Agriculture and malnutrition in India

Ashok Gulati, A. Ganesh-Kumar, Ganga Shreedhar, and T. Nandakumar

Abstract

Background. *Despite the high and relatively stable overall growth of the economy, India's agriculture sector is underperforming and a vast section of the population remains undernourished.*

Objective. *To explore the possible interplay between agricultural performance and malnutrition indicators to see whether states that perform better in agriculture record better nutritional outcomes.*

Methods. *Correlation analysis and a simple linear regression model were used to study the relationship between agricultural performance and malnutrition among children under 5 years of age and adults from 15 to 49 years of age at 20 major states using data from the National Family Health Survey-3 for the year 2005/06 and the national accounts.*

Results. *Indicators of the level of agricultural performance or income have a strong and significant negative relationship with indices of undernutrition among adults and children, a result suggesting that improvement of agricultural productivity can be a powerful tool to reduce undernutrition across the vast majority of the population. In addition to agriculture, access to sanitation facilities and women's literacy were also found to be strong factors affecting malnutrition. Access to healthcare for women and child-care practices, in particular breastfeeding within 1 hour after birth, are other important determinants of malnutrition among adults and children.*

Conclusions. *Malnutrition is a multidimensional problem that requires multisectoral interventions. The findings show that improving agricultural performance can have a positive impact on nutritional outcomes. However, improvements in agriculture alone cannot be effective in combating malnutrition if several other mediating factors are not in place. Interventions to improve education, health, sanitation and household infrastructure, and care and feeding practices are critical. Innovative strategies that integrate agriculture and nutrition programs stand a better chance of combating the malnutrition problem.*

Key words: Agriculture, India, malnutrition

Background

India has been lauded for its remarkable overall economic growth of over 8% in the past 5 years. Even during the global recession, Gross Domestic Product (GDP) still grew by 6.7% in 2008/09 and 7.2% in 2009/10, while economic growth in the developed world declined sharply. But despite this high and relatively stable growth, India's underbelly is soft. The agriculture sector is underperforming, with a growth rate of around 2.8% from 2000/01 to 2008/09, much below the Eleventh Plan and Tenth Plan targets of 4%. Malnutrition indicators have also remained stubbornly high. The Food and Agriculture Organization of the United Nations (FAO) estimates that 22% of India's population is undernourished [1]. Moreover, India's malnutrition problem is of global proportions. UNICEF in 2008 estimated that India was home to 42% of the developing world's children who were underweight (low weight-for-age) and 32% of those who were stunted (low height-for-age) [2].

This raises some questions. Is there no relation between economic and agricultural growth and malnutrition? Can better agricultural performance contribute

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The findings and views expressed in this paper are those of the authors only and should not be ascribed to the organizations with which they are affiliated.

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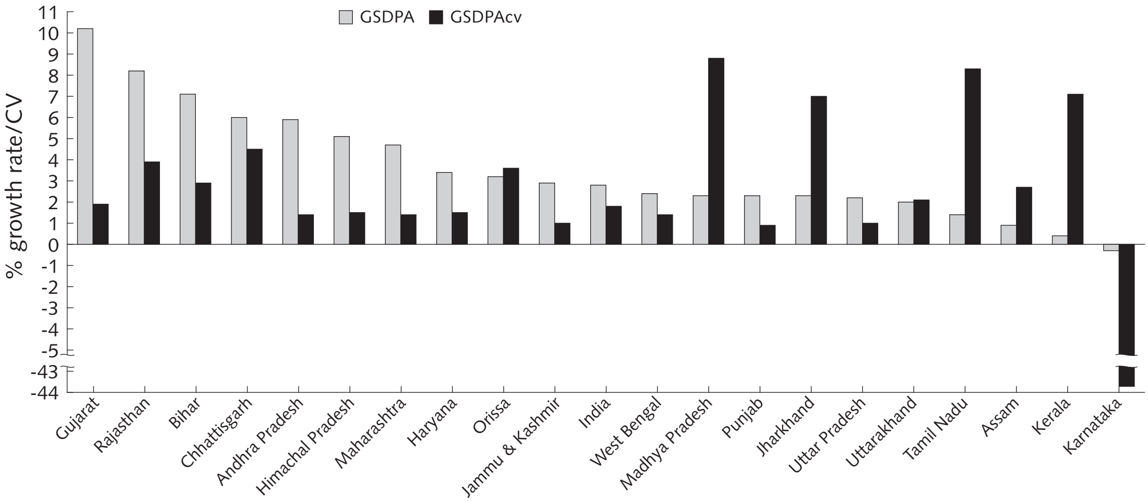

FIG. 1. Growth and volatility in agriculture and allied activities (2000/01–2008/09). States are arranged in descending order of growth rate of Gross State Domestic Product of Agriculture (GSDPA). Coefficient of variation of growth rate of GSDPA (GSDPAcv) = standard deviation/mean. For Gujarat, Maharashtra, Jammu & Kashmir and Madhya Pradesh computations are for the period from 2000/01 to 2007/08. Source: Central Statistical Organisation [4]

to bringing down malnutrition levels? This paper attempts to briefly explore the landscape of agricultural performance* and malnutrition across major Indian states in the recent period. This allows us to examine the possible interplay between agricultural performance and malnutrition indicators and see whether states that perform better record better nutritional outcomes. The paper is organized as follows. The next three sections briefly explore some aspects of India's agricultural performance across major states, highlight some aspects of India's malnutrition problem, and explore the relationship between agricultural performance and malnutrition across 20 major Indian states through correlation and regression techniques. The paper follows UNICEF's widely accepted Causes of Child Malnutrition Framework and also emphasizes the importance of variables such as women's education and status, child-care practices, and access to and utilization of household and health infrastructure in influencing nutritional outcomes, apart from agriculture and access to food. Thus, it attempts to explore the relationship between these variables and nutritional outcomes among children and adults. The final section flags some questions for future policy research and suggests some means to dovetail agricultural development and nutrition policies.

Some aspects of India's agricultural performance

India's agricultural sector has been underperforming. Although India's GDP grew at around 6.6% per annum (trend growth rate) from 1991/92 to 2008/09, agricultural growth lagged behind, at only 2.8% for the same period.** Moreover, *agricultural growth is still very volatile*. This high annual variation is often determined by rainfall and weather conditions, as much research has earlier explored. The correlation coefficient between annual growth in GDP from Agriculture and Allied Activities (GDPA) and the percentage of meteorologic subdivisions receiving deficient or scanty rainfall for the period from 1992/93 to 2008/09 is significant at −0.62. The relation is most evident for 2002/03, when more than 60% of districts had deficient or scanty rainfall and the growth rate of GDPA became negative 7.2% (while GDP growth rate fell to 3.8% from 5.8% in the previous year) [3].

