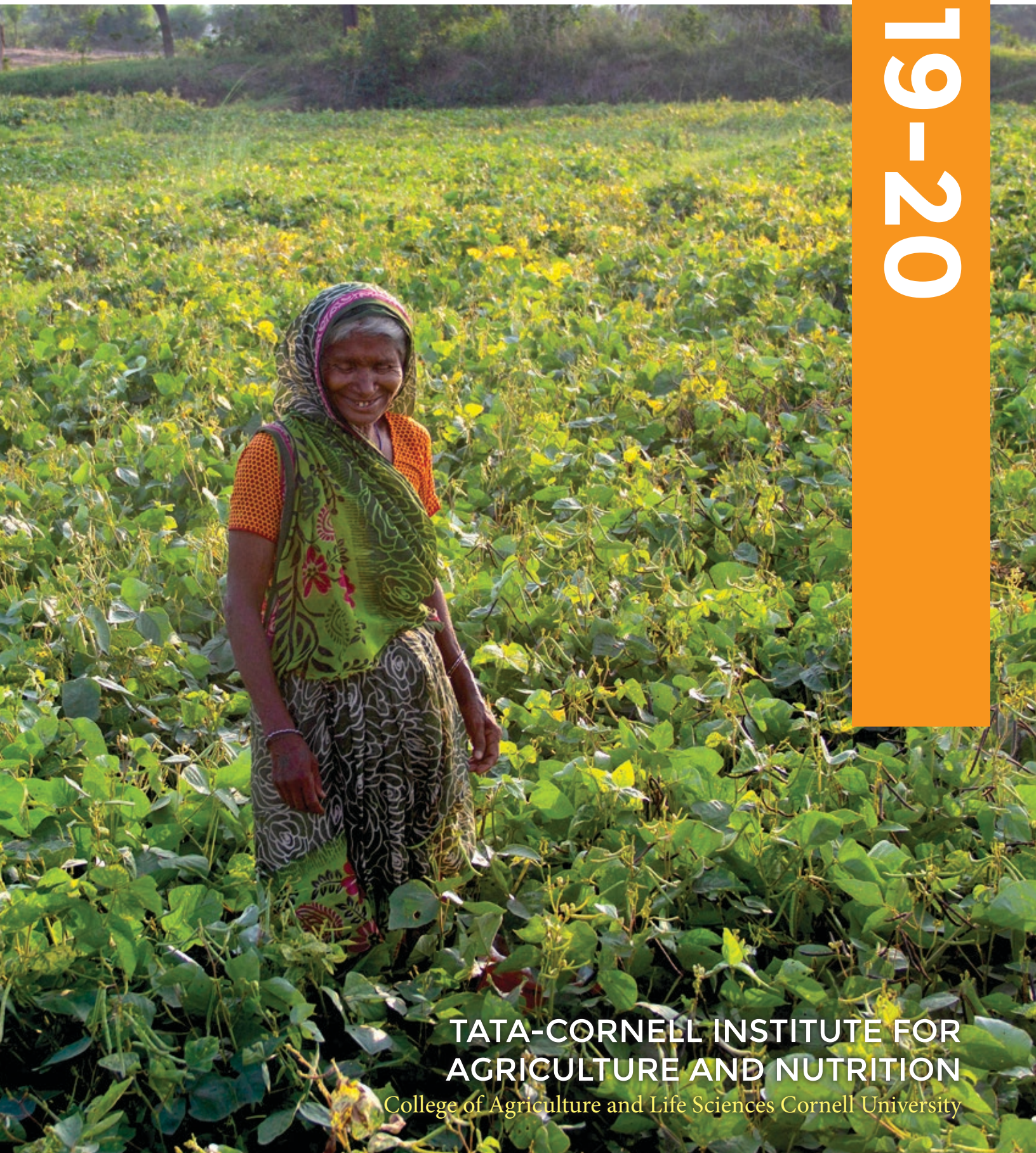


# TATA-CORNELL INSTITUTE ANNUAL REPORT

2019-20



TATA-CORNELL INSTITUTE FOR  
AGRICULTURE AND NUTRITION

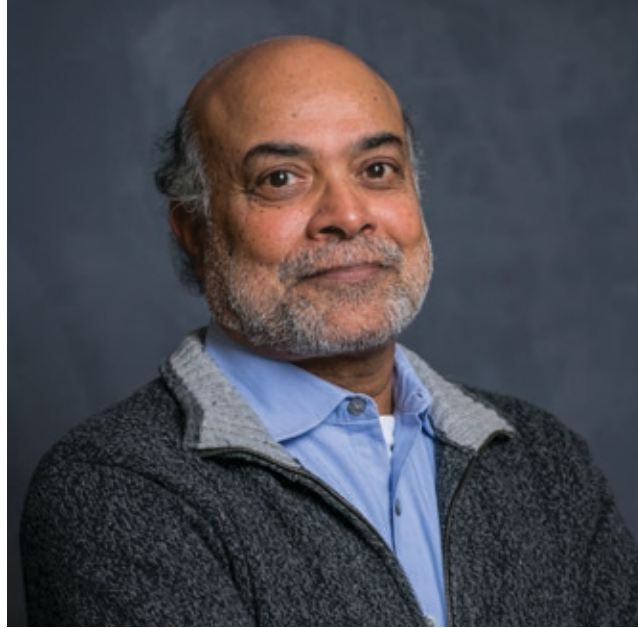
College of Agriculture and Life Sciences Cornell University



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## FROM THE DIRECTOR



The Tata-Cornell Institute for Agriculture and Nutrition (TCI) is now seven years old. I am delighted with the progress that we have made in this short period of time to build a multidisciplinary research program that is focused on addressing the chronic problems of malnutrition and rural poverty in India, and to emphasize the central role that agriculture and food system diversity plays in alleviating these problems. Our research team consists of 14 PhD students from six departments across Cornell, four master's students, and four postdoctoral associates, as well as 12 other research staff members. We are looking forward to seeing four PhD candidates, from four departments in the College of Agriculture and Life Sciences and the College of Business, graduate in 2020.

The year 2019 has been a watershed year for the release of high-quality and high-impact publications from TCI. We authored one book, five peer-reviewed journal articles, and five book chapters during the year. Our book, *Transforming Food Systems for a Rising India*, published by Palgrave MacMillan, has been extremely well received by the academic and development policy communities in India and in major donor countries. By April 2020, the free electronic version of the book had been downloaded over 40,000 times, and the book has had a significant impact on policy discussions on agricultural and food systems contributions to reducing malnutrition

in India. Our book discusses the processes, policies, institutions, and technologies needed for transforming India's food systems. We argue in favor of moving away from India's traditional focus on increasing the production of staple grains, especially wheat and maize, toward a food system that promotes diversity and nutritional quality. Improved accessibility of more nutritious foods can simultaneously address the chronic and persistent problem of undernutrition, as well as the emerging epidemic of obesity. The book can be downloaded for free at [tci.cornell.edu/food-systems-book](http://tci.cornell.edu/food-systems-book).

In 2019, we also made major contributions to the gender and nutrition literature through three TCI publications based on intensive fieldwork and rigorous empirical analysis. We showed a causal link between women's empowerment and their nutritional status, as measured by iron deficiency. We also showed that empowered women tend to enhance their nutritional status (and that of their households) through more judicious market purchases of diverse foods of higher quality and with higher nutritive values. Finally, we provided a field-based critique of the Women's Empowerment in Agriculture Index and provided guidance for its application in the Indian context. These papers can be accessed at [tci.cornell.edu/research/publications](http://tci.cornell.edu/research/publications).

I am delighted with the progress that TCI has made over the past seven years, and I am excited about the contributions that we are poised to make over the coming years. I am particularly excited by our role in enhancing the academic and development practitioner talent pool through the high-quality graduate students and postdoctoral associates that TCI has had the honor to support and mentor.

**Prabhu Pingali**  
Founding Director, TCI





# OVERVIEW

TCI is a long-term, multidisciplinary research initiative focused on creating and assessing innovative, food systems-based approaches to reducing poverty and improving nutrition and livelihoods in the developing world.

Based at Cornell University in Ithaca, New York, with offices in Mumbai and New Delhi, India, TCI blends high-quality academic research, field-based projects, and policy analysis to generate and share knowledge relevant to policymakers, research institutions, and development agencies.

### ADVANCING RESEARCH, GENERATING EVIDENCE, AND INFLUENCING POLICY

Since its founding in 2013, TCI's mission has been to produce high-quality research to aid evidence-based policymaking. Using a multidisciplinary, food systems-based approach, TCI's diverse team brings together researchers and scholars from different academic disciplines, ranging from applied economics and sociology to food, plant, and soil sciences. TCI's main agenda has been to devise innovative solutions to spur agricultural development and address the stubbornly persistent problem of malnutrition.

With funding from the Bill and Melinda Gates Foundation, TCI expanded its work in 2015 through Technical Assistance and Research for India Nutrition and Agriculture (TARINA), a project directed at promoting a nutrition-sensitive food system in India. Working with a consortium of partners led by TCI, TARINA implements agriculture and nutrition programs to resolve challenges of implementation, generate evidence, and build capacity of partner institutions.

By disseminating findings through policy briefs and peer-reviewed publications, as well as policy dialogues, workshops, and roundtable events with state governments and other stakeholders, TCI advocates for a more nutrition-sensitive food system and the refocusing of agricultural policy on improved nutrition outcomes. Through TARINA, TCI has published 14 policy briefs and organized more than 10 policy-oriented events on topics ranging from small-farm aggregation to the effects of climate variability on agriculture.

In 2019, TCI researchers authored *Transforming Food Systems for a Rising India*, which explores challenges and opportunities to achieving a nutrition-secure future. The book has been downloaded more than 40,000 times and was well received by the Indian food policy community, prompting policymakers to consider the value of a food systems-based approach that links economic growth, agricultural production, and nutrition in India.

### WIDE-RANGING AREAS OF FOCUS

TCI's current work focuses on three broad areas that relate to various, interrelated aspects of food systems: (1) institutional support systems for agricultural development, such as research and development for scientific innovations; (2) social interventions that improve individuals' access to and utilization of nutritious food; and (3) data systems, information and communications technology (ICT), and other technological innovations that enable and promote better decision-making.

In the realm of institutional support systems for agricultural development, TCI researchers and scholars are developing **scientific innovations for nutrition-sensitive food systems**, bridging gaps between research and implementation, through awareness-building, technology, and knowledge transfer. For example, TCI researches and promotes the awareness of holistic soil health, including studying the links between soil health, land management, and cropping systems, as well as soil health's impact on plant and human nutrition.

TCI's work in this area also focuses on linking farms to **value chains and markets**, which is essential for improving incomes and welfare. Addressing smallholder hindrances to market access is essential for commercialization. TCI is embarking on a new two-year study to assess challenges facing farmer producer organizations in India and Mexico, as they seek to take advantage of rising consumer demand for diverse agricultural products.

TCI's work on social interventions to improve access to and utilization of nutritious food is wide ranging, encompassing efforts around women's empowerment; food safety and loss;

water, sanitation, and hygiene (WASH); and food fortification. **Gender and nutrition** are inextricably linked in developing countries like India Agriculture is increasingly the domain of women, and women's empowerment at the community and household levels helps to ensure positive nutritional behaviors and improved intrahousehold access to food. TCI is currently examining the impact of male internal migration on women in agriculture, and in the past year, TCI researchers have made several notable contributions to the academic literature exploring the relationship between women's empowerment and nutrition outcomes.



Field-based research is a core component of the TCI program. (Photo courtesy of Jocelyn Boiteau)

**Food safety, food loss, and WASH** are crucial, interrelated factors affecting nutrition. TCI's research in this area includes community-based strategies to mitigate mycotoxin contamination of crops and efforts to understand the extent of quantity and quality food loss in Indian tomato value chains. To assess the effects of access to clean drinking water, TCI partnered with AguaClara to install piped water systems in Indian villages.

TCI's work on **food fortification and biofortification strategies** includes developing

novel sources of micronutrients for fortification, creating new fortified foods for vulnerable demographic groups, and promoting community-based fortification programs. Efforts in this area include fortifying flour with iron derived from microalgae and using cutting-edge food technology to develop nutritious puffed snacks for infants and toddlers. TCI introduced vitamin A-rich orange-fleshed sweet potatoes in several Indian villages and assessed the impact of educational workshops about vitamin A on household decisions to grow or purchase the crop. TCI's Sfurti project enlisted women's self-help groups to raise awareness of the importance of micronutrients and to sell simple, home-based fortification sachets to their community members.

To ensure that policymaking and development strategies around food systems are built on a foundation of solid evidence, TCI works to build and improve data systems and take advantage of technological innovations. Investing in **policy tools, data systems, and institutions** is crucial for supporting further research. TCI partnered with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) to expand and improve a database that is related to Indian food and agriculture systems. Also, TCI is developing metrics to measure the institutional capacity of national research centers, as part of the US government's Feed the Future initiative.

**ICTs and other technological innovations** can be important levers for spreading useful messages and improving livelihoods. TCI promotes the development and use of digital tools for resource management and soil mapping, and for designing virtual communities of best practices and developing behavior change communication strategies for positive nutrition.

### INDIA AND BEYOND

TCI is consolidating a significant body of evidence and experience around effective food systems-based strategies for improving nutrition and livelihoods in India. Due to its regional diversity, lessons from India may prove useful in other locations. Looking forward, TCI is exploring how developing countries in South Asia and sub-Saharan Africa can utilize TCI's body of work to improve nutrition outcomes in these regions.



# RESEARCH HIGHLIGHTS

## RESEARCHER SPOTLIGHT

*Kavya Krishnan*  
*TCI Scholar and PhD Candidate, Soil and Crop Sciences*



TCI scholar Kavya Krishnan is a PhD candidate in the field of soil and crop sciences. She works with India-based agricultural universities, like the Dr. Rajendra Prasad Central Agricultural University in Bihar, to advance the country's understanding of soil health.

Krishnan believes the study of soil health will help give more focused direction to overall food policy and food security.

"It's the foundation of a healthy production system but often gets ignored for more obvious fixes," she says. "Studying agricultural systems is especially important to me because it affects every single person on the planet and is of utmost importance to our continued survival."

While she enjoys working in a laboratory, Krishnan also enjoys fieldwork and interacting with people from different walks of life. The first focus group she held with farmers in Bihar was particularly moving for her.

"Having grown up in Mumbai, my work had been primarily academic till then," she says. "It was during that interaction that I fully realized the impact my work could have."

