain in more detail how India's regional patterns of agricultural development have led to vastly different nutrition outcomes, via their impacts on income (Pathway 1) and diets (Pathway 2). First, we will discuss in greater detail the differing development trajectories introduced in Section 1.3. Then, we will discuss how these different trajectories have led to different diets and nutrition outcomes.

3.1 Differing Development Trajectories

India's states have followed drastically different trajectories of growth, dictated largely by how much they have invested in agriculture. The states that have invested in the development of their agricultural sectors are still reaping the benefits in the form of higher incomes and better nutrition. States that invested early in agriculture include two of the three categories of state classifications—agriculture-led growth states and urbanizing states (Table 1.1, Section 1.3). While these two groups of states have both achieved high per capita GDP, their pathways have differed. In agriculture-led growth states, their economies are still dominated by agriculture, and the states remain largely rural. In urbanizing states, gains from agriculture were reinvested in industry and services, and agriculture has since decreased in economic importance. In contrast, in lagging states, GDP per capita is low, and nutrition suffers due to low investment in agriculture and resultant low agricultural productivity.

Man sells snacks in Kankerimal, Kalahandi district, Odisha.
Photo by Kiera Crowley.

Figure 3.1 | Rice yields by district, 3-year averages, 1966–68 and 2013–15



Punjab, Haryana, Andhra Pradesh, and Himachal Pradesh are the states where agriculture has primarily led the growth process and continues to have an important role to play in the economic development of the region. In the 1960s and 1970s, during the Green Revolution, these states invested heavily in agriculture and saw enormous increases in rice and wheat productivity (Figures 3.1 and 3.2). In the north of India, in the upper Gangetic plains—mainly in Punjab and Haryana—these productivity increases came from wide-scale adoption of high-yielding varieties (HYVs) of wheat and rice; subsidies on power, irrigation, and fertilizer; and support prices. Support prices provided important economic incentives for adopting the HYVs and investing in irrigation and inputs (fertilizer and pesticides). Farmer investment in tube wells skyrocketed, as they allowed for increased volumes of water and controlled timing of irrigation—essential attributes for HYVs, which required fertilizer delivered via irrigation.⁴⁵ Andhra Pradesh also experienced immense yield gains in rice during the Green Revolution, mainly resulting from the adoption of high-yielding,

short-duration varieties, which allowed for a second planting of rice. The gains in productivity experienced in these regions during the 1960s and 1970s allowed for reduction in poverty (Figure 3.3) and increased incomes (Figure 3.4). These states continue to benefit from high agricultural productivity growth.

States like Kerala, Karnataka, Maharashtra, and Gujarat are examples of urbanizing states. These states not only focused on agriculture but also accorded foremost status to the industrialization and manufacturing sectors, to herald the development process. These states did not have a comparative advantage in staple grain production, but instead benefitted from a growing demand for cash crops in the 1980s. Kerala invested in fruit, spice, and rubber plantations, while southern Karnataka invested in a mix of plantation crops and maize. In Maharashtra, development was spurred by investments in sugarcane plantations. Western and central India invested in cotton and oilseeds production, as is visible in the vast increases in share of cropped area under

Figure 3.2 | Wheat yields by district, 3-year averages, 1966–68 and 2013–15

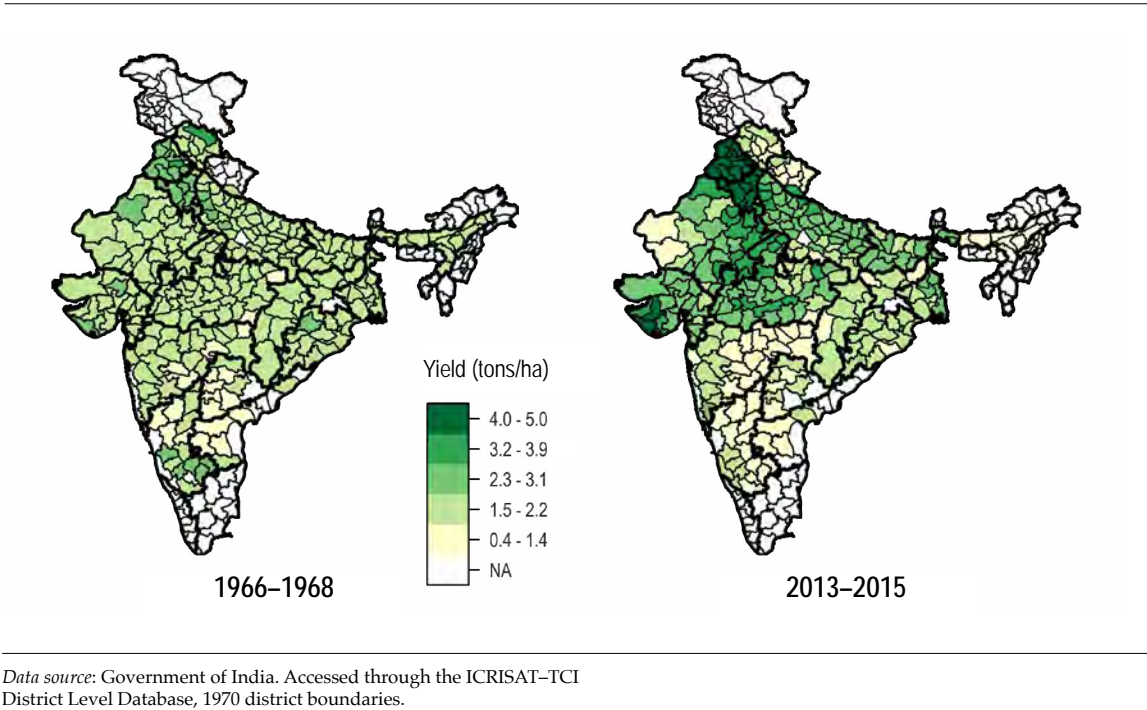


Figure 3.3 | Share of population in the poorest quintile by district, 2015–16

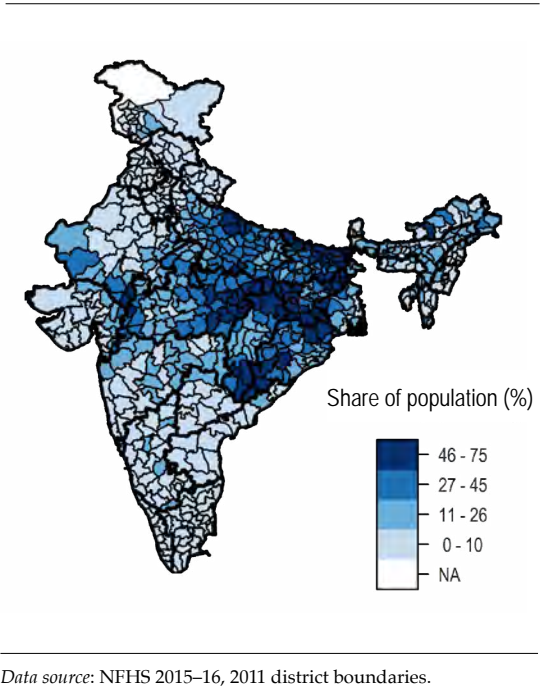
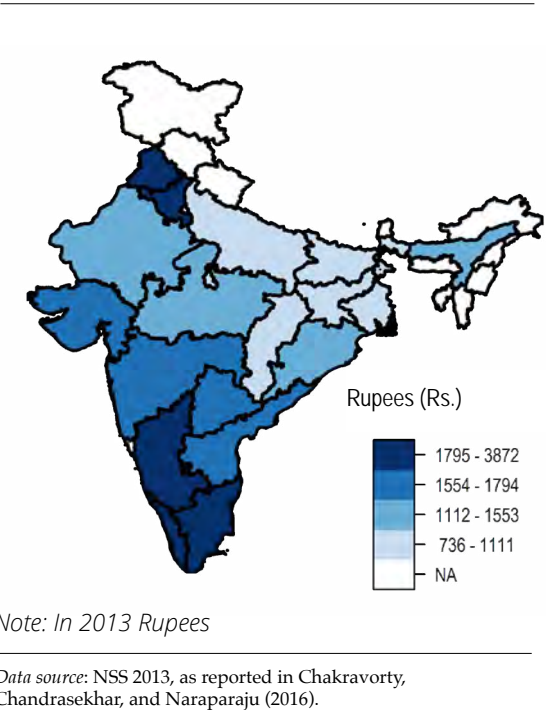
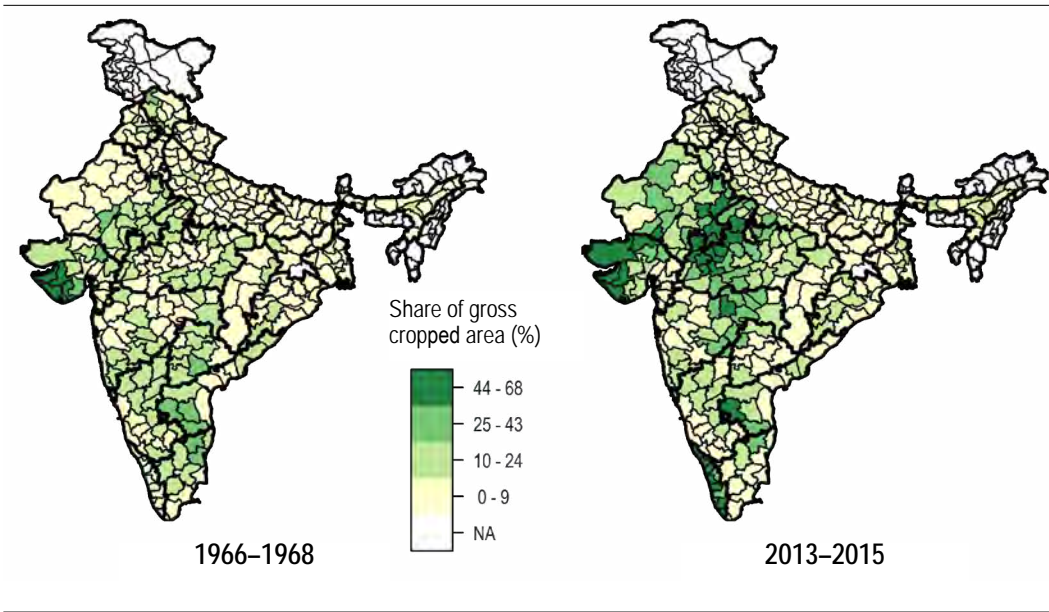


Figure 3.4 | Monthly per capita income for agricultural households by state, 2013



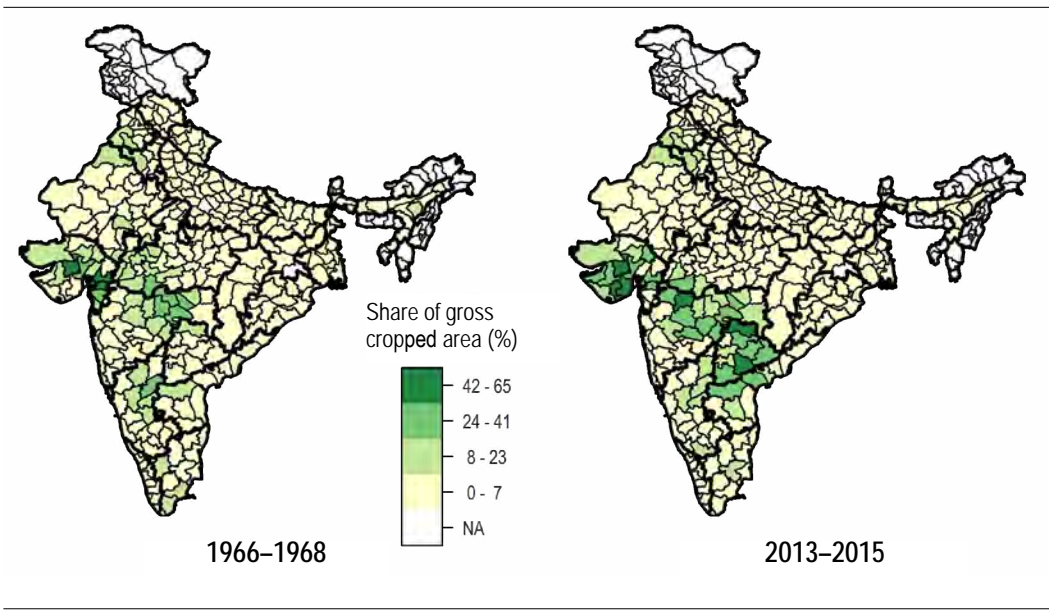
⁴⁵ Blyn (1983)

Figure 3.5 | Share of gross cropped area under oilseeds by district, 3-year averages, 1966–68 and 2013–15



Data source: Government of India. Accessed through the ICRISAT–TCI District Level Database, 1970 district boundaries.

Figure 3.6 | Share of gross cropped area under cotton by district, 3-year averages, 1966–68 and 2013–15



Data source: Government of India. Accessed through the ICRISAT–TCI District Level Database, 1970 district boundaries.

oilseeds (Figure 3.5) and cotton (Figure 3.6) in those regions. These states were then able to reinvest gains from agriculture into nonagricultural industries—hence, the decreasing share of agriculture in GDP and increased urbanization. This led to poverty rates and income levels that are comparable to the agriculture-led growth states.

Many of the states in eastern India can be classified as lagging, due to their low GDP per capita, low urbanization rates, and low productivity in the agricultural sector. In these states, the Green Revolution did not take off for multiple reasons, including unfavorable climatic conditions, lack of economic incentives, low adoption of HYVs, and lack of irrigation infrastructure and electrical connectivity.⁴⁶ As a result, incomes are still low, as is access to diverse foods.

3.2 Diet and Nutrition Outcomes

Agriculture played a key role in defining the development trajectories followed by different states, and the resulting differences in income levels have led to vast differences in diets and nutrition outcomes. Most notably, the share of cereals in the diets of people in agriculture-led growth states and urbanizing states has shrunk considerably—the share of calories consumed from cereals in these states is 48 and 50 percent, respectively, compared to 63 percent in lagging states.⁴⁷ People in states that have progressed along the development trajectory are obtaining more calories from other sources. For example, a higher share of women in these states are consuming dairy; eggs, meat or fish; and fruit on a daily or weekly basis (Figure 3.7). Consumption of legumes and green leafy vegetables, however, does not seem to follow the same trend based on the most recent available data. In fact, the share of women consuming green leafy vegetables daily

or weekly is much higher than we would expect throughout India, and especially, in the lagging regions. It is not clear why this is the case, but it is important to keep in mind that this data does not show consumption quantity. The most recent survey of consumption quantity was conducted by the National Sample Survey Organization (NSSO) in 2011–12. More recent consumption data is required for deeper analysis of dietary trends.

The trends noted here suggest that states further along the development trajectory have more diversified diets, and we argue that these diets contribute to the lower prevalence of stunted, wasted, and underweight children in these regions, as compared to the lagging states (Figure 1.12). However, there are notable exceptions—districts in agriculture-led growth states or urbanizing states in which incidence of stunting, for example, is still high (Figure 1.14). At the same time, obesity is a growing problem in most of these more developed states (Figures 1.14 and 1.15). These trends may share a common explanation: even in the more developed regions, where diets are becoming more diverse, accessibility of diverse and healthy foods is still limited. In most of northern India, including the more developed states, most women are not consuming eggs, fish, or meat daily, or even weekly (Figure 3.7). Percent of daily calorie intake from vegetables and fruits is also still quite low in many of the more developed states (NSS 2011–12 district-level data, data not shown). Instead of consuming more healthy foods, many Indians, in the more developed states, are consuming more of their calories from edible oil, processed foods, and beverages (NSS 2011–12 district-level data, data not shown). The increased intake of oils and sugars is leading to obesity and noncommunicable diseases.⁴⁸

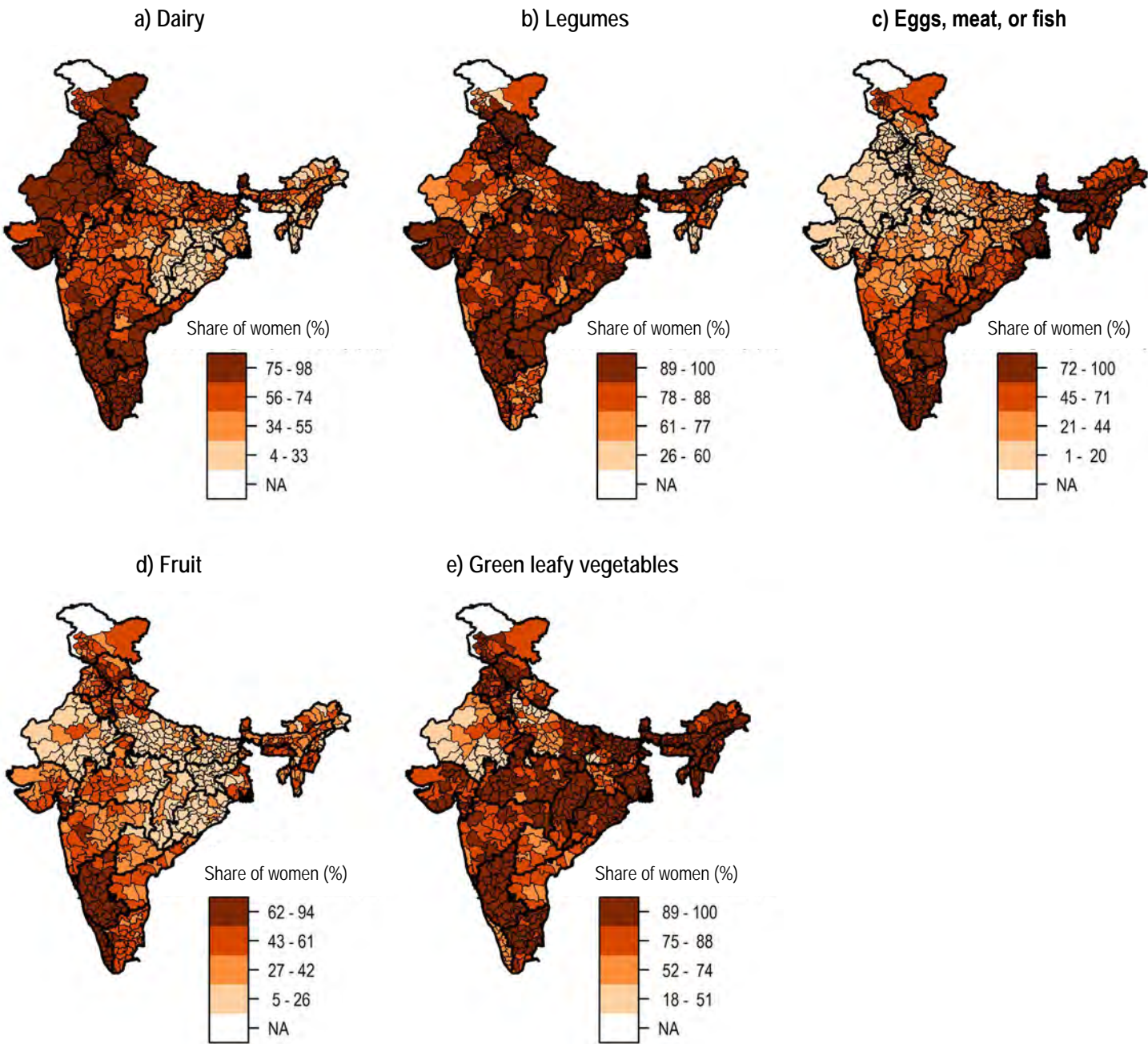
The trends noted here suggest that states further along the development trajectory have more diversified diets, and we argue that these diets contribute to the lower prevalence of stunted, wasted, and underweight children in these regions, as compared to the lagging states

⁴⁶ These factors are discussed in detail in Section 5.1

⁴⁷ Calculated from NSS 2011–12 state-level data, based on classification of states by Pingali et al. (2019) (Table 1).