There is significant spatial variation in agricultural performance. Despite low overall growth performance of agriculture, certain regions have seen much faster growth than others, and conversely some regions have seen lower than average growth (**fig. 1**). For instance, from 2000/01 to 2008/09, agriculture in Gujarat grew at around 10% per annum, whereas in Assam, Tamil Nadu, and Uttar Pradesh, the growth rate was barely 2% per annum. Yearly growth volatility is also magnified at the state level, as seen in the coefficient of variation of growth rates in Gross State Domestic Product of Agriculture and Allied Activities (GSDPAcv), and is again significantly influenced by climatic and other factors. For instance, although poorer states, such

* Agricultural performance is usually assessed in terms of agricultural income or agricultural productivity. These terms are used interchangeably in this paper.

** Data on GDP and GDPA are taken from the Central Statistical Organisation, Ministry of Statistics and Programme Implementation, Government of India.

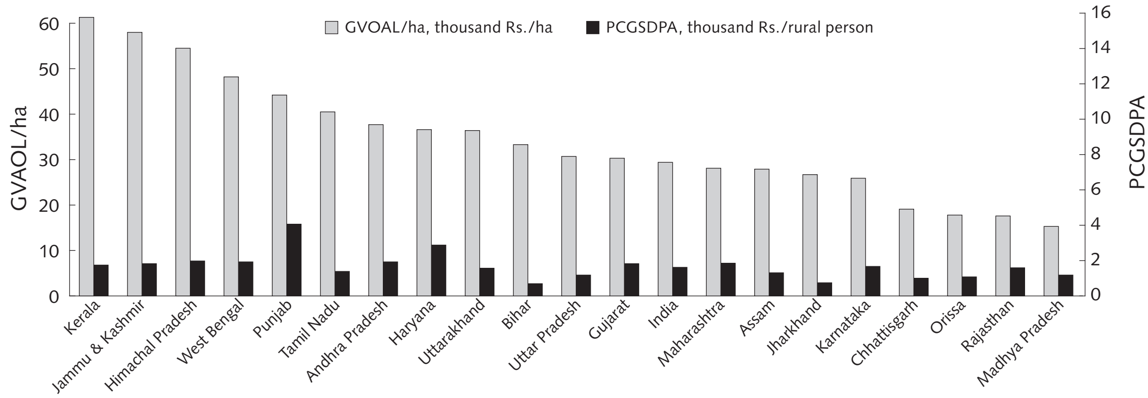

FIG. 2. Agricultural performance status across states for the 3 years ending in 2005/06.
Gross Value of Output from Agriculture and Livestock per hectare (GVOAL/ha) is in 1,000 Rs/ha at 1999/00 prices. Per Capita GSDPA (PCGSDPA) is in 1,000 Rs at 1999/00 prices. States are arranged in descending order of GVOAL/ha. Source: Central Statistical Organisation [5], Directorate of Economics and Statistics [3]

as Rajasthan, Chhattisgarh, Bihar, and Orissa, have growth rates above the average for all of India, the volatility in growth rates is still quite high. Some low-growth states, such as Jharkhand, Tamil Nadu, and Karnataka, also show very high volatility.

Other indicators of agricultural performance also show wide spatial variation. According to Per Capita Gross State Domestic Product of Agriculture and Allied Activities (PCGSDPA),* Punjab and Haryana seem to be the richest states, followed closely by Gujarat and Andhra Pradesh (**fig. 2**). Punjab's PCGSDPA was more than six times that of Bihar in 2005/06, indicating wide inequality. Apart from annual fluctuations in Gross State Domestic Product of Agriculture and Allied Activities (GSDPA), the rate of population growth is also an important factor that determines PCGSDPA level, with important implications for both food and nutritional security. In states with higher population growth rates, such as Bihar and Rajasthan, PCGSDPA tends to increase much more slowly.

The statewise Gross Value of Output from Agriculture and Livestock per hectare of Gross Cropped Area (GVOAL/ha), which is basically gross land productivity, is another indicator of agricultural performance.** It may be noted that states which experienced high growth in agriculture (GSDPA) during, say, 2000/01 to 2008/09 may not necessarily be the ones with highest land productivity, as in the case of Kerala. However, a faster growth in GSDPA over a longer period will surely lead to a higher level of land productivity. Gujarat, for instance, saw a greater than 70% increase in GVOAL/ha between 1999/00 and 2005/06 due to faster growth in its GSDPA, although the absolute value of GVOAL/ha was still lower than that in Punjab. West Bengal and Punjab, which witnessed low growth, saw very marginal increases in agricultural land productivity, although the level was still high. This may be because states that have a significant share of high-value agriculture usually have a higher GVOAL/ha; examples include spices and fisheries in Kerala, fruits and vegetables in Himachal Pradesh, and fisheries and vegetables (especially potatoes) in West Bengal. This is due to diversification toward high-value agriculture. However, some states, such as Rajasthan, that have not diversified much toward high-value agriculture have not experienced a significant rise in GVOAL/ha, despite some years of high growth in GSDPA.

Agriculture remains the largest employer. Although its percentage share of GDP has declined over the years to only around 17% (for the 3 years ending in 2008/09), the agricultural sector remains the largest employer. As of 2004/05, more than 52% of the labor force was directly engaged in agriculture [6], leaving much of the rural population still directly and indirectly dependent on the sector for their livelihood. It is important to note that recent research indicates that the contribution of the rural nonfarm sector to the economy has increased notably during the 1990s and thereafter. One estimate indicates that the proportion of agriculture in the rural Net Domestic Product fell from 64% in 1980/81 to 57% in 1993/94 and 54% in 1999/2000 and that of the nonfarm sector rose from 36% to 43% and 46% during the same period [7]. Rural nonfarm employment and incomes are also estimated to have contributed significantly to poverty reduction in the recent period [8]. However, despite the growing importance of the rural nonfarm and urban sectors, movement of labor out of agriculture has been slower than expected, with the majority of the population still directly dependent on this sector.

* Calculated using GSDPA (in constant 1999/2000 prices) and projected rural population from the 2001 census.

** These values are estimated from Gross Value of Output from Agriculture and Allied Activities data released by the Central Statistical Organisation, Ministry of Statistics and Programme Implementation, and Land Use Statistics, Ministry of Agriculture, estimated by the Ministry of Agriculture.