Prior to joining TCI, Krishnan received a joint master's degree in soil science and agroecology at the University of Wisconsin–Madison, where she examined the effect of cover crop management on mineralizable nitrogen. She earned a bachelor's degree from the SUNY College of Environmental Science and Forestry in environmental biology.

When she is not working in the lab or out in the field, Krishnan enjoys reading and writing creative fiction, especially murder mysteries and fantasy novels. She is also involved with the Cornell University Graduate and Professional Student Assembly and works with other campus organizations on diversity and inclusion issues.

## SCIENTIFIC INNOVATIONS FOR NUTRITION-SENSITIVE FOOD SYSTEMS

### DIRT MATTERS: UNDERSTANDING SOIL HEALTH IN BIHAR

Productive farms cannot exist without good soil. Yet, traditional views of soil health—the capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans—have focused narrowly on chemical properties, ignoring physical and biological aspects. Soils are dynamic and complex living systems and a thorough understanding of the interactions between the chemical, physical, and biological factors is required to determine their long-term resilience. TCI is working with several partners in India to raise awareness and build capacity to improve soil management, with a comprehensive view of soil health.

Research has shown that improving soil health can increase farm yield, as soil degradation is a major reason for the gap between typical and attainable yields. This is especially important in a state like Bihar, where extreme poverty and an immense vulnerability to climate change have hampered the state's ability to realize its yield potential and achieve food security. Although the state has made strides in agricultural growth over the past couple of years, the agricultural productivity of its two main crops, rice and wheat, are well below the national average. Decreasing use of farmyard manure and increasing use of chemical fertilizers has led to deficiencies of micronutrients, like zinc and boron, in the soil.

Led by scholar Kavya Krishnan, TCI is examining the links between soil health, land management, and cropping systems, as well as their effects on yield, by using a comprehensive assessment of soil health that measures 15 soil properties, representing physical, biological, and chemical processes. To better understand these complex systems, TCI has partnered with the local and state governments, Dr. Rajendra Prasad Central Agricultural University (DRPCA), the Cereal Systems of South Asia (CSISA), the Borlaug Institute of South Asia (BISA), and the Environmental Defense Fund (EDF). These

partnerships allow for integrating research and pooling of data and resources.

Cornell University and DRPCA have built a state-of-the-art soil health lab, housed at DRPCA. While state soil labs are mostly equipped to run chemical tests, this new lab is capable of testing soil's physical and biological features as well.

Preliminary results from Krishnan's long-term study suggest that, on average, indicator values for soil samples from Bihar are lower than that of soil sampled in the United States, requiring an adapted interpretation framework. Differences in fertilizer application do not appear to influence any of the indicators, but additions of crop residue and organic amendments appear to increase labile carbon and soil protein. Labile carbon is an energy source for microbes that help maintain a healthy soil food web, and protein plays an important role in the storage and release of organic nitrogen from the soil.



*A man tills soil on small plot of land in Uttar Pradesh. Soil health is an important factor in agricultural productivity. (Photo by Kathryn Merckel)*

This research, along with further farm trials, will provide an improved understanding of nutrient and carbon flows in Bihar. Much existing knowledge of nutrient-use dynamics in India comes from university and governmental trials that only consider a single crop and are limited to a single resource at a time, failing to account for interactions between nutrients, livestock, additional inputs, productivity, and external factors. A true understanding of nutrient and carbon flows in the region requires examining the interaction effects between nutrient resources within crop and livestock systems.

Further activities will include the exploration of low-cost, quick methods of predicting soil health using mid-infrared spectroscopy. These methods can greatly improve the speed and efficiency of data collection in India, where the need for complete and accurate information to drive policy is crucial.

### THE NUTRIENTS BENEATH OUR FEET: UNDERSTANDING THE SOIL-HUMAN HEALTH CONNECTION

You are what you eat. It's a commonly heard saying that synthesizes the role nutritious foods play in human health. Dig a little deeper, and you might update the old adage—at least as far as plant-based foods are concerned—you *are* the soil.

As part of the TCI Soil Health Project, scholar Fatma Rekik is leading a study to help understand how soil health affects human health through nutrition. The soil-to-human nutrient transmission has rarely been studied on a household level, and when it has, studies have looked at only one or two minerals. TCI's approach is holistic and comprehensive, addressing the physical, biological, and chemical attributes of soil, including 22 different minerals.

Rekik's study in Jharkhand, India, examines soil-to-human mineral transmission through rice. Rice is the most consumed staple in Jharkhand, one of the



Two women mill rice by hand in order to remove the inedible husk and bran layers. (Photo by Fatma Rekik)

poorest states in the country and with high rates of malnutrition across income levels.

Rekik collected and analyzed 43 samples of soil, rice, and human hair (a bioindicator of long-term nutrition) from rice-subsisting communities across seven districts in Jharkhand. The levels of minerals, such as iron and arsenic, were tested to assess their associations across all three mediums. Physical and biological indicators in the soil, such as available water capacity and respiration, were also tested. The study revealed that soil health is reflected

**“Our work in Jharkhand has resulted in better awareness of the importance of soil health. This is especially pronounced in rural subsistence communities.”**  
 - Fatma Rekik

nutritionally in both rice and humans. The associated benefits of physical and biological soil health for humans includes increased availability of essential nutrients like manganese, calcium, and cobalt, as well as decreased presence of potentially toxic elements like lead.

Rekik also interviewed 43 female heads of household about their dietary, health, farming, and cooking practices to assess their effects on soil, rice, and human health. Results indicate that the type of grazing livestock allowed on farm plots after harvest has a significant impact on soil health, specifically regarding levels of cadmium and molybdenum. Rice varieties, sources of cooking water, and cooking method each affect human nutrition, while landscape positions and soil texture have a significant effect on rice nutrition. For example, medium-textured soil appears to have an optimal capacity for holding onto minerals while also making them available to plants.

The results of this study are insightful for the betterment of human nutrition in malnutrition-afflicted areas. They show that healthy soil yields important nutritional benefits to humans by increasing the availability of essential minerals, and that farming and cooking methods play an important role in ensuring that those minerals make it to people's plates for consumption. Further study of those methods is warranted to maximize the benefits of healthy soils for human nutrition.

**CORRELATION BETWEEN PHYSICAL/BIOLOGICAL SOIL HEALTH AND MINERAL CONTENT IN HUMAN HAIR AND RICE**

	HAIR							
	Wet Aggregate Stability	Available Water Capacity	Soil Surface Compaction	Soil Subsurface Compaction	Organic Matter	Active Carbon	Soil Protein	pH
Aluminum					-0.35		-0.33	
Barium	-0.34							
Calcium		0.47						
Cadmium								
Cobalt	0.42					0.34		
Chromium							-0.313	
Copper								
Iron							-0.34	
Potassium		-0.4			-0.43			
Magnesium					0.4			
Manganese	0.42							
Sodium								
Nickel								
Phosphorus								
Lead								
Sulphur								
Strontium								
Titanium					-0.4		-0.34	
Vanadium								
Zinc								
	RICE							
	Wet Aggregate Stability	Available Water Capacity	Soil Surface Compaction	Soil Subsurface Compaction	Organic Matter	Active Carbon	Soil Protein	pH
Barium		0.31					0.4	-0.34
Chromium								
Potassium				0.39	0.33	0.36		
Manganese								
Sodium								-0.37
Nickel		0.36						
Phosphorus			0.31					0.31
Lead		-0.3			-0.36		-0.49	
Sulphur								
Phytate Iron				-0.41				

Pearson's correlation coefficients between physical and biological soil health indicators and mineral composition in hair and rice. Each colored cell represents a significant correlation coefficient ( $p < 0.05$ ). Orange indicated a negative relationship and green indicates a positive relationship. Blank cells indicate insignificant correlations.

### VALUE CHAINS AND MARKETS

#### AGGREGATION MODELS AND THE FUTURE OF SMALL FARMS

As the world's population increases and the demand for diverse agricultural products rises, small farms have an opportunity to play a big role and reap many benefits, if they are able to join together to form farmer producer organizations (FPOs) to increase their aggregate size. With

support from the Walmart Foundation, TCI is embarking on a two-year study to assess challenges facing FPO models in India and Mexico.

Nearly 90% of the 570 million farms around the world are small, of less than two hectares in size. Most of these farms are in low- and middle-income countries, where a substantial amount of the population are dependent on the agricultural sector. Because size determines economies of scale, small farms have an inherent disadvantage in accessing product markets, credit, management inputs, and technology. These disadvantages have kept small farms from leveraging income-growth



## RESEARCHER SPOTLIGHT

**Fatma Rekik**  
TCI Scholar and PhD Candidate, Soil Science



A National Science Foundation fellow and PhD candidate in the field of soil science, TCI scholar Fatma Rekik is an important part of TCI's Soil Health Project. Her work focuses on soil health's impact on human nutrition.

Rekik's primary research interest is soil health's effect on the socioeconomic, nutritional, and qualitative dimensions of food and agriculture in developing nations. She believes that many

of the issues that the world faces—from climate change to mass migrations—can be traced back to, and perhaps, solved by soil health.

"Soil is the foundation of life," Rekik says. "It brings communities together, both literally and figuratively. For me, soil *is* life."

Rekik decided to study soil health after spending time in Cornell University's Soil Health Laboratory and working with the US Department of Agriculture Natural Resource Conservation Service in Gainesville, Texas. "At that time, it dawned on me how wondrously powerful and crucial soils are," she says.

The soil health study Rekik leads is based in Jharkhand, India. She is thankful for the opportunity to connect with local people in the field, learn about their lifestyles, and hear first-hand about the challenges they face.

Rekik received both her Master's in soil science and Bachelor's in agricultural science from Cornell University. After completing her PhD, she hopes to join a United Nations agency or CGIAR Center.

Outside of her research, Rekik enjoys reading and acquiring new skills through workshops and online learning. She is an ardent international traveler.



opportunities, which have arisen from changing demand for diversified, high-value agricultural products through globalization, population increase, and income growth. By forming FPOs, smallholders can benefit from scale economies, and thereby, in the process, aid agricultural development and poverty reduction.

In India, the average farm size was 1.15 hectares in 2010-11, a decrease from 1.33 hectares in 2000-01. Considering this downward trend, aggregation models have become critical for the country's smallholders. In the past two decades, there has been renewed interest in the promotion of FPOs for agricultural development and poverty reduction by philanthropic actors, donors, corporations, and governments. The country continues to promote FPOs in a big way, and in 2017, the government assisted in the formation of over 3,000.



Farmers work on a plot of land. Such smallholder farmers can benefit by aggregating into farmer producer organizations. (Photo by Kiera Crowley)

Yet, despite increased focus and avenues of support, global FPO success stories are few. Low-financing opportunities and the extended gestation period required for FPOs to become self-sustaining are major factors that impede success. Other challenges include weak market linkages, high coordination costs, government interference, inadequate managerial expertise, low levels of trust among members, and exclusion of women.

TCI is committed to the promotion of producer organizations as essential for agricultural development and food security. The Walmart Foundation's focus on promoting FPOs, to develop location-specific strategies for market access to include smallholders in organized value chains, fits

squarely with TCI's research goals. In September 2019, the Foundation awarded TCI a \$1 million grant to study the FPO promotion experience by philanthropic actors, government, and private entities in India and Mexico. Knowledge gained from these experiences will allow TCI to formulate operational, context-specific FPO models that are capable of improving smallholders' income and welfare.

## GENDER AND NUTRITION

### THOSE LEFT BEHIND: UNDERSTANDING THE EFFECTS OF INTERNAL MALE MIGRATION ON WOMEN'S PARTICIPATION IN AGRICULTURE

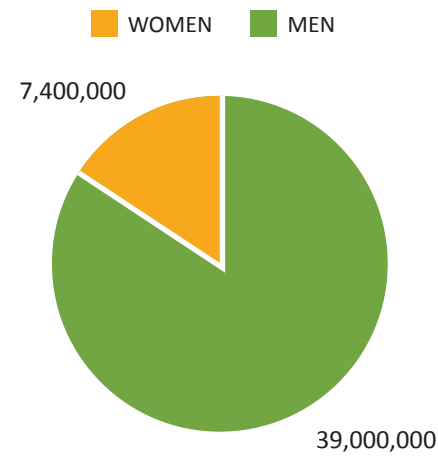
Across the developing world, hundreds of millions of people migrate seasonally in hopes of bettering their livelihoods by increasing their incomes and improving household welfare. This is especially true in India, which according to the latest census data from 2011, has around 450 million internal migrants. Due to social and gender norms, the majority of these migrants are men. TCI scholar Vidya Bharathi Rajkumar is working to understand how male labor migration affects women's roles in agriculture in rural India.

Male-dominant migration has implications for agricultural productivity as well as gender equality. As men migrate, women tend to be left behind in rural areas, usually in charge of agriculture. In several countries across Africa, Asia, and Europe, women's share in total agricultural employment has increased, a phenomenon referred to as the "feminization of agriculture." In countries like India, these women may have to shoulder the additional workload on the farm while also attending to daily domestic chores, which could adversely affect their health and productivity.

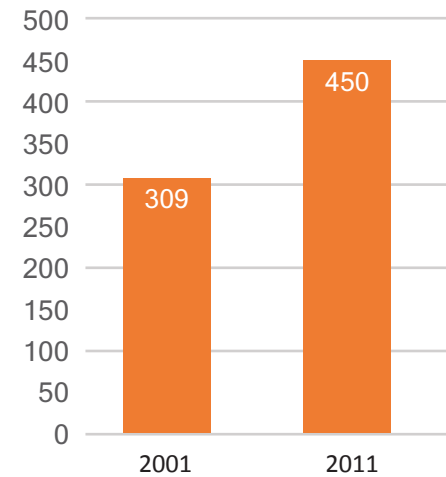
In some instances, women could also transition into new roles as farm managers. Typically, female farm managers tend to have less control over production assets and limited access to technical know-how and credit opportunities. Women who take over as farm managers, as a result of male migration, may have previously been unexposed to

INTERNAL MIGRATION IN INDIA

Migration for Work/Employment (2011)



Number of Internal Migrants in India (Millions)



Data from the 2001 and 2011 Census of India show that internal migration has increased in India and that the majority of those who migrate for work are men.

the rigors of managing a farm, which could impact agricultural production and productivity.

Using data from a nationally representative, multi-topic, household panel survey, Rajkumar is estimating the causal effects of male migration on women’s participation in agriculture in India. Preliminary results suggest that, while male migration does not affect the amount of time

women spend in agriculture, women are more likely to report becoming farm managers as a result of it.

