India has moved from food-deficit to food-surplus status. Now steps must be taken to improve the nutritional value of food.
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I READ THE GEOMORPHOLOGY special ‘Landforms in India’ (Vol. 19, Issue 110) and Agri-Tech Perspectives (Vol. 17, Issue 102) are exceptional and very valuable as they provide authentic data and statistics relevant to my field. Every time I think about a topic there is a G’nY issue on it the next month. I would request G’nY magazine to include articles on urbanisation. I would definitely recommend this magazine to everyone.—RAJESH GOYAL, GURGAON via customer feedback

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THE MAGAZINE IS informative and full of new insights. I have been reading the magazine for more than a year now. It is the best among all the educational magazines available in the market. I am glad that all the articles have pictographic representations and data since numbers and concepts are sometimes difficult to grasp. I would like to read more about issues and topics that are of significance in India today. I thank G’nY for publishing such quality magazines.—ABHAY KUMAR via customer feedback.

I HAVE BEEN READING G’nY for a couple of years now. The special issue on ‘Wildlife Sanctuary’ was very compelling. The research and data are quite riveting and the concepts are very well formulated. The magazine covers diversified topics which are fresh and intriguing. I would like to thank G’nY for bringing out exclusive issues like this.—KANCHAN SINGH via customer feedback.
I once watched an exasperated TV anchor asking a scientist that if there are so many deficiencies in our food systems—from production to consumption, where does one even begin? His helplessness rang true for most of us. Attempts to develop our food systems have been underway for several decades now. From adequate food to better nutrition, in policy we seem to have covered it all. In practice however, the outcomes are fairly dismal. What then is needed to bolster India's food systems? This dedicated issue of G'nY addressing the food imperatives, lays down some basic tenets of what can be remedied at the earliest. From bolstering the nutritional outcomes in the nation to building an understanding of what actually constitutes food choice in a given budgetary bracket, the issue outlines a gamut of thought provoking essays. With evidences of climate change already documented to have affected many crops—a more recent one being the shifting altitudinal extent of apple orchards—it is alarming that we are yet to formulate safety-nets that extend beyond extreme event insurance. Also pertinent are the quality control issues related to food—caught in a complex matrix of demand and supply, threatening to poison the entire nation.

I would like to also take this opportunity to thank Dr Nafees Meah for his involvement in developing a discourse that can perhaps help change the way we view food.
Nutrition and India’s Food Systems

Food systems are deeply entwined with food security, nutritional health, ecosystems, climate change, and prosperity. The Green Revolution enabled countries in South Asia move from food deficit to self-sufficiency, particularly in cereals. In the process, millions were lifted out of poverty. Despite this, we find ourselves dealing with the ‘triple burden’ of undernutrition, micronutrient deficiencies and overnutrition. Levels of stunting in children under 5 years of age and anaemia in women remain shockingly high across South Asia. In addition, rising temperatures are already impacting agriculture, coupled with frequent extreme weather induced crop losses.

We argue that a new paradigm on food systems is essential if we are to meet the United Nations Sustainable Development Goals. The series of articles in this issue brings together some new thinking. A key natural resource that must be better managed is water and Sinha et al. argue that improved water use efficiency, crop diversification and better regulation are needed to end the overexploitation of ground water in Northwest India. The Indian government, recognising the urgency, has launched the mission POSHAN Abhiyaan, which aims to herald a new era in food and nutrition security—elaborated on by Kar. Whether it succeeds or not will depend on food choices made by people. Demont et al. contend that we need to understand the drivers of food choices better and they describe how this might be done. The silver lining is, as Joshi illustrates how consumption patterns in India are already changing from cereal-based diets towards more nutrition-rich commodities. However, dietary diversification and increasing consumption of fruits and vegetables will be less effective, if climate change causes reduced levels of nutrients (Hemalatha and Vasanthi) or if they are contaminated with heavy metals (Mayuri). Finally, rice being the most important staple in South Asia, research at the International Rice Research Institute is seeking to unlock potential of rice as a source of better nutrition for millions of rice consumers (Ahmed et al.).
The livelihoods, nutrition, and incomes of smallholder farmers can be improved substantially if they improve on-farm productivity, increase resource-use efficiency, diversify their crops, gain better market access and find non-farm employment for their households.
AGRICULTURE, NUTRITION AND ENVIRONMENT NEXUS IN SOUTH ASIA

Food systems are at the nexus of food security, nutritional health, ecosystems, climate change, and prosperity. Agricultural policies have focused on increasing food production, but may have neglected the negative externalities on nutrition, natural capital, and biodiversity. A new paradigm on food system transformation is emerging using the concept of ‘planetary boundaries’ in defining the ‘safe operating space’ for stability of the earth system and human health.

The South Asia region, comprising Afghanistan, Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka, is home to about 1.7 billion people with a combined GDP of 3.45 trillion USD (World Bank Development Indicators 2019). More than two-thirds of the population in the region still live in rural areas and depend on agriculture, at least in part, for their livelihoods. The Green Revolution helped transform the South Asia region from one of food deficit to surplus and moved millions of people out of poverty. However, despite rapid economic growth since the 1990s, a very high incidence of poverty, hunger, and malnutrition persists in the region, particularly in rural areas (Pingali 2012).

Smallholder farmers provide about 80 per cent of the food supply in Africa and Asia (IFAD 2013). In addition, in many countries in South Asia, smallholder farmers are moving from subsistence to commercial agriculture. If over the next decade smallholder farmers can improve on-farm productivity, increase resource-use efficiency, diversify their crops, gain better market access and find non-farm employment for their households, then the livelihoods, nutrition, and incomes of millions of smallholder farmers and their families can be improved substantially.

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*The authors are* Representative for South Asia, International Rice Research Institute (IRRI); Platform Leader-Sustainable Impact, IRRI; and Platform Leader-Agri-food Policy, IRRI, respectively. n.meah@irri.org. The article should be cited as Meah N., J. Hellin and J. Balié, 2019. Agriculture, Nutrition and Environment Nexus in South Asia, Geography and You, 19(24): 6-11

*Photo Courtesy: Markus Winkler*
Despite a decreasing share of total GDP as countries undergo structural transformation the rice agri-food sector underpins regional and national economic growth and food security in South Asia. Ensuring adequate, affordable, and stable supply of rice as a staple food is a key policy goal of most governments in the region. The sector still has large untapped potential to improve livelihoods and nutrition, and increase the incomes of millions of smallholders.

All South Asian countries are also signatories to the UN’s Sustainable Development Goals and have adopted a set of goals to end poverty, protect the planet, and ensure prosperity for all by 2030. However, rapidly growing populations, increasing economic inequality, high rates of poverty, large malnourished population, a big gender gap, environmental challenges from climate change, land degradation, water stress etc. mean that achieving these for South Asia will need concerted and sustained effort.

A Renewed Focus on Food Systems
Countries in South Asia are dealing with the ‘triple burden’ of undernutrition, micronutrient deficiencies and overweight/obesity at the same time (Meenakshi 2016). Public Health Foundation of India reported that stunting in children aged under 5 years ranged from over 50 per cent (Uttar Pradesh) to 19 per cent (Kerala) (Raykar et al. 2015). In Sri Lanka, 15 per cent of children aged under 5 years are stunted (UNICEF 2018). In Bangladesh, among the children under 5 years, 45 per cent are zinc deficient, 11 per cent are iron deficient, and 21 per cent are vitamin A deficient (Ahmed et al. 2016). A study on agriculture, nutrition and the green revolution in Bangladesh found that though the country made rapid progress in rice productivity and achieved food security in terms of meeting calorie needs, there was relatively sluggish diversification in food production and consumption. There was no observed improvement in the rate of stunting in children (Headey and Hoddinott 2016).

Globally, the food system has also been adapting to rapid population growth over the last few decades. However, more than 800 million people still have inadequate access to food (FAO, IFAD, UNICEF, WFP and WHO 2019). In addition, a growing share of the world population suffers from micronutrient deficiencies or is overweight or obese, leading to an increasing prevalence of non-communicable diseases. It is now widely accepted that the existing food system has failed and the problem needs to be addressed through evolving and improved food systems.

The Oxford Martin Programme on the Future of Food defines a food system as: a complex web of activities involving the production, processing, transport, and consumption. Issues concerning the food system include the governance and economics of food production, its sustainability, the degree to which we waste food, how food production affects the natural environment and the impact of food on individual and population health.

Food systems are at the nexus of food security, nutritional health, viable ecosystems, climate change and prosperity. Until now national agricultural policies in developing countries have tended to focus on increasing food production. In most cases these policies have neglected the other roles and responsibilities of agriculture within food systems. Conventional agricultural policies do not address negative externalities on nutritional health, natural capital, and protection of biodiversity (Benton and Bailey 2019). FAO have estimated that the natural capital costs associated with crop production was 1.15 trillion USD globally i.e. over 170 per cent of its production value (FAO 2015).

It is recognised that agriculture and food policies should align with the 2030 Agenda for Sustainable Development by addressing several

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**Fig. 1: The Three Intersecting Elements of Sustainability**

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human and planet-centred goals simultaneously. This calls for profound changes in the way the agriculture, environment, health and prosperity nexus is conceived. A new paradigm on food system transformation is emerging that seeks to replace the twentieth century paradigm based on increasing crop yield and the availability of cheap food (EAT-Lancet Commission 2019).

EAT-Lancet Commission, developing the concept of planetary boundaries, proposes a 'safe operating space' for food systems based on existing scientific evidence for healthy diets and sustainable food production (EAT-Lancet Commission 2019). Operating outside this space would, they argue, increase the risk of harm to the stability of the earth system processes (such as high rates of biodiversity loss) and human health. They argue that the “scientific targets that define the safe operating space for food systems allow the evaluation of which diets and food production practices will enable achievement of the SDGs and the Paris Agreement.” To operationalise this insight would require consistency between global actions to support sustainable, inclusive and equitable socio-economic development and numerous local-level processes and innovations.

However, the concept of a sustainable diet is itself problematic. Béné et al. point out that different expert communities interpret sustainability in different ways and there is no consensus on what is meant by ‘sustainability of food systems’ (Béné et al. 2019). Thus, for agronomists, sustainability is primarily defined in terms of preserving the environmental resources underpinning food production, whereas for those from a nutrition or health perspective, a sustainable diet is one that delivers improved nutrition and ensures the right to food. A healthy diet is not necessarily an environmentally sustainable diet and it is a mistake to assume that this is the case (Béné et al. 2019).

Sustainable development is often presented as a Venn diagram with three elements: social, economic and environmental (Fig. 1). These are asserted to be of equal importance to the overall sustainability of the system. This is encapsulated in the classic definition presented by the Brundtland Commission that “Sustainable development meets the needs of the present without compromising the ability of future generations to meet their needs.”

However, one should not assume that there will always be win-win situations between the different elements of food system sustainability. In reality, there will be trade-offs in a given concrete situation. That is to say one may need to decide how much social, economic or environmental elements of sustainability to have and the timing and sequencing of these. Indeed, win-win situations may be rare or difficult to implement and, therefore, more often than not, some difficult societal choices will be needed (Béné et al. 2019).