⁴⁸ Meenakshi (2016).

Figure 3.7 | Share of the women consuming (a) dairy; (b) legumes; (c) eggs, fish, and meat; (d) fruit; and (e) green leafy vegetables daily or weekly, by district, 2015–16



Data source: NFHS 2015–16, 2011 district boundaries.

3.3 A Way Forward

It is clear from the preceding discussion that the investments that certain regions in northern and southern India made in agriculture put those regions on a development trajectory that led to increased incomes, more diverse diets, and ultimately, better nutrition outcomes. However, those same regions now suffer from increased obesity and noncommunicable diseases, largely because while calorie intake has increased and diets have become diversified, access to healthy foods—pulses, coarse cereals, fruits, and vegetables—still lags in comparison to energy-dense processed foods. At the same time, regions in eastern India that did not invest in agriculture are still experiencing high levels of undernutrition and micronutrient deficiency. Two conclusions are clear from this review: (1) investment in agriculture is essential to improving nutrition outcomes because of the income gains that it brings about, but (2) diversity in the food system has been neglected, leading to lingering malnutrition of all forms. The required next steps, therefore, need to incorporate (1) investment in agriculture, with the goal of increasing farmers’ incomes; and (2) increased access to diverse foods.

The next chapter will detail strategies for increasing farmers’ incomes via investment in agriculture. One important theme, which will also address the need to increase access to diverse foods, is investment in nonstaples. Investing in nonstaples is long overdue. The current low consumption of protein- and micronutrient-rich foods in most Indian states can be traced to persistent Green Revolution-era policies that incentivize production of staple grains by offering fertilizer and credit subsidies and price supports. Such policies have led to limited supply, and consequently, high prices of more diverse foods. These policies made sense in the 1960s, when the focus was on calorie adequacy. However, in the current situation, with malnutrition continuing largely as a result of monotonous, staple-rich diets, India must turn its focus from quantity to quality. To improve incentives for production of nonstaples, policies will need to provide public investment in market infrastructure, credit facilities, and input availability for production of nonstaple crops. Private investment in such market development will also be essential.



Madannapet daily vegetable market in Hyderabad, Telangana. Photo by Jocelyn Boiteau.

Another avenue that can encourage both production and consumption of more micronutrient-rich foods is to make changes in food-based assistance programs. Currently, the three largest food-based assistance programs in India—the Public Distribution System (PDS), the Integrated Child Development Scheme (ICDS), and the Mid-Day Meal Scheme (MDMS)—are focused almost entirely on providing staple grains. Redesigning these programs to include pulses, coarse cereals, fruits, and vegetables would go a long way toward improving diets and nutrition outcomes. States like Karnataka and Tamil Nadu are already providing millets through the PDS, and Chhattisgarh is providing iodized salt, black gram, and pulses to the poorest households. These are steps in the right direction.

In addition to reorienting policies toward nonstaples, new policies in India also need to be reoriented toward lagging regions. Specifically, there needs to be a renewed focus on agricultural growth in eastern India. Although the opportunity for these states to become competitive in staple grain production is unclear, there may be an opportunity for them to become competitive in the production of nonstaples.

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The current low consumption of protein- and micronutrient-rich foods in most Indian states can be traced to persistent Green Revolution-era policies that incentivize production of staple grains by offering fertilizer and credit subsidies and price supports.



Woman in her okra field in Bourn,
Kalahandi district, Odisha.
Photo by Kiera Crowley

4

Doubling Smallholders' Income: An Overview

As the previous chapters have illuminated, improving household income and access to diverse foods are essential pathways through which agriculture can be leveraged to improve nutrition outcomes. Achieving SDG2.3, which calls for doubling agricultural productivity and incomes of smallholder farmers by 2030, would go a long way toward propelling India along these pathways.

The Indian government put out an even more ambitious goal in 2015 of doubling farmers' incomes by 2022. The focus of both SDG2.3 and the Indian government on smallholder farmers is necessary, given that smallholders make up the majority of the farming population in India, earn substantially lower incomes than larger farmers, and are growing rapidly in numbers, as land-holdings are becoming increasingly fragmented (see Box 4.1). Looking to the future, increasing the incomes of smallholders will be essential for improving the nutrition of the country as a whole.

In order to assess the feasibility of doubling farmers' incomes, it is essential first to consider past trends. Unfortunately, this is challenging given the lack of recent data. While the National Sample Survey Office (NSSO) does administer nationwide surveys, the last survey was done in

2013. However, estimates with available data indicate that the doubling of real farm income per cultivator takes time—the last one took 20 years, from 1993–94 to 2013–14.⁴⁹ Most of this gain happened from 2004 to 2011, when farmers' income grew at a rate of 7.46 percent. This increase, however, was largely led by a decline in the number of cultivators. From 1993–94 to 2004–05, the growth rate in per farmer income was 1.96 percent, and since 2011–12, the rate has dropped to about 0.44 percent.⁵⁰ At the current growth rate, doubling incomes by 2030, as SDG2.3 calls for, seems a daunting challenge. Clearly, doubling of farm income requires significant policy change, but there has been little concerted action on it, except for the announcement of income transfers to farmers.

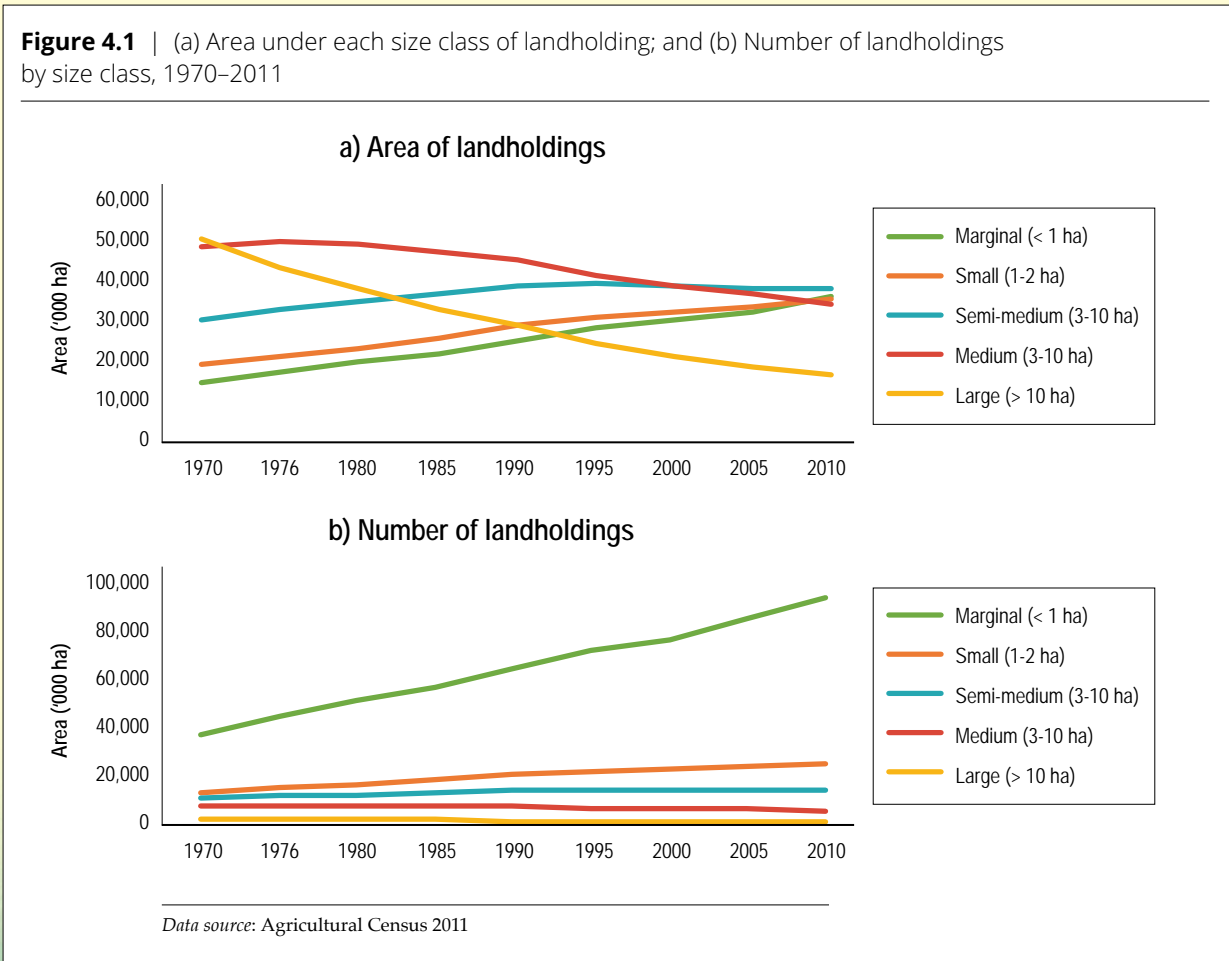
⁴⁹ Chand (2017)
⁵⁰ Chand (2017)

Box 4.1 | FOCUS ON SMALLHOLDERS

SDG2.3 and the Indian government are aligned in their emphasis on the need to double incomes of smallholder farmers. SDG2.3 calls for doubling incomes of smallholder farmers from 2015 levels by 2030, and the Indian government, using the same base year, has set a goal to double incomes of farmers (especially, but not exclusively, smallholders) by 2022. The Indian government focuses on what they term “small” and “marginal” farmers, defined as those who own 1–2 hectares (ha) and less than 1 ha of land, respectively. According to the most recent agricultural census, marginal holdings account for 67 percent of total landholdings, and smallholdings account for 18 percent. Together, small and marginal farmers account for the majority (85 percent) of the farming population.

With the number of small and marginal landholdings increasing as a result of land fragmentation (Figure 4.1), the goal of doubling smallholders’ income is not only relevant but extremely urgent, as small farmers are finding it increasingly difficult to maintain a decent standard of living and invest in productive assets.

The focus on smallholders is especially warranted, as Indian farmers’ income decreases drastically with farm size. While households with medium (2–10 ha) and large (>10 ha) landholdings earned an average monthly income in 2013 of 13,407 and 37,631 Rs., respectively, households with marginal (<1 ha) and small (1–2 ha) landholdings earned only 4,646 and 7,367 Rs., respectively.^a

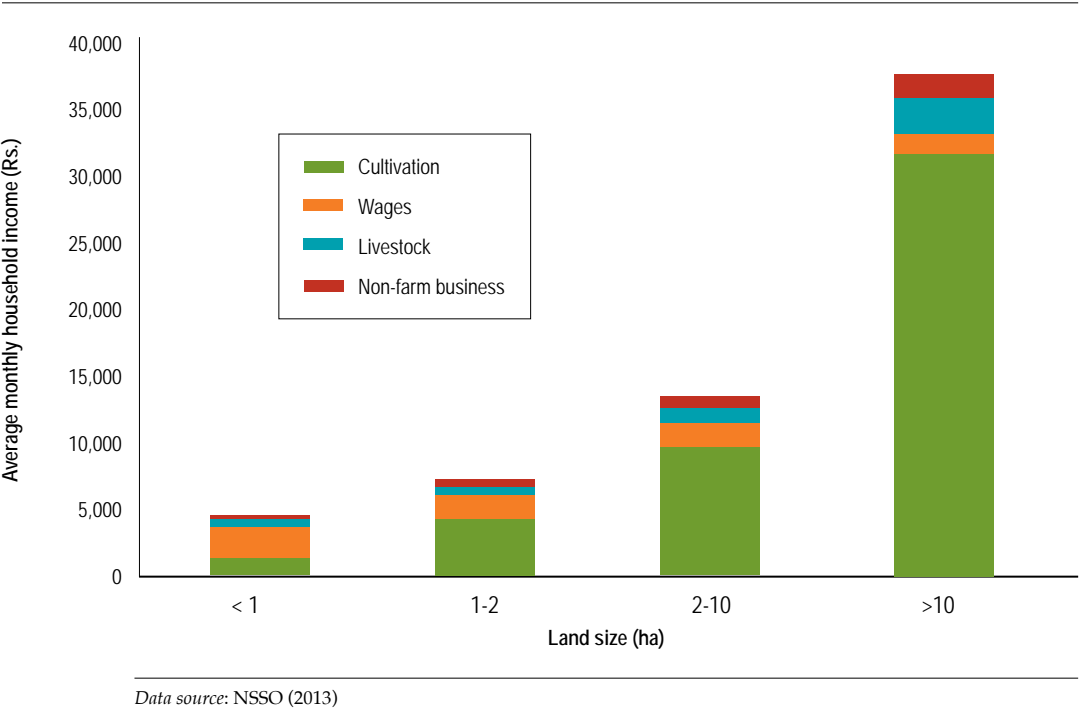


^a NSSO (2013)

To strategize how to go about doubling the income of small-scale farmers, it is helpful to look at the breakdown of income sources for those farmers. In addition to cultivation, farmers earn income from a diverse set of additional activities. The nationally representative 2013 survey of farmers revealed that cultivation is the principal source of income for 63.5 percent of farming households. The rest of the households are primarily earning income from salaried employment (22 percent), livestock (3.7 percent), nonagricultural enterprises (4.7 percent), and other forms of livelihoods.⁵¹ Given that cultivation still represents the major source of income, increasing income from cultivation is certainly an important component of increasing overall income. However, income outside of cultivation becomes increasingly important for farmers with smaller landholdings (Figure 4.2).

Although increasing opportunities for rural non-farm employment is certainly one of the avenues that should be pursued for increasing incomes, particularly for smallholders, there are many barriers to this pathway. It requires that farmers learn new employable skills and that a vibrant economy exists that can provide useful employment opportunities. Therefore, increasing income from agriculture will still be paramount for marginal farmers, at least in the short term, even as investments in nonfarm employment avenues increase.

Figure 4.2 | Income by source and landholding size, 2013



⁵¹ Chandrasekhar and Mehrota (2016)

⁵² TFP refers to the ratio of the value of output to the total value of inputs used.

⁵³ Cropping intensity refers to the number of times a field is sown within a year.

Avenues for increasing farmers’ incomes include increasing yields and total factor productivity (TFP);⁵² increasing cropping intensity;⁵³ diversifying crop and livestock systems; integrating smallholders into markets; and increasing opportunities in nonfarm employment.^{54, 55} As the first three of these avenues are related to the productivity and diversification of cropping systems, we will address these first, using a cropping systems framework to discuss prospects for each of these pathways within each major cropping system (Chapter 5). Then, in Chapters 6 and 7, we will address the prospects for increasing income via market integration and nonfarm employment.

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Given that cultivation still represents the major source of income, increasing income from cultivation is certainly an important component of increasing overall income. However, income outside of cultivation becomes increasingly important for farmers with smaller landholdings.

⁵⁴ Paroda (2018)

⁵⁵ These sources of growth were also identified in a NITI Aayog report published in 2017. See Chand (2017).



Man sells vegetables at a market in Munger district, Bihar. Photo by Mathew Abraham.