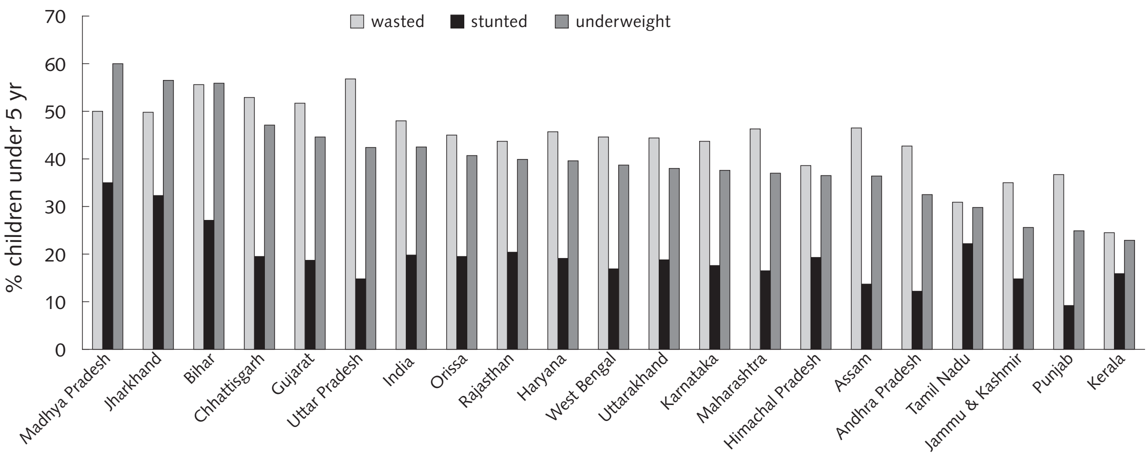

FIG. 3. Child malnutrition indicators across states, 2005/06. States are arranged in descending order of percentage of children under 5 years of age who are underweight.
Source: International Institute for Population Sciences and Macro International [9]

Some aspects of India's malnutrition problem

The extent of child malnutrition among the population is still too high. India's National Family Health Survey (NFHS) data reveal that the proportion of children who are malnourished has not changed significantly over the past few years. In 1998/99, 51% of children under 3 years of age were stunted and 43% were underweight; these figures fell only marginally to 45% and 40%, respectively, in 2005/06 [9]. Although the decline in child undernutrition is somewhat low (the proportions of children under 3 underweight and stunted fell by 5% and 12%, respectively), the reduction in child mortality seems to be more significant. The mortality rate among children under 5 years of age* fell by 22% from 1998/99 to 2005/06 (from 95 to 74 deaths per thousand live births), and the infant mortality rate fell by 16% during the same period (from 68 to 57 deaths per thousand live births; NFHS data). It is conceivable that efforts to reduce mortality rates through improvements in health and nutrition status have reduced the risk of mortality among a large section of infants and children but have not gone far enough to reduce their risk of malnutrition.

Adult malnutrition is also high, especially among women. In 2005/06, 36% of women and 34% of men aged 15 to 49 years surveyed were classified as "thin," with a body mass index (BMI) less than the internationally accepted norm of 18.5 kg/m^2 (BMI lower than this cutoff value is reflective of chronic energy deficiency and adult malnutrition). Women are worse off, and the proportion of thin women has hardly changed from 1998/99, when the value was 36%.

Micronutrient deficiencies are also high. In 2005/06, 70% of children under 5 years of age (74% in 1998/99) and 72% of women 14 to 49 years of age had some form of anemia. Data from the National Nutrition Monitoring Bureau (NNMB) and the National Sample Survey Organisation (NSSO) show that for adolescents, pregnant or lactating women, and people in the bottom 30% expenditure group (i.e., the poorest 30% of the population in terms of mean per capita expenditure), only around 60% to 75% of the protein requirement was met.**

Significant spatial variation exists in malnutrition and micronutrient deficiency. Madhya Pradesh, Jharkhand, Bihar, and Chhattisgarh fare the worst in anthropometric indicators of malnutrition. Around 50% or more of children under 5 years of age in these states are stunted and/or underweight (**fig. 3**), and more than 40% of women are thin (**fig. 4**). These numbers are almost double those for Kerala, which ranks the best in these indicators according to NFHS-3 data for 2005/06. But even in Kerala the prevalence of malnutrition is still high; 25% of children under 5 years of age are stunted and 23% are underweight, and 18% of women are thin. Somewhat paradoxically, Kerala ranks poorly in protein intake; based on mean per capita consumption expenditure (i.e., protein intake in the poorest 30% of the population in Kerala is the lowest for any Indian state) [10]. The prevalence of anemia among women is highest in the eastern states (more than 60% in West Bengal, Jharkhand, and Assam) but is unquestionably

*The mortality rate among children under 5 years of age is estimated by NFHS as the probability of dying before the fifth birthday; the infant mortality rate is the probability of dying before the first birthday.

** Gulati A, Khanna P, Soundararajan V. Proteins for the poor: Can the Indian soybean industry rise to the challenge? International Food Policy Institute and National Soybean Research Laboratory. Mimeo. 2009.

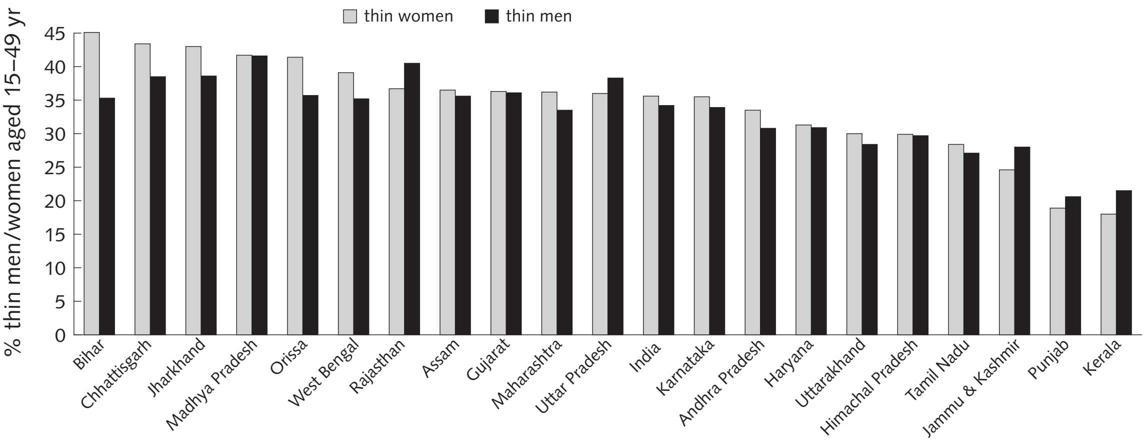

FIG. 4. Adult malnutrition indicators across states, 2005/06. States are arranged in descending order of percentage of women 15 to 49 years of age who are thin.
Source: International Institute for Population Sciences and Macro International [9]

high in other states as well (Kerala again ranks the best, with only around 32% of women suffering from any form of anemia).

Rural areas see higher rates of malnutrition. In rural areas, the prevalence of underweight, stunted, and wasting among children is 46%, 51%, and 20.7%, respectively, as compared with 33%, 40%, and 16.9% among urban children. Similarly, 41% of women and 38.4% of men residing in rural areas are estimated to be thin, as compared with 25% of women and 26.5% of men in urban areas. Poverty is also concentrated in rural areas; in 1993/94, 76% of the total poor population was classified as rural, and this number fell only marginally to around 73% in 2004/05.