Future work will explore how the effects of migration vary based on family structure—the relationship between the migrants and the women left behind—as well as social structures, like caste systems and gender norms. Upcoming work will also focus on determining potential pathways through which male migration could lead to greater female farm management and examining how migration-induced changes in women’s roles impact agricultural productivity.

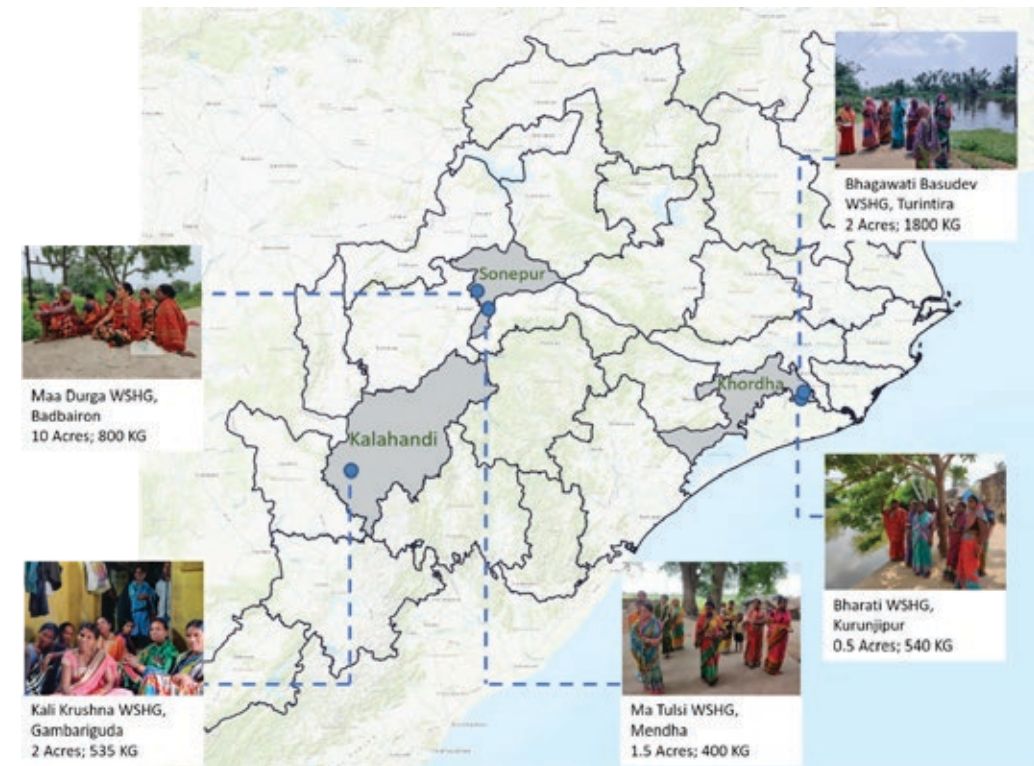
GONE FISHING: WOMEN’S SELF-HELP GROUPS AND COMMUNITY AQUACULTURE IN ODISHA

Across India, organizing women into self-help groups has been a popular method used for empowering women and lifting them out of poverty. This is particularly true in the coastal state of Odisha, where the government’s Mission Shakti program has helped six million women in more than 600,000 self-help groups since 2001. TCI scholar Anshuman Gupta spent the summer



Two women harvest green gram (mung beans). Internal migration by work-seeking men leaves women to shoulder the burden of agricultural work. (Photo by Kiera Crowley)

WOMEN'S SELF-HELP GROUPS INTERVIEWED IN ODISHA



TCI scholar Anshuman Gupta conducted group interviews with five women’s self-help groups in three districts of Odisha.

of 2019 studying the implementation of a program to promote community aquaculture by self-help groups.

Odisha’s community aquaculture initiative takes advantage of an estimated 60,000 community tanks in the state, 80% of which remain in disrepair or are not utilized. While the primary aim of the initiative is to increase rural incomes through the production of fish, like rohu of the carp family, the aquaculture program also aims to improve household nutrition by improving access to nutritious small fish like mola, or sunfish.

The program is implemented through a partnership between Mission Shakti, the Department of Fisheries and Animal Resources Development, and the Department of Panchayati Raj and Drinking Water. WorldFish, an international research organization, provides technical support through trainings and capacity building.

As a participant in TCI’s Summer Internship Program, Gupta received guidance from WorldFish to better understand the implementation of the aquaculture program and identify key factors that, if addressed, could lead to better outcomes for the project.

Through interviews with staff from WorldFish and government agencies, Gupta created an “outcomes pathway map” for the project, which demonstrates how inputs like community tanks, tools, and support staff are used to engineer outputs, such as increased fish production, higher incomes, and improved nutrition. The map also presents a set of key indicators for each input and activity, that if monitored, will ensure proper implementation of the program.

Gupta also met with women from self-help groups participating in the aquaculture program to assess their needs. To identify specific factors that could affect the program’s effectiveness, a mix of groups



TCI scholar Anshuman Gupta (second from left) speaks with women involved in aquaculture in Odisha. (Photo courtesy of Anshuman Gupta)

were chosen from areas with different levels of development, having exhibited high and low levels of productivity in their community tanks.

The women who were interviewed identified proper training as their primary need. None of the self-help groups had prior experience with aquaculture, so they lacked basic knowledge such as best feeding practices. This was exacerbated by administrative delays in their initial training. The women also said that they needed access to credit to be able to buy inputs and suggested that the poor initial quality of the community ponds meant that they had to spend a disproportionate amount of funds on cleaning. This led to diminished productivity; yet, the women reported being optimistic that they will have more success in the coming years.

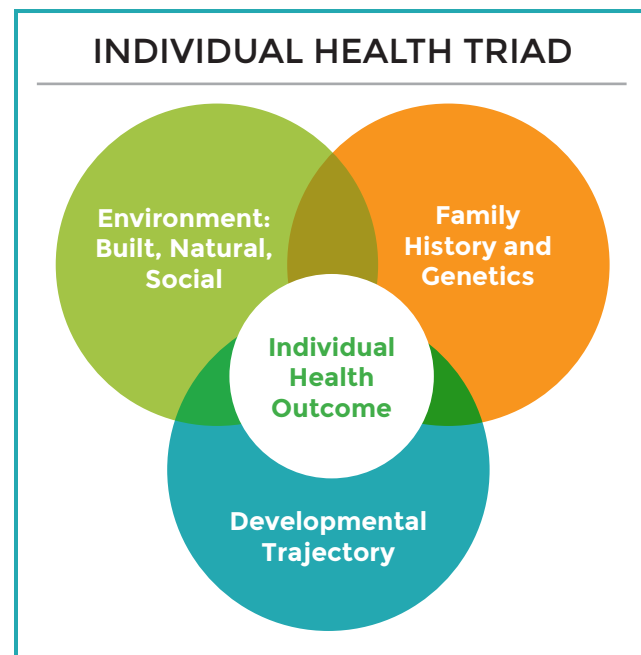
The community aquaculture program in Odisha has, by working with self-help groups, been effective in reaching some of the state's most vulnerable women. By providing increased access to credit and more timely training, the government could boost its impact.

### HOW GENOMICS CAN INFORM BIOLOGICAL INSIGHTS INTO CHILDHOOD STUNTING

When visiting India, there are a few features that become immediately apparent: bright colors, heavy traffic, and lots of people. Many of those people are a lot shorter than one might see in the West. As it

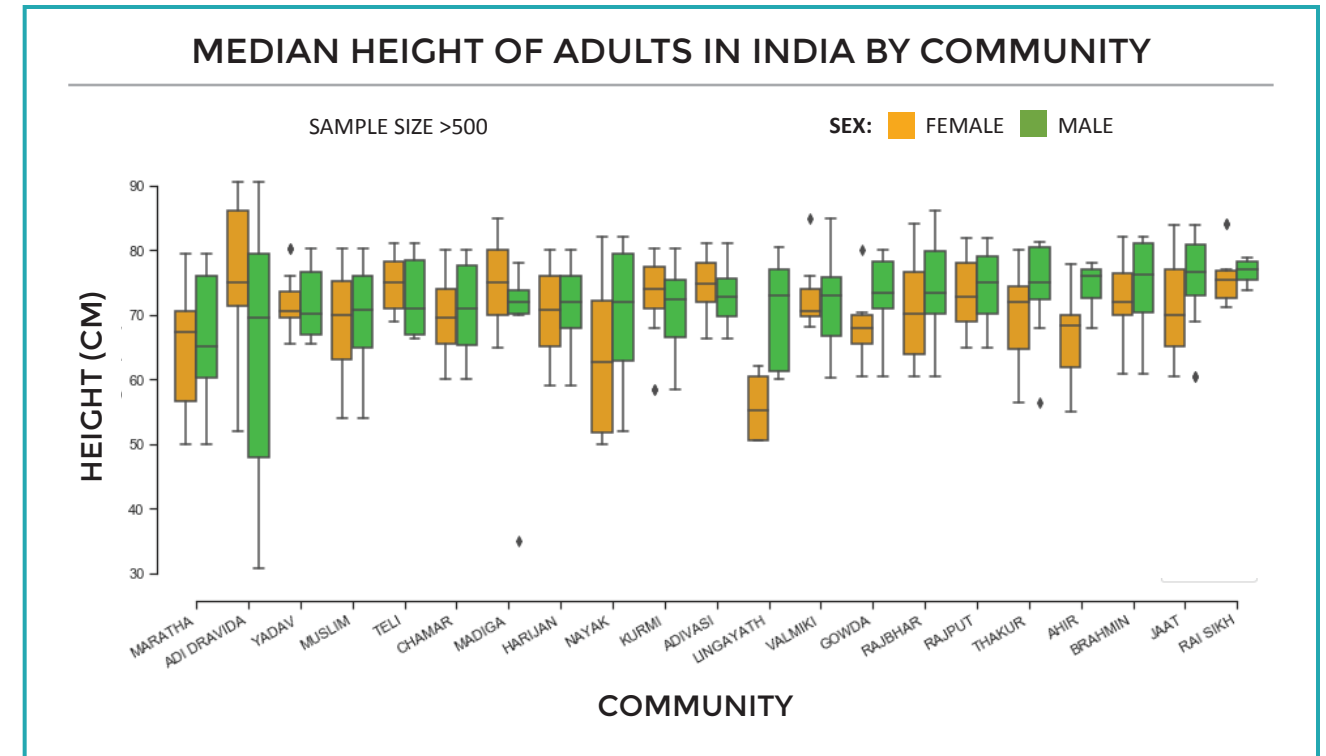
turns out, childhood stunting—height-for-age in children under five that is two standard deviations below the global standard—is more prevalent in India than most places around the world. Nearly 40% of children—roughly, 46.8 million—have stunted growth.

Children who experience stunting can suffer from lifelong adversity, including increased risk of chronic diseases, diminished mental capacity and learning ability, and reduced earnings. Stunting has traditionally been attributed to poor maternal, fetal, and early childhood nutrition, resulting in public health and policy efforts to combat the condition directed toward improving nutritional outcomes. However, despite decades of effort and millions of dollars poured into trying to solve the problem, stunting has been only slightly reduced in India.



Individual health outcomes are determined by environmental, genetic, and developmental factors.

TCI research associate Dr. Srilakshmi Raj is using genomic insights to address this problem from a new angle. A human population geneticist, she is leading a study to identify unique genomic (including genetic, epigenetic, and transcriptomic) and other biological markers for stunting, which reflect the influence of biology and the environment on health outcomes. These unique genomic and biological markers will be used to accurately predict and more effectively prevent stunting and related adverse health outcomes.



Data from the Indian Human Development Survey-II (2011-12) shows the diversity of height among different Indian communities.

The study will also provide more narrow definitions of stunting and its health outcomes, based on specific individual, household, and environmental metrics. For example, children who are anemic and stunted may show a different biological signature than children who suffer from intestinal worms and are stunted. Whether their health trajectories differ also warrants investigation. By collecting such deep records per household, Raj's research will lay the foundation for addressing large-scale public health problems in India by carefully defining the problem at the outset.

As part of the study, Raj is collecting genomic and blood biomarker data from the members of nuclear families in which a child is stunted, as well as environmental characteristics, in two environmentally contrasting regions of India. Due to the complex nature of the research, Raj is collaborating with specialists across the country, including geneticists, epidemiologists, survey teams, pediatricians, clinical geneticists, public health experts, dietitians, and others. Organizations participating in the study include the Center for Human Genetics, the Indian Institute of Science, INCLIN Trust International, BAIF Development Research Foundation, and NEERMAN.

Large-scale consortiums are starting to use similar approaches in studies conducted across multiple countries, where context, environment, and genetic makeup all differ, but a study like Raj's has never been pursued solely within India. It promises to yield great insight into the country's experience with stunting.

### HEIGHT AND GROWTH: UNPACKING DIFFERENCES IN STUNTING ACROSS EMPOWERED ACTION GROUP STATES

Stunted growth, is an indicator of the prevalence of malnutrition and is an ongoing concern in India, home to more than one-third of the world's stunted children. It is a particular concern in the country's Empowered Action Group (EAG) states—Uttar Pradesh, Bihar, Jharkhand, Madhya Pradesh, Chhattisgarh, Rajasthan, Orissa, and Uttarakhand—which lag behind the rest of the country socioeconomically, demographically, and nutritionally. TCI postdoctoral associate Sunaina Dhingra is working to explain regional disparities

and high prevalence of stunting in EAG states, in addition to determining what interventions will be most effective.

In her analysis, Dhingra adopted the classification of states, according to levels of structural transformation, as described in TCI's 2019 book, *Transforming Food Systems for a Rising India*. Structural transformation—characterized by shifts out of agriculture, increased agricultural productivity, and increased urbanization—can reveal important developmental differences between states with similar GDP indicators. In those terms, all of the EAG states, except Uttarakhand, are categorized as “lagging states,” with low GDP per capita, low rates of urbanization, and growth driven by a less productive agricultural sector. Dhingra compared them to two better performing states: Punjab, an “agriculture-led growth state,” and Tamil Nadu, an “urbanization-led growth state.”

The EAG states were compared with Punjab and Tamil Nadu along six broad categories of variables affecting nutrition: individual and household demographics; postdelivery health care; predelivery health care; mother's education and health-related variables; household and community-level hygiene practices; and household socioeconomic status. Her research shows that these factors can explain much of the difference in height-for-age outcomes between the EAG states and Punjab and Tamil Nadu, and highlights which variables would yield the greatest improvements in each state, if addressed.