5

Doubling Incomes: Cropping System Productivity and Diversification

India has a vast array of cropping systems, all of which face different challenges and will require different interventions to increase productivity and incomes. Therefore, we identify dominant agricultural systems in India and explore the prospects for productivity and income growth in each one separately. Specifically, we will assess the prospects for income growth via increasing yields and TFP;⁵⁶ increasing cropping intensity; and diversifying crop and livestock systems (see Box 5.1). While exploring prospects for income growth through agriculture, we also highlight the need for sustainability in agricultural systems and the need for these systems to adapt to a changing climate, thereby acknowledging SDG2.4, which calls for sustainability and resilience in agricultural systems.

⁵⁶ Yields can be increased either by increasing inputs, such as irrigation or fertilizer, or by adopting new technologies in the form of improved varieties or new agronomic practices. The latter pathways to increased yields also increase TFP. However, TFP can also be increased by enhancing input use efficiency, which may not increase yields but will increase net profit by reducing costs. Due to the interrelatedness of these two avenues for increasing profitability of cropping systems, they will be discussed together.

Box 5.1 | SPOTLIGHT ON DIVERSIFICATION

As we saw in Chapter 1, population increase, rise in per capita incomes, and urbanization are driving the rising demand for food products, especially for higher value products, such as fruits and vegetables, dairy and meat, and value-added processed foods. Most of these high-demand food groups lag far behind cereals in availability per capita. Meeting this rising demand is an enormous opportunity for smallholder farmers, as the value of these goods is exponentially higher than the value of staples: high-value crops (fruits, vegetables, fiber, condiments, spices, and sugarcane) contribute almost the same value of output as staple crops (cereals, pulses, and oilseeds), while occupying only 19 percent of gross cropped area.^a

The states with high productivity are natural candidates for transitioning to more diversified and commercialized production systems. However, the current policy environment is staple grain-centric, providing limited incentives for farmers to make the transition. Commercialization is particularly challenging for smallholder farmers in the lagging regions of Eastern and Northeastern India. According to Pingali and colleagues, “With investments in markets and agricultural infrastructure, such as irrigation, warehouses, and cold storage facilities, and a supportive policy

environment, ... it is possible for these regions to leap frog from the current subsistence systems to commercial operations that are focused on supplying urban demand for food diversity.”^b

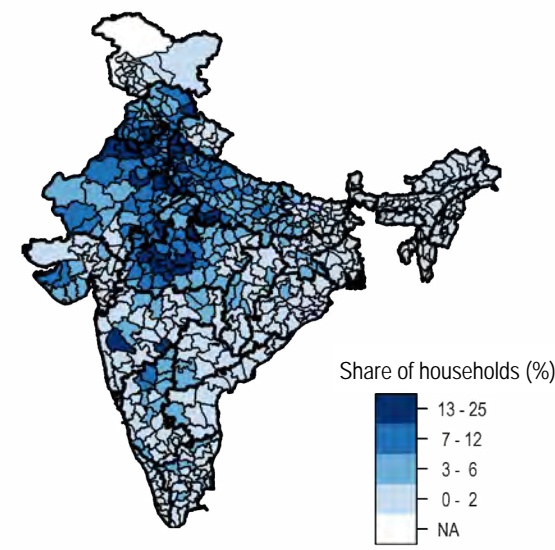
Barriers to diversification for smallholder farmers include poor access to markets, purchased inputs, technology, extension services, credit, and loans. Access to markets will be addressed in Chapter 6, and some of the same strategies, such as farmer producer organizations (FPOs) can help with access to purchased inputs. Technology dissemination and extension services need to be expanded, and increasing private sector participation in such services will be important to achieve diversification.

Access to credit and loans is also an important factor inhibiting diversification. Access to credit is extremely varied

across the country (Figure 5.1), and access to loans varies by size of landholdings (Figure 5.2). While large landholders receive almost 80 percent of their total loan value from institutional sources, farmers with marginal landholdings receive only about 60 percent from such sources. The lack of institutional loans given to marginal farmers indicates the difficulty they have in securing loans.

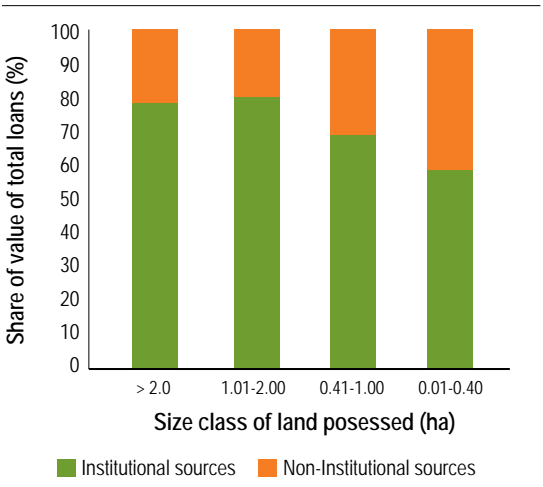
Meeting [the] rising demand [for foods such as fruits and vegetables] is an enormous opportunity for smallholder farmers, as the value of these goods is exponentially higher than the value of staples.

Figure 5.1 | Share of households, by district, that have Kisan Credit Cards with at least a Rs. 50,000 credit limit, 2011



Data source: Socio-Economic and Caste Census, 2011

Figure 5.2 | Loan sources by size class, 2016



Data source: NABARD All India Rural Financial Inclusion Survey 2016–17

^a Chand (2017)

^b Pingali et al. (2019, 10)

5.1 The Cropping Systems Approach: An Overview

The term “cropping system” is used to characterize the crops grown in a given region—a difficult task, given that the types of crops being grown vary both spatially, from farm to farm, and temporally, by growing season. India has three main growing seasons—kharif (usually the main season, harvested in autumn), rabi (usually the secondary season, harvested in spring), and zaid (usually the least common growing season, harvested in summer). In order to make sense of these spatial and temporal variations, we have identified the dominant crop in each district as the crop that, during a single growing season, occupies the greatest share of gross cropped area⁵⁷ (Figure 5.3). For systems that have a prominent secondary crop, like the rice–wheat system in the Indo–Gangetic Plain (IGP), we have included both the dominant and secondary crop. For more about how we constructed this map, see Box 5.2.

The major cropping systems that we have defined are as follows: the rice–wheat system in the IGP; rice–fallow,⁵⁸ rice–rice, and rice–other systems in eastern India; cotton and oilseed systems in central and western India; and coarse cereal and pulse systems scattered throughout the country but concentrated in western Maharashtra, northern Karnataka, and Rajasthan. The rice–wheat system spans the eastern and western IGP, which have vastly different socioeconomic and environmental conditions. In the western IGP, rice and wheat yields are among the highest in the country, but the intensive farming system is straining natural resources, and groundwater is running out. In the eastern IGP, rice and wheat yields have lagged behind, due to poor investment in agricultural infrastructure and less favorable agroclimatic conditions. Both of these regions would benefit from shifting to less water-intensive crops and adopting more sustainable and water-conserving practices in the production of rice and wheat. The eastern region also requires further investment in infrastructure. In the western region, shifting to high-value crops could provide the level of income necessary to compete with current income from procurement of rice and wheat, while also increasing the diversity of food available in the market.

In the rice–fallow regions, mainly in Odisha and Chhattisgarh, there is great potential to increase production and income by adding a crop during the rabi (winter) season, when thousands of hectares of fields currently lie fallow. Pulses and oilseeds would be ideal crops to add here, given that cultivation is possible with limited irrigation. In the rice–rice



Woman in rice field in Kandhamal district, Odisha. Photo by Maureen Valentine.

systems of Tamil Nadu and West Bengal, as in the western IGP, the focus must be on switching to less water-intensive crops and means of production, as well as to high-value crops. In the cotton and oilseed systems of central India, yields are still far below potential. Agronomic strategies to increase yields of these crops must be pursued, as well as strategies to increase water use efficiency to ensure future sustainability.

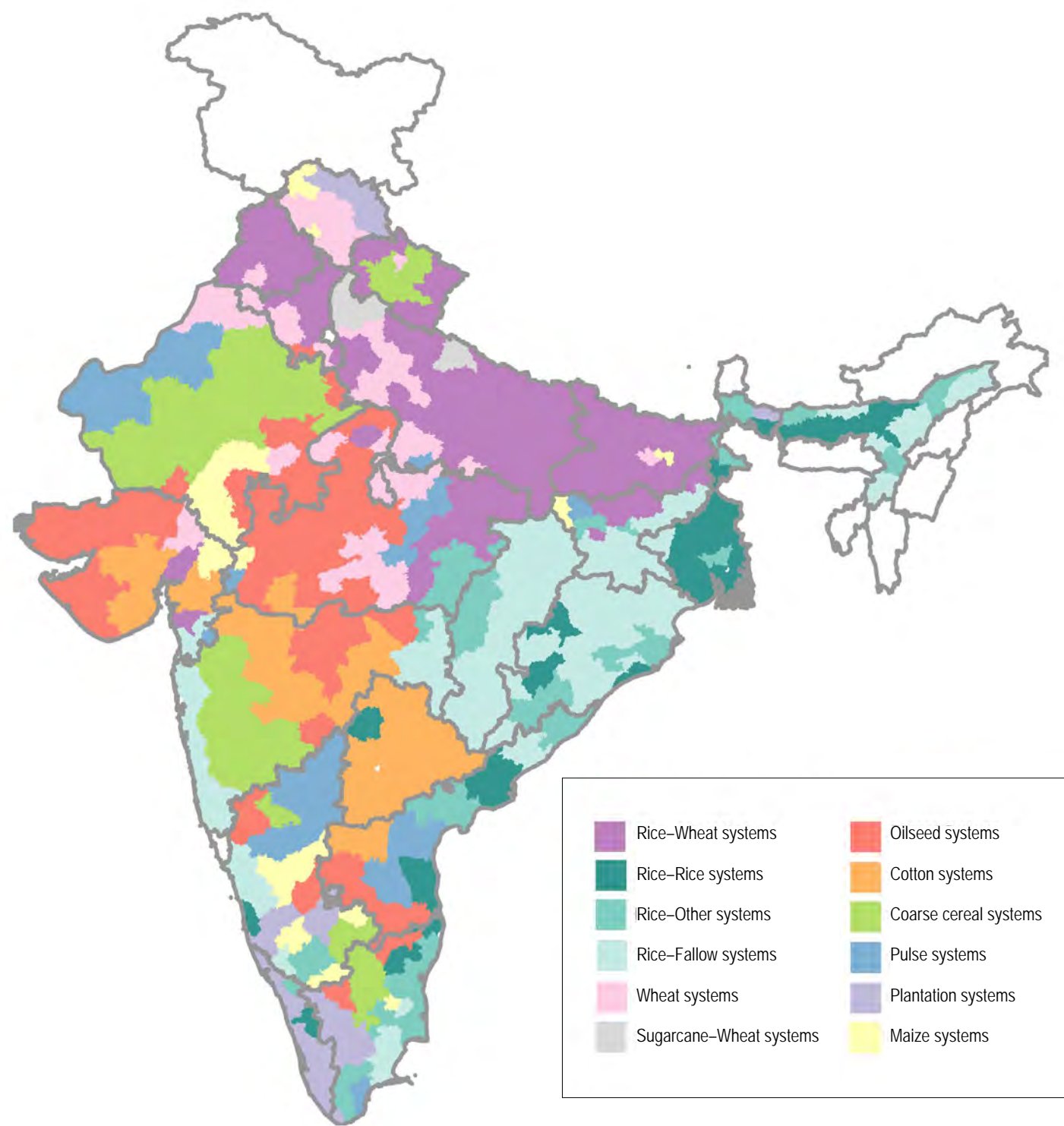
Across cropping systems, opportunity exists for diversifying to pulses and coarse cereals, as these crops are high in nutritive value and resilient to climate stress. Yields and profits from these crops can be improved by strengthening the delivery systems for quality seeds, providing training on best practices, implementing crop insurance, and encouraging the formation of farmer producer organizations (FPOs). Farmers growing coarse cereals and pulses can also benefit from rising consumer interest in these crops.

Across cropping systems, opportunity exists for diversifying to pulses and coarse cereals, as these crops are high in nutritive value and resilient to climate stress.

⁵⁷ Gross cropped area = the total area cropped in kharif, plus the total area cropped in rabi, plus the total area cropped in zaid. In other words, an area is counted as many times as there are sowings in a year.

⁵⁸ The rice–fallow system was defined as the rice-dominant districts where the cropping intensity is less than 1.22, correlating to the districts with lowest cropping intensity in our cropping intensity map, Figure 5.4.

Figure 5.3 | Dominant cropping systems by district, 2013–15



Data source: Government of India. Accessed through the ICRISAT–TCI District Level Database, 2015 district boundaries.

Box 5.2 | CONSTRUCTION OF THE CROPPING SYSTEMS MAP

1. We started with the season-wise crop area data from the ICRISAT–TCI District Level Database.^a
2. For each season, **total cropped area was calculated** by summing the areas under each crop during that season.
3. **Crops were grouped** into categories or left as a single crop, as follows:
 - a. Single crops: rice, wheat, cotton, maize, sugarcane, and tobacco
 - b. Crop groups: pulses, coarse cereals, oilseeds, plantation crops, non-cotton fiber crops, spices, and vegetables
4. For each crop or group of crops, the area under that crop or crop group during a particular season was divided by the total cropped area during that season to determine the **percent of cropped area for that season**.
5. The **percent of cropped area by season for each crop/crop group was averaged over 3 years** (2013–14 to 2015–16).
6. A **dominant crop was identified for each season** as the crop/crop group with the highest average percentage of cropped area over the 3-year span.
7. The **overall dominant crop was identified** by calculating the percentage that each season-wise dominant crop occupied of gross cropped area, and choosing the crop with the highest percentage. This way, if in a particular district, cotton was the dominant crop in kharif, for example, but a larger percent of gross cropped area was under wheat in rabi, the overall dominant crop was identified as wheat.
8. The cropping system was defined by the overall dominant crop, and **in certain cases, further distinctions were drawn**:
 - a. Two crops to define a system:

When **rice and wheat** were the dominant crops in kharif and rabi, both crops were included to define the cropping system, given that this system is well-known as the dominant feature of the Indo-Gangetic Plain.

Rice-rice systems were included, because it is important to see what districts have been successful in double-cropping rice.

Sugarcane-wheat was included as a system because in the few districts where sugarcane was the dominant crop in kharif season, wheat was always the dominant crop in rabi season.

For other systems, the dominant crop in the alternate season was not included, because there is too much variation in the alternate season crop.
 - b. Fallow season to define a system:

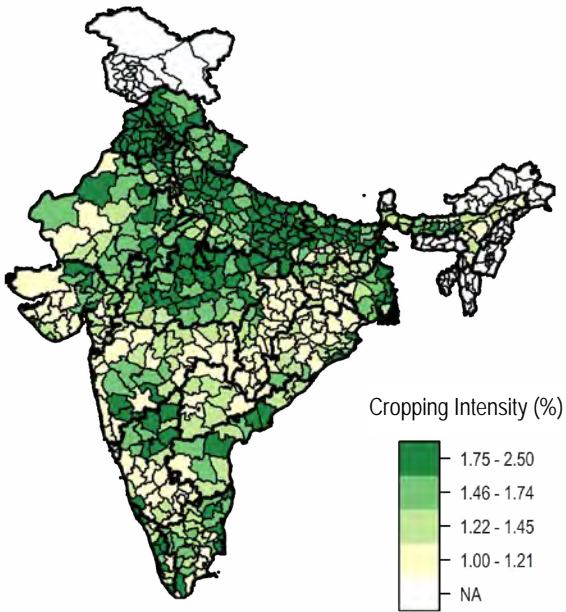
The **rice-fallow** system was defined by the districts where rice is the dominant crop, but the cropping intensity is below 1.22 (see cropping intensity map, Figure 5.4).

^a ICRISAT and TCI (2019)

5.2 Rice-Wheat Systems

The rice-wheat cropping system is the dominant cropping system in India. It occupies 20 million ha, or 18 percent of the total cropped area in the country. The system spans the IGP, from the highly productive regions of Punjab, Haryana, and western Uttar Pradesh to the less productive regions of eastern Uttar Pradesh, Madhya Pradesh, and Bihar. While the western IGP was once mainly a wheat-growing region and the eastern IGP once grew mainly rice, irrigation and high-yielding, short-duration varieties of wheat promoted by the Green Revolution made it possible to grow wheat and rice consecutively in the same field—rice in the rainy season (kharif), and wheat in the dry season (rabi). This system makes the IGP one of the most intensely cropped regions in the country (Figure 5.4). However, productivity levels decrease rapidly, moving eastward across the plain. Compared to the eastern IGP, the western IGP has a more favorable agroclimatic environment, more developed irrigation infrastructure, better electrical connectivity, and a more established procurement system,

Figure 5.4 | Cropping intensity by district, 3-year average, 2013–15



Note: Cropping intensity, at the district level, can be thought of as the average number of times that the fields in that district are sown during the year. It is calculated as the ratio of gross cropped area to the net cropped area (the total area sown during the year, with area sown more than once in a year counted only once).

Data source: Government of India. Accessed through the ICRIAT–TCI District Level Database, 2015 district boundaries.

guaranteeing that farmers receive minimum support prices for rice and wheat. Due to these regional differences, the eastern and western IGP will require different strategies for increasing productivity. However, given that these regions both have high cropping intensity, increasing cropping intensity will not be the main pathway to increased productivity for either region in this cropping system. Instead, these regions will derive growth from increasing yields, total factor productivity, and diversification.