Agricultural performance and malnutrition: Emerging linkages

The analytical framework

One of the widely accepted frameworks to conceptualize factors influencing malnutrition is UNICEF's Causes of Child Malnutrition Framework (**fig. 5**), which identifies immediate, underlying, and basic causes at the individual, household/family, and societal/macro levels, respectively. At the individual level, immediate causes include inadequate food and dietary intake (less than required intakes of calories, micronutrients, etc.) and health status, such as susceptibility to disease and illness. These are influenced by underlying factors at the household level, such as access to food and health services, maternal and child-care practices, and household amenities relating to sanitation and safe drinking water. In turn, these are influenced by some basic macro-level determinants, such as the structure of the economy and polity, institutional arrangements, etc.

In this paper, we follow this broad framework, with some adaptation to suit the data on hand to explore the relation between agricultural performance and undernutrition. The analysis is carried out for undernutrition among children under 5 years of age and adults from 15 to 49 years of age both combined and separately. The analysis proceeds in two stages. First, we examine the correlation between key indicators of undernutrition and agricultural performance across 20 major states in India.* Second, we investigate the relationship between malnutrition and agricultural performance across these major states, using regression techniques to control for some of the factors known to affect malnutrition. The results are presented after a brief description of the variables used.

Variables and data source

Normalized malnutrition index

To arrive at a broad measure of undernutrition for the population of the major states, a normalized malnutrition index is constructed combining indicators of undernutrition among children under 5 years of age and adults in the age group from 15 to 49 years. Three indicators of child undernutrition are used here: the percentages of stunted, wasted, and underweight children under 5 years of age. Each of these indicators captures a different aspect of a child's nutritional

* We have not included the union territories and northeastern states, as they have low populations and small agricultural sectors. It is important to note that in most of the northeastern states, the nutritional status of both the adult and the child populations is extremely good relative to other Indian states. Most of these states also have high literacy rates among women, good child-feeding practices, and high access to basic household amenities, such as toilets, compared with other Indian states.

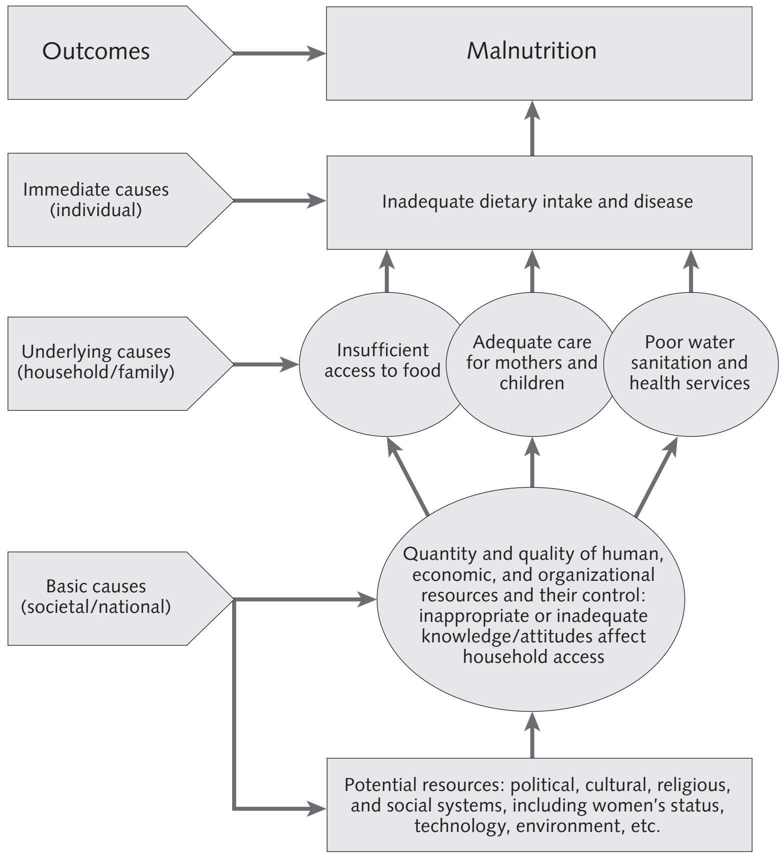

FIG. 5. Causes of malnutrition.
Source: Adapted from UNICEF [11]

status. Stunting represents linear growth retardation and indicates the long-term impact of malnutrition; i.e., it does not vary according to recent dietary intake. Wasting, on the other hand, is indicative of the child's current nutritional status determined by inadequate nutrition or food intake or an illness that has resulted in weight loss in the recent period. Underweight is seen as a composite measure that takes into account acute and chronic malnutrition [9]. With regard to adult undernutrition, the percentages of thin men and thin women (BMI less than 18.5 kg/m^2) in the population are used. The data for all these five indicators are taken from the NFHS-3 survey for the year 2005/06.

Each of these indicators of malnutrition is first normalized according to the formula:

$$\text{Normalized indicator} = \frac{\text{actual values} - \text{minimum value}}{\text{maximum value} - \text{minimum value}}$$

The normalized malnutrition index is then estimated as a simple average of the normalized values of the indicators. Three such indices are constructed: the Combined Normalized Malnutrition Index (CNMI), combining the five indicators of child and adult undernutrition; the Normalized Adult Malnutrition Index (NAMI), combining the two indicators of adult undernutrition (the percentages of thin men and thin women in the age group from 15 to 49 years); and the Normalized Child Malnutrition Index (NCMI), combining the three indicators of child undernutrition (stunting, wasting, and underweight among children under 5 years of age).

Data normalization will add robustness to the estimated index values. This can be an important exercise, because if simple percentage figures (as are available in the NFHS-3 survey) are used with equal weights, predetermined characteristics of the variables (or even the way in which variables are measured) can assign more or less than the weight required. Thus, in the absence of normalization, certain variables can pull the index in their own direction and undermine the importance of other variables included to compute the index. Normalization will enable the mean values of all the selected variables to be "equal" or "normalized" and make the indicators scale-free. The current normalization procedure is similar to that used to compute the Human Development Index and helps eliminate the