For her analysis, Dhingra used a counterfactual or regression decomposition technique known as the Oaxaca-Blinder decomposition, which reveals how much of the gap between two groups is explained by the levels of a set of underlying factors related to the outcome of interest and how much is explained by differences in the effect (or strength of association) of those factors on the outcome of interest. For example, children from a particular state could be less healthy because that state has less health care infrastructure, but the effectiveness or quality of the state's health care providers could also play a role. This technique revealed Punjab as a better comparison than Tamil Nadu for all the EAG states combined, as nearly 90% of the gap between them in height-for-age outcomes can be attributed to differences in the levels of factors affecting nutrition.

Using this decomposition technique also allowed Dhingra to build on the existing literature by revealing which factors are more consequential in each state. Although the analysis suggests a very strong relationship between improved socioeconomic status and improved height-for-age outcomes across all states, the importance of other circumstances came to light when viewed on a state-by-state basis. For example, improving the predelivery health care infrastructure in Bihar, Uttar Pradesh, and Madhya Pradesh to the same level as Punjab can help reduce the height-for-age gap in those states by almost 15%. Improving predelivery health care infrastructure in Chhattisgarh, on the other hand, would have only a very modest effect. Instead, Dhingra's analysis suggests that Chhattisgarh's emphasis should be on the betterment of hygiene practices adopted by households, particularly, by educating people about safe stool disposal practices, which would reduce the gap by 23%.

The results of this analysis contribute to the understanding of how individual EAG states can move toward improving their childhood nutrition outcomes. Such an improved understanding can help policymakers decide on which areas to focus to maximize the benefits of improved nutrition for boosting height-for-age outcomes.

## FOOD SAFETY, FOOD LOSS, AND WASH

### TOMATO TROUBLE: ESTIMATING AND UNDERSTANDING FOOD LOSS IN VEGETABLE SUPPLY CHAINS

The loss of fruit and vegetables—damaged during transport or left decaying in a warehouse—in supply chains means that the nutrients of these foods cannot be consumed by those who need them. This is an especially important problem in countries like India, where there are not enough fruits and vegetables available in the food system to meet the population's dietary needs. TCI works to understand the nature, stages, and extent of food loss of perishable vegetables along supply chains in India, seeking to aid in the creation of effective reduction interventions in order to improve food security.



Tomato traders are among those surveyed as part of TCI scholar Jocelyn Boiteau's food loss study. (Photo by Jocelyn Boiteau)

Attempts to reduce food loss are hampered by the lack of a universal definition of food loss and the lack of standard, validated methods of measurement. In an effort to develop such metrics, TCI scholar Jocelyn Boiteau is conducting an observational study to estimate and understand quantity and quality food loss of fresh tomatoes from farm to retail in Chittoor district, Andhra Pradesh, and Hyderabad district, Telangana.

Andhra Pradesh is one of India's top tomato-producing states, and Chittoor district has its greatest land area under tomato cultivation. The state is also home to the Madanapalle tomato wholesale market, one of the largest tomato markets in Asia. Tomatoes from the market are shipped all over the country, including Hyderabad.

**“We know that food loss contributes to the deficit of fruits and vegetables in India, but there is a knowledge gap in how to measure both the quantity and quality of food loss of these food groups.”**

*- Jocelyn Boiteau*

To gain a comprehensive understanding of food loss across the entire tomato supply chain, TCI's study surveys farmers, wholesale buyers, and local retailers in Chittoor, as well as tomato traders and retailers in Hyderabad. Across the surveys, Boiteau and her team gather data on self-reported

#### AT A GLANCE

- 277 farm-level surveys completed.
- 212 wholesale market surveys completed.
- 52 traders surveyed.
- 52 retailers surveyed.

loss estimates, including how many tomatoes are completely lost and how many are damaged and have reduced quality. They also assess loss objectively by counting crates at different stages and gathering quality data using line-scaling methods.

Survey data collection in Chittoor district began in February 2019, and in Hyderabad in April 2019. In Chittoor, surveys are conducted with farmers on harvest days and with farmers and tomato traders on auction days at Madanapalle. To date, 277 farm-level surveys and 212 wholesale market surveys have been completed, with 149 farm households participating. Enrollment of wholesale traders is ongoing, with 84 participating so far. In Hyderabad, monthly surveys are conducted with 52 vegetable traders across three vegetable markets run by the state government, in addition to 52 retailers located across Hyderabad city.

Data collection will continue through September 2020, so as to account for differences in loss across the seasons.

## RESEARCHER SPOTLIGHT

*Jocelyn Boiteau*  
TCI Scholar and PhD Candidate, International Nutrition



A PhD candidate in the field of international nutrition, TCI scholar Jocelyn Boiteau leads the Institute's efforts on food loss. Her study of quantity and quality loss in Indian tomato supply chains aims to develop metrics for measuring loss that can contribute to effective, evidence-based reduction strategies.

The link between supply chains and nutrition is of particular interest to Boiteau. "Often when we think about people's diets, we focus on consumption and consumer decision-making, but there's a lot that happens to food on the supply side, and it's all very dynamic," she says. "I'm motivated to study food loss to better understand the problem and contribute evidence that can be used to improve food systems to deliver nutritious food to all people."

The ability to spend extended time in the field afforded to her by TCI has allowed Boiteau to gain deep insight into the context of her work. "I feel that I have a greater personal investment in the project and also a better understanding of the data and where it is coming from than if I had spent most of my time in Ithaca," she says.

Boiteau credits her team in India for the success of her research, particularly their ability to engage with study participants during their work hours. "We have been very conscious to build and maintain their trust throughout the process," she says.

Boiteau received her Bachelor's in nutritional sciences from Cornell University, completed a dietetic internship at Brigham and Women's Hospital to become a registered dietitian, and briefly worked on agriculture and nutrition activities with a local organization in Rajasthan, India. Before returning to Cornell, she worked as the project administrator for the Food Aid Quality Review at the Friedman School of Nutrition Science and Policy at Tufts University.

In her spare time, Boiteau enjoys cooking and exploring new foods, running, and hiking. She loves reading and is rarely without her Kindle.

Though ongoing, these surveys are providing valuable insights about how different actors on the supply chain perceive quantity and quality food loss. For example, some farmers have seen weather and climate-related afflictions, such as sun blisters, contribute to the loss of tomato crops. The perceived risk of loss has also been observed to influence farmers' decisions to grow one crop over another.

The data collected thus far also reveals that supply chain actors may perceive important tomato-quality attributes differently.

When completed, this study will improve understanding of both quantity and quality food loss and provide a clearer picture of how and why it occurs in supply chains. Ultimately, it will contribute to the development of food loss prevention strategies that increase the availability of nutritious fruits and vegetables.

## MANAGING MYCOTOXINS: REDUCING THE NUTRITIONAL AND SOCIOECONOMIC BURDENS OF UNSAFE FOOD

Exposure to fungal toxins, or mycotoxins, in the diet can lead to cancers, immune deficits, and growth impairment in vulnerable populations, and are associated with spoilage that reduces productivity and profitability of smallholder agriculture. Mycotoxins, such as aflatoxin and fumonisin, are abundant in Indian food systems, but rural, resource-poor communities in the region are rarely equipped with the tools and capacities required to adequately assess food safety. Spearheaded by TCI scholar Anthony Wenndt, TCI is working to address mycotoxin management in Unnao, Uttar Pradesh, by exploring the potential for participatory research for monitoring and mitigating mycotoxin exposures in communities underserved by formal regulatory infrastructure.

Since 2017, TCI has engaged 10 at-risk village communities in designing, testing, and evaluating preharvest and postharvest mycotoxin intervention strategies. A comprehensive, year-long longitudinal survey of mycotoxin contamination in 184 participating farmers' grain stores was conducted, testing paddy (rice), wheat, pearl millet, groundnut, and maize for several major mycotoxins.

Participatory research, a co-learning approach that engages communities in designing and conducting investigations on their own terms, was used to guide target communities in diagnosing sources of exposure in the food system and identifying locally accessible intervention opportunities.

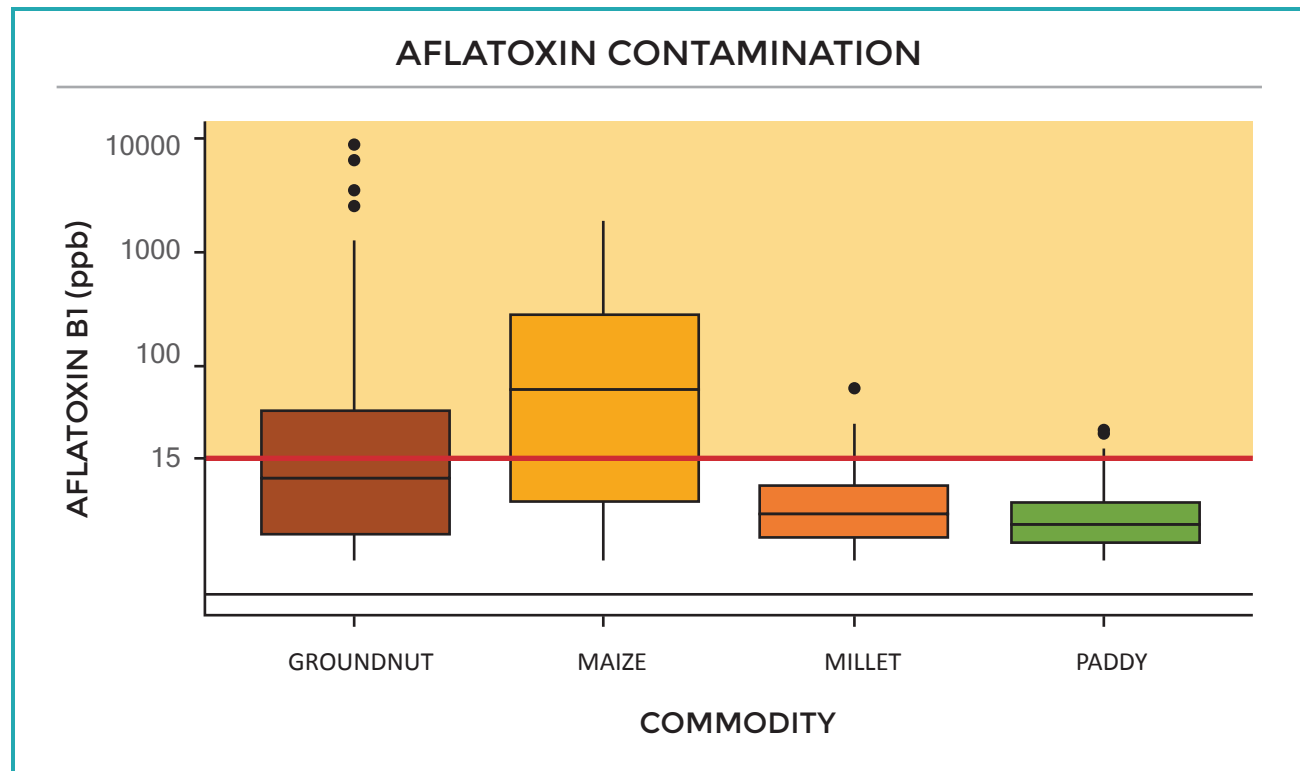
Survey results indicate that there is substantial mycotoxin contamination in local food systems. Among the commodities commonly stored in the study sites, 44-75% of samples had detectable aflatoxin, with mean levels in maize and groundnut

### AT A GLANCE

- Longitudinal mycotoxin survey and hermetic storage intervention trial was conducted in 184 households, comprising 6 villages in Unnao District, Uttar Pradesh.
- Mycotoxin levels were appraised in about 2,000 samples of stored grain over six time points (sampling every two months). Aflatoxin was detected in 44-75% of samples; fumonisin detected in 84-91% of samples.
- Household-level storage trial had a 91% success rate among participating farmers. Hermetic bags were successfully integrated into local markets, but farmers were reluctant to invest despite a high interest in the technology.
- At present, farmer research network activities have expanded to 10 villages and over 400 households in Unnao.

far exceeding the Indian legal limit of 15 parts per billion. For fumonisin—a toxin associated with esophageal cancer and other ailments—84% and 91% of maize and pearl millet samples were contaminated, respectively, with means for both commodities exceeding the regulatory limit of 2 parts per million.

The survey indicated that there is strong seasonal variation in contamination levels, but that little of



Overall aflatoxin contamination levels for each of the sampled commodities, with the red line indicating the Indian regulated maximum (15 parts per billion).

this variation is due to the duration of storage time. Both preharvest and postharvest factors play roles in mycotoxin status, but field-based interventions are likely more important for exposure prevention.

In conjunction with the longitudinal survey, the participatory diagnostic process in village communities identified storage improvement as a top priority for food safety intervention. Wenndt conducted a trial of hermetic storage bags, which protect grain from pest infestation

**“Participatory research is a bridge, linking scientific insights to local knowledge and letting the two learn from and influence one another.”**

- Anthony Wenndt

and microbial contamination. After five to seven months of storage, 91% of households reported that the technology effectively prevented infestation and grain spoilage. After the first season, all

participating households reported that they would continue using hermetic storage in subsequent seasons, with 90% self-reporting that they were “very confident” in their understanding of the technology’s principles.

Despite great local interest in the technology, Wenndt found that, after installing retail sales points in the marketplace, actual sales were far less consistent with the self-reported willingness-to-pay, likely due to the higher cost of hermetic bags compared to their conventional alternative. In response to this observation, another round of participatory diagnoses elevated several less expensive preharvest seed and soil treatment options, which are presently under investigation.

Through the process, TCI has successfully demonstrated the utility of participatory research, not only for devising and testing food safety interventions, but for leveraging collective resources to bring innovative technologies to local marketplaces.

Findings to date provide a strong evidentiary foundation supporting the utility of participatory



Sack-based storage of groundnuts and other foods can leave them susceptible to mycotoxin contamination. (Photo by Anthony Wenndt)

research as a mycotoxin prevention and food safety management strategy. TCI has developed and iteratively prototyped a series of participatory research modules, which can be readily adapted and deployed across many food system contexts to match farmers’ varying needs to locally specific intervention options.

Present efforts include working to enrich leadership capacity in the farmer research network, exploring opportunities for network-facilitated economic gains, and bolstering multilateral partnerships that can afford farmer-researchers continued access to innovative food safety solutions.

### DOWN THE PIPE: ACCESS TO PIPED WATER, TIME SAVINGS, AND HEALTH COSTS

For those in cities or developed countries, who need only turn on the faucet at the kitchen sink to get water, it can be difficult to imagine living without access to safe drinking water. Yet, 29% of the world population lives without it. In India, only

**“Understanding the economic impact of unsafe drinking water can help us design policies that can improve the standard of living for people in rural areas.”**

- Shiuli Vanaja

40% of people have piped water in their homes. TCI is working to make access and availability of clean water a reality for more people living in rural areas.