**Sustainable Food Value Chains**

An effective food system transformation will necessitate firm commitments at the international and national levels to foster the required policies and investments at national and local levels. In practical terms, this would need to include four main dimensions: (i) underpinning healthier populations by enabling access to nutritious and healthy food for all; (ii) guaranteeing sustainable food production, processing, trade, and retailing; (iii) mitigating and adapting to climate change; and (iv) improving smallholder farmer livelihoods and resilience by enhancing prosperity in farming and rural communities.

One contributor to operationalise the food system transformation is to develop sustainable food value chains for appropriate cropping and mixed livestock/fish systems tailored for specific regions and agroecologies (Fig. 2). The idea is to strengthen the value chain so that the objectives of higher farmgate prices and better quality of food products for consumers are achieved. As part of a burgeoning literature on food value chains, the FAO has developed guiding principles on sustainable food value chains which can be used as a framework for upgrading value chains. By a food value chain, we mean:

*the full range of farms and firms and their successive coordinated value-adding activities that produce particular raw agricultural materials and transform them into particular food products that are sold to final consumers and disposed of after use, in a manner that is profitable throughout, has broad-based benefits for society and does not permanently deplete natural resources.*

A value chain approach would engage the private sector actors and ensure that the focus is on increasing the overall productivity, aggregate profitability and efficiency of food production. Smallholder farmers in South Asia would be the overall beneficiaries provided that there is the
necessary trust between the value chain actors (based on the principle that everyone receives their fair share) and there is a clear market demand-led process. Given that the vast majority of farmers in South Asia are smallholders, this entails some horizontal coordination between producers i.e. some kind of Farmer Producer Organisations (FPOs) or more flexible associations, as well as vertical coordination. Failing that, there is the risk that other actors in the value chain will assume a dominant position. Research has shown that rice value chains in India and Bangladesh are changing rapidly. Farmers are selling directly to millers, by-passing village traders—disintermediation—and thereby retaining more of the value (Reardon, Minten, Chen and Lourdes 2013).

However, in some food value chains modern food industry firms (e.g. supermarkets) are making major inroads in South Asia (especially in South East Asia) and, in order to ensure consistent and higher quality of agricultural products, are entering into contract farming arrangements. Evidence shows that contracts as part of this vertical integration vary from those where farmers are provided with most inputs (e.g. seeds, machinery and training) to those where they are contracted simply to provide raw agricultural products.

As regards improving nutrition, this could be addressed by meeting the market demand for fruits and vegetables. Whether primary producers will diversify their own diets and thereby improve their nutritional status is a more complex issue. Gillespie et al. reporting on the results of the Leveraging Agriculture for Nutrition in South Asia (LANSA) initiative have shown that the various pathways from agriculture, as a source of food production and livelihood, to nutrition do not operate in isolation but interact. For example, if women’s role in agriculture as labour increases but is not accompanied by an increase in decision making power within the family, then the nutritional outcomes for them and their children may become worse (Gillespie et al. 2019). This calls for, not only more research, but also for more nuanced interventions by public authorities aiming to improve nutritional and health outcomes.

In respect of environmental sustainability, the value chain should seek to create additional economic value without adversely impacting natural capital. There may be a need to recognise and negotiate trade-offs between the actors in the...
value chain as more environment friendly value chain products may not generate the additional income for farmers. However, there is increasing evidence that in developing economies consumers are willing to pay a premium for environment friendly food products (Ba, de Mey, Thorond and Demont 2019). For the rice sector, the Sustainable Rice Platform, a global alliance of agricultural research institutions, agri-food businesses, and public sector and civil society organisations has been established by United Nations Environment Programme and IRRI (SRP 2017). This has developed standards and performance indicators for sustainable rice cultivation covering social, economic and environmental dimensions of rice production that contribute to an increased global supply of affordable rice, improved livelihoods for producers and reduced environmental impact of production.

Way Forward
The Green Revolution helped transform the South Asia region from one of food deficit to surplus and moved millions of people out of poverty. Despite rapid economic growth experienced across the South Asia region since the 1990s, a very high incidence of poverty, hunger, and malnutrition persists—particularly in rural areas. It is now widely accepted that the existing food system has failed and the problem needs to be addressed through evolving and improved food systems. In South Asia, one contribution to operationalising the food system transformation is to develop sustainable and inclusive food value chains for appropriate cropping and mixed livestock/fish systems tailored for specific regions and agroecologies. For this to happen, there will need to be policy coherence and convergence at local, national and global levels and articulation of the inevitable trade-offs between nutritional health, environmental sustainability, economic prosperity and food security.

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SRP (The Sustainable Rice Platform) 2017. Available at: http://www.sustainablerice.org/
The Ghaggar River basin along the Punjab-Haryana border has shown the greatest decline in groundwater levels since the 1970s.
By Rajiv Sinha, Suneel Kumar Joshi & Suman Kumar

AFTERSHOCKS OF THE GREEN REVOLUTION IN NORTHWEST INDIA

Post-Green Revolution, India has witnessed a dramatic increase in wheat and rice production from 50 to 203 million tonnes between 1950 and 2000. This transformation has come about, in part, through the expansion of groundwater irrigation in northwestern India. However, large-scale groundwater pumping has aggravated waterlogging, salinisation, pollution and caused a steep decline in water tables. Improved water use efficiency, crop diversification and better regulations are needed to arrest the over-exploitation of groundwater across the region.
The Green Revolution in India in the 1960s introduced modern technology, including high-yield variety (wheat and rice) seeds, irrigation facilities, and chemical fertilisers in several states of northwest India. The country soon experienced a dramatic increase in annual agricultural production from 50 in 1950-1951 to 203 million tonnes in 1999-2000 (Kumar, Singh and Sharma 2005). The contribution of major crops such as rice and wheat increased from ~3 to 20 per cent and from ~50 to 85 per cent, respectively (Rodell, Velicougna and Famiglietti 2009) due to intensification and extensification. Despite this promising beginning, the intensification of cropping has caused degradation of water and soil due to salinisation, soil erosion, waterlogging, deforestation, over-exploitation of groundwater, and pest and disease problems.

Intensive groundwater extraction during the past four decades to fulfill agricultural demand has led to a dramatic decline of groundwater level in northwest India so much so that this region is referred to as the largest hotspot of groundwater depletion in the world (Long et al. 2016). With an average groundwater recharge rate of only ~90 mm/year, restoring the excessively depleted groundwater resource in this region is extremely challenging.

The area under cultivation has increased from ~75 to 90 per cent from 2004 to 2011 for Punjab, and from ~49 to 61 per cent for the same period for Haryana (CGWB, 2006, 2011, 2014) (Fig. 1). This, in turn, has resulted in unprecedented groundwater abstraction resulting in most parts of northwest India being categorised as ‘over-exploited’ as per the assessment in 2013 (Fig. 2). Over time, the effects of the withdrawal are propagated through the system as heads decrease at greater distances from the point of withdrawal. To better understand this, the spatio-temporal distribution of groundwater decline in northwest India needs to be understood at a high spatial resolution.

The climatic condition in northwest India is subtropical with hot summers and cold winters. The highest and lowest temperatures recorded here are around 48°C and around 1°C respectively. Nearly 85 per cent of the total annual rainfall occurs during the monsoon season. This is unevenly distributed across the region gradually increases from 200 mm in the southwest to 1800 mm in the northeast region in northwest India.

**Pattern of Water Level Depletion in Northwest India**

The magnitude of groundwater depletion, which

![Fig. 1: Long-term trend of agriculture land and crop production](image-url)

The area under cultivation in Punjab has increased from around 75 per cent of the total area to 90 per cent of the total area between 2004 and 2011. For Haryana the increase was from around 49 per cent of the total area to 61 per cent.

is a global issue, was not properly understood until recently. Globally the groundwater extraction rate is ~1500 cubic km per year compared to the global recharge rate of ~12600 cubic km per year (Scanlon et al. 2012). Gravity Recovery and Climate Experiment (GRACE) satellite missions, that provide low-resolution data covering large areas, are widely used to monitor large-scale groundwater storage change in aquifer systems. However, high-resolution monitoring data for groundwater levels remain indispensable because groundwater depletion can be highly localised in an aquifer system (CGWB 2014).

The available rates of depletion of groundwater in northwest India are quite variable (Table 1). While studies have provided average estimates of groundwater loss at a regional scale, no systematic high-resolution studies on groundwater depletion are available for the region. No information is available on groundwater depletion based on in situ measurements of groundwater observation wells except in one study (MacDonald et al. 2016). Most of the studies present very low-resolution and short-period estimates, and cannot be used for developing sustainable aquifer management plans. Therefore, high-resolution spatial and temporal data from in situ measurements from a large number of groundwater observation wells are required for better understanding of the groundwater system. Besides, groundwater modelling for predicting the groundwater dynamics under different scenarios of groundwater management options is urgently needed.

Recent research based on the historical groundwater level data for the period 1974-2010
Unprecedented groundwater abstraction in northwest India after the Green Revolution has resulted in many parts of the region being categorised as ‘over-exploited’. Sources: Dynamic Ground Water Resources of India (as on 31st March 2013), June 2017. Central Ground Water Board, Ministry of Water Resources, River Development & Ganga Rejuvenation.

The aquifer system in northwest India consists of large sedimentary fans deposited by the Sutlej and Yamuna rivers that set the thickness, stacking pattern, and connectivity of individual aquifer bodies. These individual bodies are limited in thickness and width and are not laterally extensive. The number, dimensions, and connectivity of the aquifer bodies help determine the magnitude of groundwater decline. The spatial
### Table 1: Estimates of groundwater depletion in northwest India

<table>
<thead>
<tr>
<th>Period</th>
<th>Method</th>
<th>Study area</th>
<th>Storage loss</th>
<th>Rate of GW depletion (cm/year)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002 - 2008</td>
<td>GRACE</td>
<td>Northwest India</td>
<td>109 Cubic km</td>
<td>4.0±1.0</td>
<td>2</td>
</tr>
<tr>
<td>2002 – 2008</td>
<td>GRACE</td>
<td>Northern India</td>
<td>54±9 Cubic km per year</td>
<td>–2</td>
<td>4</td>
</tr>
<tr>
<td>2002 – 2013</td>
<td>GRACE</td>
<td>Northern India</td>
<td>–2</td>
<td>2.4±0.59</td>
<td>13</td>
</tr>
<tr>
<td>2003 - 2013</td>
<td>GRACE</td>
<td>Northwest India</td>
<td>20.4±7.1 Gigatonnes per year</td>
<td>2.4±0.59</td>
<td>5</td>
</tr>
<tr>
<td>2005 – 2010</td>
<td>GRACE</td>
<td>Northwest India</td>
<td>14±0.4 Cubic km per year</td>
<td>3.1±0.1</td>
<td>6</td>
</tr>
<tr>
<td>2003 - 2012</td>
<td>GRACE</td>
<td>Punjab</td>
<td>2.1±0.1</td>
<td>–1.25</td>
<td>6</td>
</tr>
<tr>
<td>2003 - 2014</td>
<td>GRACE</td>
<td>Ganga basin</td>
<td>1.4±0.5 Cubic km per year</td>
<td>–2.1</td>
<td>14</td>
</tr>
<tr>
<td>2002 – 2012</td>
<td>Groundwater well data</td>
<td>Punjab</td>
<td>2.6±0.9 Cubic km per year</td>
<td>–2.1</td>
<td>9</td>
</tr>
<tr>
<td>2002 - 2012</td>
<td>Groundwater well data</td>
<td>Haryana</td>
<td>1.4±0.5 Cubic km per year</td>
<td>–2.1</td>
<td>9</td>
</tr>
</tbody>
</table>

Source: GRACE 2002-2014 and CGWB 2002-2012

heterogeneity in the system that is imposed by geomorphic and depositional setting of the fans must, therefore, be considered in any aquifer management scheme. This understanding has also helped in the development of probabilistic maps of likely paleo-channel positions using existing aquifer thickness data and simple geomorphic rules that govern channel geometry and fan construction (van Dijk et al. 2016). Recent modelling efforts have also shown that much of the spatial variation in groundwater decline in northwest India in response to abstraction can be explained by the underlying geological heterogeneity of the alluvial aquifer system, in which the storage capacity is controlled by the aquifer percentage (van Dijk et al. 2019).