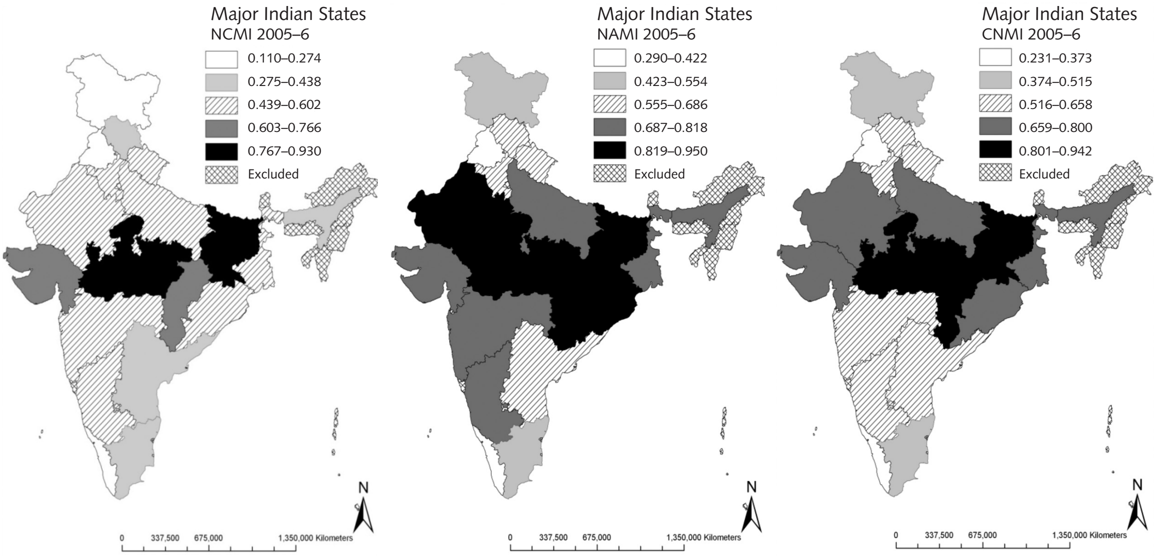

FIG. 6. Maps of normalized nutrition indicators across Indian states, 2005/06. The equal intervals method has been used to classify the data.
CNMI, Combined Normalized Malnutrition Index; NAMI, Normalized Adult Malnutrition Index; NCMI, Normalized Child Malnutrition Index

bias of scale.* One of the advantages of constructing such a normalized malnutrition index is that it provides a single summary measure of undernutrition that covers different aspects of child and adult malnutrition. Admittedly, the concept of nutrition is much broader, and these indices may not be adequate to capture all the aspects of the undernutrition problem. Rather, their purpose is to function as simple proxies to assess and compare the level of statewise nutritional outcomes. It may be noted here that these indices collectively represent a little more than 60% of the population. They do not capture the nutritional status of children between 5 and 14 years of age or those adults who are over 50 years of age. **Figure 6** shows the geographic spread of malnutrition indicators across Indian states.

Factors impacting nutrition

We focus on five dimensions that may cause undernutrition: income and agricultural performance, women's education, care practices, basic household amenities and infrastructure, and access to and utilization of health services by women and children.**

Agricultural performance and income. Many studies (for instance, Haddad et al. [12]) have observed that higher levels of income and income growth, along with improvements in healthcare, feeding practices and diets, etc., can contribute to malnutrition reduction. As seen earlier, a large proportion of the poor and malnourished live in rural areas where agriculture remains the primary occupation. From this perspective, augmenting incomes from agriculture is one of the most critical avenues through which agriculture can impact nutritional outcomes of farm households via increased access to quality food. Improvements in agricultural performance can also increase food availability at the local and national levels (home production, local markets, and national food availability), bring down food prices, and stimulate the development of the rural nonfarm sector [13–15].***

Our hypothesis is that the level of agricultural performance (prosperity) is a more suitable indicator than annual agricultural growth to assess the relation between agriculture and malnutrition.**** This is partly because many states that have experienced low growth in recent years may actually be agriculturally prosperous, as in the case of Punjab due to high growth rates

* Shariff A, Gulati A. Hunger and malnutrition in India: Concepts and Indexing. International Food Policy Research Institute mimeo, 2009.

** It is beyond the scope of this paper to explore an exhaustive list of causes determining undernutrition, such as dietary quality and food intake, institutional interventions, national food availability, political and economic structure, etc.

*** It can be noted that improvements in agricultural performance may not lead to improvements in nutrition status if the benefits of these improvements are not equitably distributed in the population. It is, however, beyond the scope of the current paper to factor in distributional inequities.

**** We do not measure trends in GSDPA and changes in nutritional status in this paper. It can be noted that annual average GSDPA growth is very volatile at the state level and thus this indicator may not be the most appropriate to assess the relation between agriculture and malnutrition. In many cases, this volatility results in even state trend growth rates not being statistically significant. This said, it can be emphasized that fast and inclusive agricultural growth is still essential to push up the level of agricultural performance and prosperity.

in the past or Kerala due to diversification toward high-value agriculture. The reverse is also true in some cases. For example, although Bihar has seen rapid growth in the recent period, its level of agricultural prosperity is still very low. Since malnutrition is a cumulative outcome determined by the interplay of multiple factors over many years, the relative levels of agricultural prosperity may be more relevant than growth rates over a specified number of years. To capture agricultural performance, the following two indicators have been used (using average values for the 3 years ending in 2005/06): Gross Value of Output from Agriculture and Livestock per Hectare of Gross Cropped Area (GVOAL/ha) in 1,000 Rs/ha at constant 1999/2000 prices, and Per Capita Gross State Domestic Product from Agriculture and Allied Activities (PCGSDPA) in 1,000 Rs/rural person at constant 1999/2000 prices. The latter measure provides a proxy for agricultural income and prosperity for the rural population across various states.*

Women's status and education. The status of a woman's nutrition and her position in the household and society are significant not only for the well-being of the woman but also for the short- and long-term nutritional status of her children. Smith et al. observed that the number of underweight children drops significantly if women and men have equal status in society [16]. Besides constituting roughly half the population, women make important decisions on family health, education, and feeding and are the primary caregivers. Poor and ill-informed decisions can conversely have adverse consequences for the health, education, and nutrition status of children (and other family members), accompanied by a high risk of transmission of chronic malnutrition to future generations.

In order to capture the differential status of women across states, we consider the literacy rate among women aged 15 to 49 years (denoted by LitW), taken from the NFHS-3 survey. This indicator also captures the importance of education and awareness in determining nutritional outcomes. Smith and Haddad, in a cross-country analysis of 63 countries for the period from 1970 to 1996, estimated that women's education is the most critical factor in the reduction of child malnutrition, accounting for 43% of the total reduction that took place during the period [17]. In the Indian case, Dev et al. observed that the presence of an educated member in the household and women's empowerment strongly influence participation in education and child-related safety nets [18].

Child-care practices. Care practices in the household and community can have significant impacts on the nutritional status of both children and adults. They are commonly seen as the provision of time, attention, and support to meet the physical, mental, and social needs of the growing child and other members of the household [19]. Care practices commonly include behavioral aspects, such as care of women (rest, food intake, etc.), feeding and food preparation practices, hygiene practices, care practices during sickness and disease, etc. To capture this dimension, we consider the following two variables from the NFHS-3 survey for 2005/06: the percentage of children born in the 5 years preceding the survey who were breastfed within 1 hour after birth (denoted by BFED1HR), and the percentage of children aged 6 to 23 months living with their mothers who were given foods from the appropriate number of food groups during the day or night preceding the NFHS-3 survey (denoted by Child_AFG).**

Household infrastructure and amenities. Basic household infrastructure and amenities, such as improved sources of water and sanitation, are important for the food and nutritional status of the household members, since they have major effects on susceptibility to disease and the capacity to provide adequate caregiving practices. Data again have been taken from NFHS-3, and we focus on two key indicators. One indicator is the percentage of households with improved sources of water for drinking, cooking, and washing hands; these are households that use water piped into the dwelling, yard, or plot; water from a public tap or standpipe, tube well or borehole, protected dug well, or protected spring; or rainwater or bottled water (denoted by hhIWater). The second indicator is the percentage of households with a toilet facility in the house (denoted by hhToilet).