Lack of clean water in the home brings with it a host of problems. Most worryingly, it puts people at risk of water-borne diseases, like typhoid and diarrhea, the latter being one of the leading causes of death for children under the age of five. It also takes away time, as family members—often women and girls—must fetch water from sources far from the home. The time spent transporting water could otherwise be spent doing productive activities, like working at a job, farming, or attending school.

Led by scholar Shiuli Vanaja, TCI’s research in this area is twofold. First, it is building piped-water systems in rural areas and studying their effects on women’s time-use patterns. Second, TCI is conducting water quality tests in regions where such tests are rare, using the results to understand and improve the nutrition and health outcomes of the households in these regions.



A woman gets water from a spigot connected to one of the AguaClara piped-water systems. (Photo by Shiuli Vanaja)

In Jharkhand state, Vanaja conducted a yearlong field survey to measure the time spent in water collection across seasons. The study included six villages, three of which were provided with solar-powered, piped-water systems from TCI partner AguaClara. In villages with piped-water systems, households saved an average of nearly 60

minutes per day on water collection, compared to households without them. Women in the AguaClara villages increased the time spent in their primary occupation by 20% per day.

Vanaja also observed that even in households with piped water, family members were sometimes traveling outside their homes to fetch water from public water sources. She learned that, in the rural society of Jharkhand, women are motivated by perceptions about the quality of drinking water. Sometimes, they feel that certain water sources have better quality, compared to others, including more conveniently located sources such as the piped water they have at home. Existing social norms and beliefs affect their perceptions and preferences regarding drinking water.

To assess drinking water quality and measure the presence of waterborne vectors that cause diseases like diarrhea, an 18-month survey was conducted in 30 other (non-AguaClara) villages in two districts of Jharkhand. Water quality was measured by testing for the presence of *E. coli* bacteria in the drinking water stored at home, as well as at other village water sources.

The chosen water source, in addition to hygiene practices at home, like handwashing, were shown to be important determinants of drinking-water quality in the 30 villages. Households that made better choices regarding the source of drinking water had a lower risk of diarrhea.

The research demonstrates that water infrastructure like AguaClara piped-water systems have a beneficial impact beyond access to clean drinking water. The time savings for women and other family members involved in water collection can be a boon for their household productivity. The research also shows, however, that access to clean water is not necessarily a guarantee that people will use it. The perception of quality is an important factor in rural Indian women's choice of water source.

To reduce health costs associated with waterborne diseases, it is important to understand the drivers of rural women's perceptions about the quality of drinking water and devise behavioral change programs to favorably modify those perceptions.

## FOOD FORTIFICATION AND BIOFORTIFICATION STRATEGIES—FROM LAB TO COMMUNITY

### BIOREFINERY TO KITCHEN: ADDRESSING IRON DEFICIENCY USING MICROALGAE-FORTIFIED FLOUR

Few foods are as appealing as freshly made roti, a common Indian flatbread. What if that roti were fortified with iron, a mineral that performs a critical function in the human body? It could help tackle a nutritional disorder that afflicts more than 600 million people in India, with tragic long-term consequences. TCI is exploring an innovative approach to curbing iron deficiency by fortifying wheat flour, using a byproduct of the biofuel industry.

Iron is a key nutrient involved in the synthesis of hemoglobin, which allows red blood cells to carry oxygen. Low iron levels in the blood, or iron-deficiency anemia, can cause impaired cognitive function and delayed physical growth in children, as well as long-term reduced working capacity. India has high rates of iron-deficiency anemia and pays a steep price for it in terms of mortality, disability, and lost productivity.

**“I had the opportunity to conduct fieldwork with communities that had high rates of reported iron-deficiency anemia. To be able to put a face to my research gave me extra motivation to do this work.”**

**- Rohil Bhatnagar**

Fortifying staples like wheat with iron has long been considered a cost-effective public health approach to reducing iron deficiency, but ideal, bioavailable sources of iron that can be effectively utilized in food products have proven elusive.

TCI scholar Rohil Bhatnagar is working to change that. He is leading an effort to use defatted green microalgae called *Nannochloropsis oceanica*, a byproduct of the biofuel industry, as a novel source of iron. With 3,530 mg of iron per kg, the microalgae compares favorably to other iron sources in terms of bioavailability, which means more of it can be absorbed and used by the body.

The bioavailability of microalgae was confirmed in a TCI lab study conducted with iron-deficient mice. Mice that were fed a diet that included microalgae-extracted iron had improved hemoglobin levels and a two-fold increase in iron storage in the liver, compared to an iron-deficient control group.

Bhatnagar also conducted a safety assessment study of continuous microalgae consumption, since having excess iron in the body has been shown to have adverse health effects. In the study, mice fed high levels of microalgae did not experience any negative effects, such as oxidative stress, iron bioaccumulation, or inflammation.

After determining the safety and efficacy of microalgae as an iron source, Bhatnagar conducted household surveys, focus group discussions, a village-level market assessment, and interviews with local medical practitioners in Gujarat, Jharkhand, and Bihar, India, to determine the ideal food for fortification. Because wheat flour is widely consumed and available through the Public Distribution System in India, it was selected as a potential vehicle.

However, an important challenge remained. The microalgae has an unattractive green color and unpleasant fishy aroma that could be very unappealing when added to roti. Additionally, the interaction between iron and lipids present in the wheat flour may cause undesirable color changes over time. To overcome these challenges, Bhatnagar encapsulated the microalgae in water-in-oil-in-water emulsions using conventional homogenization. Microcapsules, developed using this technology, enabled flour to be fortified without unwanted colors or smells and were also stable at temperatures typically used to bake bread like roti (~220°C/430°F).

This work provides a novel approach to combatting global iron malnutrition and exhibits the vast potential of microalgae as an effective and safe source for fortification. Current and future work

is focused on assessing shelf-life changes in microalgae-fortified wheat flour. A sensory study will also be conducted to assess any significant differences between fortified and unfortified roti.

### POWER PUFFS: CREATING NUTRITIOUS PUFFED SNACKS FOR TODDLERS

In recent years, parents have increasingly turned to puffed snacks, which quickly dissolve in the mouth, as a first finger food for their children. It is easy to see why: typically flavored with fruit or cheese, the puffs are shelf stable, portable, offer the convenience of self-feeding, and can be eaten without making the mess generated by other snacking. Many parents give their toddlers puffs during weaning, when a sudden shift from mother's milk leaves them in need of vital nutrients. Most puffs, however, are starch-based and offer little nutritional value. This lack of nutritive value is especially problematic in countries with high rates of childhood undernutrition, like India.



TCI scholar Bindvi Arora monitors the supercritical fluid extrusion system while producing a test batch of puffed snacks. (Photo by Dan Verderosa)

TCI scholar Bindvi Arora is conducting research aimed at creating protein-rich baby foods, with a special focus on properties like quick disintegration, smooth mouth feel, and ease of handling. Essentially, she is developing a milk-based puff, which would provide all the benefits of traditional puffs, but with increased nutritional value.

To accomplish this, Arora is using a novel technology called supercritical fluid extrusion. Starch-based puffs are typically made using

steam-based extrusion cooking, which involves high temperatures that can damage heat-sensitive macronutrients and micronutrients, rendering them unusable by the human body. Because Arora's process uses supercritical carbon dioxide—which exists at a point where liquid and gaseous phases coexist—as a low-temperature blowing agent, the protein-based puffs retain their nutritional value.

For extruded material to be quickly disintegrating, it needs to be highly porous and well-expanded, allowing saliva to quickly enter its structure. Testing so far has focused on using different carbon dioxide injection pressure, temperature, and water levels during the extrusion process in order to maximize expansion.

Further research will focus on shortening the dissolve time using ingredients that can contribute to the disintegration of extruded milk-based protein, such as hydrolyzed milk protein, saccharides, and calcium-chelating agents.

This research is making significant steps toward developing nutritious, easily eaten foods for toddlers who may be at risk for undernutrition.

### SWEET NUTRITION: ADDRESSING MICRONUTRIENT DEFICIENCIES THROUGH ORANGE-FLESHED SWEET POTATOES

The Indian food system's heavy focus on staple grains, like rice and wheat, combined with stubbornly high poverty rates, leaves many people's diets lacking important nutrients like vitamin A, which plays a crucial role in eye, lung, and immune system functions. TCI is working to address vitamin A deficiency through the cultivation and consumption of vitamin A-rich orange-fleshed sweet potatoes. These efforts show that, with adequate education and institutional investments in developing varieties suitable for the region, the crop has the potential to catch on with producers and consumers.

Led by scholar Kathryn Merckel, TCI embarked on a project in Uttar Pradesh to improve diet diversity in mothers and children through the introduction of orange-fleshed sweet potatoes, along with educational messages for parents on proper diets

for young children. Data collected in the region before the project began suggests that children may not be eating diets adequate in vitamin A. Fewer than 2% of parents reported their children had received vitamin A supplements in the past year, and knowledge about healthy diets was observed to be lacking, with only 7% of parents reporting that they thought fruits or vegetables were good foods for infants.

Working with TARINA consortium partner Grameen Development Services, TCI provided farmers with training on how to cultivate orange-fleshed sweet potatoes. Vines were provided to those who wished to try growing the potatoes, and simple messages about health and diet were discussed during the monthly trainings. Half of the villages included in the study were randomly selected to also receive monthly, intensive educational programming on nutrition, with messages designed to target the most common troubles that parents experienced when trying to ensure that their children ate healthy, age-appropriate foods.

Previous research in East Africa has shown that projects, which introduced orange-fleshed sweet potatoes without intensive education, were as effective as those with the education component, in terms of increasing vitamin A intake. However, since the crop is new to North India, it was not known how important the education component would be to promoting acceptance of the food. Findings from the study indicate that parents in villages that did not receive intensive nutrition education learned valuable information about the



*Orange-fleshed sweet potatoes are rich in vitamin A, an important micronutrient that contributes to healthy eye, lung, and immune system functioning. (Photo by Kathryn Merckel)*

### AT A GLANCE

- Over 1,300 households were surveyed across 15 villages.
- Half of all households grew, purchased, or received orange-fleshed sweet potatoes.
- 85% of intervention households reported interest in buying orange-fleshed sweet potatoes.
- 17 percentage point increase in awareness of vitamin A measured after intervention.

health benefits of orange-fleshed sweet potatoes and proper child feeding, just as well as in villages that did.

Compared to control villages that received no intervention at all, parents in either set of intervention villages could name, on average, one additional strategy to improve children's health, such as providing a diverse diet, at the end of the study. The percentage of households in intervention villages that reported being aware of vitamin A jumped from 10% to 27% over the course of the study, while control villages saw no change. At the end of the study, respondents who had heard of vitamin A could list an average of one-and-a-half more food sources rich in vitamin A than respondents at the outset.

Nearly every respondent in intervention villages had heard of orange-fleshed sweet potatoes by the end of the study, and 85% of households in both sets of intervention villages reported that they would buy them if they were available in their market.

Despite these increases in knowledge about healthy diets and interest in eating the sweet potatoes, cultivation of orange-fleshed sweet potatoes faltered after the first year of the intervention. Farmers were accustomed to using their land to grow cereal grains and were not willing to allocate sufficient space to successfully grow sweet potatoes. Climate change has led to periods of severe flooding and drought in the region, making preservation of vines difficult from season to season.

Setbacks aside, this study demonstrates potential for orange-fleshed sweet potatoes in the region. Many households reported enjoying the taste of sweet potato leaves, which are edible and rich in vitamin A. Price premiums were attractive to farmers wishing to sell tubers in the market, provided that customers were educated about their health benefits.

Future interventions with orange-fleshed sweet potatoes will require varieties better suited to the North Indian agroclimate, continued parental education about the importance of vitamin A-rich foods for children's health, and ongoing promotion of the agricultural and nutritional benefits of the crop.

### SFURTI: BUILDING A SUSTAINABLE, HOME-BASED FLOUR FORTIFICATION PRODUCT

In the fight against undernutrition, fortified staples like flour can help ensure that people consume critical micronutrients. Yet, in many areas of India, smallholder farmers do not purchase flour at the market, opting instead to grow their own grains and bring them to local millers for processing into flour. To address micronutrient deficiency among these communities, TCI spearheaded the Sustainable Flour Fortification Initiative, known as Sfurti, providing an easy-to-use, home-based method for fortification.

Initiated in 2016, the project involves the distribution of Sfurti powder—containing iron, folic acid, and vitamins A and B<sub>12</sub> for mixing into flour—in 15 tribal villages of Songadh block in Gujarat's Tapi district. The Sfurti initiative is implemented by the Women's Federation of Self-Help Groups—Shree Surbhi Swasahay Federation, with assistance from TCI and partner organizations BAIF Development Research Foundation, Sight and Life, the Tata Institute of Social Sciences, and Maharaja Sayajirao University.

The initiative was implemented in three stages. In the first stage, Sfurti powder sachets were sold door-to-door by women from the self-help groups, known as Sfurti Bens or Sfurti sisters, who also raised awareness of the importance of micronutrients. During stage one, 69% of the households demonstrated a willingness to purchase



the powder sachets, and 25% bought them regularly.

In the second stage, the Sfurti sisters limited their role in five of the 15 villages to raising awareness, with Sfurti sold only at millers, instead of door-to-door. During stage two, 62% of households demonstrated a willingness to purchase the powder sachets, and 49% bought them regularly, twice the number of regularly consuming households in the first stage.

For the third stage, TCI and its partners took a step back, and the self-help groups assumed all responsibility for selling the sachets, with their profits funding the initiative. Only regularly consuming households from the second stage were targeted, 62% of which were regularly consuming in the third stage. In all, 79% of the sachets were sold during this stage.



Fortifying wheat-based flour can help increase consumption of micronutrients. (Photo by Mathew Abraham)

TCI scholar Karuna Salve, who helped implement Sfurti as a program officer, undertook a case study of the project, comparing its three stages in order to account for challenges faced by the self-help groups, as well as the implementing partner organizations. She found that for programs like Sfurti to succeed, building trust among target communities, with limited access to education and information, is crucial. Enlisting influential people in villages can be helpful in this regard. Salve also identified the women's self-help groups as an important factor in the program's successes because of the group members' social skills and their positions in each village and hamlet. Of the households in the study that regularly consumed Sfurti, most included a woman from one of the self-help groups.