5.2.1 Current yields and regional variation

Yields of rice and wheat in India benefitted greatly from the Green Revolution policies that favored staple grains by offering subsidies on fertilizer, irrigation, power, and high-yielding varieties. Since 1950–51, the productivity of rice and wheat has increased by 286 and 408 percent, respectively—surpassed only by maize, which has also benefitted from Green Revolution policies, and cotton, which benefitted from the Bt cotton introduced in 2002 (Figure 5.5). Yields, however, vary greatly between the western and eastern IGP. Rice yields are highest in Punjab, where they exceed 3.7 tons/ha in most districts (Figure 5.6). However, rice yields fall below 2.5 tons/ha in most districts of Uttar Pradesh and Bihar. Wheat yields exceed 3.6 tons/ha in both Punjab and Haryana, and exceed 2.4 tons/ha in most districts of western Uttar Pradesh (Figure 5.7). However, in most districts of eastern Uttar Pradesh and Bihar, wheat yields fall below 2.5 tons/ha.

The differences in yield between the eastern and western IGP are the result of a multitude of inter-related factors, including climate, economic incentives, adoption of high-yielding varieties, irrigation infrastructure, and electrical connectivity. Climate is an extremely important factor that belies all other factors. Due to climatic variation, potential yields, defined as “the maximum yield of a variety restricted only by the specific climatic conditions of a particular season” are highest in the northwestern IGP, and decrease by 28 percent for rice and 34 percent for wheat, moving eastwards toward West Bengal.⁵⁹ Specifically, the eastern IGP receives lower solar radiation and higher daily minimum temperatures, resulting in increased respiration, decreased photosynthesis, and a shortened vegetative and grain-filling period.

In addition, the eastern IGP is more prone to both flooding and drought. In the rainy season, Bihar and West Bengal are particularly prone to flooding, and Uttar Pradesh is particularly prone to drought. Drought in Uttar Pradesh affects 20 percent of the state’s total rice crop.⁶⁰

⁵⁹ Ladha et al. (2003, 53)

⁶⁰ Kannan, Paliwal, and Sparks (2017)

Figure 5.5 | Percent change in yields of major crops in India from 1950–51 to 2017–18

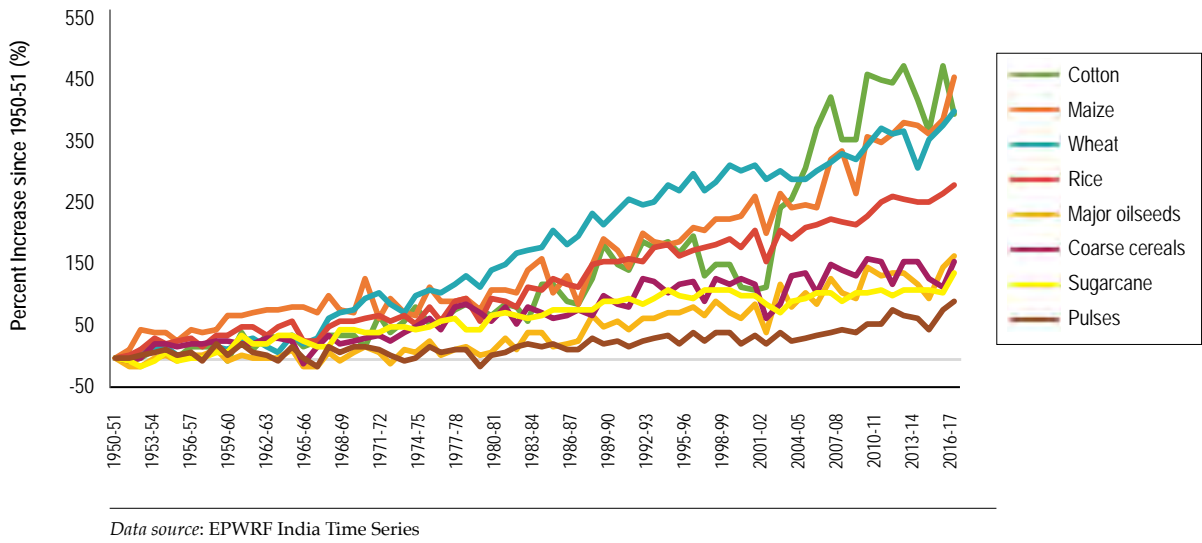
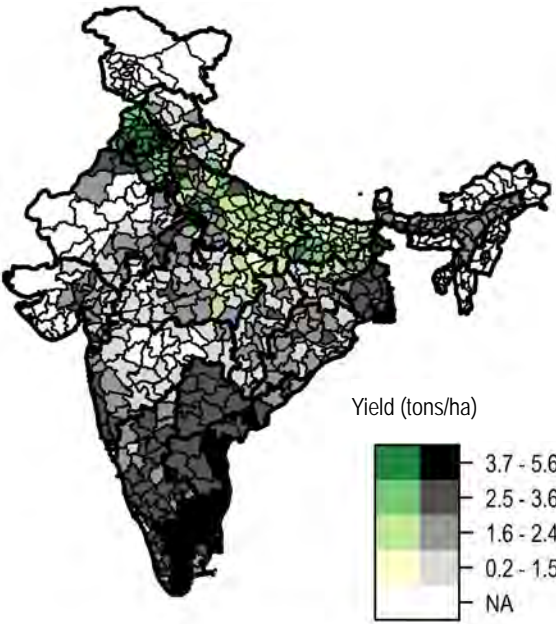


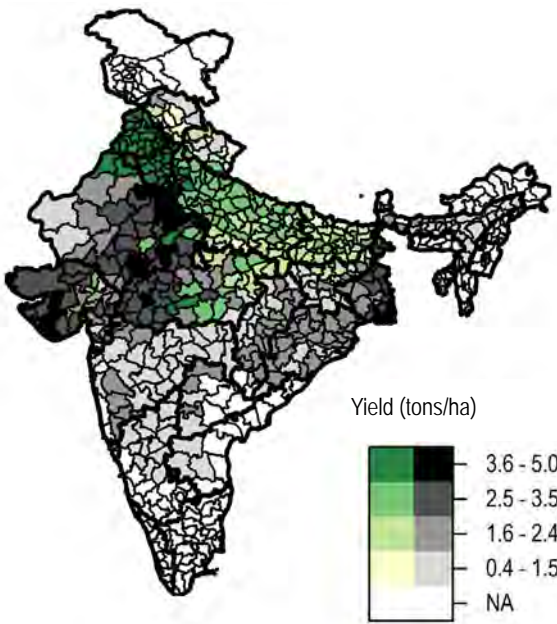
Figure 5.6 | Rice yields, by district, in the rice-wheat cropping system, 3-year average, 2013–15



Note: Areas within the cropping system are represented in green.

Data source: Government of India. Accessed through the ICRIAT–TCI District Level Database, 2015 district boundaries.

Figure 5.7 | Wheat yields, by district, in the rice-wheat and wheat-dominant cropping systems, 3-year average, 2013–15



Note: Areas within the cropping system are represented in green.

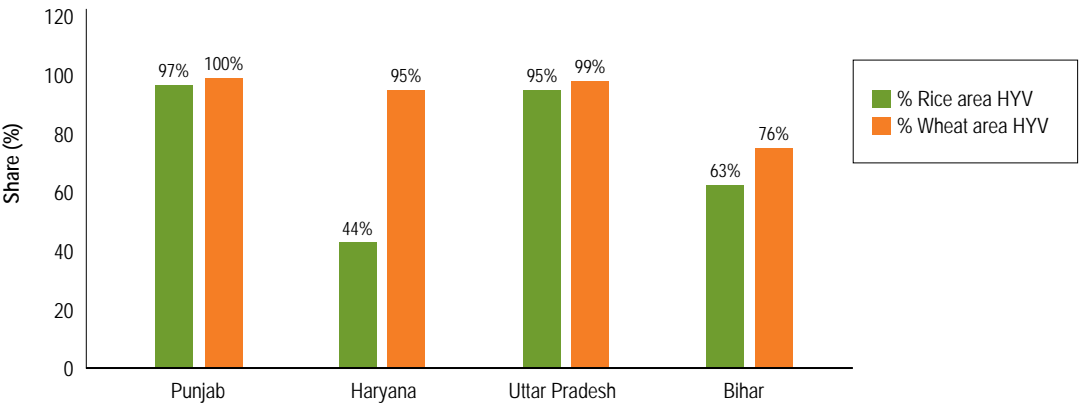
Data source: Government of India. Accessed through the ICRIAT–TCI District Level Database, 2015 district boundaries.

Beyond the climatic factors, the Green Revolution played a large role in differentiating yields between the western and eastern IGP. As discussed earlier, states in the western IGP invested heavily in Green Revolution technologies, providing subsidies on power, irrigation, and fertilizer, and offering support prices to incentivize adoption of HYVs. The adoption of HYV wheat has reached almost 100 percent in Punjab, Haryana, and Uttar Pradesh (Figure 5.8). The adoption of HYV rice in Punjab and Uttar Pradesh is also almost 100 percent, though in Haryana, it is only 44 percent, mainly because Haryana produces mostly Basmati rice for export, which is lower yielding but of higher value. Overall, the full package of Green Revolution technologies has led to high yields in the western IGP.

In the eastern IGP, however, Green Revolution technologies took longer to catch on. Adoption of HYVs was slower and is still at just 76 percent and 63 percent for wheat and rice, respectively, in Bihar. Although HYV adoption in Uttar Pradesh is now almost 100 percent for both these crops, rice and wheat yields across the state still lag behind Punjab, and wheat yields are especially low in eastern Uttar

Pradesh compared to the western region of the state. This pattern in yields is somewhat reflected in the map of cropped area irrigated by wells (Figure 5.9). Although tube well development in eastern Uttar Pradesh has grown in recent years, most districts still have less tube well irrigation than western Uttar Pradesh. Some of the districts in Uttar Pradesh with a lower share of cropped area irrigated by tube wells still have a high share of cropped area irrigated. However, a significant percentage of that irrigation is coming from canals, which are not as reliable for the volume of water and precise timing of irrigation required by HYV crops. Bihar also lags behind in tube well development and total share of cropped area irrigated. Even in areas where there is infrastructure for tube well irrigation, utilization of that irrigation is severely hindered due to poor access to electricity. As a result, farmers often depend on expensive diesel for pumping groundwater, which either discourages irrigation or reduces farmers’ returns from cultivation. Lack of irrigation is particularly problematic in Uttar Pradesh because of the high frequency of droughts, even during the kharif season. Although these states have invested heavily in irrigation and electricity in recent years, further investment is necessary.

Figure 5.8 | Share of rice area and wheat area under high-yielding varieties, 2012–13



Note: The most recent available data for HYV area is from 2012–13. Data for Uttar Pradesh are from 2011–12 (most recent available).

Data source: Authors’ calculation from 2012–13 HYV area data in Table 4.2.1 of “Agricultural Statistics at a Glance 2017” (Government of India 2019), and 2012–13 total crop area data in “5-Year Estimates of Food Grains” (Directorate of Economics and Statistics 2020).

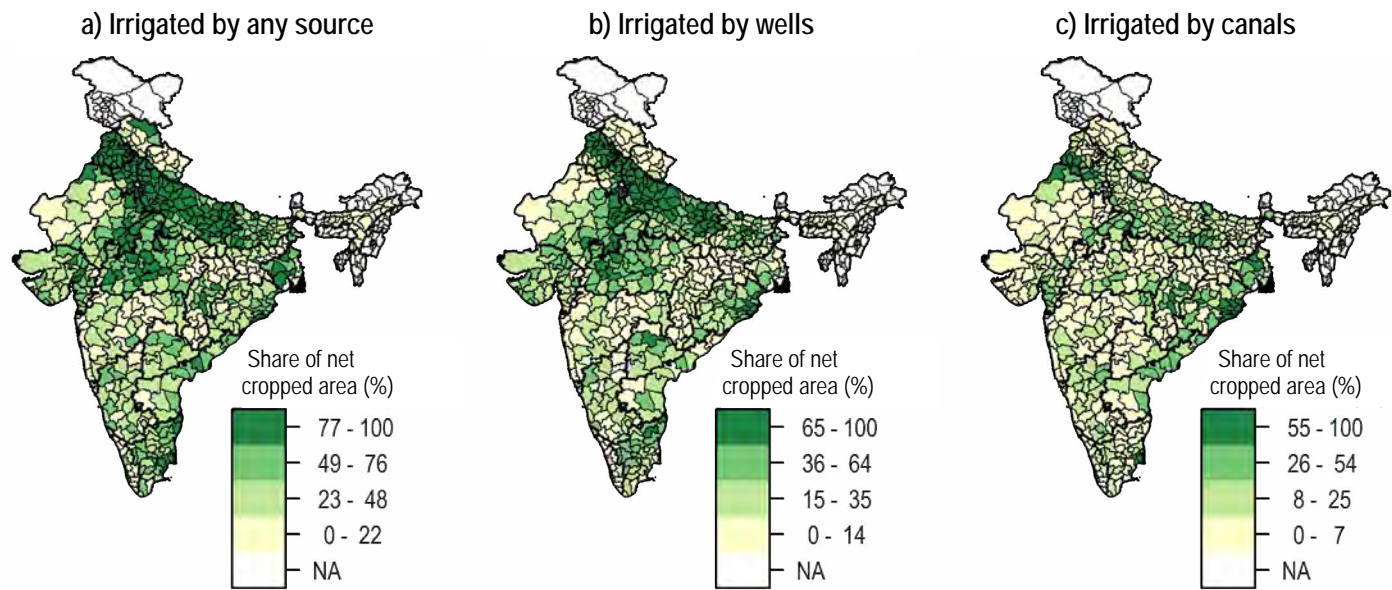
5.2.2 Increasing yields and total factor productivity

In the eastern IGP, there is significant opportunity for yield improvement of rice and wheat, both via investment in irrigation and electrical infrastructure, and via adoption of improved varieties and agronomic practices that can increase TFP. For example, practices showing promise for increasing rice yields include establishing and holding to an optimum date for transplanting rice; adopting hybrid rice varieties that are shorter in duration, and therefore, less susceptible to drought; supplemental post-establishment irrigation; and/or direct seeding of rice.⁶¹ Management practices associated with increased wheat yields in the eastern IGP include early sowing with long-maturing varieties; higher rates of fertilizer application, especially potassium; zero-tillage; and more frequent irrigation.⁶² The combination of direct-seeded rice and zero-tillage wheat has been shown to increase system productivity, reduce production costs, increase net profit, and minimize climate risks compared to conventional practices.⁶³ Zero-tillage, residue management, and crop diversification in rice–wheat systems have also been shown to improve productivity by improving soil organic carbon and soil biological quality.⁶⁴

In both the western and eastern IGP, an important pathway to increasing TFP will be through more efficient use of fertilizer. In both kharif and rabi seasons, nitrogen application is high throughout the IGP (Figure 5.10). In fact, in most cases, farmers are overapplying nitrogen, leading to serious environmental consequences. Of the nitrogen fertilizer applied to rice in the IGP, between 35 and 40 percent is lost to leaching.⁶⁵ This causes pollution of drinking water, and eutrophication of water bodies. Therefore, increasing nutrient use efficiency by changing agronomic practices will be an important source of productivity improvement. In addition, it will be important for all areas in the IGP to pursue more balanced fertilizer application. Currently, urea is by far the most widely used fertilizer because of its low price in comparison to other fertilizers. As a result,

In the eastern IGP, there is significant opportunity for yield improvement of rice and wheat, both via investment in irrigation and electrical infrastructure, and via adoption of improved varieties and agronomic practices that can increase TFP.

Figure 5.9 | Share of net cropped area, by district, irrigated by (a) any source, (b) wells, and (c) canals, 3-year average, 2013–15



Note: Maharashtra data is from the Ministry of Agriculture District Contingency Plans, which report irrigation data from 2005 to 2010, depending on the district. No more recent data is available from Maharashtra.

Data source: Government of India. Accessed through the ICRISAT–TCI District Level Database, 2015 district boundaries.

⁶¹ Balwinder-Singh et al. (2019) ⁶³ Devkota et al. (2019) ⁶⁵ Chhabra, Manjunath, and Panigrahy (2010)
⁶² Park, Davis, and McDonald (2018) ⁶⁴ Jat et al. (2019)

nitrogen is applied at far greater rates than phosphorus, potash, and micronutrients. Studies have shown that balanced application of nutrients and the addition of micronutrients, particularly zinc, has vast potential to increase yields in rice–wheat systems.⁶⁶

Another area for increasing TFP in the western IGP is through more efficient water use. Irrigation in the western region has been developed to such an extent that groundwater is now starting to run out. Almost all of the districts in Punjab and Haryana and several of the districts in western Uttar Pradesh are already in the overexploited stage of groundwater development, according to the Central Groundwater Board (Figure 5.11).⁶⁷ By adopting methods such as drip irrigation and conservation tillage, farmers can both slow the depletion of groundwater and reduce the cost of irrigation. Switching to less water-intensive crops will also be necessary to address the state of severe groundwater depletion. Similarly, by adopting methods

like precision agriculture (i.e., applying the right amounts of fertilizer at the right times and in the right proportions), farmers can reduce the pollution caused by indiscriminate fertilizer use and reduce the cost of cultivation.⁶⁸

5.2.3 Diversification

Diversification in both the eastern and western IGP has decreased since the 1960s, as the Green Revolution’s focus on wheat and rice pushed out production of more diverse and nutritious grains, such as coarse cereals and pulses. Now, as demand for diverse food is rising, there is an opportunity for farmers to diversify production and take advantage of this demand. Indeed, Uttar Pradesh and Bihar are already beginning to rise to the increased demand for diversity. The dairy sector has seen impressive growth in both these states in recent years, but the gains have been due to increased production, and productivity has remained low.⁶⁹ Increasing productivity of dairy cattle, as well as expanding milk processing, can go a long way

toward increasing farmers’ incomes in these states.⁷⁰ In addition to the dairy industry, fruit and vegetable cultivation is another avenue for diversification. Uttar Pradesh and Bihar are the second and third largest producers of potatoes, and the potato yields are comparable to the all-India average. Yields of okra, brinjal, onions, and tomatoes are even higher in Bihar than the national average, indicating an opportunity for further diversification into these crops. In addition to meeting a rising demand, diversification out of rice can also contribute to reducing agricultural burning, which is causing severe air pollution in northern India.