Access to and utilization of healthcare services. Finally, we consider two basic indicators of maternal and child healthcare services that reflect access to and utilization of healthcare infrastructure and services, which are also based on data from the NFHS-3: the percentage of the last live births in the 5 years preceding the survey that were assisted by health personnel (doctor, auxiliary nurse midwife, nurse, midwife, lady health visitor, or other health personnel) (denoted by ShWdel_HP); and the percentage of children aged 12 to 23 months who have received all basic vaccinations, i.e., BCG, measles, and three doses each of DPT and

* We have also carried out the analysis using the Per Capita Gross State Domestic Product (PCGSDP) (in 1,000 Rs/person, at constant 1999/2000 prices for the 3 years ending in 2005/06) and obtained similar results as reported later in the paper. However, because the focus of this paper is on the linkage between agriculture and malnutrition in particular, we have preferred to report only those results involving the agricultural performance variables.

** According to NFHS-3, the food groups are the following: infant formula, milk other than breastmilk, cheese, yogurt, or other milk products; foods made from grains or roots, including porridge or gruel and fortified baby food; vitamin A–rich fruits and vegetables; other fruits and vegetables; eggs; meat, poultry, fish, shellfish, and organ meats; beans, peas, lentils, and nuts; and foods made with oil, fat, ghee, or butter. It is recommended that breastfed children receive foods from three or more food groups and nonbreastfed children receive foods from four or more food groups.

polio vaccine (excluding polio vaccine given at birth) (denoted by C_Vaac).

Results

The correlations between the Combined Normalized Malnutrition Index (CNMI) and factors that could affect malnutrition among adults and children are reported in **table 1**. Agricultural performance and income measures (GVOAL/ha and PCGSDPA) show high and significantly negative correlations with CNMI. Other variables that have a strong influence on CNMI include women's literacy, the presence of a toilet in the home, and healthcare variables for both women and children. Unexpectedly, the indicator of access to improved sources of drinking water has a low and nonsignificant correlation with CNMI.

To investigate the relationship between agriculture and malnutrition, we estimate a simple linear regression model with CNMI as the dependent variable and the factors mentioned above as the explanatory variables with the data for the 20 major states. As seen above, many of these explanatory factors show strong correlations among each other. It is also possible that there is some endogeneity among them; for example, agricultural performance could itself be influenced by literacy levels. This would suggest that the estimation procedure should account for possible endogeneity among the regressors. In this situation, the Instrumental Variables (IV) approach is usually suggested as a better technique than Ordinary Least Squares (OLS). The IV approach would yield consistent estimates when the variables that were used as instruments were highly correlated with the endogenous explanatory variable but had no direct association with the outcome under study (here malnutrition). In practice, however, the present dataset does not contain variables that could be good instruments. Variables such as literacy levels that could potentially be used as instruments do not qualify here, since they are expected to influence both the dependent variable (malnutrition) and other regressors, such as agricultural performance. In such a situation, the IV approach fails to yield consistent estimates [20]. Hence, as far as possible, we have tried to use combinations of regressors that are not expected to suffer from endogeneity, so that OLS yields consistent estimates. In particular, it was observed that regressions involving the women's literacy variable (LitW) and the toilet variable (hhToilet) seem to suffer from the endogeneity problem. Given that the dataset is a cross-section for one year, we have allowed for heteroscedasticity of a general form in these estimations; i.e., the t statistics are computed using robust standard errors.

Two models have been finally chosen based on the overall significance of the regression equation (F statistic and R-squared) and the stability and significance of the coefficients of the explanatory variables (**table 2**). As hypothesized, agricultural performance or income out to be a strong factor influencing CNMI in both of the chosen models. Another variable that shows a strong relationship with CNMI is women's healthcare (ShWdel_HP). Women's literacy (LitW) (model 1) and access to toilet (hhToilet) (model 2) also are important variables. Some of the child-care variables, as well as access to improved water (hhIWater), do not turn out significant in the final results. The fact that access to improved sources of water does not seem to be significant in this exercise may be explained in part by the fact that the majority of households (66%) do not treat water (by boiling, straining, etc.) before drinking it. The proportion of households that treated water was higher in rural areas (73%) than in urban areas (51%) in 2005/06 [9]. Although the proportion of households performing basic sanitation practices such as handwashing is not explicitly recorded in the NFHS-3, the survey data show that the proportion of households using "bottled water, improved source for cooking,

TABLE 1. Correlation matrix: CNMI and explanatory factors, 2005/06

Variable	CNMI	GVOAL/ha	PCGSDPA	LitW	hhIWater	hhToilet	ShWdel_HP	C_Vaac	BFED1HR
CNMI	1								
GVOAL/ha	−0.773*	1							
PCGSDPA	−0.676*	0.425***	1						
LitW	−0.764*	0.649*	0.467**	1					
hhIWater	−0.2495	0.2022	0.51**	0.1312	1				
hhToilet	−0.782*	0.691*	0.546*	0.789*	0.0698	1			
ShWdel_HP	−0.734*	0.498**	0.415***	0.689*	0.2124	0.539*	1		
C_Vaac	−0.695*	0.68*	0.438**	0.766*	0.218	0.477**	0.69*	1	
BFED1HR	−0.438**	0.245	−0.0315	0.713*	−0.1463	0.41***	0.552*	0.602*	1

Source: authors' estimates.

*$p < .01$, **$p < .05$, ***$p < .10$.

CNMI, Combined Normalized Malnutrition Index; GVOAL/ha, Gross Value of Output from Agriculture and Livestock per Hectare of Gross Cropped Area; PCGSDPA, Per Capita Gross State Domestic Product of Agriculture and Allied Activities; LitW; Women's literacy, hhIWater, improved access to water; hhToilet, access to toilet; ShWdel_HP, women received assistance from health personnel during child delivery; C_Vaac, children vaccination; BFED1HR, breastfed within one hour after birth.