Isotopic signatures of groundwater from this region show different flow systems: a) local flow system up to the depth of 80 m below ground level (bgl), which is recharged by direct infiltration of precipitation and canal or river, and b) intermediate and regional flow system below 80 m bgl, which is older; possibly recharged under different hydro-meteorological conditions (Joshi et al. 2018).

**Shift from Rain-Fed Agriculture to Groundwater-Reliant Irrigation**

Since the Green Revolution, groundwater levels across the Punjab and Haryana have shown a steady decline. The agriculture practices which initially used to be dependent on surface water irrigation (i.e. canal) shifted to groundwater. This expanded irrigation to areas not covered by surface irrigation and helped India transform from a nation reliant on food imports to a net food exporter. Currently 54 and 27 per cent of the total irrigated area in Haryana and Punjab respectively are fed by the canal system. The remaining 46 and 73 per cent area are covered by groundwater irrigation (Ambika, Wardlow and Mishra 2016). In the state of Punjab in northwest India the area irrigated by groundwater via tubewells has increased from 55 to 75 per cent during 1970-2002 with a corresponding decrease in the area under canal irrigation (Kumar et al. 2008). This is also manifested in a spectacular increase in the number of tubewells from ~0.2 to 1.3 million during 1966-1967 to 2011-2012 in Punjab, and ~0.03 to 0.7 million during 1966-1967 to 2011-2012 in Haryana in northwest India (Sharma et al. 2008; CGWB, 2011) (Fig. 3).

Currently the tubewell density in northwest India is more than 15 per square km (Ambast, Tyagi and Raul 2006). A recent study suggests that a remarkable shift from centrifugal to submersible pumps happened in this region during 2001-2005.
as a response to the falling groundwater level. This shift has facilitated the exploitation of deeper well areas with abundant aquifer material. This enhanced knowledge of tubewell drilling and adoption of new technologies aided the shift (Kaur and Vatta 2015).

It is obvious that the move from rainfed agriculture to groundwater-reliant irrigation came at an enormous cost. Large-scale pumping of groundwater led to increasing land and water degradation, waterlogging and salinisation in highly irrigated areas, pollution of water resources and a steep decline in the water table; all of which now pose a grave threat to the water and food security of the country.

Another reason for groundwater salinity is the excessive use of fertilisers. This has been one of the primary reasons for the drop in groundwater quality in northwest India since the Green Revolution. Poor water quality has led to the emergence of several diseases in animals and decreased grain quality, in turn affecting human health. High nitrate content in groundwater in Punjab has also been attributed to the increase in fertiliser use (Bajwa et al. 1993).

Current Strategies for Aquifer Management and Way Forward

The rapid drawdown of the northwest Indian aquifer system indicates that the management of alluvial aquifers in India needs a serious rethink. Sustainability of groundwater resources can be achieved by either increasing the supply of surface water or reducing the demand for groundwater. Under the given conditions the former is not readily plausible. Therefore, demand can be addressed by improving irrigation efficiency, diversifying crop types to less water-hungry ones, and addressing farm economics through energy pricing. It is also important to emphasise that the spatial patterns of depletion are quite diverse and strong control of geomorphic setting on groundwater depletion is more than obvious in this region. The combination of geomorphic and stratigraphic mapping, a promising but relatively under-explored approach, is possible given the wealth of data held by Central Ground Water Board and state groundwater boards and the advent of new technologies of terrain mapping. Understanding of geomorphic/stratigraphic controls of groundwater depletion can help in determining the most appropriate management strategies such as where to plan artificial recharge or to advise crop management.

The severity of the problem demands regulatory
mechanisms to arrest the over exploitation of groundwater across the region. The Indian government has made some efforts in this direction and circulated the Model Ground Water Control and Regulation Bill as early as 1970 to all the states. It was subsequently revised in 1992, 1996 and 2005 and redrafted in 2016. It is heartening to note that more than 15 states have already made provisions for groundwater legislation based on the Model Bill circulated in 2016. Some more laudable efforts include the constitution of Central Ground Water Authority (CGWA) in 1997 by the Supreme Court of India to regulate the indiscriminate boring and withdrawal of underground water in the country. The CGWA has since ‘notified’ several areas where no new wells are permitted except for small diameter drinking wells.

In addition to these regulations, public awareness about the groundwater crisis has also increased and community efforts to save this valuable resource have been multiplying. In several states such as Maharashtra, Madhya Pradesh, Gujarat and Sikkim, farmers have come together to manage this valuable resource by developing protocols for pumping water, sequencing of water use, establishing distance norms between wells and tubewells, etc. and these have already started yielding positive results. However, massive support from government agencies is required if these efforts are to be upscaled to cover the entire country which has a varied hydro geology and different levels of water stress.

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POSHAN ABHIYAAN
FOR A MALNUTRITION FREE INDIA

By Basanta Kar

POSHAN Abhiyaan or National Nutrition Mission (NNM) will synergise governmental bodies and key sectors of the economy, resulting in reshaping the nutritional landscape of India.
To achieve malnutrition-free status, India’s development agenda needs to tackle its ‘double burden’ of malnutrition, under-nutrition and obesity at the same time. It is in this context that the POSHAN Abhiyaan provides an opportunity to counter malnutrition and usher in a new era in food and nutrition security.

India has been making significant investments in achieving food and nutrition security through structured public-funded programmes. In fact, India entrenches the right to food in its Constitution. Article 47 of the Constitution mandates the State to raise the level of nutrition of its citizens. India’s flagship nutrition programme—the Integrated Child Development Services (ICDS) Scheme was launched on October 2, 1975 to take this directive forward. The scheme, which is still in operation, is one of the world’s largest community based programmes. Its beneficiaries include children up to the age of 6 and pregnant and lactating mothers. The aim of the scheme is to improve the health, nutrition and education of the beneficiaries. Thereafter, the National Food Security Act (NFSA) 2013 was put in place to provide “food and nutritional security…by ensuring access to adequate quantity of quality food at affordable prices…” (Jamuda 2019).

India’s Nutrition Landscape

Anaemia in adolescent girls perpetuates the cycle of malnourishment for subsequent generations. As anaemic girls grow into adults, subsequent pregnancies not only endanger their own health by way of pre-term deliveries and high risk of maternal haemorrhages, but also put their children at a higher risk of anaemia and of being born as ‘low-birth weight’ babies—perpetuating an unending loop.

As many as 26.8 per cent of Indian women marry before turning 18 (NFHS-4). Early marriage, limited life skills, little or no education, low economic and social self-reliance, lack of nutrition-hygiene-family planning related counselling and more, trigger a cascading
effect. The outcome is poorly planned families, malnutrition, and heightened challenges with larger groups of vulnerable women and children. The need for a nutrition revolution, therefore, has never been more urgent.

However, the challenge of undernutrition in India is compounded by yet another burden—20.7 per cent women and 18.6 per cent men in India are reportedly obese or overweight (IIPS 2017). This ‘double burden of malnutrition’, therefore has an immense negative bearing on the nutritional status of India. By the year 2040, India needs to bring down its key indicators of malnutrition-stunting, wasting, undernutrition and anaemia to single digits. For this to happen, the Annual Average Rate of Reductions (AARRs) for each indicator needs to be four to five times that of the current rate (Table 1).

A life cycle approach is needed for India to achieve ‘zero’ hunger and reduce malnutrition deaths by 2040. This requires prioritising nutrition-intensive investments for the first 1000 days of life (from conception to two-years) recognising it as the first window of opportunity. The next step is prioritising interventions for enhancing nutrition for adolescent girls—the mothers of tomorrow, as they represent the second window of opportunity for making ‘nutrition for all’ a reality.

The POSHAN Abhiyaan, intending to work through a digital platform has currently disseminated guidelines covering all aspects of the ICDS-CAS software implementation up to the district level. Extensive capacity building programmes and community based events (CBEs) are also being organised in Anganwadi centres and field visits are being conducted in the aspirational districts and high priority states (PIB 2019).

**Micronutrient Deficiencies**

Deficiency of essential vitamins and minerals or ‘hidden hunger,’ is a key cause of malnutrition. NFHS-4 data reveals that only 47 per cent, or less than half, of all women in India consume dark green, leafy vegetables daily and 38 per cent consume them weekly. 45 per cent women consume pulses or beans daily and an equal percentage consume them weekly. 54 per cent women do not consume fruits even once a week and only a third consume either chicken, meat, fish, or eggs daily (Fig. 1) (NFHS-4). Inadequate dietary intake of micro nutrients by women dulls their contribution as human capital and compromises the health of the future generations.

According to NFHS-4, only 9.6 per cent of children aged 6-23 months received an adequate diet. The percentage of young children (6-8 months) introduced to complementary feeding declined from 52.7 in 2006 to 42.7 per cent in 2016. Low productivity, poor cognitive and physical development, and increased morbidity and mortality arise from micronutrient deficiencies and contribute to India’s disease burden. The annual GDP losses from low weight, poor growth of children, and micronutrient deficiencies are, on average, 11 per cent in Asia and Africa. This is greater than the loss experienced in the 2008–2010 financial crisis (Paris 2016).

Iron deficiency anaemia, for instance, affects mental and physical development and is associated with 20 per cent of maternal deaths. India has one of the highest incidences of birth defects, with more than 50 per cent ascribable to Neural Tube Defects (NTDs), despite half of all NTDs being preventable with adequate folic acid intake prior to and during early pregnancy. Other deficiencies, for instance that of vitamin D and A and zinc can be easily remedied with timely interventions. The national programme for vitamin A supplementation, initiated in the 1970, has significantly reduced clinical manifestations in young children. Currently, three major strategies with varying levels of success are being used.