Hybrid maize has seen particular success in Bihar, where adoption of hybrid varieties has long since reached 100 percent,⁷¹ and yields in certain districts have increased exponentially in the last decade. Maize yields in Purnea, Araria, and Katihar districts have been especially high in recent years: in Purnea and Araria, yields in 2018 were 9,188 and 7,397 kg/ha, respectively, thrice and twice 2008 values.⁷² In Katihar, yields reached 10,366 kg/ha in 2016, though they fell to 6,927 kg/ha in 2018. These yields are far above the state average of 4,771 kg/ha. Bihar has a special advantage with respect to maize production: it produces maize in the rabi season, when most states are not producing it. This means that maize from Bihar fills a demand from processing units during this time—a demand that originates largely from the growing poultry industry.

Diversification will also be important in the western IGP. In 2013–14, the government began a Crop Diversification Program in the Green Revolution states to move away from water-intensive crops and toward pulses, oilseeds, maize, and agroforestry.⁷³ So far, however, the strategy to shift area out of rice and wheat has not been working, due to the strong disincentive to diversify, arising from the procurement system for rice and wheat. To address this problem, these states must do more to support diversification by investing in infrastructure for processing, cold storage, and marketing. Other mechanisms to incentivize diversification must also be explored.

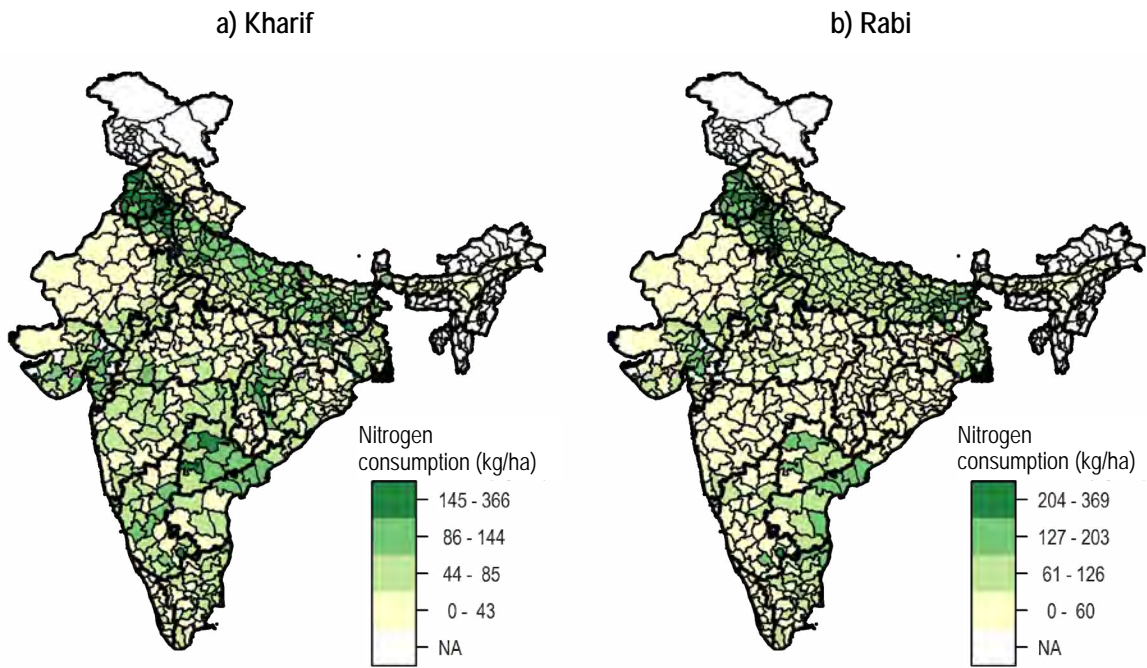
5.3 Rice-based Systems

Outside of rice–wheat systems, other rice-based systems include rice–fallow, rice–rice, and rice–other (Figure 5.3). In the rice–other systems, the rabi crops can be pulses, oilseeds, coarse cereals, or maize. Rice–fallow rotations are found mainly in Chhattisgarh, Odisha, and Jharkhand, where

Hybrid maize has seen particular success in Bihar, where adoption of hybrid varieties has long since reached 100 percent, and yields in certain districts have increased exponentially in the last decade.

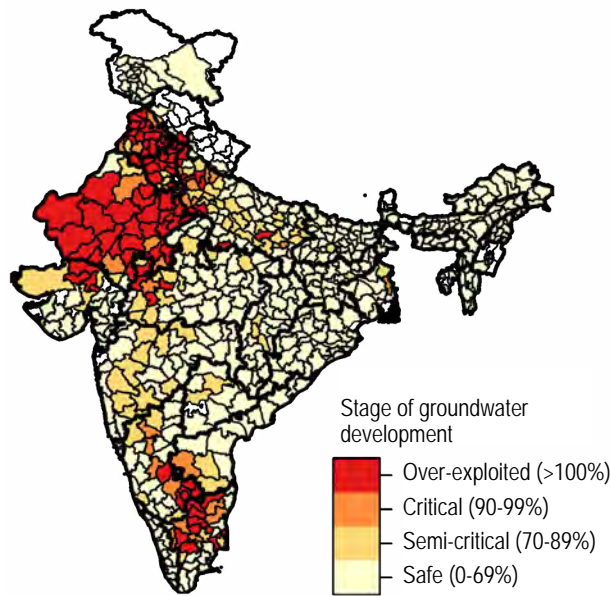
yields are among the lowest in the country (Figure 5.12). Rice–rice rotations are found mainly in West Bengal, parts of Assam, and parts of Andhra Pradesh. A second crop of rice is possible in these regions because of the adoption of short-duration, high-yielding varieties, and therefore, yields are also higher in these systems. In Tamil Nadu, most rice-growing districts cultivate mainly pulses in the rabi season. Cropping intensity in the rice–rice system varies and is highest in eastern West Bengal, East Godavari district of Andhra Pradesh, and Barpeta and Morigaon districts of Assam (Figure 5.4).

Figure 5.10 | Nitrogen consumption, by district, in (a) Kharif and (b) Rabi seasons, 3-year average, 2013–15



Data source: Government of India. Accessed through the ICRISAT–TCI District Level Database, 1970 district boundaries.

Figure 5.11 | Stage of groundwater development by district, 2013



Note: Stage of groundwater development refers to the ratio of annual groundwater draft to net annual groundwater availability.

Data source: Government of India. Accessed through the ICRISAT–TCI District Level Database, 1970 district boundaries.

⁶⁶ Panwar et al. (2018). ⁶⁸ Sapkota et al. (2014) ⁶⁷ CGWB (2017) ⁶⁹ Hoda, Rajkhowa, and Gulati (2017); Verma, Gulati, and Hussain (2017)

⁷⁰ Hoda, Rajkhowa, and Gulati (2017); Verma, Gulati, and Hussain (2017) ⁷¹ FICCI (2018) ⁷² Department of Agriculture, Government of Bihar ⁷³ Government of India (2016)



Flooded rice field in Kandhamal district, Odisha.
Photo by Maureen Valentine.

5.3.1 Current yields and regional variation

Rice yields are highest in systems where cropping intensity is highest. In West Bengal, yields are between 2.5 and 3.6 tons/ha (Figure 5.12). In parts of Andhra Pradesh and most of Tamil Nadu, rice yields are comparable to yields in Punjab—above 3.7 tons/ha. In the rice–fallow systems of eastern India, rice yields lag far behind the rest of India. The average rice yields of most districts in Odisha, Chhattisgarh, Jharkhand, and Assam are between 0.2 and 2.4 tons/ha.

In West Bengal, Andhra Pradesh, and Tamil Nadu, rice yields are high due to broad adoption of HYVs, enabled by well-developed irrigation facilities. The lower rice yields in West Bengal, compared to Andhra Pradesh and Tamil Nadu, could be due to environmental factors: West Bengal, among all other states, is most prone to flooding, and the rice crops are severely affected by blights.⁷⁴ In Chhattisgarh, Odisha, and Jharkhand, low yields can be explained by a variety of factors, including severe weather anomalies—mainly drought, but also some flooding in parts of Odisha;⁷⁵ lack of irrigation infrastructure; low input use; adverse soil conditions; and low adoption of high-yielding varieties. As in Uttar Pradesh and Bihar, even in areas where tube well infrastructure has been developed, it is often not accessible due to the lack of electricity and the high cost of diesel. Though investments in electricity and irrigation in this region have increased in recent years, there is still work to be done. Due to the lower

In Chhattisgarh, Odisha, and Jharkhand, low yields can be explained by a variety of factors, including severe weather anomalies—mainly drought, but also some flooding in parts of Odisha; lack of irrigation infrastructure; low input use; adverse soil conditions; and low adoption of high-yielding varieties.

⁷⁴ Kannan, Paliwal, and Sparks (2017)
⁷⁵ Kannan, Paliwal, and Sparks (2017)

intensity of irrigation in this region (Figure 5.9), it is more susceptible to drought during the dry season. Lack of irrigation infrastructure also makes fertilization more difficult, and together, these factors limit the adoption of HYVs, and thus, limit yields.

5.3.2 Increasing yields and total factor productivity

In the low-yielding regions of eastern India, there is still vast room for improvement in rice yields. To increase productivity of rice, the Indian government’s Ministry of Agriculture and Farmers’ Welfare suggests promotion of HYVs, including basmati and aromatic non-basmati varieties for export; promotion of varieties tolerant to salt, stress, and climate pressures, and varieties suited to specific areas, from deep water to uplands; direct seeded rice (DSR); promotion of farm implements such as the drum seeder to increase efficiency; promotion of balanced nutrient fertilization based on soil tests; and adoption of plant protection measures, such as integrated pest management (IPM) and ensuring the use of the latest generation agrochemicals to avoid residual effects.⁷⁶

Adoption of drought-tolerant varieties will be an important method in eastern India, both for increasing yields and for increasing TFP. One drought-tolerant variety that has been developed and promoted in eastern India is called Sahbhagi Dhan. In field experiments, Sahbhagi Dhan has been found to exhibit higher yields in irrigated, moderate drought, and severe reproductive-stage drought conditions, compared to popular varieties.⁷⁷ The physiological traits that allow this variety to be so successful include higher emergence rates under germination-stage stress; high ratio of lateral roots (horizontal, branched roots that enhance water uptake) to total root length; high harvest index (proportion of grain to above-ground biomass) under drought; and high yield stability across wet seasons.⁷⁸ Seeds had already been distributed to 370,650 farmers in South Asia (mostly in India), as of 2013.⁷⁹ More recently, further research has shown that, although Sahbhagi Dhan yields well under reproductive-stage drought, its performance decreases under vegetative-stage drought.⁸⁰ The same research identified three more varieties that perform well under drought stress in both the reproductive and vegetative stages.

In addition to variety improvement, switching from anaerobic to aerobic cultivation of rice may also hold promise for improving productivity, by increasing TFP in the face of drought. In the East India Plateau, comprising the states of Jharkhand

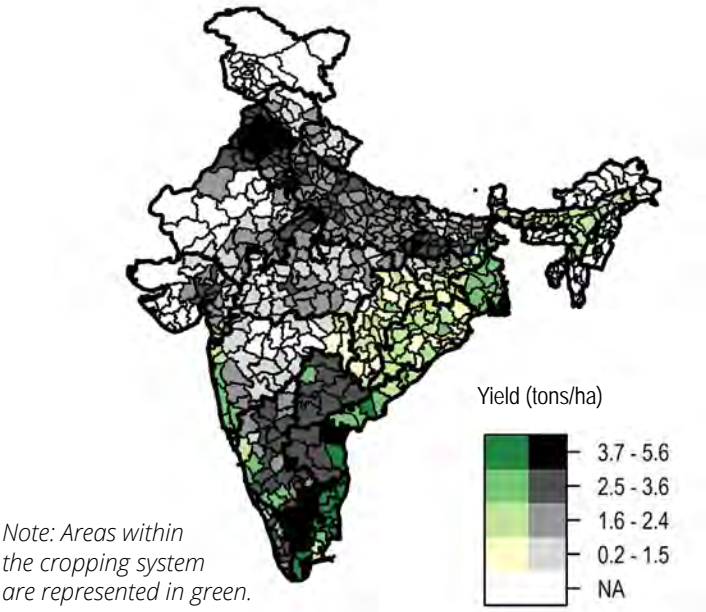
and Chhattisgarh and parts of West Bengal, Bihar, and Odisha, the majority of rice is grown under submerged conditions. One of the main constraints on rice yields in these regions is the length of time that the rice is submerged, which is often not long enough for rice to reach maturity.⁸¹ However, there is typically enough soil water in these areas for non-flooded crops, including aerobic rice, to reach maturity.⁸² Therefore, cultivation of aerobic rice could lead to much higher productivity and less susceptibility to drought.

Switching to aerobic rice cultivation will also be important in Tamil Nadu, where groundwater resources are severely depleted (Figure 5.11). In particular, aerobic cultivation with drip irrigation holds promise for increasing TFP in Tamil Nadu. In a field study in Tamil Nadu, drip irrigation improved yields in aerobic rice by 29 percent and increased water savings by 50 percent, compared to conventional aerobic rice cultivation with surface irrigation.⁸³ Though the study did not measure the water use savings compared to the traditional submerged rice cultivation, the amount of water saved in anaerobic cultivation is no doubt vast.

Given the extreme depletion of Tamil Nadu’s groundwater resources, other measures, in addition to switching to anaerobic cultivation, will be necessary to sustain rice yields. One way to address depletion of groundwater resources could be to increase groundwater recharge, as Gujarat has done by building several medium- and large-sized dams across major rivers connected by canal irrigation, and numerous small dams (also called “check dams”) across small, medium, and large rivers.⁸⁴ These check dams in Gujarat are connected to lift irrigation systems, which provide irrigation to farms that were previously out of reach of canal irrigation. Building dams could help Tamil Nadu to save some of the 71 percent of water that runs off without being used during heavy monsoon rains.⁸⁵

Adoption of drought-tolerant varieties will be an important method in eastern India, both for increasing yields and for increasing TFP.

Figure 5.12 | Rice yields, by district, in the rice-dominant cropping systems, 3-year average, 2013–15



Data source: Government of India. Accessed through the ICRISAT–TCI District Level Database, 2015 district boundaries. Government of India. Accessed through the ICRISAT–TCI District Level Database, 2015 district boundaries.

⁷⁶ Department of Agriculture (2018)
⁷⁷ Raman et al. (2012)
⁷⁸ Anantha et al. (2016)

⁷⁹ Dar et al. (2014)
⁸⁰ Swain et al. (2017)
⁸¹ Cornish et al. (2015)

⁸² Cornish et al. (2015)
⁸³ Parthasarathi et al. (2018)

⁸⁴ Chinnasamy and Agoramoorthy (2015)
⁸⁵ Chinnasamy and Agoramoorthy (2015)

5.3.3 Cropping intensity

Cropping intensity in the rice–fallow regions of eastern India is the lowest in the country. Only 18, 19, and 21 percent of the cultivated areas in Chhattisgarh, Odisha, and Jharkhand, respectively, are cultivated more than once. This is in drastic contrast to Tamil Nadu and West Bengal, where 49 percent and 64 percent, respectively, of the cultivated area is cropped more than once.⁸⁶ There is no question that planting a crop on land that is currently left fallow during the rabi season could drastically increase production and incomes. However, adding a rabi crop is not possible without at least some irrigation. One of the biggest limitations to irrigation in eastern India is lack of power. A potential solution is solar irrigation pumps. Minor irrigation provided by such pumps would allow for cultivation of crops like pulses and oilseeds.

Diversification to crops with lower water requirements, like pulses and oilseeds, will be an important pathway for increasing agricultural incomes in all rice-growing regions.

5.3.4 Diversification

Diversification to crops with lower water requirements, like pulses and oilseeds, will be an important pathway for increasing agricultural incomes in all rice-growing regions. In the low-yielding regions where irrigation is lagging, increasing production of these crops during the rabi season will provide a way to increase cropping intensity with minimal development of groundwater. In West Bengal, diversification toward these crops can increase incomes because of the higher value, relative to the boro rice traditionally grown in the dry season in that state. Diversification toward pulses and oilseeds in West Bengal is also important for the future sustainability of production in the state; the boro rice that was once a boon to yields has been linked to unsustainable depletion of groundwater, arsenic contamination in groundwater, and the development of a semi-permeable drainage barrier.⁸⁷ Although the stage of groundwater development in most of West Bengal is still considered safe (Figure 5.11), according to the Central Groundwater Board, Murshidabad and Nadia use 87 percent and 92 percent of the total available groundwater, respectively, putting them in the semi-critical and critical stages of development, respectively. West Bengal has already undergone

⁸⁶ Calculated based on district-level, season-wise crop area data accessed through the ICRISAT–TCI District Level Database (ICRISAT and TCI 2019).
⁸⁷ Ray and Ghosh (2007)

diversification toward oilseeds (mainly mustard), potato, and vegetables and fruits,⁸⁸ but to ensure future sustainability, the state will have to stay away from the more water-intensive crops, like potatoes, and focus on oilseeds and pulses.