TABLE 2. Regression results: CNMI

Variable	Model 1	Model 2
PCGSDPA	−0.025**	
t value	−2.31	
Elasticity	−0.253	
GVOAL/ha		−.005*
t value		−2.85
Elasticity		−0.282
LitW	−.005**	
t value	−2.54	
Elasticity	−0.438	
hhToilet		−.003*
t value		−2.7
Elasticity		−0.237
ShWdel_HP	−.003**	−.004*
t value	−2.55	−3.85
Elasticity	−0.257	−0.294
Constant	1.24	1.153
t value	14.44	17.89
Adjusted R^2	0.77	0.812
F value	16.76	24.52

Elasticities of CNMI with respect to each of the explanatory variables are computed by using the expression
Elasticity (e) of independent variable = coefficient of independent variable/(mean CNMI value/mean independent variable value).
Source: authors' estimates.
*p < .01, **p < .05, ***p < .10.
CNMI, Combined Normalized Malnutrition Index; GVOAL/ha, Gross Value of Output from Agriculture and Livestock per Hectare of Gross Cropped Area; PCGSDPA, Per Capita Gross State Domestic Product of Agriculture and Allied Activities; LitW; Women's literacy, hhToilet, access to toilet; ShWdel_HP, women received assistance from health personnel during child delivery.

handwashing" in 2005/06 was only 0.3% at the national level, 0.1% in rural areas, and 0.8% in urban areas [9].

Adult undernourishment status was highly negatively correlated with agricultural performance, women's literacy, the presence of toilet facilities in the house, and maternal healthcare indicators (**table 3**). Regression models for NAMI confirm the significance of these variables in influencing adult nutrition outcomes (**table 4**).

TABLE 4. Regression results: NAMI

Variable	Model 1	Model 2
GVOAL/ha	−0.007***	−0.006*
t value	−3.09	−3.07
Elasticity	−0.34	−0.29
LitW	−0.003*	
t value	−1.56	
Elasticity	−0.266	
hhToilet		−0.003***
t value		−1.72
Elasticity		−0.19
ShWdel_HP	−0.003**	−0.003**
t value	−2.14	−2.67
Elasticity	−0.205	−0.23
Constant	1.28	1.21
t value	19.36	26.13
Adjusted R^2	0.77	0.79
F value	32.04	28.98

Source: authors' estimates.
*$p < .01$, **$p < .05$, ***$p < .10$.
NAMI, Normalized Adult Malnutrition Index; GVOAL/ha, Gross Value of Output from Agriculture and Livestock per Hectare of Gross Cropped Area; LitW; Women's literacy, hhToilet, access to toilet; ShWdel_HP, women received assistance from health personnel during child delivery.

Similarly, the Normalized Child Malnutrition Index (NCMI) also shows a strong correlation with agricultural performance, women's literacy, and proportion of households with toilet facilities (**table 5**). Child-care practices (breastfeeding within 1 hour after birth and provision of appropriate food groups) and access to health services (vaccination in particular) also seem to matter for NCMI. The regression results (**table 6**) clearly support these patterns. Among the child-care

TABLE 3. Correlation matrix: NAMI and explanatory factors, 2005/06

Variable	NAMI	GVOAL/ha	PCGSDPA	LitW	hhIWater	hhToilet	ShWdel_HP
NAMI	1						
GVOAL/ha	−0.785*	1					
PCGSDPA	−0.682*	0.425***	1				
LitW	−0.759*	0.649*	0.467**	1			
hhIWater	−0.238	0.2022	0.511**	0.131	1		
hhToilet	−0.765*	0.691*	0.546**	0.787*	0.07	1	
ShWdel_HP	−0.701*	0.498**	0.415***	0.689*	0.212	0.539**	1

Source: authors' estimates.
*$p < .01$, **$p < .05$, ***$p < .10$.
NAMI, Normalized Adult Malnutrition Index; GVOAL/ha, Gross Value of Output from Agriculture and Livestock per Hectare of Gross Cropped Area; PCGSDPA, Per Capita Gross State Domestic Product of Agriculture and Allied Activities; LitW; Women's literacy, hhIWater, improved access to water; hhToilet, access to toilet; ShWdel_HP, women received assistance from health personnel during child delivery.

TABLE 5. Correlation matrix: NCMI and explanatory factors, 2005/06

Variable	NCMI	GVOAL/ha	PCGSDPA	LitW	hhIWater	hhToilet	C_Vaac	Child_AFG	BFED1HR
NCMI	1								
GVOAL/ha	−0.682*	1							
PCGSDPA	−0.606*	0.425***	1						
LitW	−0.707*	0.649*	0.467**	1					
hhIWater	−0.249	0.2022	0.511**	0.131	1				
hhToilet	−0.745*	0.691*	0.546*	0.787*	0.07	1			
C_Vaac	−0.625*	0.68*	0.436**	0.766*	0.218	0.477**	1		
Child_AFG	−0.517**	0.749*	0.112	0.674*	−0.027	0.492**	0.674*	1	
BFED1HR	−0.53**	0.245	−0.032	0.713*	−0.146	0.41***	0.602*	0.456**	1

Source: authors' estimates.
$^*p < .01$, $^{**}p < .05$, $^{***}p < .10$.
NCMI, Normalized Child Malnutrition Index; GVOAL/ha, Gross Value of Output from Agriculture and Livestock per Hectare of Gross Cropped Area; PCGSDPA, Per Capita Gross State Domestic Product of Agriculture and Allied Activities; LitW; Women's literacy, hhIWater, improved access to water; hhToilet, access to toilet; C_Vaac, children vaccination; Child_AFG, children 6 to 23 months who were given appropriate number of food groups; BFED1HR, breastfed within one hour after birth.

variables, only BFED1HR is significant. Child_AFG and C_Vaac also showed significant relationships with NCMI, but the regression involving these variables did not perform as well as the two models reported in **table 6**.

Concluding remarks

The above results are based on a limited sample with just 20 observations across the major states of India. Further research is required to firm up these findings and ensure their robustness. Nevertheless, some important conclusions emerge.

Indicators of the level of agricultural performance or income show a strong and significant relationship with the indices of undernutrition among adults and children. This suggests that improvement in productivity can be a powerful tool to reduce undernutrition among the vast majority of the population, especially in countries where a large proportion of the population is dependent on agricultural livelihoods. Improvement in productivity commonly occurs with faster growth in yield (driven by better inputs and technological advances) and/or diversification into high-value agriculture (fruits and vegetables, fisheries, and livestock). Punjab and Haryana are typical examples of the first instance: i.e., higher growth in yield of key cereal crops resulting in a high level of agricultural prosperity. States with high GVOAL/ha driven by a significant proportion of high-value agriculture include Kerala, Himachal Pradesh, West Bengal, and Andhra Pradesh. At the other end are states like Madhya Pradesh, Chhattisgarh, and Rajasthan, with low agricultural performance and high rates of undernutrition.