**Dietary diversity:** This is the most sustainable, long-term approach for tackling malnutrition and micronutrient deficiency. However, the availability, accessibility and affordability of different kinds of foods for diverse diets is a challenge. Also, ensuring the knowledge of these foods and how they are suitable for different life-stages, environments, economic and social contexts, poses a serious question, especially for the poor and marginalised.

**Supplementation:** Government programmes for Vitamin A supplementation and iron-folic acid (IFA) supplementation for pregnant women and adolescent girls have been in operation for over five decades. However, they have exhibited sub-optimal impacts. For instance, only 23.6 per cent women consume IFA tablets during pregnancy and for women in the lowest wealth index, this figure is 13.8 per cent. Similarly, 45.2 per cent of
children (6-59 months) receive Vitamin A and for children in the lowest wealth index, the figure is 37.5 per cent (MWCD 2014). Two other obstacles to nutrition supplementation programmes are diluted public accountability which inhibits access; and myths, misconceptions and limited awareness, which contribute to low compliance. **Food fortification:** India, as part of its medium and long-term strategy, needs to adopt universal and mandatory food fortification along with the promotion of bio-fortification. Food fortification, a process by which vitamins and minerals are added to commonly consumed foods, offers a good opportunity to improve the micronutrient status of people without changing their food habits.

Food fortification started in 1953, with vanaspati ghee fortified with vitamin A, followed by salt iodisation in 1962 and milk fortification with vitamin A and D for three years from 1989 onwards. Rajasthan’s dairy cooperative continues to fortify low-fat milk and many units voluntarily fortify edible oil with Vitamin A and D. The low cost of fortification of staple foods—for instance wheat flour can be fortified by 8-10 paisa per kg, milk by 2.5 paisa per kg, rice by 2 rupees per kg and salt by 3-4 rupees per kg—supported by comprehensive regulation, makes it an economically viable solution for addressing malnutrition.

Mandatory fortification can multiply nutritional benefits more equitably than voluntary fortification, while ensuring compliance to food safety and quality standards. Some staple foods distributed via government-funded programmes can be fortified in accordance with the Food Safety Standards Authority of India (FSSAI) standards—for example, salt with iron and iodine; wheat flour with iron, folic acid and vitamin B12; refined oils with vitamin A and D; milk with vitamin A and D; and rice with iron and other micro-nutrients. Fortified foods supplied via public-funded programmes like the targeted

<table>
<thead>
<tr>
<th>Indicators (per cent)</th>
<th>Current Status NFHS-4 (2015-16)</th>
<th>Current AARR- (2005-06 to 2015-16)</th>
<th>Required AARR to reach single digit values by 2040</th>
<th>Projected targets for 2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children under 5 years who are stunted</td>
<td>38.4</td>
<td>2.2</td>
<td>5.50</td>
<td>9.3</td>
</tr>
<tr>
<td>Children under 5 years who are wasted</td>
<td>21.0</td>
<td>-0.6</td>
<td>3.00</td>
<td>9.8</td>
</tr>
<tr>
<td>Children under 5 years who are underweight</td>
<td>35.7</td>
<td>1.7</td>
<td>5.00</td>
<td>9.9</td>
</tr>
<tr>
<td>Children (6-59 months) who are anaemic (Hb &lt;11.0 g/dL)</td>
<td>58.4</td>
<td>1.7</td>
<td>6.90</td>
<td>9.8</td>
</tr>
<tr>
<td>Non-pregnant women (15-49 years) who are anaemic (Hb &lt;12.0 g/dL)</td>
<td>53.1</td>
<td>0.4</td>
<td>6.50</td>
<td>9.9</td>
</tr>
<tr>
<td>Pregnant women (15-49 years) who are anaemic (Hb &lt;11.0 g/dL)</td>
<td>50.3</td>
<td>1.4</td>
<td>6.30</td>
<td>9.9</td>
</tr>
<tr>
<td>All women (15-49 years) who are anaemic (Prevalence)</td>
<td>53.0</td>
<td>0.4</td>
<td>6.50</td>
<td>9.9</td>
</tr>
</tbody>
</table>

**Table 1: Transforming Nutrition Landscape of India by 2040: Bringing Down Malnutrition to a Single Digit Status**

Above table illustrates the current status of key indicators for malnutrition in India; progress achieved in ten years (2005-16 to 2015-16) and projected targets for 2040. To achieve single digit data for indicators the Annual Average Rate of Reductions (AARRs) needs to be 4 to 5 times the current rate. For analysing projections for year 2040, NFHS-4 data is used. AARR is average relative percent decrease per year in prevalence or rate, and has reference period between NFHS-3 and NFHS-4(AARR). A negative sign indicates increase.
Fig. 1: Nutritional Intake of Women and Children

![Bar chart showing nutritional intake of women and children]


Fig. 2: Link Between Agriculture and Improved Nutrition

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**Encouraging the production of nutrient-rich foods and taking steps in accordance with seasonality, affordability, availability, demand etc. of food items can boost nutritional levels in the household.**

- **In agriculture's domain**
  - Nutritious food production and supply
  - Seasonal fluctuations in food accessibility
  - Affordability of nutritious foods
  - End-user demand
  - Consumption of nutritious foods
  - Safety of food supply
  - Women's empowerment in agriculture

- **Not solely in agriculture's domain**
  - Child anthropometry (stunting and wasting)
  - Maternal nutritional status
  - Anemia

---

**Maternal and child undernutrition**

- Disease
- Inadequate dietary intake
- Immediate causes

**Household food insecurity**

- Inadequate care and feeding practices
- Underlying causes

**Unhealthy household environment and inadequate health services**

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**Immediate causes**

- Disease
- Inadequate dietary intake

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**Underlying causes**

- Household food insecurity
- Inadequate care and feeding practices
- Unhealthy household environment and inadequate health services

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**In agriculture’s domain**

- Nutritious food production and supply
- Seasonal fluctuations in food accessibility
- Affordability of nutritious foods
- End-user demand
- Consumption of nutritious foods
- Safety of food supply
- Women’s empowerment in agriculture

**Not in agriculture’s domain**

- Child anthropometry (stunting and wasting)
- Maternal nutritional status
- Anemia
Public Distribution System (PDS), benefit the most marginalised and reach at least 67 per cent of the population (Majumder 2001). Introducing food fortification in other key government funded programmes such as the ICDS supplementary nutrition programme and the Mid-Day Meal (MDM) programme can also benefit pregnant and lactating mothers, and children (6-72 months) by addressing micronutrient deficiencies.

**Bio-fortification:** Yet to be explored in India, bio-fortification brings into focus the critical role agriculture can play in uplifting the nutritional status. Figure 2 emphasises the role of agriculture in boosting nutritional levels in the household, by encouraging production of nutrient-rich foods and taking into account seasonality, affordability, availability, demand and other key factors.

Inculcating dietary diversity for better nutrition with sustainable agriculture will also help promote women smallholder farmers. There is a deficit in maternal diet and complementary feeding for infants in India. The complementary feeding for a child between six and 24 months is less than 10 per cent. The agri-nutrition focus will ensure that mother and child have access to a diversified diet, leading to a sustainable solution. Along with the promotion of diet diversity, interventions have to be made to address the food value chain from farm to finger. Quality assurance and quality control mechanisms along the value chain should be patronised so that pregnant and lactating mother as well as the children have access to safe and nutritious food. Promotion of dryland agriculture and nutritious cereals is also necessary. Naturally biofortified crops like minor millets, Indian gooseberry (*amla*), drumsticks, spinach etc. can increase dietary diversity and address micronutrient deficiencies.

**Way Forward**

Given the wide prevalence of malnutrition in India, micronutrient malnutrition in particular, supplementation and promotion of dietary diversity, coupled with regulated food fortification of staples and robust public distribution mechanisms, provide solutions that will benefit the masses.

However, policy action must form the cornerstone for addressing malnutrition. It is, therefore, essential for policy makers to align the national and state goals with the UN Sustainable Development Goals. Strengthening the country’s regulatory system to improve food safety standards and better convergence of agricultural and public health strategies is extremely important. A proposed Agri-Nutrition Convergence Action Plan can encourage cohesive action by relevant ministries and departments and be pivotal to understanding the needs of producers and consumers and responding to their demands for healthier, more nutritious food.

India currently ranks 114 out of 132 countries in terms of levels of stunting in children. With India emerging as an economic superpower in the 21st century, these figures are indeed alarming and a cause for dismay. In order to achieve ‘malnutrition-free’ status, India’s development agenda needs a much stronger focus on nutrition that can be achieved by evidence-based action and by making informed choices regarding food and health.

**References**


Achieving healthier diets requires a thorough understanding of the diversity and drivers of food choice. The International Rice Research Institute developed a ‘Food Choice Application’ featuring 162 unique Bengali dishes and captured the weekly meal plans of 177 low to middle income households in West Bengal. Food choices varied by gender and between urban and rural communities affected primarily by budget constraints and to a lesser extent by behavioural change communication towards healthier diets.

By Matty Demont, Marie Claire Custodio, Jhoanne Ynion, Arindam Samaddar, Rochie Cuevas, Anindita Ray (Chakravarti) & Suva Kanta Mohanty

**WHAT AFFECTS HOUSEHOLDS’ FOOD CHOICE IN WEST BENGAL?**

The Food Choice Application maps the weekly food portfolio of a household by featuring dish options during five eating occasions over the week.
The authors are Senior Economist-Market Analysis Research Cluster Leader; Senior Associate-Market Research Scientist; Assistant Scientist-Market Research; Lead Specialist-Agricultural Anthropologist; Scientist-Sensory Profiling at IRRI, Philippines; Assistant Professor at Maharani Kasiswar; College, Kolkata and Professor at KIIT University, Bhubaneswar, respectively. m.demont@irri.org. The article should be cited as Demont M., M. C. Custodio, J. Ynion, A. Samaddar, R. Cuevas, A. Ray (Chakravarti) & S. K. Mohanty, 2019. What Affects Households’ Food Choice in West Bengal?, Geography and You, 19(24): 26-30.
The EAT-Lancet Commission recently urged the world that we need to achieve ‘planetary health diets’ that prioritise human health at minimal environmental footprint for the nearly 10 billion people likely to inhabit earth by 2050 (Willett et al. 2019). However, to render diets healthier, policy makers first need to understand the diversity of food choice and the drivers that affect it. To capture this, the International Rice Research Institute (IRRI) collaborated with Maharani Kasiswari College, Kolkata and KIIT University, Bhubaneswar (DFC 2019). Aimed at understanding the behavioural drivers of food choice in West Bengal, the project involved a target population of urban and rural households in low and middle income groups.

**Food Choice Application (FCA)**

One of the primary deliverables of the project was an interactive application that was used to capture the diversity of food choices in West Bengal. After inventorying, preparing, standardising, analysing and photographing dishes in Maharani Kasiswari College food lab, the team identified 162 unique Bengali dishes. These dishes were then worked into an application—the Food Choice Application (FCA) and allocated to five eating occasions: breakfast, morning snack, lunch, afternoon snack and dinner (Fig. 1).