TCI scholar Kasim Saiyyad, who served as Sfurti's program coordinator, also studied the initiative, focusing on its decentralized approach to community health. He found that engaging women's self-help groups to implement the program empowered the women with a livelihood activity and successfully created a network of village-level entrepreneurs who could provide nutrition services at beneficiaries' doorsteps.

In rural areas where consumption often occurs via informal markets, formal market interventions to improve nutrition can have only a limited effect. The full experience of Sfurti shows that a self-sustainable, nutrition-oriented product is possible, and with the inclusion of local communities and their acceptance of the product, it can be a successful means of promoting nutrition and providing access to essential micronutrients in such communities.

## POLICY TOOLS, DATA SYSTEMS, AND INSTITUTIONS

### DISTRICT-LEVEL DATABASE FOR INDIA: TCI PARTNERS WITH ICRISAT ON INNOVATIVE DATA PLATFORM

Data is key to creating efficient and effective interventions aimed at the development of the agricultural sector and improving nutrition. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), has long been the repository for district-level data related to India's agricultural systems. In 2019, TCI and ICRISAT initiated a project to improve and expand upon the District-Level Database for Indian Agriculture and Allied Sectors.

Researchers and policymakers have long struggled to find geographically disaggregated data on a host of indicators related to India's food systems and growth patterns. ICRISAT had collected disaggregated agricultural data but only from 1966-2011 and based on 1961 district boundaries that have since changed. The TCI-ICRISAT project helped to collect data from 2011-2015 and expanded the data to include a more comprehensive set of variables related to food and agriculture systems, including impacts



**“Thanks to the joint efforts of ICRISAT and TCI, this important database now has a much more comprehensive set of variables, looking at everything that has to do with food and agricultural systems in India. With this platform, we can look at how food systems are changing and set priorities for agricultural research and investments.”**

*– Prabhu Pingali*

on consumption, nutrition, income, and poverty reduction.

The new database brings together data for 571 districts in 20 states. Crucially, the data has been “apportioned” to control for the creation of new districts and changes to district boundaries, empowering researchers to look at the diversity in growth patterns across India from a historical perspective.

Where data was missing or not available at finer scales, the project used cutting-edge techniques like satellite imaging to capture information related to variables like nighttime light intensity, irrigated area, or wind speed.

In all, the database includes 74 data sets, 1,030 variables, and more than 11 million datapoints. This wide range of data can easily be downloaded and compiled via an open-access, web-based dashboard.

With this comprehensive data platform, researchers, policymakers, and others can greatly benefit, thereby enabling greater understanding of agricultural development and nutrition.

*Visit the District-Level Database for Indian Agriculture and Allied Sectors at [tci.cornell.edu/research/district-level-database-india](http://tci.cornell.edu/research/district-level-database-india).*

## RETHINKING INDIA'S SOCIAL WELFARE ARCHITECTURE

How do you help those who have been left behind by economic development? One of the policy levers with which governments try to reduce poverty and promote equitable growth is by assisting the deserving with unconditional benefits, like food, income, and nutritional support. In India, there

is little debate over the need for such safety-net programs, but designing them to be efficient and effective has been a major policy dilemma. A forthcoming book from TCI tackles the issue and calls for regionalized reforms.

India has many safety-net programs, including in-kind food assistance, nutritional support to pregnant and lactating mothers, free meals in schools, a rural employment guarantee, and an old-age stipend. These provisions have been institutionalized through constitutional legislation that recognizes a citizen’s “right to education, food, and work,” but with continued, widespread poverty and undernutrition, the economics of these programs has been called into question. Many are not only expensive but reach very few, are prone to corruption, and are generally mismanaged. Current policy discourse has begun to move toward alternative programs, like cash transfers.

TCI director Prabhu Pingali and postdoctoral associates Andaleeb Rahman and Aditya Shrinivas are co-authoring a book that directly tackles the issue of social welfare effectiveness. Their work is centered around the regional differences in India’s structural transformation. They argue that India is simply too large and diverse a country for one-size-fits-all solutions.

**“Reforms to safety net programs are arguably the most hotly debated social policy concerns in the country in recent times, but the arguments put forth thus far have been limited to a complete overhaul of the system or total maintenance of the status quo. We argue that one must step back and first articulate social policy objectives, which are based upon regional imbalances in the country.”**

*– Andaleeb Rahman*

Over the past 70 years, the many regions of India have developed differently, owing to their comparative advantages in production, varied geographies, and distinct governance structures.

Similarly, drivers of growth have been different across regions. Most importantly, states’ abilities to adopt newer technologies and their effectiveness in

ensuring that those in need are not left out, rely on the different institutional and governance networks in each region.

Rethinking India’s developmental priorities, with an eye towards each region’s specific context, must be the first step in any attempt to solve long-standing issues, like poverty and undernutrition, through an overhaul of the country’s social safety nets.

## THE FEED THE FUTURE INNOVATION LAB FOR CROP IMPROVEMENT: TCI DEVELOPING A METRIC TO MEASURE INSTITUTIONAL CAPACITY

Cornell University is leading a new, global crop-improvement research project aimed at the advancement of plant breeding tools, technologies, and methods to increase yields, enhance nutrition, and increase resilience to pests and diseases. The Feed the Future Innovation Lab for Crop Improvement is an integrated research and delivery program that will support national breeding programs in East and West Africa, South Asia, and Latin America. The five-year, \$25-million project is funded by the US Agency for International Development and is a part of the US government’s Feed the Future initiative.

A central aim of the program is to empower national research centers, building their institutional capacities to help the centers achieve nutritional, economic, and social goals for economic development and to achieve food and nutrition security. TCI is a partner in the program, planning to measure the institutional capacities of national research centers in delivering genetic gains and new products to enable economic growth, resilience, and nutritional development. Specifically, TCI’s work will ascertain the institutional capacities created by the innovation lab and study how the capacities have led to genetic gains and the introduction of new, economically relevant, and resilient crops, which enable food and nutrition security in their respective regions.

The institutional capacities of research centers are defined by their capital endowments, human capital, management, and technical capacities,

which allow the centers to undertake activities that allow for diffusion of technology in breeding programs. Tracking the development of institutional capacity and diffusion of technology in breeding programs is essential for assessing the success of agricultural research in new technology implementation and the adoption of new practices; understanding the multidimensional impact of research on productivity, farm incomes, nutrition, and social inclusivity; and revealing constraints, bottlenecks, and challenges of technology development and diffusion.

Understanding the factors that influence and drive the successful adoption of tools, technologies, and methods will be essential to recognizing how innovation labs and scientific support groups can be successfully initiated and sustained.

## ICT AND TECHNOLOGICAL INNOVATIONS FOR IMPROVED LIVELIHOOD

### INDIAN FOOD SYSTEM CHALLENGES AND TECHNOLOGICAL INTERVENTIONS: AN INVESTMENT PLATFORM

As India inches toward becoming the most populous country in the world by 2030, ensuring adequate amounts of nutritious foods for the population is a major challenge. Agricultural technology will play a vital role in ensuring India’s future food security and meeting the second Sustainable Development Goal to “end hunger, achieve food security and improved nutrition and promote sustainable agriculture.”

Through a project funded by the Danish Embassy in India, TCI aims to identify areas within the Indian food system where investments in technology can address current and future food security concerns and bring together agricultural research and development organizations onto a common platform for consultation and dialogue.



TARINA

## TECHNICAL ASSISTANCE AND RESEARCH FOR INDIAN NUTRITION AND AGRICULTURE: GOALS AND APPROACH

Technical Assistance and Research for Indian Nutrition and Agriculture (TARINA) is a consortium that connects policy-focused research partners with community-level, impact-focused implementation partners to address the complex problem of malnutrition in India. Led by TCI, TARINA merges the evidence-generating expertise of Cornell University, Emory University, the International Food Policy Research Institute (IFPRI), and Tata Institute of Social Sciences (TISS) with the technical capabilities of leading development partners—BAIF Development Research Foundation, CARE India Solutions for Sustainable Development, Grameen Development Services (GDS), and Tata Trusts. Collectively, the consortium aims to promote a more diversified food system that enhances the availability and affordability of nutrient-rich foods for India’s rural population and creates a sustainable platform to mitigate malnutrition.

TARINA was founded in December 2015, with a US\$13.4 million grant awarded to TCI from the Bill & Melinda Gates Foundation.

### TARINA’S RESULTS FRAMEWORK: FROM EVIDENCE-BASED INTERVENTION TO ENABLED POLICY PLATFORM

Objective 1 of TARINA’s Results Framework focuses on field-based implementation, specifically, on redesigning agricultural projects to ensure positive nutrition outcomes at scale. This is achieved through the integration of nutrition-focused objectives, actions, and metrics into agricultural projects implemented by NGOs and development partners in three Indian states—Bihar, Odisha, and Uttar Pradesh.

Objectives 2 and 3 are more research- and policy-oriented goals. Both objectives focus on evidence generation, advocacy, and capacity building for the

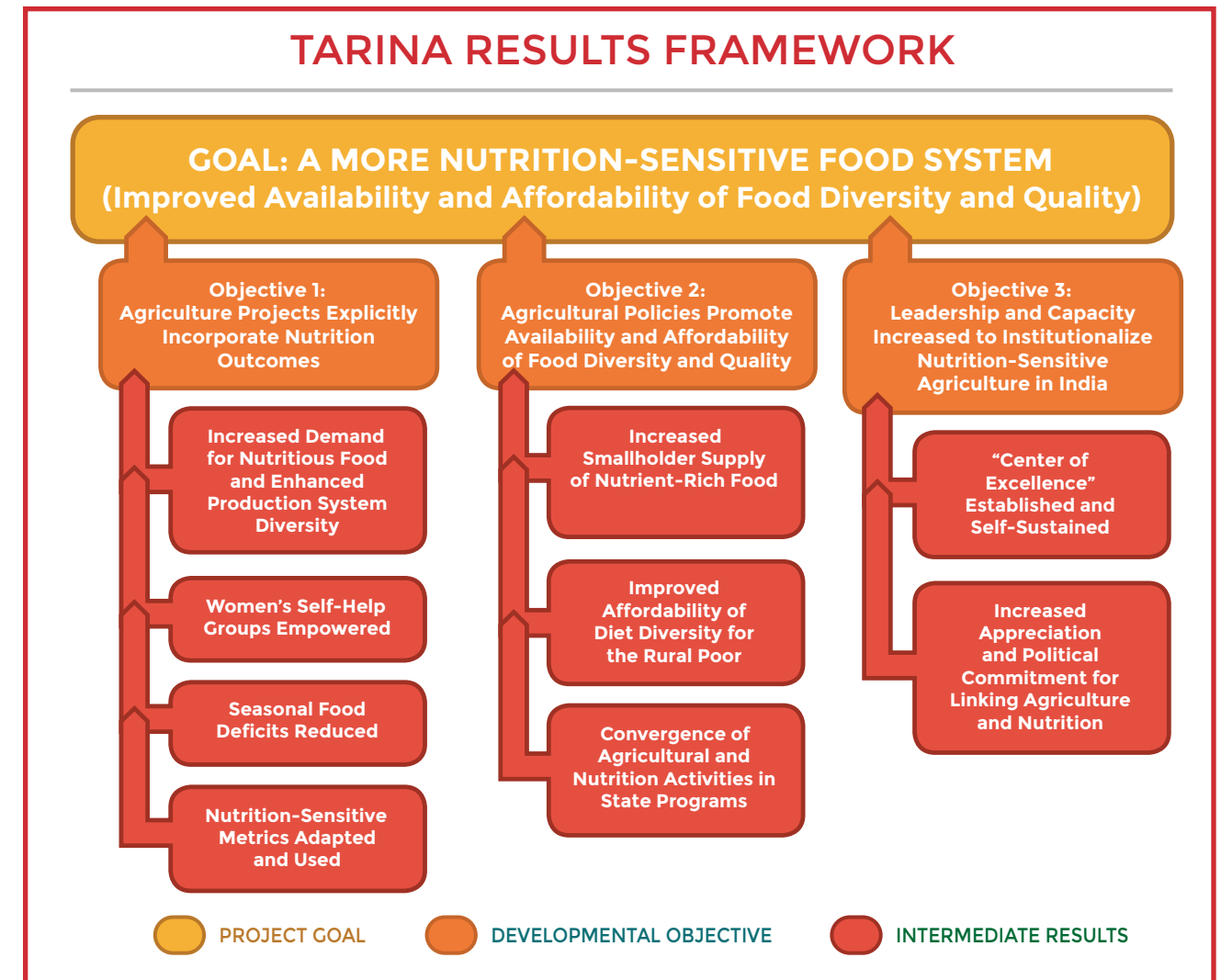
design and implementation of nutrition-sensitive agricultural programs and policies. Drawing upon TARINA’s ground-level interventions through implementing partners (BAIF, CARE, and GDS) at various locations; evidence-based research done by TCI scholars and TARINA research partners (IFPRI and Emory University); and from microlevel studies undertaken by implementing partners, TARINA continues to strengthen its knowledge base for making the rural food system more nutrition sensitive in intervention districts.

TARINA is a unique program with a live connection between intervention, evidence, and advocacy. The field-level programs are continuously informed by TARINA’s active monitoring, learning, and evaluation system. TARINA utilizes the collective evidence to influence policy through various advocacy platforms: by disseminating innovative research products through peer-reviewed publications, policy briefs, and manuals; and through engagement in discourses, in the form of roundtables, workshops, and consultations with impact makers. The Center of Excellence within TARINA leads and supports the generation of evidence, in translating the findings into high-value research products, and utilizing the research products for building capacity and influencing policy around the food system and nutrition in India.

### TARINA’S FOOD SYSTEMS APPROACH: SUSTAINABLE MITIGATION OF MALNUTRITION

TARINA advocates going beyond traditional food security for a sustainable mitigation of Indian malnutrition. TARINA aims to redirect agricultural policy away from “staple grain fundamentalism” toward a much broader food systems focus, which considers the need to build better connections between agriculture and nutrition. More specifically, it emphasizes agricultural pathways to improve the rural poor’s year-round access to affordable, diverse, and high-quality foods that are rich in micronutrients.

A food system includes all individuals, enterprises, and institutions that influence the supply, demand, consumption, and absorption of food micronutrients. TARINA’s food systems approach



Three objectives and nine intermediate results make up TARINA’s overarching goal to create a more nutrition-sensitive food system in India.