5.4 Cotton and Oilseed Systems

Cotton and oilseed production dominate cropping systems from Telangana to Gujarat and up into western Madhya Pradesh (Figure 5.3). While Telangana produces mainly cotton and Madhya Pradesh produces mainly oilseeds, both of these crops are grown in Gujarat and Maharashtra. Cotton production in India grew exponentially after the introduction, in 2002, of Bt cotton, which carries an insecticidal trait that kills bollworms. As of 2017, 92 percent of the total cotton area in India was planted with Bt cotton.⁸⁹ The genetically modified Bt cotton successfully reduced bollworms, allowing yields to increase. However, yield increases have varied, depending on location.

Soybean is by far the most prominent oilseed crop in India. Soybean production began a rapid expansion in India after the Indian government, in 1971, launched an aggressive campaign to support the crop’s development.⁹⁰ The motivation for the campaign was to offset the international trade imbalance in edible oils, which was widening due to increasing demand. As part of the campaign, the Indian government worked with research institutes, private producers, and the National Seed Corporation to ensure the supply of good quality seed. From 1975 to 1985, the All India Coordinated Research Project on Soybean, launched by the Indian Council of Agricultural Research (ICAR), developed 18 centers across the country to improve the technological base for soybean production. These centers worked to develop high-yielding, disease-resistant, and early-maturing varieties of soybean that could fit into rotation with wheat and be used as a companion crop with crops like maize, cotton, and millets. These new varieties saw substantial success, especially in Madhya Pradesh, where millions of hectares of land were left fallow in the kharif season under traditional cropping systems and could easily transition to soybean production.⁹¹ Soybean also became preferable to other kharif crops, like maize, sorghum, and pulses, due to its higher drought tolerance and higher net returns. Other factors leading to the rise of soybean production include improved irrigation, input subsidies, and training on best practices provided through extension.

⁸⁸ Maji et al. (2015)
⁸⁹ ISAAA (2018)
⁹⁰ Bisaliah (1986)
⁹¹ Bisaliah (1986)

5.4.1 Current yields and regional variation

Cotton yields, in the cotton-dominant districts of Telangana, Maharashtra, and Gujarat, range mostly from 0.1 to 0.6 tons/ha (Figure 5.13). They are lowest in Maharashtra, mostly below 0.3 tons/ha. Cotton yields in western Gujarat are higher, ranging from 0.7 to 1.1 tons/ha. Among districts where oilseeds are dominant, oilseed yields are highest in Gujarat, ranging mostly from 1.0 to 2.1 tons/ha (Figure 5.14). In Maharashtra and Madhya Pradesh, oilseed yields are mostly below 0.9 tons/ha.

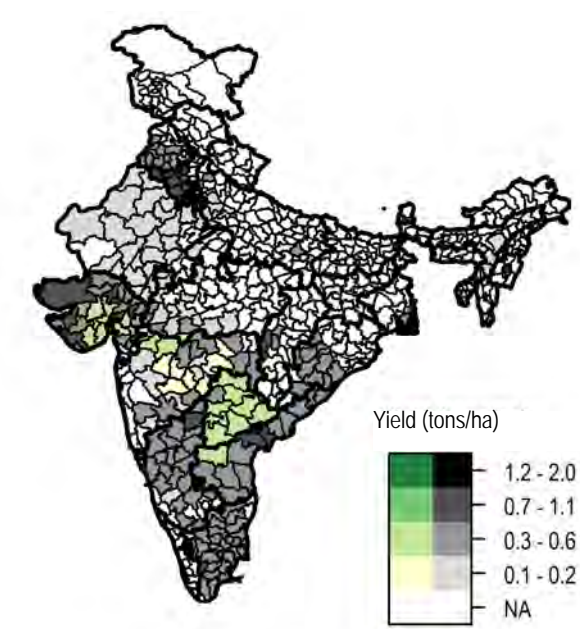
For both cotton and oilseeds, yields are highest in Gujarat. Factors explaining higher yields in this state may include the state’s emphasis on market orientation and its development of irrigation.⁹² Not only has Gujarat built large- and medium-sized dams across major rivers, but it has also given equal importance to check dams, as discussed previously. A plethora of check dams have provided irrigation to farms not covered by the canal system and increased groundwater recharge in rural villages. Check dams are connected to lift irrigation, which is supported by the abundant electricity in the state, generated by hydroelectric dams.

5.4.2 Increasing yields and total factor productivity

Strategies to improve soybean productivity must address challenges, such as erratic rainfall, high temperatures, timely availability of quality inputs, limited mechanization, and poor adoption of technology. The most obvious solution is to increase irrigation. In a simulation study of potential yields and yield gaps in 21 major soybean regions in India, the average yield potential of irrigated soybean was 3,020 kg/ha (3.02 tons/ha) and that of rainfed soybean was 2,170kg/ha (2.17 tons/ha).⁹³ However, actual yields across all the locations in the study were significantly lower than either of these potential yields, at just 1,000 kg/ha (1 ton/ha). This indicates that adoption of technology could increase yields greatly, both in rainfed and irrigated environments. Technologies that can increase yields include use of recommended pesticides and herbicides, timely sowing, seed treatment with fungicides, line sowing, intercropping, manual weed management, optimum seed rate, balanced use of fertilizers, irrigation management, and integrated pest management.⁹⁴ In addition, there may be scope for genetic improvement to increase soybean’s tolerance to biotic and abiotic stresses. In a discussion of soybean genetic improvement, Agarwal and colleagues suggested that “Further improvement in yield will depend on genetic diversity of parents, plugging the yield loss due to stress and improving the genetic architecture of the plant.”⁹⁵

⁹² Chinnasamy and Agoramoorthy (2015)
⁹³ Bhatia et al. (2008)
⁹⁴ Bhatia et al. (2008)
⁹⁵ Agarwal et al. (2013, 297)

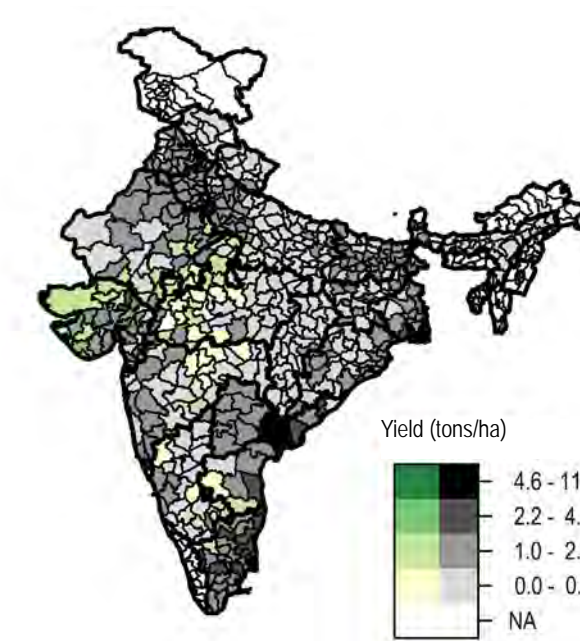
Figure 5.13 | Cotton yields, by district, in the cotton-dominant cropping systems, 3-year average, 2013–15



Note: Areas within the cropping system are represented in green.

Data source: Government of India. Accessed through the ICRISAT–TCI District Level Database, 2015 district boundaries.

Figure 5.14 | Oilseed yields, by district, in the oilseed-dominant cropping systems, 3-year average, 2013–15



Note: Areas within the cropping system are represented in green.

Data source: Government of India. Accessed through the ICRISAT–TCI District Level Database, 2015 district boundaries.

Cotton also has scope for yield improvement, as indicated by the yield gap between Gujarat and Maharashtra. Although irrigation is a major factor in this gap, and continued investment in irrigation is necessary, there are also agronomic practices that can help increase yields. For example, cotton grown with reduced tillage and a legume crop interseeded as a green manure has been found to produce higher yields than cotton grown with conventional tillage with no green manure.⁹⁶ This yield enhancement is likely because reduced tillage and green manure cause improvement in the soil's physical properties, allowing it to retain more moisture.⁹⁷ Addition of phospho-compost or poultry manure, as part of an integrated nutrient management practice, has also been shown to improve cotton yields.⁹⁸ Finally, injection of fertilizer into a drip irrigation system has been shown to improve cotton yields, compared to use of surface irrigation with soil application of fertilizers.⁹⁹ Drip irrigation has also been shown to improve cotton yields by 49 percent over surface irrigation, and increase net returns by 47 percent.¹⁰⁰

5.4.3 Cropping intensity

In addition to focusing on yield improvement, some regions have the potential to increase agricultural incomes by increasing cropping intensity. Although Madhya Pradesh and eastern Gujarat have higher cropping intensities already, mostly because of the wheat crop in the rabi season, Maharashtra and Telangana have potential to increase production during the rabi season.

5.5 Opportunities for Diversification Across Cropping Systems: Pulses and Coarse Cereals

Pulses and coarse cereals both suffered from the single-minded focus on rice and wheat during and after the Green Revolution. The combination of subsidies and HYVs made rice and wheat more profitable in irrigated environments and pushed pulses and coarse cereals out of the Indo-Gangetic plains and northern Green Revolution states (Figures 5.15 and 5.16). Coarse cereals have also been pushed out of the cotton and oilseed belt (Figure 5.16). However, due to the high nutritive quality of pulses and coarse cereals, as well as their resilience to variable climates, these crops have much to contribute in reaching SDG2.

Pulses and coarse cereals both suffered from the single-minded focus on rice and wheat during and after the Green Revolution.

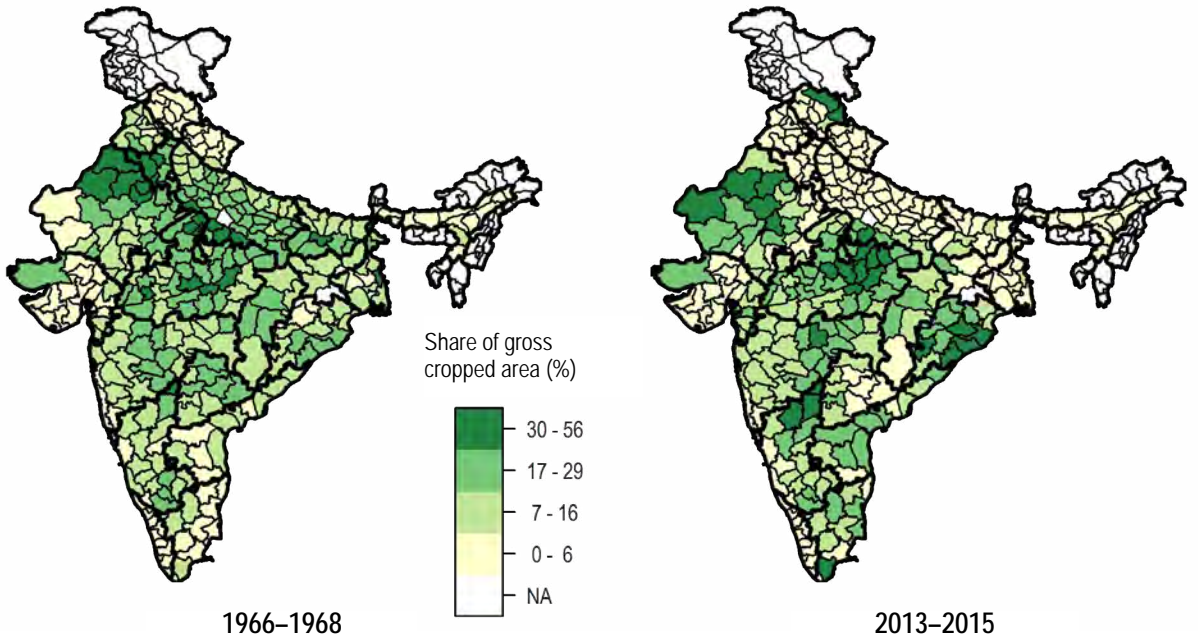
5.5.1 Pulses

There is no question that demand exists to support increasing the production of pulses. Although consumption of pulses per capita is declining, the rising population has caused overall consumption to increase, and domestic production is not keeping pace. From 2000 to 2012, production of pulses in India fell short of demand by 2 to 3 million tons annually.¹⁰¹ In addition, pulses are rich in complex carbohydrates, micronutrients, protein, and B vitamins—all essential nutrients for a healthy diet. Pulses are also low in fat and rich in fiber, which make them excellent for managing cholesterol, digestive health, and regulating energy levels.¹⁰²

There is a real opportunity for smallholder farmers to fill the demand for pulses. Indeed, since being pushed out of the IGP, pulse production has already increased in certain districts of Madhya Pradesh, Karnataka, Andhra Pradesh, Tamil Nadu, and Odisha (Figure 5.15). It has been suggested that pulses are replacing less productive crops in these states.¹⁰³ For example, chickpea is replacing cotton in Karnataka and barley in Madhya Pradesh.¹⁰⁴ Another factor in the increase in pulse production in these states is the spread of new short-duration and wilt-resistant varieties, which have enabled farmers to add pulses into a rotation.¹⁰⁵ Most of the regions with a high share of cropped area under pulses also have high cropping intensity, indicating that pulses are often grown in rotation with other crops. The new improved varieties of pulses are also more tolerant to heat stress, and therefore, have worked well in central and southern India.

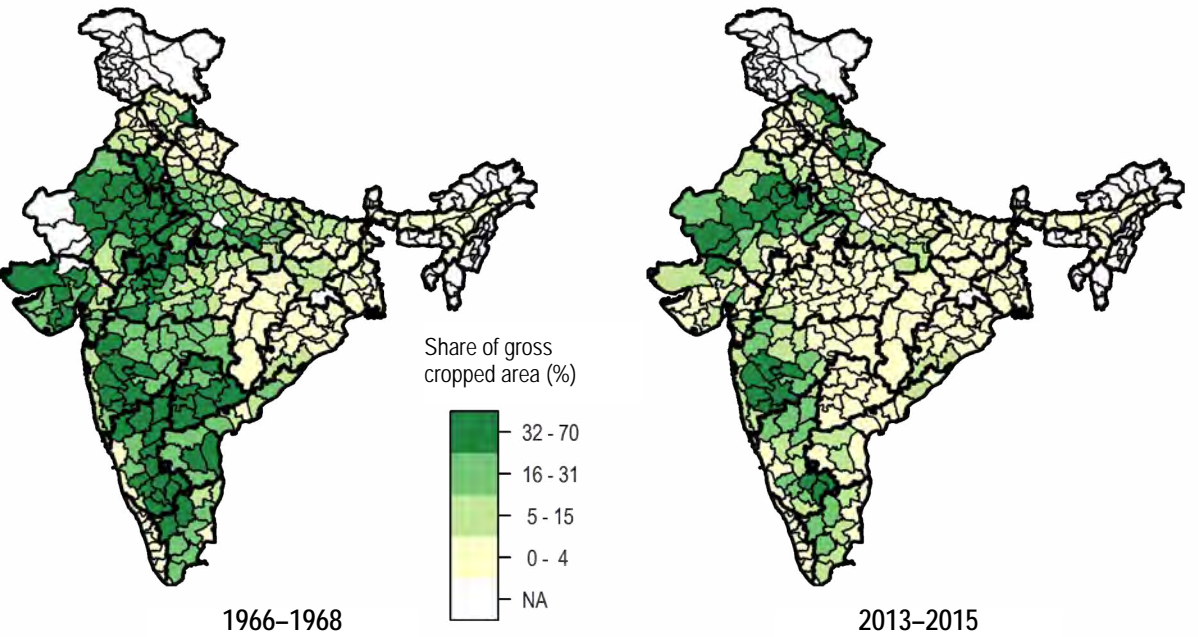
Significant opportunities for continued expansion of pulse production exist in states like Odisha, where large tracts of land lay fallow after the rice crop is harvested. Studies have shown that, if even just 10 percent of the 6–8 million hectares of rice-fallow land was converted for pulse production each year, there could be an additional 1 million hectares of land producing pulses within 5 years.¹⁰⁶ However, several steps are necessary to enable adoption of pulses by smallholders in these areas. First, the government must implement an efficient crop insurance scheme to minimize risks to farmers. Second, avenues such as establishing FPOs must be pursued to connect farmers to markets, so that farmers are assured they have a place to sell their crop (see Box 6.2). Developing storage facilities will also be essential for linking farmers to markets. Third, efforts must be made to encourage farmers' adoption of these crops. This includes developing short-duration varieties that will fit into rotation with other crops. Finally, the government must invest in research and development to increase yields of these crops.

Figure 5.15 | Share of gross cropped area under pulses by district, 3-year averages, 1966–68 and 2013–15



Data source: Government of India. Accessed through the ICRISAT-TCI District Level Database, 1970 district boundaries.