The FCA maps the weekly food portfolio of a household by featuring all dish options that can be consumed during five eating occasions over seven days of the week. Respondents can specify the number of servings of the dish their household is planning to consume, where each serving represents the quantity for one adult. As the servings increase, a budget bar indicates the available per cent budget left for the household’s use. The FCA was pretested for refining the functionality of the application and was made available in both English and Bengali.

The FCA treats weekly food choice of a household as an investment decision under a budget cap. Next, it treats the dish as the unit in the investment decision-making. The FCA allows households to invest in a combination of dishes for their weekly food consumption for all relevant occasions until their budget is exhausted. A fixed budget allocated to a household is imputed in the application and is adjusted in real time. Households may invest until their budget is exhausted or they can keep savings for other purposes.

**Behavioural experiments**

The FCA was subsequently used in behavioural experiments with a random sample of urban and rural households in low and middle income classes in West Bengal (IRRI 2018). A total of 14 experimental sessions were jointly implemented by IRRI and Aeon Market Research Private Limited from 28 November to 3 December 2018 in Kolkata, then from 3–4 December 2018 in Siliguri. Out of the 14 sessions, 11 were held in Kolkata and three were conducted in Siliguri.

In each session, 12 to 15 households were invited and each household comprised both husband and wife. A total of 192 households participated in the experiment. The sessions were randomly assigned to a treatment and control group. During the ‘treatment sessions’, households were exposed to a behavioural change communication (BCC) broadcast featuring nutritionist Anindita Ray Chakravarti from Maharani Kasiswari College, Kolkata. The BCC provided insights into how households in West Bengal can improve their diets and dietary patterns to improve their health status. After the broadcast, an IRRI animator explained how a participant may navigate the app (Fig. 1).

Each household received a food budget which was randomly drawn from a list of weekly food expenditures of similar households surveyed previously in the same area. This means that some households received a lower budget and others a higher budget than what they would normally have at their disposal to purchase food. The random treatment enabled an understanding of

![Fig. 1: A view of the Food Choice Application](image-url)

The application assists households in planning their optimal weekly meal portfolio under a given budget constraint.
how budget affects choice of food. Both the head of the household and their spouse were given the opportunity to plan their household meals using the app, first individually and then jointly as a couple (Fig. 2). This process enabled researchers to capture the diversity of food choices and preferences through a gender perspective and capture intra household decision making.

The app yielded interesting outcomes. As there was a budget constraint posed at the outset, households sometimes traded off taste for nutritional and health attributes, in particular after exposure to the BCC on healthier diets. Figure 3 in fact shows how much the low to middle income households spent on feeding their household for the week and how they allocated their food budgets among several food groups—starch, vegetables, non-vegetable dishes (meat, fish), fruit, pulses and dairy. The food portfolios by gender, urbanity, level of exposure to the BCC and budget constraints were compared. It is observed that men tend to spend a higher portion of their given budget on food as their amount unspent was smaller than their women counterparts’ savings. Women, on the other hand were found to invest more in non-vegetable dishes, while men invested slightly more in starchy dishes and pulses. Large differences were found when comparing urban and rural West Bengal. Rural households tended to spend more on starchy dishes, vegetables and pulses, while urban households invested more in non-vegetable dishes and dairy at the expense of vegetables and pulses.

When looking at the average food portfolios in Figure 3, we do not observe a strong overall effect of exposure to the BCC, although information on healthy diets seems to boost overall spending on food somewhat and particularly on non-vegetable dishes. Food choice seems to be largely determined by budget availability.

**Way Forward**

The interactive application is a useful tool that can help households plan their household meals. They can also be used in behavioural experiments to study diversity and drivers of food choice among the masses and to educate people about healthy food choices. The FCA is flexible and can be easily adapted to:

- other socio-economic target populations (e.g., low, middle or high income classes, populations suffering from malnutrition, indigenous
Fig. 3: Food choice of low to middle income households in West Bengal by gender, urbanity, budget constraints and level of exposure to behavioural change communication (BCC) on healthier diets.

Acknowledgement
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References
Rivers served as a flourished mode of trade and passenger routes in India in the past. However, with the advent of Railways and Roads, the Waterway mode gradually lost its steam.

Government established the Inland Waterways Authority of India under an Act of Parliament on 27th October 1986 to promote waterways again. The Authority provides for development and maintenance of infrastructure for shipping and navigation such as fairway, navigation aids, terminals and warehouse facilities, pilotage services, slipway for vessel repair, salvage assistance and DGPS connectivity to National Waterways.

In 2016, 106 new national waterways under the National Waterways Act, 2016 were declared. With the 5 existing National Waterways (NW), the addition of the new ones takes the total number to 111 in the country. Out of the newly announced waterways, development work is underway on ten of them. India has 14500 kilometres of navigable inland waterways.

Interventions on India’s National Waterways are being made as part of a wholly inclusive, economic and environment friendly efforts of IWAi and is being done in the spirit of working with the nature.

Inland Waterway Transport (IWT) is the most environment-friendly mode of transport, compared to the other surface based modes of transport. It is a non-water consumptive transportation with minimal resource depletion. As per the Inland Vessels (Prevention & Control of Pollution & Protection of Inland Water) Rules, 2016, adequate wastewater reception & treatment facility for operation of IWT terminals is being provided for waste-water generated from IWAI terminals and vessels.

It will facilitate reduction of pressure on Railway network and National Highways, relieving congestion, reduced emissions from vehicles and railway engines on non-electrified routes, thereby reducing carbon emission and project footprint.

LNG/CNG engines which are proposed to be used on inland vessels have lower noise level and air emission than diesel engines. This has less impact on ambient noise level.

Due to minimum requirement of land acquisition, there will be insignificant impact on ecology & biodiversity, agricultural activities as well as on the livelihood of the people.

Further, keeping in line with Government’s commitment towards putting in place safety mechanisms while creating such an infrastructure, IWAI has worked on putting up the highest health and safety standards for operation of terminal facilities and navigation operations and state-of-art river information systems / stations which will work similarly on the lines of Air Traffic Controls to monitor the vessel movement and water channel 24 x 7 through GPS enabled access.

IWT provides supplementary mode of transport which is cost effective, fuel efficient and environment friendly.
Transformation of agriculture through diversification and commercialisation is contributing to rural transformation and is helping reduce poverty.

Food System Transformation in India

By P K Joshi

From food deficit to self-sufficiency and then to surplus production, India is moving towards a ‘sustainable’ food system. Changing consumption patterns from cereal-based diets towards more nutrition-rich commodities and increased expenditure on non-food items are all fuelling the demand for services such as education, health and transport.
The author is Former Director-South Asia, International Food Policy Research Institute, New Delhi, India. pkj.in@outlook.com. The article should be cited as Joshi P. K., 2019. Food System Transformation in India, Geography and You, 19(24): 32-37.
The Indian food system is transforming rapidly. Both production and dietary systems are changing, driven by rising population, growing economy, expanding urbanisation, unfolding globalisation and changes in tastes and preferences. India is gradually moving towards a sustainable food system which includes both production and consumption systems. The new food system attempts to promote nutritive, safe, healthy and affordable food and to address concerns related to natural resources and environment. Production and consumption patterns are diversifying to enhance incomes and improve food and nutritional security.

In India a large section of the population is dependent on agriculture—more than 50 per cent of the total workforce depends on it for employment and livelihood (Government of India 2018). Any transformation in the production system will have consequences on food consumption and nutritional security. Indian agriculture is dominated by small and marginal farmers (with land holding < 2 ha) constituting 82 per cent of the total holdings. As the majority of them are poor and undernourished it is a significant challenge to help transform the food system. In this paper, we shall present the drivers of transformational change and its implications on poverty and nutritional security.

**Food Production System**

India has made phenomenal progress in the production of food commodities. For instance, production of foodgrains went up from 176 in 1990-1991 to 282 million tonnes in 2018-2019 (Government of India 2018). Production of pulses, which are rich in protein, went up from 14 to 24 million tonnes during the respective periods. Production of milk jumped from 54 in 1990-1991 to 176 million tonnes in 2017-2018. The corresponding increase in egg production was from 21,101 to 95,217 million, and of fish from 3836 to 12610 tonnes. Such a quantum jump in production transformed India from food deficit to self-sufficient and ultimately to surplus in most of the commodities. India is well integrated with international markets in several commodities. India’s export has gone up from 17.9 billion USD in 2009-2010 to 38.5 billion USD in 2018-2019—an increase of 115 per cent in just nine years (FAO undated). There is enormous scope of further increasing food production if right policies and adequate food safety measures are put in place. Food production system is diversifying in favour of high-value commodities—such as horticulture, livestock, dairy and fish. The commodities are now contributing to 67 per cent in total value of agricultural output (Birthal and Joshi 2006) and can be well utilised by small and marginal farmers. These labour-intensive commodities enable small and marginal farmers to use their comparative advantage of having more family labour. Moreover, with the change in consumers’ food basket, rising per capita income, integration of markets and improvement in infrastructure, the production of these high-value commodities also marks an upward swing. The absence of effective and inclusive value chains and markets, however, result in price uncertainties and lead to farmers’ distress, especially for those growing cereals in rain fed areas. In case of milk, poultry and fish cooperatives, inclusive value chains are developed. Farmers gain out of these innovative arrangements. The downside is that commodities face the risk of price volatility and losses due to their perishable nature. As per the Ministry of Food Processing, the post-harvest losses are estimated to be as high as 25-30 per cent. The food production system, therefore, is facing six key challenges:
- declining landholding size;
- tardy shift of labour from agriculture to non-agricultural sector;
- deceleration in technological gains;
- inefficient, unorganised and fragmented agri-markets;
- degradation of land and water resources; and
- increasing frequency of extreme climatic events affecting production and prices.

Transformation of agriculture through diversification and commercialisation is contributing to rural transformation and is helping reduce poverty. Relative profitability, access to markets and roads and urbanisation are key drivers for agricultural diversification in favour of high-value food commodities. Studies have also shown that diversification in favour of fruits and vegetables is more pronounced in small holdings (Birthal and Joshi 2006). The government also plays an important role in promoting diversification in favour of high-value food
commodities through investment in agricultural research and extension, effective policies (investment, subsidies, and prices), institutions (finance and marketing), and infrastructure development (especially irrigation, water, rural roads and markets). Several programmes have been launched by the Indian government to target ‘doubling of farmers incomes’ by 2022. Programmes have been framed to:
- increase yield (use of improved varieties and technologies);
- reduce costs (save water and fertiliser);
- diversify production portfolio (in favour of more remunerative commodities, especially dairy, poultry and horticulture);
- promote value-addition (sorting, grading, and processing); and
- link farmers with remunerative markets (for instance electronic-National Agricultural Market (e-NAM), characterised as one-nation one-market).

Food Consumption System
The expenditure pattern of the Indian consumer is rapidly changing. On an average a rural consumer’s expenditure on food items declined from 72.8 to 52.8 per cent between 1972-1973 and 2011-2012 (Deshmukh 2018). The expenditure on non-food items during same period increased sharply from 27.2 to 47.2 per cent. In urban areas, the expenditure on food items declined from 64.5 to 42.5 per cent during the same period. This decline in food expenditure marked a growing demand for services, education, health, transport, and household durables—scooters, cars, mobile phones, fridges, televisions, etc.