**LOCATIONS AND PARTNERS**

STATE	DISTRICT(S)	PARTNER(S)
Bihar	Munger	BAIF
Odisha	Kalahandi and Kandhamal	CARE India
Uttar Pradesh	Maharajganj	GDS and Tata Trusts

TARINA works with NGO and development partners in the three Indian states of Bihar, Odisha, and Uttar Pradesh.

examines factors that influence both agriculture and nutrition within and between stages of the food supply chain, as well as among households, villages, districts, and beyond. TARINA's food systems approach is twofold. It involves not only ground-level interventions at various stages of the food supply chain but also policy reforms to support diversification of agricultural production. Establishing a "crop-neutral" policy environment that ensures a level playing field for the production and marketing of nutritious non-staples, such as fresh fruits, legumes, and livestock products, is critical to creating a more robust and diversified food system.

### Diversifying the Local Food System: Intensified Production Diversification

TARINA is engaged with local communities to diversify local crop production by adding pulses, vegetables, and oilseeds to staple grain cultivation in the intervention villages of Bihar, Odisha, and Uttar Pradesh. During the last four years, TARINA has intensified the promotion of growing non-staples by facilitating timely seed supply, strengthening market linkages, enhancing capacity through training for farmers, and addressing local constraints that affect diversification efforts.

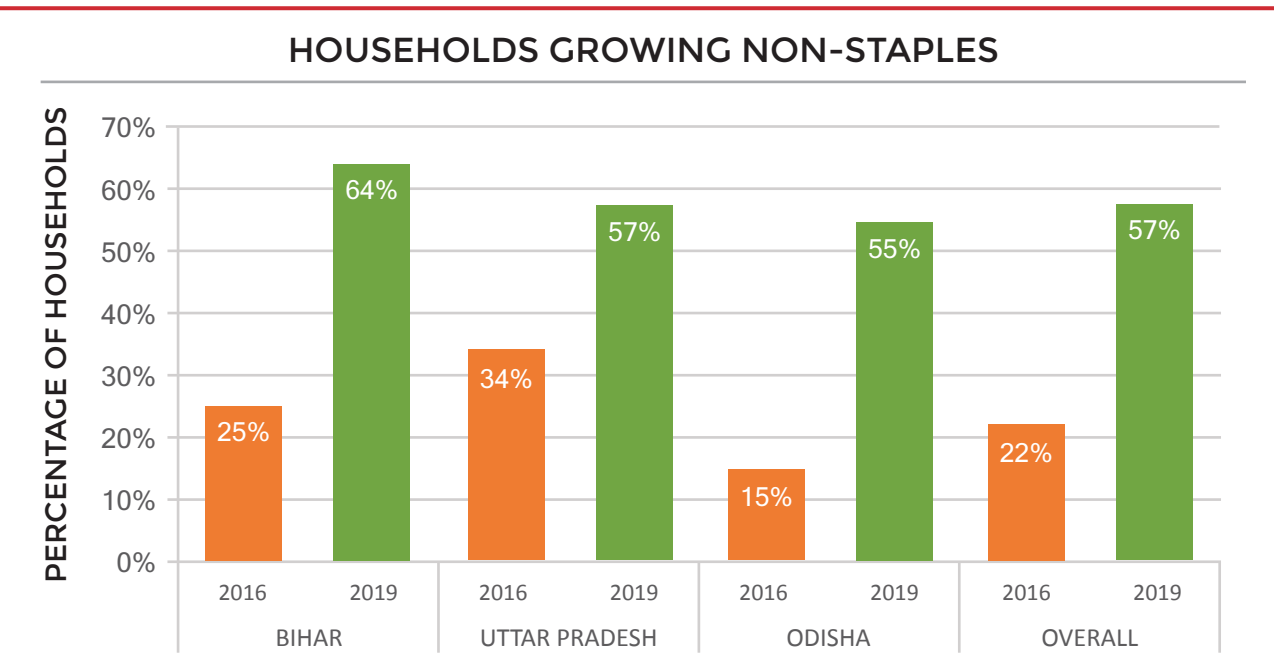
Four years of intensive effort on the ground has

created a positive change in production toward a diversified agriculture. Out of 24,173 households in intervention villages, TARINA has empowered 15,315 households, covering 5,325 acres of land, to practice diversified agriculture. Although just 22% of households grew non-staples at the time of the TARINA baseline survey in 2016, 57% were doing so as of the 2019 midline survey.

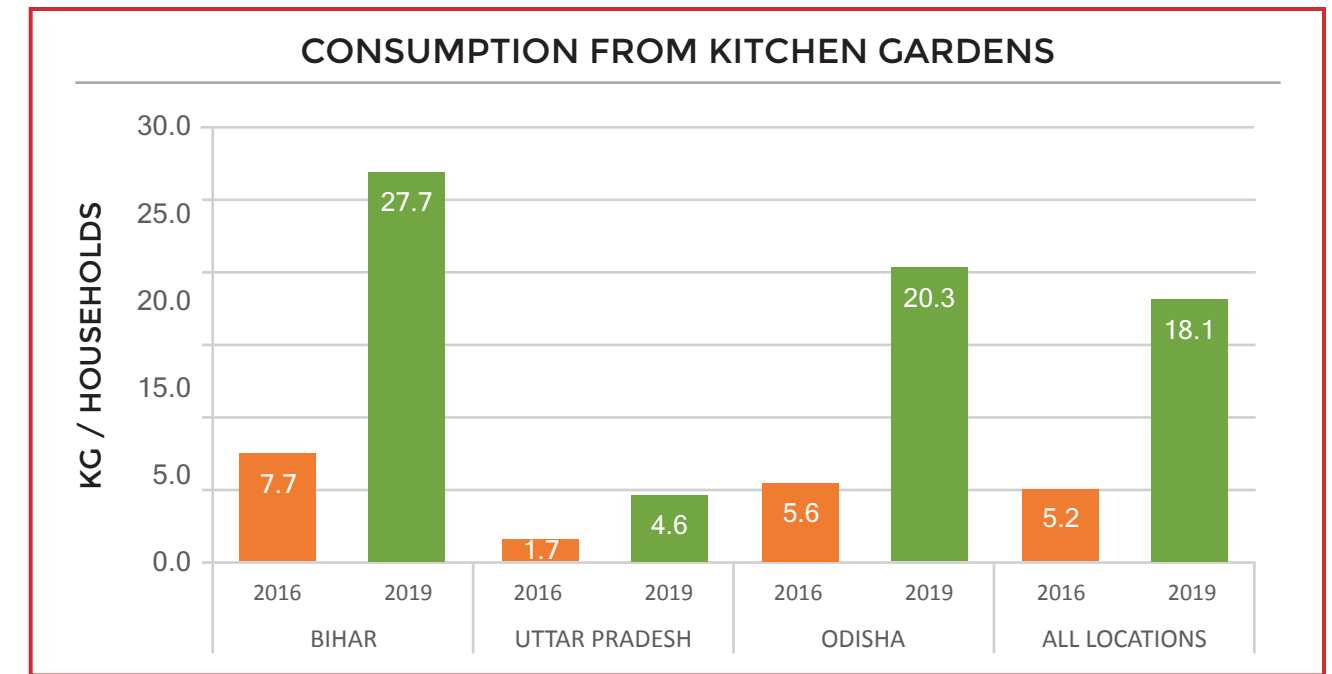
### Promoting Livestock: Strengthening Income Pathways and Enhancing Food System Diversity

Promoting livestock—including small ruminants like goats, as well as poultry, and dairy production—is another TARINA strategy for supporting a more diversified food system through strengthened income pathways. Interventions for improved health services and advanced livestock management, through community-owned platforms, have been the core of TARINA's livestock promotion program.

After four years, TARINA is engaged in 148 villages to promote poultry and goat rearing, and dairy production. Since 2016, there has been a 20% increase in households adopting goat or poultry rearing, or dairy production. Surveys further reveal a 28% increase in the household-level availability



The TARINA baseline and midline surveys reveal that more households are diversifying their crops to include non-staples.



Data from the TARINA baseline and midline surveys show an increase in consumption from kitchen gardens.

of milk, eggs, or meat over the same time period. Consumption also increased, with 31% of households reporting that they consumed milk, eggs, or meat in 2019, compared with just 20% in 2016.

In addition to diversifying diets, evidence shows that TARINA's livestock program also has enhanced household incomes. The average income from livestock among the households practicing livestock rearing increased from INR 665 to INR 1,126 from 2016 to 2019.

### Promoting Kitchen Gardens

TARINA has invested in innovative approaches to expand at-home horticulture to ensure availability and accessibility of diverse foods across seasons. Input supports, like seed supply; trainings on practices, including land preparation and pest management; and raising of dietary awareness, are some of the key components of the intervention to promote smart kitchen gardening.

As of 2019, 11,890 households had received interventions to motivate and support kitchen gardening. Since 2016, the percentage of households with kitchen gardens has increased from 11% to 40% overall. Evidence suggests that kitchen gardens are becoming more productive

as well. The average three-month production of a kitchen garden rose from 7 kg per household in 2016 to 22.5 kg per household in 2019, a more than 220% increase in food production.

Moreover, survey data suggests that kitchen gardens are positively changing consumption patterns. Consumption of fruits and vegetables from kitchen gardens increased by more than 300% since 2016.

### Empowering Women in Agriculture through Self-Help Groups

TARINA believes that a sustainable mitigation of malnutrition can be effectively achieved by engaging and empowering women in agriculture. The intervention programs administered by TARINA are delivered through engendered community platforms. Self-help groups not only empower women but also help to ensure that programmatic efforts meet their intended goals.

Thus far, TARINA has created or strengthened 448 women's self-help groups in its intervention districts, as well as 40 water user groups and 11 buck (goat) user groups. Between 2016 and 2019, there has been an almost twofold increase in women's association with self-help groups.

TARINA also has enabled self-help groups to provide community training for different aspects of women's empowerment. Panel data suggests that TARINA-led groups trained more than three times as many women in 2019, as they did in 2016. As a result, survey evidence suggests that women across the intervention districts have increased participation rates related to agricultural decision making. There is a clear indication that self-help group members participate more in decision-making processes than do nonmembers.



TARINA promotes raising livestock like goats to diversify diets and supplement household income. (Photo by Maureen Valentine)

To increase women's access to markets, TARINA helped to form local producer groups, held trainings on topics like price information, and facilitated buyer-seller meetings. Survey evidence shows that the percentage of households with market access for crops, livestock, and kitchen garden products increased from 25% to 48% between 2016 and 2019. Women's income from agriculture also doubled in that time period.

### Bringing Positive Nutrition Behavior through Social and Behavioral Change Communication

Improving positive nutrition-related behavior is an essential component for strengthening a nutrition-sensitive food system. TARINA's social and behavioral change communication interventions aim to shift individual-, household-, and community-level behavior toward better nutrition practices and to create a social landscape for sustainably changed positive behavior. A nutrition gender toolkit, focused on gender empowerment, improved dietary consumption, and sanitation, was

used to promote change among individuals and households, while mass campaigns, workshops, and meetings promoted change at a community level.

More than 20,000 individuals, 80% of whom are women, were reached through these interventions. Evidence of the program's success includes an increase in women reporting that they now eat meals with their families, rather than waiting until their families have finished, which leads to more adequate consumption by the women. Survey results also show that women and households reported more diverse diets after participating in the programs.

### POLICY ENGAGEMENT

TARINA has been engaged with policymakers and stakeholders at the state and national levels to develop a discourse around nutrition-sensitive agriculture. In 2019, TARINA initiated and led three high-value, policy engagement events:

#### Developing Biofortified Crop Value Chains in South Asia, January 2019

TARINA, in collaboration with IFPRI and the Institute of Economic Growth (IEG), conducted a workshop focused on improving nutritional security with biofortified crops in India and South Asia.

#### India Achieving SDG2 by 2030, January 2019

TCI director Prabhu Pingali delivered the 11th Foundation Day Lecture at the Trust for Advancement of Agricultural Sciences, entitled "Can India Achieve SDG2 – Eliminate Hunger and Malnutrition by 2030?"

#### First Nutrition Spectrum, November 2019

TCI participated and disseminated TARINA's vision for prioritizing nutrition-sensitive food policies among top policymakers, researchers, and other stakeholders.

### CAPACITY BUILDING

Improving the capacity of the key players in nutrition-sensitive agriculture and creating a cadre of leadership is one of TARINA's three objectives.

With the expertise and research products of its Center of Excellence, TARINA builds capacities of partner organizations, grassroots and frontline coworkers, and other stakeholders. TARINA has conducted several workshops and training programs on monitoring and evaluation of agriculture-related intervention programs, as well as utilizing metrics in agriculture and food systems, among other topics.

### Scaling up Learnings

Based on impact stories and lessons from interventions, TARINA aims to vertically scale up its successful models of making local food systems more nutrition sensitive. In its fifth year, TARINA is intensifying engagement with local, state, and federal governments to integrate its learning into government programs. Some key areas of engagement with national and state government departments include:

- National-level engagement to provide technical assistance to *Poshan Abhiyan*, the national government's program for mitigating malnutrition. The TARINA Center of Excellence is assisting the *Poshan Abhiyan* on developing a strategy for convergence between different departments and transferring the strategy to the state level.
- In Odisha, TARINA plans to assist the Department of Agriculture in strengthening the linkages between agriculture and nutrition by utilizing evidence from TARINA's production diversification programs.
- TARINA also aims to share and advocate for integration of its best practices for empowering women in agriculture with the Odisha state government's Mission Shakti, which works to optimize self-help groups for livelihood empowerment.
- In Bihar, TARINA is working to providing technical assistance to the state's livelihood mission, the Jeevika Special Purpose Vehicle, to enhance the capacity of frontline workers and program implementers in the areas of crop diversification, livestock promotion, and behavior change.
- In Uttar Pradesh, TARINA is working to integrate its learning and successful models for diversifying the local food system, layering onto the agriculture work plan in the state.

- TARINA is also planning to work with the Uttar Pradesh rural livelihood mission to strengthen its programs for empowering women in agriculture.

TARINA is also working to strengthen nutrition-sensitive program implementation at the district level and will intensify its policy advocacy efforts at the national and state levels to provide an adaptable roadmap for making the food system more nutrition sensitive.