Figure 5.16 | Share of gross cropped area under coarse cereals by district, 3-year averages, 1966–68 and 2013–15



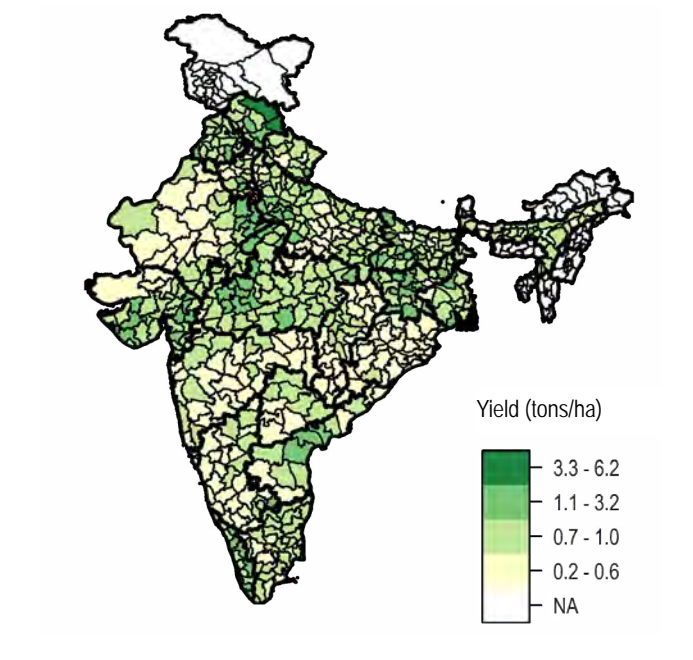
Data source: Government of India. Accessed through the ICRISAT-TCI District Level Database, 1970 district boundaries.

⁹⁶ Blaise (2011)
⁹⁷ Blaise (2011)
⁹⁸ Reddy et al. (2017)
⁹⁹ Jayakumar, Surendran, and Manickasundaram (2015)
¹⁰⁰ Kalhapure et al. (2019)
¹⁰¹ Chandra et al. (2017)
¹⁰² FAO (2016)
¹⁰³ Roy, Joshi, and Chandra (2017)
¹⁰⁴ Roy, Joshi, and Chandra (2017)
¹⁰⁵ Kumar and Raju (2018)
¹⁰⁶ Kumar and Raju (2018)

Although certain districts have achieved relatively higher pulse yields, pulse yields are still exceedingly low in many of the districts where they occupy a relatively greater share of cropped area—notably in Odisha, Karnataka, and Maharashtra (Figure 5.17). Overall, the average pulse yield in India is only 0.76 tons/ha, compared to 2 tons/ha in China.¹⁰⁷ Pulse yields have lagged behind largely because of poor availability of quality seeds—a result of agricultural investments being directed mainly toward rice and wheat. For example, the amount of certified pulse seeds prepared by the Seeds Division of the Department of Agriculture and Cooperation was enough to cover only about 32 percent of the area under pulse production in the triennium ending in 2012–13.¹⁰⁸ The actual quantity of certified pulse seeds delivered in 2010–11 was only enough to cover 25 percent of the area under pulses.¹⁰⁹ Lack of quality seeds is especially problematic on marginal, unirrigated lands where pulses are mostly grown. To increase yields, the government must strengthen the delivery of quality seeds and also provide training on best practices. Customizing farm equipment for small-holders and developing pest- and disease-resistant cultivars can also help to improve pulse yields.

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Figure 5.17 | Pulse yields by district, 3-year average, 2013–15



Data source: Government of India. Accessed through the ICRISAT–TCI District Level Database, 2015 district boundaries.

5.5.2 Coarse cereals

Similar to pulses, coarse cereals present an important opportunity to reduce consumption of irrigation water, increase adaptability to climate change, and increase nutrient supply in Indian diets. Pearl millet, for example, is adaptable to drought and high temperatures, tolerant of saline and acid soils, adapted to marginal lands, and has fewer pest problems, compared to other cereals.¹¹⁰ It also has high nutritional value: pearl millet is high in energy, dietary fiber, and proteins, with a balanced amino acid profile. It also has many essential minerals, some vitamins, and antioxidants.¹¹¹ One modeling study found that, if the rice area in each district was replaced by the alternative coarse cereal (maize, finger millet, pearl millet, or sorghum) with the lowest water requirement, demand for irrigation water would decrease by 33 percent; production of protein, iron, and zinc would increase by 1, 27, and 13 percent, respectively; and production of calories would decrease by only 5 percent.¹¹²

Unlike pulses, there is no region where coarse cereal cultivation has experienced any notable increase in area since the Green Revolution era (Figure 5.16). However, there has been a national movement to promote millets, due to their nutritional value as well as their hardy characteristics, which make them well adapted to harsh environments without irrigation. This latter characteristic is especially important as India faces the challenges of climate change, including rising temperatures and more frequent droughts. It was for these reasons that the Indian Government made 2018 the National Year of Millets, with the hope of boosting millet production. Karnataka has been especially active in promoting millets; since 2017, the state’s department of agriculture has been organizing an annual Organics & Millets International Trade Fair, which aims to spread awareness about the health benefits of millets. The government of Karnataka has also collaborated with a food delivery start-up in Bengaluru to start a millet-based menu.¹¹³

In order to increase production and productivity of coarse cereals, it will be necessary to both induce demand and encourage supply. Part of the reason for the decrease in consumption of millets over the last few decades is the lack of processing facilities at the farm level and the resulting laborious nature of cooking millets.¹¹⁴ Therefore, one avenue for increasing demand is to focus on value addition. ICAR–Indian Institute of Millets Research (IIMR) is leading the way in this regard, having developed and commercialized a variety of value-added millet products.¹¹⁵ Raising awareness

about the nutritional benefits of coarse cereals, eliminating social stigma attached to coarse cereals, and including millets in PDS and/or MDMS can also increase demand. The Indian government’s inclusion of pearl millet under the National Food Security Mission, PDS, and Rashtriya Krishi Vikas Yojana to promote millets as “Nutri-cereals” is a step in the right direction; so, too, is the Initiative for Nutrition Security through Intensive Millets Production, launched in 2011, which promotes processing and value addition technologies to generate demand for millets.¹¹⁶ While these pathways to increasing demand are certainly important, there is evidence that the majority of future growth in demand for coarse cereals like pearl millet will come from the feed industry (specifically, poultry and cattle), breweries, and the starch industry.¹¹⁷

On the supply side, it will be important to increase awareness among farmers of the suitability of millets to dryland agriculture and their adaptability to climate change. In addition, development and distribution of HYVs, technical assistance, buyback arrangements, and insurance schemes will be key to increasing productivity and limiting risk for farmers, thereby encouraging more farmers to take up production of these crops. FPOs can also help by allowing small-holder farmers to be able to collectively supply industries with the large quantities they require.

Increasing production of coarse cereals in India will also require increasing yields. The average yield of the three major coarse cereals in India excluding maize (barley, millet, and sorghum) is 1.7 tons/ha. This is extremely low, as is evident when compared to China, where the average yield of these same three crops is 3.7 tons/ha.¹¹⁸ Furthermore, the yields in most of India are below 1.7, and in most of Rajasthan, Maharashtra, Telangana, Chhattisgarh, and Odisha, the yields are below 1.0 tons/ha (Figure 5.18). The average is only brought up by districts in Punjab, as well as a few districts in Andhra Pradesh and Tamil Nadu, where yields are between 2.8 and 5.9 tons/ha.

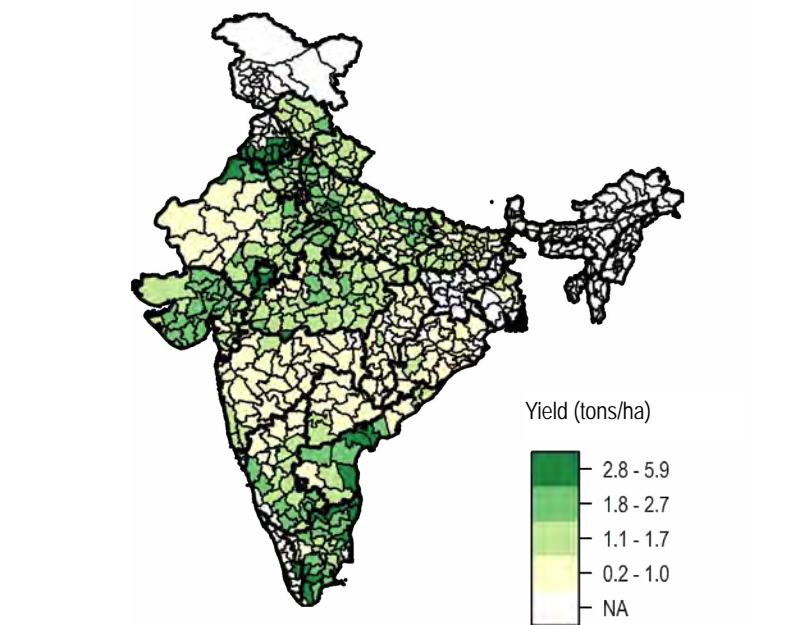
Low yields of coarse cereals are largely a result of the fact that they are grown mainly on marginal lands, with little or no irrigation (Figure 5.9). Lack of access to water has made it difficult or impossible for farmers to adopt HYVs of other crops, leading to the continued domination of coarse cereals in these regions. At the same time, yields of coarse cereals have remained low because of this lack of irrigation. Development of at least minimal irrigation will be necessary to improve the yields of these crops.



Man sells masoor dal (red lentils) at a market in Munger district, Bihar. Photo by Mathew Abraham.

In order to increase production and productivity of coarse cereals, it will be necessary to both induce demand and encourage supply.

Figure 5.18 | Coarse cereal yields by district, 3-year average, 2013–15



Data source: Government of India. Accessed through the ICRISAT–TCI District Level Database, 2015 district boundaries.

¹⁰⁷ FAOSTAT (2020)
¹⁰⁸ Singh (2014)
¹⁰⁹ Singh (2014)
¹¹⁰ Jukanti et al. (2016)
¹¹¹ Jukanti et al. (2016)
¹¹² Jukanti et al. (2016)
¹¹³ Jukanti et al. (2016)
¹¹⁴ Rao et al. (2017)
¹¹⁵ Rao et al. (2017)
¹¹⁶ Reddy et al. (2018)
¹¹⁷ Reddy et al. (2018)
¹¹⁸ FAOSTAT (2020)



Woman laughing in Maharajganj district, Uttar Pradesh.
Photo by Jonathan Miller.

6

Doubling Incomes: Market Integration

In order to translate increased productivity and diversification into increased income, smallholders must be integrated into markets. Improved market infrastructure can increase farmers' income by decreasing transactions costs and enabling greater price realization. For small and marginal farmers, transaction costs are typically very high, due to low economies of scale, low bargaining power, poor connectivity to markets, and lack of information about prices and quality standards.¹¹⁹ Often, there are several intermediaries between the farmer and the retailer, leading to lower prices for farmers' produce.

Traditionally, farmers across India sell their produce at Agricultural Produce Market Committees (APMC) markets, called *mandis*, where the small number of licensed traders and commission agents often results in collusion and less than optimum prices for farmers' produce.¹²⁰ In recent years, a number of initiatives have been undertaken by the government to reform APMCs. Market reforms implemented in Karnataka have been successful in improving prices received by farmers.¹²¹ Karnataka has implemented an innovative method to expand competitiveness by facilitating trading between *mandis*. The state government partnered with the National Commodity and Derivatives Exchange (NCDEX) Spot Exchange to create Rashtriya e-Market Services (ReMS), a company that offers an e-trading platform and provides

facilities for grading and standardization.¹²² ReMS works under the umbrella of the Unified Market Platform (UMP), also implemented by NCDEX, which aims to unify all *mandis* in the state for single trading. Under the UMP, a farmer's lot of produce is given an identification number and assayed so that information about the quantity and quality of the lot can be posted on the ReMS portal.¹²³ Buyers or traders who have a unified market license and are registered with ReMS are then able to bid on the farmer's produce online, from any location. Traders from other states and bulk institutional buyers are also registered with ReMS. This broadens the pool of buyers considerably, effectively eliminating the possibility of collusion to suppress prices. It also enables farmers to directly sell their produce online, removing middlemen.

¹¹⁹ Pingali et al. (2019)

¹²⁰ Reddy (2016)

¹²¹ Bihar, on the other hand, did away with the APMC Act in 2006.

¹²² Chand (2016)

¹²³ Chand (2016)

Market reforms implemented in Karnataka have been successful in improving prices received by farmers.

Box 6.1 | GOODS AND SERVICES TAX

Along the different levels of the production value chain for commodities, various indirect taxes are levied in India by the central and state governments. In a bid to streamline the system, the Government of India, on July 1, 2017, introduced a Goods and Services Tax (GST)—a single tax which incorporated the many taxes and levies collected in the production and trade of commodities. Following the global “good practice” framework in taxation, India adopted the GST to ensure a more integrated national market. It also reflects the government’s ambition of “One Nation, One Market,” in the same spirit as e-NAM. GST requires a paper trail whereby, along each node of the supply chain, transactions and value-added are recorded. For a developing country, it broadens the tax base, formalizes the process, and increases compliance.

The new GST has critical implications for the agricultural sector. With the introduction of GST, e-NAM also gets bolstered. Before GST, differential market taxes or levies in interstate transactions led to price distortions in agricultural markets. GST, through subsuming the various entry taxes at the state borders, is expected to reduce transit time and food wastage, thereby contributing to marketing efficiency. However, there are worries that it might escalate the input costs and inhibit farm mechanization. Also, contrary to the global practice, GST eludes the “one tax” aspect of the system with a five-rate structure. For example, processed food products, like fruit juices or jams, are now under a higher tax bracket. Raw agricultural commodities, like grains, milk, fresh fruits, and vegetables, etc., fall under the zero-tax category, since they are consumed by the masses.

Although there has been little research on the impact of GST on agriculture, given its recent implementation, it is an important variable for assessing changes in production and consumption patterns in recent times.

Following Karnataka’s lead, the central government, in 2016, launched an electronic trading platform for the National Agriculture Market (e-NAM), which is expected to be a “pan-India electronic trading portal that networks the existing APMC *mandis* to create a unified national market for agricultural commodities.”¹²⁴ This virtual platform is expected to improve the competitiveness of agricultural markets, by eliminating traders’ cartels to enable greater price realization for farmers.

Still in infancy, e-NAM currently covers around 9% of the existing APMCs, with a greater share of farmers, mainly small and marginal farmers, continuing to rely on village traders and market intermediaries to sell their produce. Preliminary evaluations of this initiative highlight its potential but suggest that improving market access requires more than a technological fix. Institutional constraints, as in the case of APMCs, continue to plague e-NAM, too. Karnataka’s experience suggests that marketing reforms need be supported through legal and institutional means.¹²⁵ One institutional change that will help to support e-NAM is the goods and services tax (GST), introduced in July 2017 (see Box 6.1). However, more clarity is still needed on how the central government and state governments will handle disbursement of funds and disputes around trading restrictions. Similarly, there has to be greater incentive for farmers to participate in the platform, through better infrastructural and informational facilities. Finally, the role of commission agents (the middlemen that these new structures are striving to eliminate) must still be considered. Ignoring them could be potentially dangerous, as they often provide agricultural inputs, information, and loans to farmers in the absence of state-provided functions. Market integration of the sort envisioned through e-NAM, therefore, not only calls for “... greater institutional capacity, public investment, regulatory innovation, and context-specific implementation [but] ... also requires much greater acknowledgment of and preparation for both the gains and losses from integration and their consequences for the millions of lives, livelihoods and economic and social transitions involved in the process.”¹²⁶

Apart from these government-initiated marketing reforms, newer forms of vertical coordination (VC) between the buyers and sellers, by which retailers bypass these intermediaries and form direct linkages with farms, can address many of these problems, too. One form of VC is contract

farming, in which a contract that specifies time of delivery, quantity, quality, and variety is agreed to in advance by both the farmer and the retailer or wholesaler. Although vertical coordination has the potential to help small farms, it also introduces new costs associated with setting up and managing contracts. These costs can be reduced by aggregation models, such as FPOs, by which farmers organize themselves in groups to jointly access markets (Box 6.2). FPOs can also help farmers to access factor markets, such as credit, inputs, and technology; lower contracting and operating costs; reduce fixed costs of quality determination; reduce transportation costs; and enable better linkages to financial services.¹²⁷

Apart from these government-initiated marketing reforms, newer forms of vertical coordination (VC) between the buyers and sellers, by which retailers bypass these intermediaries and form direct linkages with farms, can address many of these problems, too.

Box 6.2 | FARMER PRODUCER ORGANIZATIONS

The relevance of farmer producer organizations (FPOs) in India comes from the fact that the average size of a farm in the country is 1.12 hectares, which is among the smallest in the world. Small farms have an inherent disadvantage in accessing markets, credit, management inputs, and technology due to low economies of scale. Despite increasing demand for diversified, high-value agricultural products due to urbanization, population increase, and income growth, small farms have not leveraged these income-growth opportunities. Through aggregation under FPOs, smallholders can benefit from scale economies, rather than expansion of land ownership, by way of joint access credit, inputs, technology, and markets.

In the past two decades, there has been renewed interest in the promotion of FPOs by philanthropic actors, donors, corporations, and governments for agricultural development and poverty reduction. India continues to promote FPOs in a big way, but despite increased focus and avenues of support, FPO success stories are few. The extended gestation period required for FPOs to become self-sustaining and low financing opportunities for them are significant factors. Other challenges, such as weak linkages to markets, high coordination costs, high government interference, inadequate managerial expertise, low levels of trust among members, and exclusion of women, remain concerns.

TCI is committed to the promotion of FPOs. We see them as essential for agricultural development and food security. Our research agenda is geared toward designing and promoting socially inclusive, economically viable FPOs in India. TCI’s Walmart Foundation-funded project on FPOs will assess the promotion experience by philanthropic actors, government, and private entities in India and Mexico. Learnings from these experiences will allow TCI to formulate operational, context-specific FPO models capable of improving smallholder’s income and welfare. The project also intends to develop action–research projects and operationalize a dissemination platform in India by which stakeholders promoting, initiating, and building FPOs can access information, technical help, and guidance.