Even among food items, consumer demand is changing from cereal-based (high calorie) to high-value food (high nutrition) commodities with similar trends in rural and urban areas—though urban areas exhibited a higher intensity. In rural India the annual per capita demand for cereals declined from 182.4 kg in 1983 to 139.6 kg in 2011. The corresponding values for urban consumers were 141.6 kg and 123.5 kg, respectively (Brouwer and Joshi 2016). On the contrary, the demand for vegetables, fruits, milk, meat, poultry and fish increased during the same period. There are projections that foodgrain demand would be 277 million tonnes in 2020 and 318 million tonnes in 2030. India has already exceeded the foodgrain production of 282 million tonnes in 2018-2019 above the projected demand by 2020. Similarly, production of fruits and vegetables in 2018-19 (314.5 million tonnes) was more than the demand projected (242 million tonnes) for 2020 (Government of India 2018). The country is now facing the challenge of managing surplus food production.

The demand for processed food is also growing in India. There are projections that the Indian processed food market is expected to grow to 543 billion USD by 2020 from 322 billion USD in 2016, at a compounded annual growth rate of 14.6 per cent (Invest India). Available statistics reveal that the organised food processing industry employs approximately 1.85 million people with an investment of 32.75 billion USD and an aggregate output of around 158.69 billion USD. The Indian government has also relaxed conditions for foreign direct investment (FDI) in the food processing sector. The industry attracted about 9.08 billion USD FDI between 2000 and 2019 (DPIIT 2019). It is expected that the FDI flow will increase with growing demand for processed food commodities.

Major food-processing industries are of grains, sugar, edible oils, beverages and dairy products. A boost to the food processing industry is expected to generate employment opportunities...
and increase incomes which, in turn, will trigger demand for non-food items and contribute in economic and rural transformation.

**Implications on Poverty and Malnutrition**

Structural changes, policy support and social safety net programme have led to fall in poverty in India. The all-India Poverty Head Count Ratio (PHCR) slipped to about 24 per cent in 2015 from a high of 41 per cent in 1977-1978 and 36 per cent in 1993-1994. The Expert Group (Rangarajan Committee) estimated that 31 per cent of the rural population and 26 per cent of the urban population were below the poverty line in 2011-2012. The all-India ratio was 30 per cent (Government of India 2014). A World Bank study also revealed that poverty declined by 1.4 per cent annually during the post-reform period (post-1990) compared to 0.4 per cent annually prior to 1991. Also, within the post-reform period, poverty declined faster in the 2000s than in the 1990s (World Bank undated).

According to the United Nation Development Programme, India has lifted 271 million people out of poverty in the 10-year period from 2005-2006 to 2015-2016 (UNDP 2018). The key factors that helped in a higher decline in poverty during this period included: (i) a higher economic growth of 7-8 per cent annually, (ii) agricultural growth of around 4 per cent annually, (iii) increase in rural

The production of fruits and vegetables in India during 2018-2019 was 314.5 million tonnes, much more than the demand projected.
non-farm employment from 23.7 per cent in 1999-2000 to 35.9 per cent in 2011-2012, (iv) high growth in agriculture and rural wages, and (v) launch of several social-safety nets and social protection programme such as the National Food Security Act (consisting of Public Distribution System), Integrated Child Development Programme, and Midday Meal Scheme; and Mahatma Gandhi National Rural Employment Guarantee Act. According to projections, India will be able to achieve the Sustainable Development Goals (SDGs) on poverty by 2030 based on both global (previously 1.25 USD and currently 1.90 USD) and national poverty lines.

On malnutrition, the progress in reducing stunting, underweight and wasting was slow between 1990 and mid-2000s. Roughly 48 million out of 159 million stunted children of the world are from India (about 30 per cent). The stunting rate of children below three years, declined from 53 per cent in 1992-1993 to 48 per cent in 2005-2006 and further to 38 per cent in 2015-16 (UNICEF undated). Prevalence of anaemia among women is acute; it has fallen slowly from 53 in 2000 to 51 per cent in 2016. However, there are large interstate and intra-state variations on undernourishment (Public Health Foundation of India 2015), the problem being more acute in the eastern states of Bihar, Odisha, Jharkhand, Madhya Pradesh and Chhattisgarh.

Dietary imbalance and lifestyle are also causing obesity. According to ICMR-INDIAB, in 2015 more than 135 million individuals in India were obese (Ahirwar and Mondol 2019). In order to achieve the SDG on hunger and malnutrition, India will have to make a concerted effort in improving agriculture-nutrition linkages, women empowerment, health care, sanitation, drinking water, nutrition awareness and education by adopting the convergence approach. Steps such as ‘Transformation of Aspirational District Programme’ launched in 2018 have been initiated as an attempt to combat hunger and malnutrition.

Way Forward
Transformation of food systems is leading to improvement in food and nutritional security. Government programmes are contributing significantly in different ways to strengthen food system for nutritional security. Since India has already achieved production targets set for 2020, efforts are needed to improve distribution of nutritive food, especially among the poor and undernourished, by empowering them and improving diets for food and nutritional security. Dietary imbalances due to lack of purchasing power and education and the problem of undernourishment still persist despite surplus production of food commodities.

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By Hemalatha & S Vasanthi

Achieving country and global nutrition targets is essential for delivering the Sustainable Development Goals 2030. Despite concerted efforts of the Indian government and its partners, malnutrition persists at critical rates. Understanding the interlinkages between climate change, agriculture and nutrition can help enhance health and productivity.
The interlinkages between climate change, agriculture and nutrition in the context of achieving the sustainable development outcomes for better health and well-being are increasingly being recognised as significant and complex. Globally, in spite of having made considerable progress, nearly all countries continue to contend with the multiple burdens of malnutrition. More than 800 million people are still undernourished; over 2 billion suffer from micronutrient deficiencies; while paradoxically 1.8 billion adults are overweight or obese (Meybeck et al. 2018).

International deliberations and policy-level discussions point towards increasing food insecurity, lack of availability and access to safe food and drinking water, poor hygiene and sanitation, sub-optimal maternal and child care practices and lack of infrastructure for health care facilities as being some of the key drivers for nutritional insecurity (WFP 2012). In India, malnutrition, especially undernutrition persists despite various nutrition interventions. Among the indicators of child undernutrition, stunting and wasting have received much attention as they continue to remain at critical rates with stunting affecting nearly 38 per cent children under the age of 5 and 20 per cent affected with wasting (IIPS and ICF 2017).

The critical role that nutrition plays in achieving sustainable development has been reiterated in numerous global targets including the Global Nutrition Targets 2025 (WHO 2014) and the Sustainable Development Goals 2030 (UN 2016). The cornerstone is identified as the reduction in malnutrition that causes stunting, wasting, low birth weight as well as obesity in children under the age of 5. However, in India we continue to underachieve our development targets—young children and women being the worst affected.

Investment in public health and food security programmes needs a coherent approach with strategic investments in evidence-based research and development. Investment is also needed in building a more robust nutrition-sensitive agriculture and market infrastructure to enhance productivity while mitigating the adverse impact of climate change. Investing in more cohesive programmes with the agriculture sector, will not only boost the sector’s growth rate but will also support the government’s drive to double farmers’ incomes by the year 2022 while enhancing nutrition and food security outcomes.

The complex phenomenon of climate change involving changing weather patterns and increased incidence of extreme weather events is expected to impact food systems through multiple channels (Pingali et al. 2019). Perhaps the largest impact of climate change on nutrition indicators in India arises from the rise in average temperatures. This affects seasonality, crop yield, nutrient composition, soil health and crop production. These impact food quality, availability and access to nutritious food.

**Climate Change Impact on Nutrient Composition**

Temperature trends in India—annual and seasonal, between 1901 and now, show that India is getting consistently warmer. As per the Indian Meteorological Department (IMD) the annual mean temperature in India has increased by nearly 1.2°C since the beginning of the 20th century. The vulnerability of India to a changing climate is high because its agricultural system feeds 17.5 per cent of the world’s population with limited land and water resources (2.4 per cent of land and 4 per cent water globally available) (MoAFW 2015-16). If warming continues as per the current trends, the average daily temperatures in India can be as high as 29.1°C by the end of the century up from 25.1°C now (World Bank Data undated). Projections of climate change for the period 2020–2039 based on comprehensive surface temperature data for India for the period 1969–2005 that include daily grided maximum, minimum, and mean temperatures, indicate a possible reduction in crop yield of 4.5–9 per cent (Ross et al. 2018). Extreme temperatures and droughts may shrink farmer incomes by 4–14 per cent for key crops with the marginal farmers in rain-dependent regions being the worst-affected (World Bank Data undated).

It is estimated that by 2050, there would be
between 4 and 8 per cent to even as high as 25 per cent decrease in crop yields (Pingali et al. 2019). While the largest decreases are predicted for crops such as wheat, maize, bajra and chickpea, modest decreases are predicted for rice and sorghum. With increasing temperatures wheat and sorghum crop yields are predicted to decrease by 6 to 7 per cent in overall productivity by year 2050. Protein and micronutrient-rich nutria cereals like sorghum (millets) and coarse cereals like pearl millet and finger millet and pigeon pea, and groundnut, will be the worst-affected crops (Sharma and Pingali 2018).

Interestingly, the increase in atmospheric CO2 improves crop growth performance by increasing the rate of photosynthesis and water use efficiency. Increase in photosynthesis is between 24−43 per cent at 660 ppm CO2 while at 550 ppm a benefit of 8−10 per cent may be seen (Aggarwal 2008). But the beneficial effects of higher CO2 levels are reported to decrease with associated increase in temperature above a crop specific level and increased variability of rainfall (FAO, 2017; Pingale, 2019). Each degree Celsius increase in global mean temperature has been shown to decrease average global yields of wheat by 6 per cent, rice by 3.2 per cent, maize by 7.4 per cent, and soybean by 3.1 per cent (Zhao et al. 2017). Increased carbon dioxide (CO2) concentrations in the atmosphere has been shown to decrease micronutrient levels in rice and wheat. Wheat grains grown at elevated CO2 levels had 9.3 per cent lower zinc and 5.1 per cent lower iron. It was also observed that elevated CO2 was associated with lower protein content in rice and wheat, with a 6.3 per cent decrease in wheat and 7.8 per cent decrease in rice grains (Myers et al. 2014).

In India, a third of the population is at risk of not meeting its protein requirements (Swaminathan et al. 2012). The NSSO survey also observed decrease in energy and protein levels over time. The intake of micro nutrients particularly iron, vitamin A, riboflavin, and folic acid was grossly deficient (50 per cent of recommended daily intake) which is in keeping with the inadequate intake of micronutrient-rich fruits and vegetables.