### PUBLICATIONS

- Gupta, Soumya, Vidya Vemireddy, Dhiraj Singh, and Prabhu Pingali. 2019. "Adapting the Women's Empowerment in Agriculture Index to Specific Country Context: Insights and Critiques from Fieldwork in India." *Global Food Security* 23: 245-55.
- Gupta, Soumya, Vidya Vemireddy, and Prabhu Pingali. 2019. "Nutritional Outcomes of Empowerment and Market Integration for Women in Rural India." *Food Security* 11: 1243-56.
- Gupta, Soumya, Prabhu Pingali, and Per Pinstrup-Andersen. 2019. "Women's Empowerment and Nutrition Status: The Case of Iron Deficiency in India." *Food Policy* 88: 101763.
- TCI-TARINA. 2019. "TARINA District Fact Sheet on Women Empowerment in Agriculture." TCI-TARINA Fact Sheet No. 3, August.
- TCI-TARINA. 2019. "Emergence of Aggregation Models in the Agricultural Sector: Roles, Strengths, and Challenges." TCI-TARINA Policy Brief No. 13, August.
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PUBLICATIONS

## TRANSFORMING FOOD SYSTEMS FOR A RISING INDIA

In 2019, TCI director Prabhu Pingali, postdoctoral associate Anaka Aiyar, assistant director Mathew Abraham, and postdoctoral associate Andaleeb Rahman authored *Transforming Food Systems for a Rising India*, an important book that explores various challenges and opportunities to achieve a nutrition-secure future for India through diversified production systems, an improved health and hygiene environment, and greater individual capability to access a balanced diet.



*Transforming Food Systems for a Rising India* has been downloaded by more than 40,000 readers since it was published, and was the second-most widely downloaded book in Palgrave and Springer's economics portfolio in 2019. Readers of the book include those working in academia and those working with policymakers to ensure global nutrition security. Over 600 viewers watched via livestream when the book was launched from the International Food Policy Research Institute in Washington, DC. Pingali shared lessons from the book at two leading institutes on food security issues, the Food Security Institute at Stanford University in California and the M. S. Swaminathan Research Foundation in India, while Aiyar presented major lessons from the book with policymakers and attendees of the 2019 South Asia Food Systems Transformation Conference in Yangon, Myanmar.

A major advantage of the food systems lens utilized in the book is that its lessons can be extended to understanding policies required for ensuring nutrition security among other poor and emerging countries.

As set forth in the book, the Green Revolution successfully increased calorie sufficiency, facilitated economic development, and reduced hunger across India. However, the policy environment locked smallholders into a staple grain-focused production system that has benefited some more than others. Consequently, regional inequality has grown, and progress in the reduction of undernutrition has been slow. Additionally, the lack of accessibility to dietary diversity has led to greater incidence of obesity, even in rural areas. Meanwhile, climate change threatens to seriously impact non-staple crops on which many of the poor rely for dietary diversity.

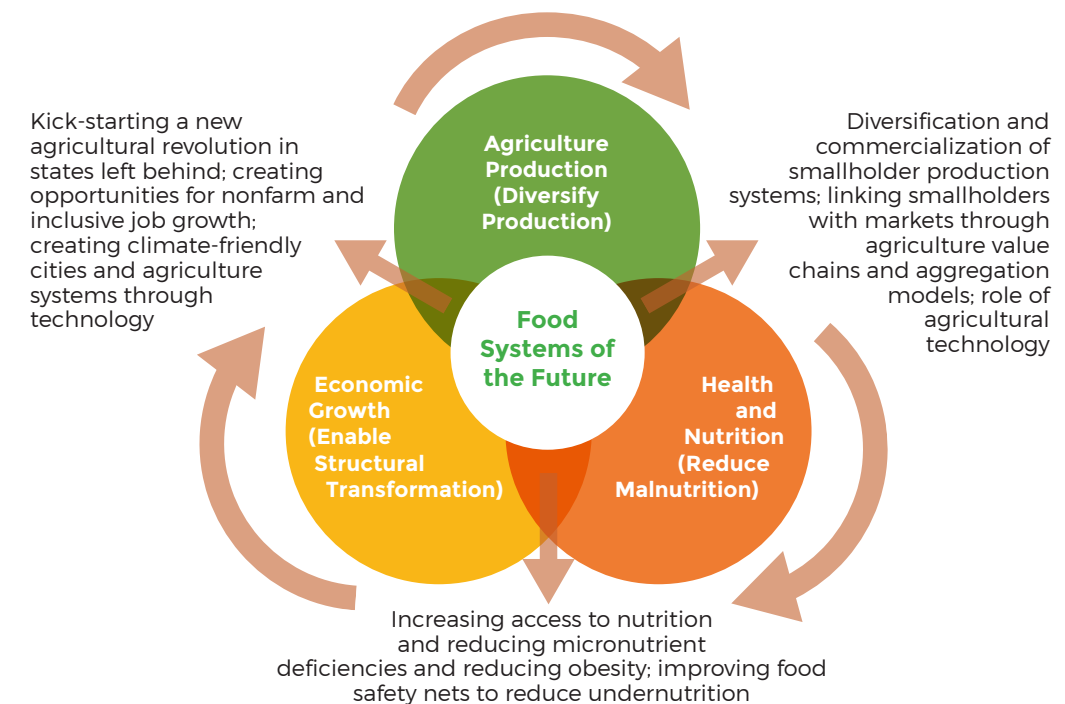
In light of these challenges, the book proposes the following lessons:

- A state-specific approach to development challenges is the way forward. A one-size-fits-all policy approach will continue to strengthen the position of fast-developing states at the expense of the least-developed states within the country.
- Increasing access to affordable, nutritious, and diverse diets is the key to addressing the triple burden of malnutrition: undernourishment, micronutrient deficiencies, and obesity.
- Growing demand for dietary diversity in urban areas has increased the volatility of prices of non-staples, impacting the affordability of nutritious diets. However, growing demand for dietary diversity can be leveraged to increase supply for nutritious foods while also increasing smallholder remuneration.
- To implement the first three lessons, infrastructure investments in the food value chain are required. This includes investments to connect rural and urban markets, as well

as support for the development of a rural nonfarm sector that can be leveraged to improve rural food security by reducing food waste and loss.

- On the supply side, supporting the development of farmer-producer organizations will facilitate the commercialization of smallholder farmers in response to the growing interconnectedness between urban and rural food markets, enabling smallholder farmers to earn more as a result.
- Diversifying the current scope of agricultural and food grain policies and formalizing procurement through the introduction of grades and standards can ensure that farmers benefit from on-farm diversification.
- More research is needed on the impacts of climate change on non-staples and on crops that are important to the poor.
- The scope of current safety net policies should be broadened. It should include ensuring greater nutritional security through dietary diversity, using all potential tools available, such as cash, in-kind supplements, and other measures.
- Technology investments of the future, including in the agriculture sector, need to be climate-smart. They need to account for differences in inter- and intra-community adaptation capabilities and support the development of allied environmental resources while protecting food systems from climate uncertainties.

### A MULTI-SECTORAL APPROACH FOR FOOD SYSTEMS TRANSFORMATION



*A holistic approach toward welfare development and nutrition security links agricultural development, health and nutrition, and economic development goals with each other.*



## THREE TCI PUBLICATIONS SHOW THE POTENTIAL OF WOMEN'S EMPOWERMENT

In the effort to improve nutrition in developing countries, women's empowerment in agriculture is a pathway that has gained considerable traction. In smallholder-farming households, the thinking goes that the more that women are empowered to make agriculture-related decisions, the more power they have to choose to grow, buy, and consume diverse, nutritious foods. TCI advanced the understanding of how this pathway impacts nutrition in three journal articles published in 2019.

### ADAPTING THE WOMEN'S EMPOWERMENT IN AGRICULTURE INDEX TO INDIA

In "Adapting the Women's Empowerment in Agriculture Index to Specific Country Context," published in *Global Food Security*, TCI research economist Soumya Gupta, alumna Vidya Vemireddy, researcher Dhiraj Singh, and director Prabhu Pingali drew upon their field experience to modify the Women's Empowerment in Agriculture Index (WEAI)—a popular



TCI research shows that empowering women to make more decisions related to agriculture can lead to better nutrition outcomes. (Photo by Kathryn Merckel)

multidimensional method of assessing women's empowerment based on their access to resources and ability to make decisions in agriculture—so that it reflects the reality of agriculture in India. For example, while the WEAI's group membership sub-indicator includes membership in any group, TCI's Index is focused on self-help groups, which play an important role in Indian women's agricultural activities.

When applied to survey data collected as a part of TCI's TARINA program, the adapted index reveals that at least 80% of women across the four districts surveyed are disempowered in agriculture. The main drivers of disempowerment are lack of membership in agriculture-related self-help groups, lack of ownership of land, and lack of control over income.

Compared to the WEAI, TCI's adapted index shows significantly lower levels of women's empowerment in agriculture. These results demonstrate that while the WEAI is a useful method for measuring empowerment, it must be modified to fit local contexts to impact public policy in a meaningful way.

### WOMEN'S EMPOWERMENT AND MARKET INTEGRATION

In an article in *Food Security*, "Nutritional Outcomes of Empowerment and Market Integration for Women in Rural India," Gupta, Vemireddy, and Pingali used their adapted empowerment index to demonstrate that women who are empowered in agricultural decisions have higher levels of dietary diversity, meaning that they are more likely to eat a diet containing a range of nutritious non-cereals, like pulses, meat, dairy, and eggs.

The study, which also used TARINA survey data, accounts for a household's market integration in terms of how much it spends on buying a diverse array of food from local markets. Greater household purchases of non-cereals are associated



Empowered women are able to use their influence over agricultural decisions to diversify household diets. (Photo by Kathryn Merckel)

with higher levels of dietary diversity for women. TCI's analysis revealed that, for a given level of market integration, empowered women are better able to translate their influence into purchases that diversify their diets. Taken together, these results reinforce the notion that Indian agricultural policy should be reconfigured in a way that promotes both women's empowerment and household market integration for improved nutritional outcomes.

### EMPOWERMENT'S IMPACT ON MICRONUTRITION

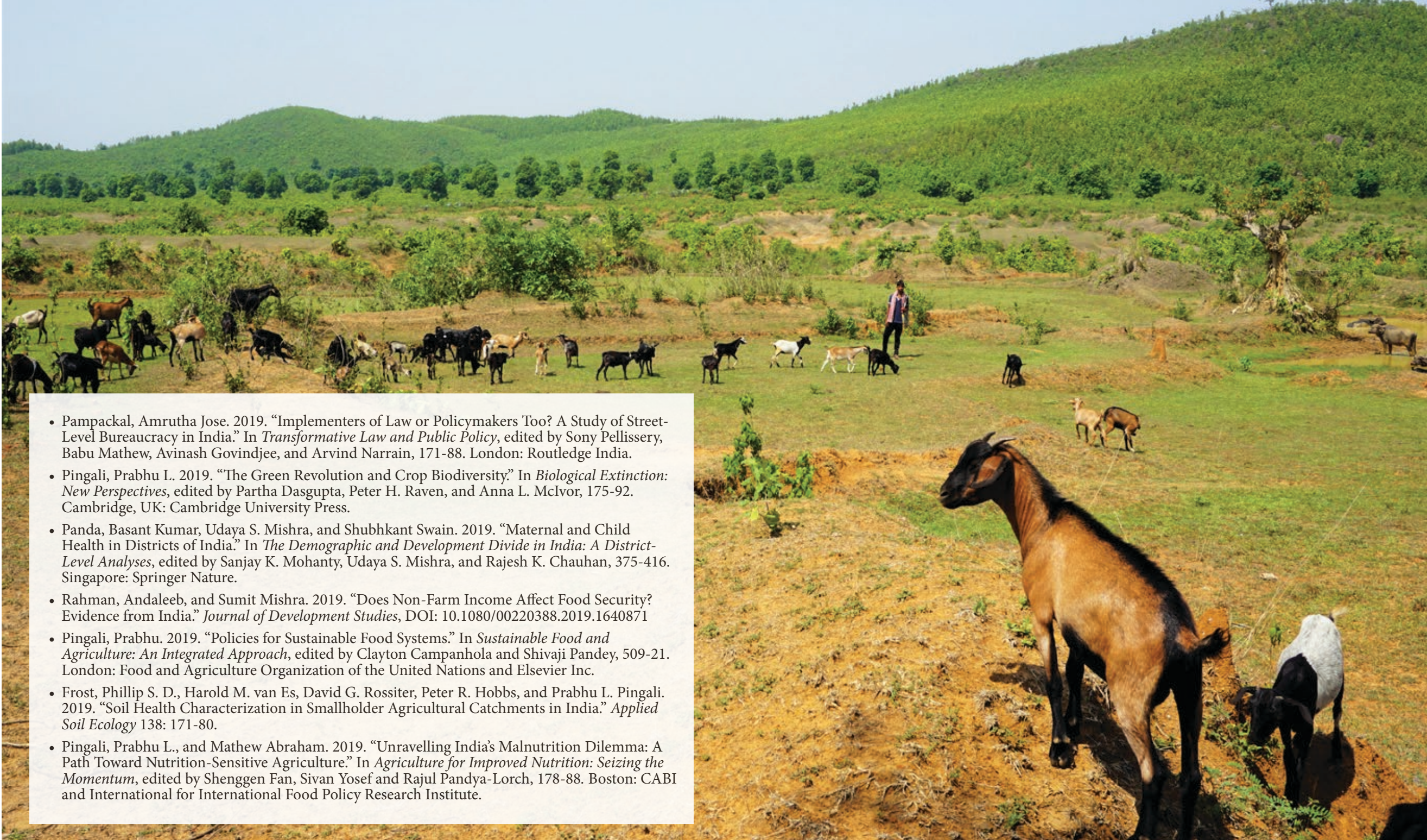
In "Women's Empowerment and Nutrition Status: The Case of Iron Deficiency in India," a *Food Policy* article by Gupta, Pingali, and Per Pinstrip-Andersen, the WEAI was used to study the relationship between women's empowerment and blood iron levels. The study marks the first time the WEAI has been used with the explicit measurement of medical biomarkers for women's iron deficiency status.

Using multiple iron markers from blood tests from 960 women, Gupta, Pingali, and Pinstrip-Andersen found the likelihood of poor iron status declines as empowerment levels improve. They also examined the women's dietary intake and found that, although empowerment levels are associated with improved iron status, the dietary factors are not. This suggests that the empowerment pathway can hold great potential as a non-dietary pathway for addressing micronutrient outcomes in women.

These three articles are only the latest contributions from TCI researchers to the literature that examines the link between women's empowerment and nutrition. TCI continues to build on previous research in this area, improving upon measurement methodology and demonstrating the important role that women's empowerment plays in improving nutritional outcomes.

To read the three articles, visit [tci.cornell.edu/research/publications](http://tci.cornell.edu/research/publications).

## MORE TCI PUBLICATIONS FROM 2019



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