¹²⁴ See Government of India, National Agriculture Market: <https://enam.gov.in/web/>
¹²⁵ Aggarwal, Jain, and Narayanan (2017)
¹²⁶ Chatterjee and Krishnamurthy (2020)

¹²⁷ Chatterjee and Krishnamurthy (2020)



Focus group discussion
in Sarobag, Kalahandi
district, Odisha.
Photo by Kiera Crowley.

7

Doubling Incomes: Nonfarm Employment

As we have already discussed, farmers in India earn their livelihoods from a portfolio of activities, and the doubling of farm incomes between 1993–2013 relied on a decline in the share of cultivators across the country. However, among the large share of India's population that lives in rural areas, 64 percent of the workforce is still primarily engaged in agriculture.¹²⁸ At the same time, the share of agriculture in overall GDP has been declining—it contributes only 39 percent of the total rural net domestic product now.¹²⁹ The fact that the share of people dependent on agriculture for their livelihoods vastly exceeds the share of agriculture in total output is a symptom of the slow structural transformation of the country. Facilitating this surplus labor to move out of agriculture remains one of the major challenges for increasing agricultural productivity and farm income.

¹²⁸ Chand (2017)

¹²⁹ Chand (2017)

Facilitating this surplus labor to move out of agriculture remains one of the major challenges for increasing agricultural productivity and farm income.

As can be seen in Figure 7.1, while the share of cultivators in the rural population has declined significantly in many districts since the 1960s, the share of agricultural laborers has increased to a similar extent, indicating that although people are moving away from cultivation, they are staying in the agricultural sector. Until labor begins moving into other sectors, we will not see a dramatic increase in labor productivity in agriculture.

Indeed, diversification to nonfarm sectors is a significant and growing trend in much of the developing world.¹³⁰ Rural households tend to diversify their livelihood activities into nonfarm sectors for a variety of reasons, which can be classified as “pull” and “push” factors. The “pull” factors include more attractive economic opportunities—higher payoffs and lower risk. Regions with well-developed agricultural sectors lend themselves particularly well to diversification, as growth in the agricultural sector can “generate rising demand for nonfarm goods and services and provide raw materials to support processing and trade.”¹³¹ This increased economic activity, in turn, increases demand for labor, leads to higher wage rates, and results in the emergence of high-return nonfarm activities, also encouraging urbanization. The “push” factors include seasonal drop in income from farming; drop in income due to climate factors, such as drought; chronic

insufficiency of farming income, which can result from a multitude of factors, including shrinking size of landholdings due to population pressure and strong variability in farm incomes. Another push factor is credit or insurance market failure; in this case, farmers can use nonfarm activity to self-insure and finance agricultural inputs.

In India, the nonfarm sector grew steadily during the 30 years prior to 2004, and accelerated in the late 1990s and early 2000s.¹³² Of the 56 million new rural jobs created between 1993 and 2004, 6 out of 10 were in the nonfarm sector.¹³³ By 2004, the nonfarm sector employed nearly 30 percent of India’s rural workforce,¹³⁴ which grew to 36 percent by 2011.¹³⁵ Among all rural households (not just the households involved in cultivation), the share of income from nonfarm sources increased from 33 percent in 2004–05 to 41 percent in 2011–12.¹³⁶

Looking to the future, Pingali and colleagues posit that an important area of growth for the nonfarm sector will come from provisioning the cities: “As India grows through a rapid process of urbanization, ... [p]rovisioning the cities is the new growth opportunity for rural areas and could lead to accelerated rural transformation.”¹³⁷ Emerging value chains, they argue, could absorb surplus labor, especially women and youth. Areas for growth in employment will include agribusiness logistics, such as aggregation, storage, and processing, and food-related services, such as restaurants, supermarkets, and food delivery. Small towns and middle spaces are particularly fertile grounds for this type of nonfarm diversification, and an increased focus on such places could help the rural population to share the benefits of urban economic growth.¹³⁸

In India, the nonfarm sector grew steadily during the 30 years prior to 2004, and accelerated in the late 1990s and early 2000s.

¹³⁰ Hagglblade, Hazell, and Reardon (2007)

¹³¹ Hagglblade, Hazell, and Reardon (2007, 126)

¹³² Lanjouw et al. (2011)

¹³³ Lanjouw et al. (2011)

¹³⁴ Lanjouw et al. (2011)

¹³⁵ Chand (2017)

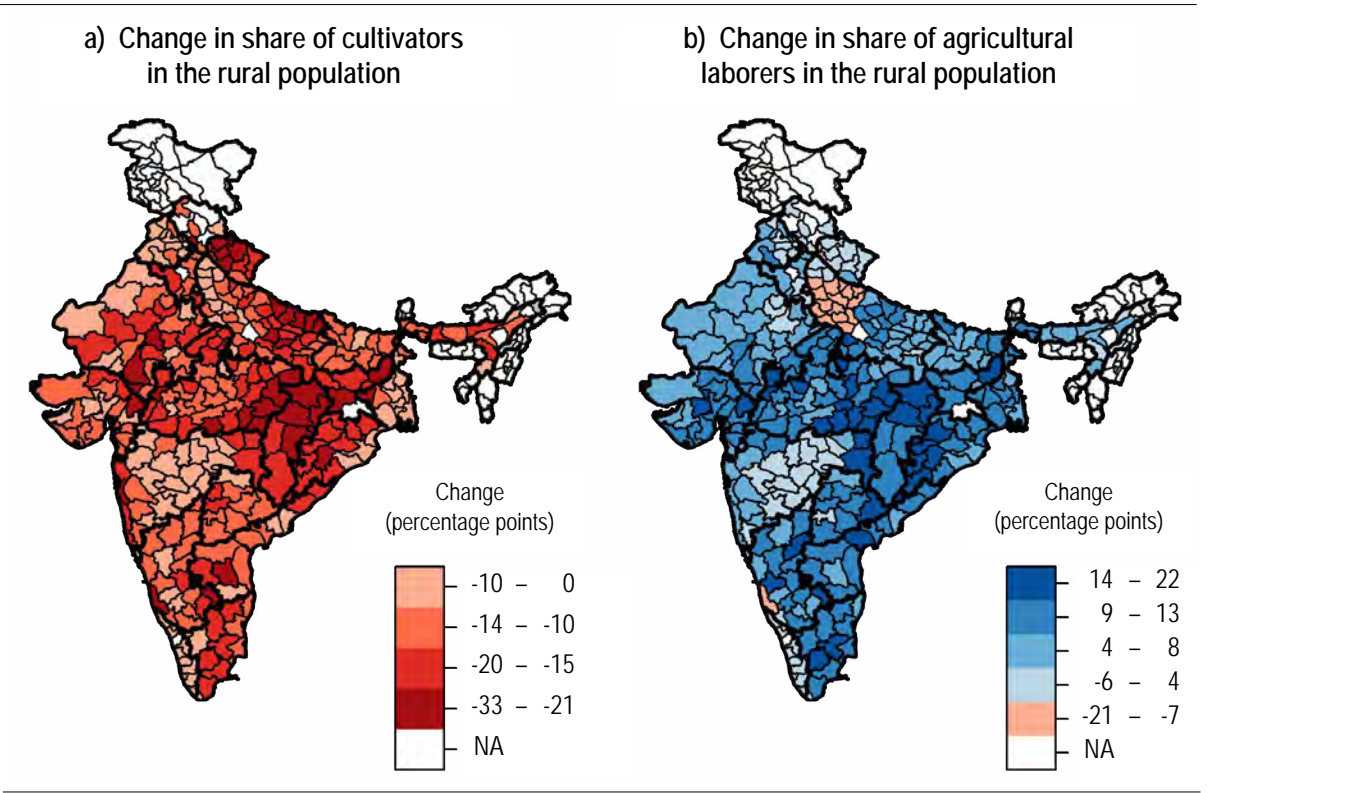
¹³⁶ Desai and Vanneman (2019)

¹³⁷ Pingali et al. (2019, 6)

¹³⁸ Pingali et al. (2019)



Figure 7.1 | Percentage-point change in (a) share of cultivators and (b) share of agricultural laborers in the rural population, by district, 1961–2011



Data source: Population Census 1961 and 2011, 1970 district boundaries.



Woman speaks in focus group discussion in Bournia, Kalahandi district, Odisha. Photo by Kiera Crowley.

8

Conclusions

Invest in agriculture for poverty reduction and improved nutritional outcomes.

Investments in agriculture are essential to kick-start economic structural transformation, which further leads to greater household incomes and improved nutritional outcomes. In India, the extent of investment in agriculture varied greatly between states. Some states, notably in eastern India, lag far behind in agricultural productivity, incomes, and nutrition. Reasons for this low productivity include a variable climate, lack of economic incentives, low adoption of high-yielding varieties, limited irrigation infrastructure, and limited electrical connectivity. Even when irrigation infrastructure is present, its utilization is hindered by lack of electricity. Therefore, continued investment in agriculture is essential to increasing farm productivity and income, especially in the lagging states. In the more advanced states, the role of markets, and innovations in the supply chain, become more important. Similarly, investments in agricultural research and development are essential to the innovation of newer technologies to boost agricultural growth, and thus, agricultural incomes.

Food policy should look beyond staple grains and focus on enhancing the availability and affordability of diverse, nutrient-rich foods.

Increasing income is not enough to eradicate all forms of malnutrition. This is evident in regions where, despite increases in household incomes, consumption of nutritious foods continues to be low, while consumption of cheaper processed food is increasing, and obesity is a rising problem. Undernutrition, in the form of poor micronutrient intake, exists alongside overnutrition. In order to address obesity, as well as undernutrition and micronutrient deficiency, policies must be directed to increasing the availability, affordability, and accessibility of diverse and nutritious foods. Currently, the policy narrative and the production systems, including market infrastructure, credit facilities, input availability, and extension services, are largely focused on staple grains—rice and wheat. The government needs to shift investment in these arenas to focus on nonstaples, such as pulses, coarse cereals, and fruits and vegetables. Doing so will facilitate diversification for smallholder farmers, thereby also offering opportunity for higher and more stable incomes. Investments should particularly target pulses and coarse cereals, as they are more resilient to drought stress and also are excellent sources of nutrition.

Clear delineation of agroecologies and cropping systems will ensure effective targeting of technology and policy interventions.

India has a vast array of cropping systems, which have not been classified well, and each faces different challenges and will require different interventions to increase productivity and incomes. In this report, we classify India’s various cropping systems by their production patterns. In the rice–wheat system of the western IGP, groundwater is being depleted rapidly, and rice–wheat yields do not have much room for improvement. Therefore, we suggest a focus on input–use efficiency, as well as a move toward high-value crops. In the eastern IGP, there is still much potential for gains in rice and wheat yields via improved irrigation infrastructure and electrical connectivity, as well as improvements in agronomic practices and adoption of stress-tolerant varieties. Diversification out of rice and wheat is also an important strategy there, as early success in hybrid maize has demonstrated. In the rice–fallow regions, mainly in Odisha and Chhattisgarh, potential for increasing incomes and productivity lies in utilizing the fallow season to plant pulses or coarse cereals. Crop diversification would also require improvements in public infrastructure, such as electrical connectivity and minor irrigation infrastructure. In the cotton and oilseed systems in the semi-arid zones of central India, yields are still far below potential, so agronomic strategies to increase yields of these crops must be pursued, as well as strategies to increase water use efficiency to ensure future sustainability.

Investments in research and development and evidence-based policy interventions are needed to encourage and support production of foods rich in micronutrients.

Micronutrient deficiencies are persistent regardless of income class in India. Investments in research and development (R&D) are essential for enhancing the supply of micronutrient-rich crops, both through production diversity, as with orange-fleshed sweet potato and other vegetables, as well as through biofortified crops. Iron-fortified pearl millet and zinc-fortified wheat, promoted by HarvestPlus, show great potential for reducing iron and zinc deficiencies. R&D is necessary for identifying new opportunities for biofortification. Investments in rural market infrastructure and promotion of on-farm diversity of production systems can also lead to enhanced supply and accessibility of micronutrient-rich food.

Support smallholder integration into markets to enhance food system diversity and increase farm incomes.

Smallholder farmers typically face very high transaction costs in selling their produce due to low economies of scale, little bargaining power, poor connectivity to markets, and insufficient information about prices and quality standards. This is particularly true for perishable products, such as vegetables, fruits, and livestock products. Rural market infrastructure investments, market reforms, and farmer aggregation models, such as FPOs, are essential to overcoming these barriers to improve farm price realizations. Market reforms can reduce transaction costs by removing the middlemen, and by allowing farmers to connect directly to buyers. Encouraging the growth and development of FPOs can help farmers to gain access to credit, inputs, and technology, as well as lower contracting and operating costs, reduce fixed costs of quality determination, reduce transport costs, and enable better linkages to financial services.

Connecting rural communities to urban food value chains provides new and expanding opportunities for income growth.

Rural–urban connectivity is expected to increase at a faster pace. Urban areas will grow in size, and villages will begin to exhibit more urban characteristics, leading to greater economic activity along the rural–urban continuum. This provides a great opportunity for villages and smaller towns to take advantage of urban demand for diverse food products. Such changes also provide avenues for employment growth in food-based sectors and agribusiness supply-chain logistics, such as aggregation, storage, and processing, in addition to food-related services, such as restaurants, supermarkets, and food delivery. Absorbing surplus labor into these nonfarm sectors will contribute to greater farm labor productivity and higher household incomes through livelihood diversification.

Policies that explicitly promote rural women’s empowerment lead to improved nutrition outcomes for women and their households.

Rural women in India tend to be disempowered and therefore have smaller roles in agricultural and household decision-making. Research has shown that women who are more empowered are less likely to be deficient in micronutrients and more likely to eat a diet containing a range of nutritious non-cereals, like pulses, meat, dairy, and eggs. Therefore, it is essential to promote policies that empower women, such as women’s literacy programs and behavior change programs. Given that women who are involved in agriculture-related self-help groups have been found to be more empowered, policies should support such groups. Findings that women in more market-oriented households are more empowered further suggest that policies to increase market integration will also help to increase women’s empowerment. Finally, labor-saving technologies should also be pursued to free up women’s time for nutrition-related activities.



Children in Maharajganj district, Uttar Pradesh.
Photo by Kathryn Merckel.

Infrastructure investments in improved drinking water supply, sanitation facilities, and hygiene practices lead to better overall health and nutrition outcomes.

Better dietary intake may not have as great an impact on increasing nutritional outcomes as might be expected, if the ability to absorb nutrients is compromised by poor hygiene. Toxins in food and pollutants in water are two of the main threats to hygiene. Therefore, policies to improve hygiene must focus on food safety, sanitation facilities, sanitation practices, and drinking water supply. As TCI research has shown, food safety measures should include promoting the use of airtight grain storage bags, which will reduce the prevalence of mycotoxins in the food system. To reduce open defecation, a major threat to sanitation, policies should focus not only on building toilets, but also on behavior change interventions. Finally, the quality of drinking water must be improved by building infrastructure for more piped water and simple water treatment systems. Households with better quality drinking water have a lowered risk of diarrhea, and thus, better overall nutrition.

Redesign food-based assistance programs to include pulses and coarse cereals.

Distribution of food grains through PDS is an essential part of the agricultural policy and also includes procurement, storage, and transportation. Limiting PDS to rice and wheat, however, creates perverse incentives for the farmers through the pre-announced minimum assured prices. Such policies discourage diversification away from staple food grains, while household dietary preferences suggest a move toward nonstaples. PDS should therefore be redesigned to include more nutritious items, such as pulses and coarse cereals. There have been a few initiatives by state governments, but the PDS basket is still lacking in diversity. The government should set up better market infrastructure to promote production and procurement of nonstaples, thereby supporting food system diversification from farm to plate.

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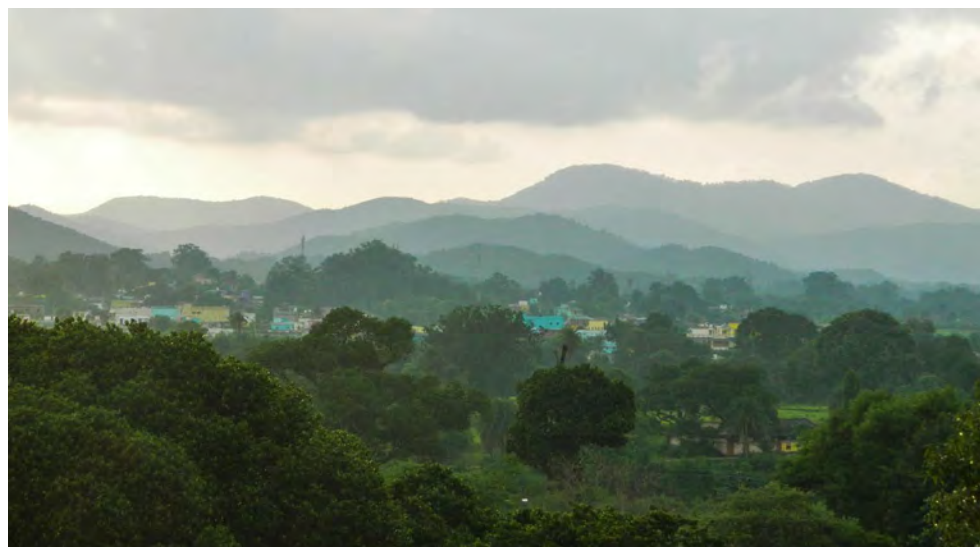
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