A global model that estimates the physiological relationship between lack of food and stunting, showed that climate change will lead to an increase in moderate stunting of 1 to 29 per cent by the year 2050, compared with a future without climate change (Lloyd et al. 2011). There would be a greater impact on rates of severe stunting, which would increase by 23 per cent in Sub Saharan Africa and 62 per cent in South Asia. In India, stunting in the under 5 age group is still high with concomitant increase in overweight and obesity among children and adults (IIPS and ICF 2017).

Impact on Disease Burden Arising from Lack of Micronutrients

Consumption of vegetables, fruits, and animal source foods is needed for dietary diversity and is linked to meeting the micronutrient needs (Fanzo, Davis, McLaren and Choufani 2018). Fruit and vegetable production are labour-intensive activities and climate change induced temperature rise could lead to decreased labour productivity as a result of heat stress. The International Labour Organisation estimates that loss in productivity because of heat stress could be the equivalent of India losing 34 million full-time jobs by 2030 (ILO 2019). It is also estimated that by 2050, climate change could lead to decrease in the production and hence intake of fruits and vegetables. Food availability and accessibility as well as the nutritional quality of foods are influenced by food prices. Increasing food prices may further lower the nutritional quality of dietary intakes, exacerbate obesity and amplify health inequalities (Lake et al. 2012).

It is estimated that nearly half the soils on which food crops are grown in India are deficient in zinc, iron, manganese and copper etc. The resultant dietary zinc deficiency for instance is a predisposing risk factor for diarrhoea, pneumonia, and malaria in children; accounting for nearly 800,000 deaths and 20 per cent of perinatal mortality worldwide (Black et al. 2013). In India, diarrhoea is the third-leading cause for childhood mortality for children under 5 (Lakshminarayanan and Jayalakshmy 2015).

Way Forward

Despite the reduction in the total gross cropped area of food grains since 1951, the production of major crops during 2016-17 was 275 million tonnes—a record high. Although food production has been increasing steadily—climate change induced nutritive loss along with losses associated with post harvest activities, processing and distribution have a profound influence on food availability. Thus, food and nutrition security for the growing population is likely to be more difficult to meet in the rapidly changing future. In fact, the full implications of climate change on nutrition
particularly with respect to micronutrient status are yet to be studied. Limited access to nutrient dense crops/foods, decreased dietary diversity, together with higher accessibility to less nutrient dense crops and intake of carbohydrate rich crops with reduced intake of micronutrients have the potential to increase the prevalence of undernutrition and overweight among children and non-communicable diseases among adults.

The impact of climate change on nutrition through effects on food production and availability may be conceptualised as follows:

- Climate change impacts through increase in CO\textsubscript{2} may result in decrease in micronutrient levels;
- Paradoxically, the physiological requirements of micro nutrients may increase to deal with the climate change stress; and
- A resultant increase in intake of calories may occur with higher availability of less nutrient dense foods leading to altered body composition and resulting in diseases such as obesity, diabetes, etc. as well as micronutrient deficiencies.

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Fresh vegetables in urban areas are mostly sourced from peri-urban areas, which serves as an important source of income for peri-urban farmers.

By Mayuri Chabukdhara

HEAVY METAL CONTAMINATION IN VEGETABLES GROWN IN PERI-URBAN AREAS
There is an increasing demand for vegetables in mega cities and large towns, especially among urban consumers, mostly met by vegetable production in the peri-urban areas. However, farming practices using wastewater and large amounts of agrochemicals along with atmospheric depositions of heavy metals have resulted in contamination posing a health threat to consumers.

With a burgeoning population in India, the demand for food is increasing manifold. In addition to meeting the demand, ensuring food safety poses a major challenge. India ranks as the second-largest producer of fresh vegetables in the world after China with a total production of around 163 million tonnes per year (Ministry of Statistics and Programme Implementation 2018). The state of West Bengal is the largest producer followed by Uttar Pradesh (Fig. 1). Vegetables are a rich source of vitamins, minerals, proteins, antioxidants and fibres and constitute an important part of diet because of their dietary benefits and affordability. However, long-term consumption of vegetables contaminated with pollutants like heavy metals and pesticides residues poses a serious risk to health.

Although metals such as copper, zinc, manganese, iron, cobalt and molybdenum are required in trace quantities by plants and are necessary for the normal growth and functioning of human and animal bodies, metals such as arsenic, antimony, cadmium, lead, mercury, and tin are non-essential and toxic in nature (Hussain 2019). Heavy metal exposure can lead to severe diseases such as cardiovascular and neurological disorders, kidney and bone diseases, disruption of hormonal balance, growth impairment and abnormalities in children etc. Due to the risk associated with heavy metal contamination in food, there are national and international regulations on maximum permissible levels of these metals in food items (Radwan and Salama 2006).

Possible sources of metal contamination in vegetables in India are wastewater irrigation and sewage sludge, geological sources, mining and smelting activities, increased use of agrochemicals, irrigation sources such as polluted river water, atmospheric deposition, waste dumping and effluent discharges into open or kaccha drains etc.

Our country is undergoing a rapid shift from an agriculture-based economy to an industry and service based economy. Due to this shift there has been a massive increase in anthropogenic activities which contribute to contamination in food. The situation is further exacerbated by haphazard urbanisation and unplanned development. Fresh vegetables in urban areas are mostly sourced on a small scale from peri-urban areas, thus providing an important source of income for peri-urban farmers (Hu et al. 2013). Large volumes of wastewater generated from industrial and residential areas of these large towns flow untreated or only partially treated.
areas near industrial clusters the large volumes of wastewater generated are discharged through open or *kachcha* drains which usually do not have adequate lining or boundaries. These open drains flow directly into rivers, polluting them and making them unfit for irrigation and other domestic uses. Such practices also pollute the groundwater through percolation or leaching and contaminate the soil where vegetables and other food crops are produced. Therefore, it is important that wastewater treatments are followed rigorously with an adequate discharge system. Long-term wastewater irrigation of vegetables grown in peri-urban areas may cause potential health risks to consumers purchasing vegetables from local markets.

Plant bioaccumulation marks the concentration of heavy metals in vegetables. Several studies from different peri-urban areas of the country reveal heavy metal contamination in vegetables way above the permissible limits (Table 1). In many cases lead and cadmium levels are found to exceed the WHO safe limits, indicating a potential risk to human health.

Possible mitigation and management measures include,

- Regular monitoring of soil-vegetable systems;
-证券交易

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**Fig. 1: Vegetable Production in India (2013-14)**

![Vegetable Production in India (2013-14)](source)

*Source: Indian Horticulture Database, 2013-2014, National Horticulture Board, Ministry of Agriculture*
- Better control of the overuse of agrochemicals;
- Use of treated wastewater for irrigation;
- Proper treatment of effluents/wastewater before discharge followed by discharge in well-designed drainage systems to restrict percolation and overflow into agricultural fields;
- Remediation through low-cost technologies/ecotechnologies in highly contaminated fields or avoidance of cultivation in such fields;
- Restriction on waste dumping in open fields; and,
- Filtration/treatment system in industrial units releasing air pollutants containing heavy metal pollutants.

**Way Forward**
There is currently a lack of awareness about food safety related to heavy metals and other such contaminants in raw vegetables. Farmers in the peri-urban areas should be informed about the harms of using sewage and industrial wastewater for irrigation. In addition, consumers need to be made aware of the risks of consuming contaminated food. In India the Food Safety and Standards Act, 2006 is the overarching authority that consolidates laws related to food safety standards and gives statutory powers to the Food Safety and Standards Authority of India (FSSAI). However, this Act is not enough to prevent heavy metal contamination. Collaborative efforts by government and non-government agencies and the public at large (including farmers) can address

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**Fig. 2: Sewage Generation and Treatment Capacities in India**

the challenge of food contamination. Further, regular monitoring and availability of sufficient scientific data may help prevent heavy metals contamination in vegetables and other food crops.

Reference


<table>
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<tr>
<th>Vegetables</th>
<th>Village/City</th>
<th>Cu</th>
<th>Cr</th>
<th>Pb</th>
<th>Cd</th>
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<td>45.18 ± 3.11</td>
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<td>12.44 ± 0.63</td>
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HEIRLOOM RICES
A REPertoire OF GENETIC WEALTH

By Ahmed Regina, Cecilia Acuin & Nese Sreenivasulu

With 3000 genomes of rice varieties now sequenced, plant breeders are identifying new genes for traits such as better grain quality, yield, nutrition and biotic and abiotic stress tolerance. Working with partners, International Rice Research Institute (IRRI) and the Centre of Excellence in Rice Value Addition (CERVA) at IRRI-SARC are prioritising this research.
Heirloom rice varieties are embedded in the social, cultural and religious lives of many Asian societies due to their unique features and medicinal and nutritional virtues.
Rice is an unparalleled commodity in human civilization. It has consistently served as a food from the Neolithic era to the contemporary world. With the Green Revolution, rice yield doubled during 1961-1985 and created novel rice value chains for capturing export market opportunities and its sustainable production for urban domestic markets. Rice is a staple food that provides nearly 42 per cent of the calories for more than half the people of the world. Distinct genomic and morphological features underpin the broad taxonomic classification of rice into 20 wild rice and two cultivated rice classes, the *Oryza sativa* (Asian) and *Oryza glaberrima* (African) (Chang 1987). Spread across many geographies, naturally adapted landraces occur within each of the major subspecies of Asian rice— indica, japonica and javanica (an alternate nomenclature for tropical japonica). Significantly, many of these offer immense health and nutritional benefits.

The ability of an organism to adapt to the changing environment while retaining grain quality and nutritional benefits depends on the magnitude of the genetic variation it carries. Insufficient genetic variation makes a species prone to extinction. Genetic diversity helps maintain genetic gain for traits that influence productivity and resistance to pests and diseases. Thus genetic diversity is the cornerstone of any plant improvement programme. Nucleotide sequence variation within the genetic makeup is exploited by plant breeders to develop varieties with superior traits like higher yield, preferred grain quality and tolerance to biotic and abiotic stresses. Recently, 3000 rice genomes of landraces and pre-breeding material were sequenced (Wang et al. 2018) to identify novel genes associated with various agronomic traits including grain quality and nutritional quality (Anacleto et al. 2019).

Landraces come about through domestication of wild rices via traditional farming practices and have clearly identifiable and unique phenotypes while remaining genetically more diverse than most modern rice varieties (Dedeurwaerdere and Hannachi 2019). The multitude of traditional rice landraces provide a vast reservoir of genetic diversity for the plant breeders to work with. While the Green Revolution introduced high yielding, fertiliser responsive and dwarf rice varieties to meet increasing food demand, many farmers still preferred to grow traditional landraces for subsistence cultivation under marginal soil and environmental conditions. Furthermore, in many Asian societies, traditional landraces are embedded in the social, cultural and religious lives of the people due to their unique features, medicinal values and nutritional virtues.

### Treasures of Heirloom Rices

Many heirloom varieties and speciality rices are believed to possess distinct aromas, flavours and textures and nutritional benefits. Heirloom specialty rice value chains offer enormous potential to increase smallholder farmers’ income by increasing access to high value domestic and export markets. Many South Asian and African smallholders still grow heirloom cultivars as opposed to modern high-yielding ones, as they fetch premium prices for their unique taste and aroma.