Improving agricultural performance is a critical and necessary condition to reduce malnutrition but is not a sufficient condition. Our results also bring out the multidimensional nature of malnutrition. Access to sanitation facilities and women's literacy in particular are found to be strong factors affecting malnutrition. To date, more than 55% of Indian households do not have a toilet facility in the house, something which is fundamental to human dignity [9]. Our results also highlight the importance of women's literacy in influencing nutritional outcomes. The NFHS-3 reported that 45% of all female respondents aged 15 to 49 years, and 55% of those in rural areas, were illiterate. Literacy and basic sanitation directly impact the ability of women, men, and children to maintain personal hygiene and adopt

TABLE 6. Regression results: NCMI

Variable	Model 1	Model 2
PCGSDPA	−0.032*	−0.02*
t value	−2.850	−2.220
Elasticity	−0.417	−0.260
LitW		−0.004
t value		−1.170
Elasticity		−0.491
hhToilet	−0.004*	−0.004
t value	−2.160	−1.500
Elasticity	−0.344	−0.369
BFED1HR	−0.005*	
t value	−3.330	
Elasticity	−0.304	
Constant	1.025	1.053
t value	12.100	7.600
Adjusted R^2	0.731	0.643
F value	15.760	12.840

Source: authors' estimates.
$^*p < .01$, $^{**}p < .05$, $^{***}p < .10$.
NCMI, Normalized Child Malnutrition Index; PCGSDPA, Per Capita Gross State Domestic Product of Agriculture and Allied Activities; LitW; Women's literacy, hhToilet, access to toilet; BFED1HR, breastfed within one hour after birth.

related care practices.

These findings have important implications for policy intervention to tackle the problem of malnutrition in the country. The Indian government has recognized malnutrition as a serious problem in every plan document. However, a pressing issue is the absence of a comprehensive and functioning National Nutrition Strategy. During the 1950s and 1960s, because of the food shortages, nutritional security was seen as dependent on first making food available to the masses by increasing grain production. The first nutrition-specific intervention scheme was launched under the Department of Food (consisting of "mobile food and nutrition extension services," i.e., nutrition education and fortification of some food items, such as iodization of salt) and the Applied Nutrition Scheme under the Ministry of Rural Development (in selected blocks, nutrition education activities and assistance in production and preparation of foods through community gardens, poultry farming, fish culture, etc.).

Thereafter, direct nutrition intervention through the Special Nutrition Programme under the Integrated Child Development Scheme (ICDS; now called the Supplementary Nutrition Programme) and the Mid-Day Meals Scheme (MDMS) was launched to address the nutritional needs of children and women. Other than these, relevant schemes include food-based safety nets such as the Food for Work Programme under the National Rural Employment Scheme and state-specific schemes and initiatives. By the 1990s, the main initiatives to address nutritional security were via the food management system (buffer stocks and the Public Distribution System (PDS) network), food supplementation through the ICDS and MDMS, nutrition education through the Nutrition Board and ICDS, and health interventions to address the physical symptoms of malnutrition, micronutrient deficiencies, and maternal health.* As commonly noted in the literature, although these schemes are important and have much potential, they are still poorly implemented [21]. In order to remove the "curse" of India's malnutrition problem, agricultural performance and productivity improvements seem to be critical, based on the findings of this paper. A successful future nutrition reduction strategy ought to be integrated and dovetailed with certain aspects of agricultural development strategies. This can be done at many levels.

One option at the sowing stage is biofortification of crops with essential nutrients such as iron, zinc, and vitamin A, after suitable research, quality testing, and trials. This can directly improve the quality of food intake and diets and improve nutritional outcomes in the immediate term and at the individual level. Research under the HarvestPlus Initiative in 12 countries in Africa, Asia, and Latin America indicates that developing and disseminating biofortified crops is a highly cost-effective means of reducing micronutrient malnutrition in the developing world. The percentage reduction in the burden of vitamin A deficiency was greatest with the introduction of biofortified sweet potato varieties (between 38% and 64%); for iron deficiency, the reduction in the burden was greatest with the introduction of biofortified beans (between 16% and 36%) [22]. The adoption of fortified food ought to be integrated with larger production and cropping strategies to make the food widely available and cost-efficient.

Growth in productivity via diversification into high-value agriculture (fruits and vegetables, fisheries, and livestock) can also promote nutritional security. First, high-value agriculture can be instrumental in boosting incomes of farmers, especially smallholders and woman-headed households. Special focus on the vulnerable, such as woman farmers and cultivators and woman-headed households, in providing access to credit, special training and extension programs, etc. can be useful. The resultant income growth can emerge as one of the most sustainable means to improve nutritional outcomes, as households whose income has increased tend to invest in better quality and quantity of food as well as housing and essential household amenities. Second, it also provides more nutritious food for short-run self-consumption purposes. In Bangladesh, for instance, more than 3% of the rural population (including children) suffered from night-blindness due to severe vitamin A deficiency in the early 1980s. Homestead production of fruits and vegetables and livestock rearing, combined with nutrition education, was launched to combat vitamin A deficiency from the early 1990s onwards (especially targeting households represented by women). The intakes of nutritional food increased, especially among women and children. One study showed that children of households with gardens consumed 1.6 times more vegetables and 48% more eggs, a rich source of vitamin A, than children of households without gardens [23]. Because such high-value products are perishable, postharvest activities, such as handling, transport, storage, processing, quality control and testing, and marketing, are critical to preserve and even enhance their nutritional value.

As noted earlier, dietary diversification can be instrumental in improving nutritional outcomes. A large part of the Indian diet still depends on cereals (especially in poorer households), which do not always offer the best-quality nutrients. Gulati et al.** estimated that rural Indians obtain 66% and urban Indians 56% of their proteins from cereals, which are of poorer quality than proteins from pulses, meat, fish, and eggs. The bottom 30% of the population in terms of mean per capita

* Refer to various Five Year Plans of the Planning Commission, Government of India.

** Gulati A, Khanna P, Soundararajan V. Proteins for the poor: Can the Indian soybean industry rise to the challenge? International Food Policy Institute and National Soybean Research Laboratory. Mimeo. 2009.

expenditure are the most dependent on cereals, with rural Indians obtaining 76% and urban Indians 67% of their proteins from cereals. Bridging the protein deficit is more challenging among the poor because of the higher cost and limited availability of high-quality protein sources. This scenario also holds true for other critical nutrients, such as vitamins and iron. Thus, apart from on-farm diversification, innovative solutions are also necessary for the conception and implementation of policies to combat malnutrition and micronutrient deficiencies.

For instance, to tackle the protein deficit, a more cost-effective and nutritious option is to use soybean meal (which has 40% protein compared with 20% to 25% in pulses) in food-based safety nets. India has witnessed relatively high growth in the soybean crop. Between 1981/82 and 2008/09, production rose from 0.5 to 10.8 million MT, but most of the increased output has been used by the feed industry or exported. Reconstituted soybean flour (*dhal*) can be sold through the public distribution system, as well as distributed in the Mid-Day Meals Scheme and Integrated Child Development Scheme in cooked meals to enrich dietary intake.

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