Traditional rice varieties differ from each other in growth duration, photoperiod sensitivity, grain size, shape, colour and endosperm properties. The small and medium grain aromatic rice varieties are regarded as a separate class of non-basmati aromatic rice, which possess unique quality characteristics. Uttar Pradesh and the eight North Eastern states—Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura, are home to some of the finest quality scented rice varieties. While the long-grained basmati rice is grown in Punjab, Haryana, western Uttar Pradesh and Uttarakhand, the small and medium grained scented rice varieties are distributed all over Uttar Pradesh.

‘Kalanamak’, the scented black pearl of Uttar Pradesh, is a popular variety from eastern Uttar Pradesh. Other well known, traditional rices include, Chakhao, Tai and Joha—originally from Assam, grown in upland and lowland ecologies in the states of Assam, Manipur and Mizoram. Other popular traditional aromatic rice cultivars include Krishna Bhog, Brimphul, Kalamunia and local basmati which are grown in Sikkim and Tripura. Navara, Kunjinellu, Gandhkasala and Jeerakasala from Kerala and Karunguruvi, Karuppu Kavuni and Kappakar are some traditional landraces from South India. Despite the low yields and lack of promotion, the farmers...
still grow heirloom cultivars because they are valued by local consumers and fetch a premium in local markets.

Systematic characterisation of these traditional varieties for grain quality and nutritional traits are yet to be conducted in India despite it being home to thousands of rice landraces. India is currently the world’s leading rice exporter, generating 4.71 billion USD during 2018-19 fiscal year (Agricultural Market Intelligence Centre 2018-19). However, the country’s export is restricted to only high quality basmati and long-slender grain market segments. As of now the global scented-rice market is growing at 12 per cent per annum (Mishra 2015). However, India appears to have very few aromatic varieties to offer in this market other than basmati.

### Food and Nutrition Security in India

Agriculture today faces the complex challenges of assuring food security and nutrition needs and reducing rural poverty and doing so in a safe and sustainable way. In India, foodgrain production has seen an impressive five-fold increase in the last half century with India becoming a net food exporter. GDP has doubled in a decade from 1.2 trillion USD in 2007 to 2.6 trillion USD in 2017. Extreme poverty has dropped from 46 to 13.4 per cent over the same period (World Bank 2019). However, the rates of improvement in food security and undernutrition are inconsistent with these productivity gains. Furthermore, gains within the country are highly uneven.

India is still home to about a quarter of the world’s undernourished people. Deficits in energy intake (relative to requirement) are higher in rural areas, in poorer and larger households, and among women. However, access to the public distribution system has been found to have a significant positive effect on calorie and protein intake, largely through the access to cereals (Kumar et al. 2012).

Although child stunting rates have declined substantially from 49 to 38 per cent, and the percentage of underweight children has been reduced by 35 per cent during 2006-2014; there are large inter-state differences. Nearly 1 in 2 children under the age of five are stunted in Uttar Pradesh, Bihar and Jharkhand, while the figure is only 1 in 4 in Goa and Kerala. Rates of anaemia, an important marker of micronutrient deficiencies and poor child development, are even more staggering. Almost 70 per cent of 6-59 month olds are anaemic, as are more than half of the 15-49 year old women (Raykar et al. 2015).

At the same time, increasing prosperity has exacerbated problems of overweight and obesity and non-communicable diseases such as diabetes among urban and emerging mid-to-upper income populations. More affluent southern states such as Goa, Tamil Nadu and Kerala, as well as highly-urbanised Delhi have overweight/obesity (BMI > 25) prevalence of over 28 per cent (Ahirwar and Mondal 2019), while corresponding rates for poorer states like Bihar and Jharkhand are less than 12 per cent (IIPS 2017). The prevalence of overweight adults above 20 years of age has more than doubled from 9 per cent in 1990 to 20.4 per cent in 2016, with every state experiencing this increase (India State-Level Disease Burden Initiative Diabetes Collaborators 2018). About 26 per cent of diabetes disability-adjusted life-years (DALYs) in India are attributed to being overweight—and diabetes rates are the highest in Kerala, Tamil Nadu, Delhi, Goa and Punjab.
From Value Addition to Nutritionally Sensitive Agriculture

The co-existence of undernutrition and overweightedness and obesity (the double burden) is a challenge that necessitates multifaceted strategies and delivery mechanisms. Several regions of the world have transitioned to a situation where non-communicable diseases are the main causes of poor health. Increasing incidences of diet-related health conditions such as type II diabetes, cardiovascular dysfunctions, bowel disorders, several types of cancers and symptomatic micronutrient deficiencies have caused agricultural and food scientists to look to developing health-promoting food crops and food products. Rice, being a major staple food in Asia, can play a major role in delivering nutritional and health benefits. These include landraces used for treating a number of ailments such as fever, diarrhoea, ulcers, wounds and burns. Navara from Kerala, Laicha from Chattisgarh, Bhat moori from Tamil Nadu and Black Rice from Manipur are just a few such varieties that claim to possess medicinal benefits (Savitha and Kumari 2016). With the increasing rates of cancer around the world, attention has turned to identifying dietary sources of tumour suppressors. This has brought several rice landraces into limelight. Ample variability in phytochemicals with antioxidant activity such as anthocyanins, phenolic acids, flavonoids and Vitamin E is found to be enriched in pigmented rather than non-pigmented landraces (Rajendran et al. 2018) and the therapeutical and nutraceutical values of the former are coming to light. For instance, human derived carcinoma cell line studies indicated the chemopreventive potential of brown rice extracts on breast and colon cancer cells (Hudson et al. 2000).

Biofortification of rice requires donor lines with enhanced accumulation of target micronutrients such as zinc and iron in the grain. When the accumulation is mostly in the outer aleurone layer of the grain, it results in a high micronutrient brown rice. When these nutrients accumulate in the inner white endosperm tissue, it results in micronutrient enriched milled or polished rice, which is widely preferred. A range of micronutrients is observed in traditional landraces compared to modern varieties. They have the potential to be used as donor lines. Application of new technologies such as transcriptomics on landraces has revealed exploitable genetic variability in the expression of metal ion transporters that controls localisation of nutrients in the grain (Neeraja et al. 2018). Such knowledge derived from landraces will shed light on the mechanisms through which we can enhance storage of these nutrients in the endosperm which is essential to improving the nutritional value of milled rice. Several important genetic regions have been identified to enhance zinc content in milled rice. Biofortified rice lines enriched with zinc content of rice grain have been released in Bangladesh, Indonesia and India—for instance DRRdhan 45, BRRIdhan 72 and IR Nutri Zinc. To address the needs of people suffering from obesity and type II diabetes, the glycemic index genetic regions have also been identified in rice (Anacleto et al. 2019).

Conservation and Value Exploitation

To overcome the challenges faced by traditional rice landraces and better exploitation of their value, International Rice Research Institute (IRRI) has undertaken the task of characterising gene bank collections of traditional rice accessions for their superior quality and nutritional properties. IRRI established high-throughput phenotyping methods to screen milling quality, cooking quality and nutritional quality of traditional landraces as well as breeding populations. To specifically cater to the research, service and capacity building needs of South Asia, the South Asia Regional Centre (IRRI-SARC) at Varanasi was set up in 2018. The Centre of Excellence in Rice Value Addition (CERVA) at IRRI-SARC is committed to supporting the interests of farmers and regional and national authorities in safeguarding local landraces, popularising the landraces through authentication of their virtues, enhancing their area under cultivation, and bringing greater economic returns to farmers. Scientific substantiation of traditional knowledge on grain quality, medicinal properties and nutraceutical values of landraces is an area of research that CERVA has prioritised. Following the establishment of a state of the art facility for research on grain quality, nutritional quality and food safety, CERVA is progressing with comprehensive grain quality profiling of
traditional landraces collected from various regions of India.

Way Forward
Acceptable grain quality is an indispensable requirement for an improved rice variety. Defining grain quality of rice is not straightforward because it depends on the perceptions of target consumers who may differ in what they value. The wide variability in nutrient composition and grain quality existing within landraces allows potential responses from increasing nutrient density (through higher micronutrient contents) to lower glycemic indices (for diabetics) coupled with consumer specific acceptable grain quality.

References
**Term Talk**

A helpful glossary of important terms related to nutrition, food systems and agronomic and policy interventions are presented before you. These terms will help you navigate this issue of G’nY and understand the implications of better agricultural practices and food habits.

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
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<tbody>
<tr>
<td><strong>Anthropogenic Activity</strong></td>
<td>Anthropogenic activities mean human activities which affect nature. These activities cause changes in nature which would not have been possible without human influence.</td>
</tr>
<tr>
<td><strong>Landrace</strong></td>
<td>A landrace is an agricultural plant species that has been grown in a specific local environment over a long period of time and has adapted to the environmental conditions of the area of cultivation.</td>
</tr>
<tr>
<td><strong>Bio-fortification</strong></td>
<td>Bio-fortification is the process by which nutrient levels in crops is improved during plant growth rather than during processing of the crops.</td>
</tr>
<tr>
<td><strong>Micronutrient</strong></td>
<td>The term micronutrient is used to describe vitamins and minerals as opposed to macronutrients which include proteins, fats and carbohydrates. The human body requires smaller amounts of micronutrients relative to macronutrients.</td>
</tr>
<tr>
<td><strong>Family Food Basket</strong></td>
<td>Family food basket is a term for a set of food items used by a population which is sufficient to adequately cover the energy requirements of each member of the family.</td>
</tr>
<tr>
<td><strong>Food Deficit</strong></td>
<td>Food deficit is defined as the intensity of food deprivation in a country. Intensity of food deprivation is the number of people whose dietary intake falls short of the minimum requirement.</td>
</tr>
<tr>
<td><strong>Stunting</strong></td>
<td>Stunting is the impaired growth and development of children mostly due to poor nutrition. 38 per cent of Indian children younger than 5 years of age are stunted.</td>
</tr>
<tr>
<td><strong>Sustainable Development Goals</strong></td>
<td>The Sustainable Development Goals (SDGs) are a set of 17 goals and 169 targets adopted by all United Nations Member States in 2015 as a universal call to action to end poverty, protect the planet and ensure peace and prosperity for all people by 2030.</td>
</tr>
<tr>
<td><strong>Groundwater Depletion</strong></td>
<td>Groundwater is water that seeps into the ground and accumulates underneath. Groundwater depletion is the result of long-term water-level declines caused by sustained and unrestrained groundwater pumping.</td>
</tr>
<tr>
<td><strong>Wasting</strong></td>
<td>Wasting, or low weight for height, is a result of malnutrition. It is a strong predictor for mortality among children under the age of 5. 20 per cent of Indian children under 5 years of age suffer from wasting due to acute undernutrition.</td>
</tr>
<tr>
<td><strong>Green Revolution</strong></td>
<td>The Green Revolution is an umbrella term for a number of successful agricultural experiments in the 1960’s that drastically improved agricultural production, especially in developing countries.</td>
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